

# A Manual for Rural Freshwater Aquaculture

Rural Fisheries Programme  
Department of Ichthyology  
and Fisheries Science  
Rhodes University



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# A MANUAL FOR RURAL FRESHWATER AQUACULTURE

by the

**Rural Fisheries Programme  
Department of Ichthyology and Fisheries Science  
Rhodes University**

for the

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and

**Department of Agriculture, Forestry and Fisheries**

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In 2004, the Rural Fisheries Programme of the Department of Ichthyology and Fisheries Science, Rhodes University, completed a project on behalf of the Water Research Commission (WRC) to assess the contributions of rural aquaculture to livelihoods. It became apparent that although the current contributions were low, the potential was significant. To exploit this potential, Project K5/1580//4 was solicited by the WRC in 2005, co-funded by the Department of Agriculture, Forestry and Fisheries (DAFF), and undertaken by Rhodes University.

This project was formulated to address a number of issues, such as developing provincial aquaculture strategic plans, revitalising state hatcheries, training of extension officers, and the development of a manual to complement the training. An inclusive process to develop an aquaculture training manual for extension officers was followed. The provincial branches of the Department of Agriculture made inputs on the content and structure of the manual and drafts were then sent to DAFF and other stakeholders for review and comments. It is envisaged that this manual will continue to be modified and reviewed as aquaculture in South Africa grows in order to reflect the needs of the extension officers over time. The manual is not only intended for the training of extension officers, but is also resource material to be used in the field when interacting with farmers.

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## Chapter 1

# Introduction to aquaculture

### Introduction

The definition of aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as through regular stocking, feeding or protection from predators. Farming also implies individual or corporate ownership of the stock being cultivated.

The definition does not include fisheries, which is the harvesting of organisms from the wild of which there is no ownership or intended intervention to increase production. Hydroponics is the culture of terrestrial plants in water instead of soil and is not considered as aquaculture.



Egypt is the largest aquaculture producer in Africa. This farm produces tilapia in ponds and in tunnels.

Compared to agriculture which is thought to have started about 10 000 years ago, the practice of aquaculture has only been around for about 2 500 years. The first records of aquaculture are from China where carp (*Cyprinus carpio*) were cultured. Aquaculture in Africa has been practiced since the time of the ancient Egyptians who farmed tilapia in ponds adjacent to the Nile River.

At present, the contribution of aquaculture to worldwide food production is considerably

less than that obtained from captive fisheries, although this is changing as feral stocks become depleted. For example, in 1999 the worldwide aquaculture production of animals and plants was 43 million metric tons compared to 94 million metric tons from fisheries. As many of the world's fish stocks are in serious trouble due to over-fishing, aquaculture has been identified as a practice to provide protein that would otherwise have come from the ocean. In 1999, the contribution of aquaculture in sub-Saharan Africa to the total world aquaculture production was less than 1% in terms of tonnage produced. Aquaculture in sub-Saharan Africa has immense potential as a means of increasing food security, and the aim of this manual therefore is to provide information to prospective local fish farmers. In areas such as the Phillippines and Indonesia, China, Vietnam and Israel, aquaculture now produces a substantial and ever-increasing proportion of the fish consumed by their respective populations, together with a percentage that is exported to other countries.

Aquaculture should not be seen purely as a way of producing food. There are many forms of aquaculture that produce a marketable commodity that is not eaten, but sold for cash, that can in turn be used to purchase food. A flourishing example of this is the ornamental fish trade, where fish are produced for sale to the international pet trade. Often one or more species of fish are produced by small-scale family-owned farms which operate at a low technological level, but whose markets are guaranteed by the setting up of cooperatives that purchase the total farm production for an agreed price, and do all the further marketing. This enables these small-scale operators to have an assured income, resulting in food security for their families.

Another often ignored form of aquaculture is the production of quality seed for sale to other fish farms in the form of fingerlings. It is undeniable that one of the causes of repetitive failure in African pond aquaculture since 1945 is the widespread use of poor-quality founder stock. A frequent problem is the use of inbred



Aquaculture in Africa has traditionally been carried out in extensively managed large ponds, using either fertilization or some supplemental feeding of the fish.

fish found in local ponds and then further inbred by so-called hatcheries and distributed to local production farms in the belief that the stock quality did not matter. There is a need for producing quality fingerlings with traits for fast growth, cold tolerance and even colour-enhancement to obtain greater market acceptance and value, as has been done in the Philippines, with their GIFT tilapia (genetically improved farmed tilapia), a red-coloured and fast-growing strain of *Oreochromis niloticus* which outperforms the wild strains and is now almost universally used in aquaculture.

If water is available to grow fish, aquaculture offers more choice than farming on land. This is because there is almost always a suitable species of fish that can be cultured in the available conditions. However, it is important that only species with requirements compatible with the region's environmental conditions are cultured. For example, trying to grow a coldwater species such as trout in warm water will not work; however, tilapia or catfish would do well in warm water.

Some of the reasons why a farmer or small land owner might start fish farming:

- Fish are an important source of high-quality food
- Fish farming can help a farmer make better use of his/her land
- Fish farming can provide extra money.

### Types of aquaculture

The practice of aquaculture varies widely and differs in the intensity of culture, level of water exchange and structures used, with each method having its own set of benefits and problems. Aquaculture can be broadly grouped into three intensities:



Deciding on the way in which you intend to make money out of aquaculture requires planning and expert advice.

*Extensive* – This uses large stagnant ponds that allow only a low stocking density and rely on natural production to feed the animals (i.e. there is no supplemental feeding). Management and skills input are low.

*Semi-intensive* – This is much like extensive culture, however there is a greater degree of intervention either through feeding and/or improvement of water quality through aeration and partial water exchange. This allows for an increase in the production of livestock when compared to extensive systems. Management and skills input occur at a medium level.

*Intensive* – Livestock are maintained at high stocking densities and feeding comes solely from introduced feeds. The culture systems tend to be highly technical and rely on electricity to operate. The space required is relatively small and the system is designed to optimize water use and quality. Management and skills input are high.

In some parts of the country, where climatic factors are against the year-round production of warmwater fish species, there is still potential for either coolwater aquaculture, or seasonal production as with any other 'crop' in agriculture. For example, there is no reason why, if fingerlings are available, that harvests of tilapia (or other warmwater species) at the end of summer should not be followed by that of trout at the end of winter. There are many parts of the country where summer water temperatures are ideal for warmwater species for seven months of the year, and for coolwater species for the balance. With a little imagination and careful planning, a similar system to those farmers who currently grow a crop of winter wheat, followed by maize or other summer crop, may also be used for fish rearing. All it takes is the belief that it is possible, and some careful planning of the production methods.



Fish can be produced in intensive systems (far left) requiring pumps, tanks and other equipment, or in ponds (left), as commonly used in most parts of Africa.

### The history and present status of freshwater aquaculture in South Africa

During the late 1960s and 1970s various government agencies promoted freshwater aquaculture. Well-equipped hatcheries were constructed in many parts of the country to supply fingerlings to both private and government projects. Of the 13 government hatcheries then existing, the three remaining are operating at reduced capacity and efficiency. Most of the hatcheries and rural projects remain 'mothballed', with the basic infrastructure still there. What are the reasons for this reduced activity in aquaculture since the 1980s, and why did the fish projects not succeed?

- There was little planning and support;
- Training in basic fish biology, husbandry skills and marketing was lacking;
- Stock was randomly selected from locally available fish, with no attention to improved strains or selection for favourable traits such as fast growth or cold tolerance.

If these obstacles can be overcome then most of these facilities can be revitalised and made operational without starting from scratch. The purpose of this manual is to avoid the mistakes made in setting up or running these former projects and to guide interested parties along routes that, if followed, will ensure success.

In the warmer coastal parts of both the Eastern Cape and KwaZulu-Natal, warmwater aquaculture has high potential due to the relative abundance of water in these regions and the milder winter temperatures. Further inland, at higher altitudes, and in the Free State and North West provinces, a lack of water or extreme seasonal temperatures make aquaculture difficult. In these regions, a possible focus on seasonal 'crops' of warmwater and coolwater species at different times of year should be sought. In all provinces, the potential for producing ornamental fish is high, especially where this can be done utilizing tunnels or climate-controlled buildings, or by seasonal production during the warmer months.

In neighbouring countries there are many examples of successful aquaculture ventures. Zimbabwe (at Lake Kariba), Zambia and Malawi all have successful tilapia farms, both large and small scale. On almost every hotel menu and in most food outlets in these countries you will find freshwater fish for sale which has been cultured locally. South Africa should be no different.

## Frequently asked questions

Q: *Does one need lots of water for fish farming?*

A: No, the Israelis (for example) farm fish in one of the driest parts of the world. The quantity of water available determines the methods used, whereby intensive water recirculating methods tend to predominate where water is scarce, and extensive ones where water is abundant.

Q: *Do you need a university degree in zoology or ichthyology to become a successful fish farmer?*

A: No, a good practical ability is more important, although a basic understanding of and 'feel' for animal husbandry is essential. If you have no 'feel' for animals, do not become a fish farmer.

Q: *Can a farmer use his dam or water-storage tanks for aquaculture?*

A: Generally, no, in that these tend to be either unmanageable because they cannot be drained and the stock managed, or too small in that the feed needed to grow a worthwhile number of fish would soon pollute the small water volume of the storage tanks without filtration. However, dams can be wellused for cage-type aquaculture (see Chapter 4).

Q: *Is aquaculture a fulltime occupation or an alternative to other farming practices?*

A: It can be either, depending on its scale. Some fish farmers are also crop or other livestock farmers, while others are fully occupied managing their fish farms which leaves no time for other occupations.

Q: *Is fish farming profitable?*

A: Fish farming is a business just like any other, and the growing of the fish is only one aspect, just like the growing of crops is only one aspect of traditional farming. The farmer also needs to be competent at harvesting, processing and selling the harvest, and in running the other essential aspects of a business, such as the keeping of records, maintenance of machinery and equipment, managing staff, and marketing the product. It is only if he/she is successful at doing or delegating all these functions will the business be profitable.

Q: *If I have no money, can I start fish farming?*

A: Clearly, if you want to start your own operation of any type, you need some sort of start-up capital, otherwise you should gain experience on someone else's fish farm first. A small-scale operation can develop into a viable business if carefully designed. For example, some of the Far East family-run fish farms are very small and only grow one species of fish in a few simple ponds. If you are prepared to cooperate with others doing likewise, and pool your resources, you may well succeed in creating a good business. Your expectations must be realistic though, and you will not become an exporter of fish from just half a dozen ponds.

Q: *What expertise do I need to undertake my own fish farming venture?*

A: A spirit of hard work coupled with preparedness to undertake more than just fish farming itself. If you are going to call a mechanic every time your vehicle needs an oil change, or an electrician when you need to wire up a pump, rather go and become a desk-bound civil servant, as fish farming demands that one be a master at many trades. Be prepared to try to learn how plumbing works, dams are built, fish breed, and don't depend on others to fix the daily problems associated with the lifestyle of a fish farmer. Like agriculture, it is generally an outdoor, healthy and exciting lifestyle that can lead to some frustration at times, but much work satisfaction and rewards as well. You will never be bored!



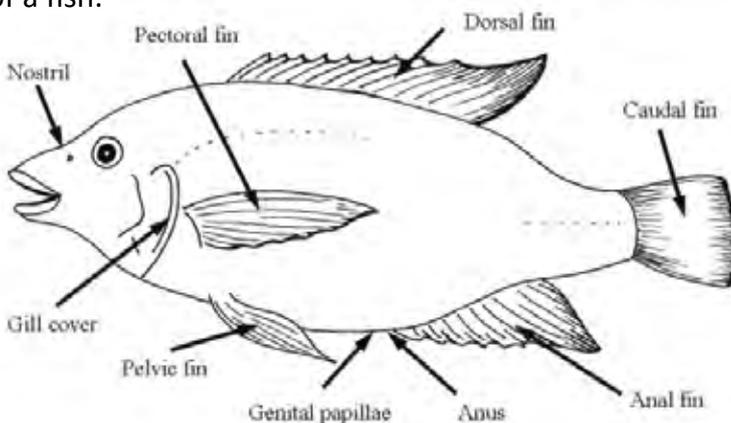


## Chapter 2 Fish biology

### Fish biology

Like any animal, a basic understanding of how fish function is necessary if one is to try to culture them. Fish are different to land animals as they have evolved to live in water, which makes movement, breathing, buoyancy and food or predator detection very different to that encountered on land. One of the most fundamental differences between fish and land animals is that the former are essentially weightless in their environment and dependent on it for their temperature, being 'cold-blooded', and this means that they neither need food energy for fighting the force of gravity nor for keeping themselves warm, as do land animals like cows and sheep. This makes their conversion of feed into mass more efficient than with land animals, given the right environmental conditions.

The diagram below outlines the typical features of a fish.



The external features of a typical fish.

### Movement

Fish have evolved into various shapes and forms depending on how and where they live in water. Fast-swimming species (such as tigerfish or trout) are streamlined and tend to be torpedo-shaped, with big eyes as they use their eyes to hunt. Conversely, bottom-dwellers generally use touch to find their food, like catfish which have small eyes and a wide, flat head with barbels that search the bottom for food.

Instead of fur, fish have scales, which are

stronger and more streamlined. The scales offer protection from other aggressive fish as well as act as a barrier to parasites. Some fish (e.g. catfish) do not possess scales but instead have a slimy layer of mucus for protection, which sometimes makes handling large specimens very difficult.



### Breathing

Fish obtain oxygen from the water via their gills which are found at the side of the head, covered by the operculum plate. The gills are composed of finely branched filaments (which look like feathers) across which oxygen diffuses from the water into the blood which is then pumped around the body. By actively pumping water using the mouth and gill cover (operculum), the fish ensures that water is constantly passing over the gill filaments. Except for catfish, which in addition to gills may have an air-breathing organ, all fish require water to survive. When a fish is removed from the water the gill filaments collapse on one another and oxygen cannot diffuse across the filaments fast enough, so the fish 'drowns' due to a lack of oxygen.

### Digestion

The digestive system of a fish species depends on what it eats. Fish that eat other fish tend to have a short digestive tract (gut or intestine) as they can get the nutrients they require from their high-protein diet. Plant material is harder to digest as it contains cellulose, which is difficult to break down and digest. Therefore, fish such as tilapia which eat plants or algae tend to have longer digestive tracts as the food needs more time to digest.

Food enters the mouth where it is broken down into smaller pieces before entering the oesophagus (throat), which carries the food to the stomach. The stomach adds acid and enzymes to the food to help break it down. The food then enters the intestine, which helps digest the food as well as absorb the nutrients required by the fish. Once all the nutrients have been removed from the food, the faeces is excreted through the anus. Some fish (e.g. tilapia) have almost no stomach, but only a very

long intestine: this is because they eat almost all the time, and low-protein food is continually moving along the gut and being slowly digested. Some predatory fish (e.g. tigerfish, bass or catfish) have stomachs to hold their larger prey until it is broken down and digested.

### **Reproduction**

Fish breed in a number of different ways. Most lay eggs but some give birth to live young. In freshwater fish, the fertilized eggs usually sink to the bottom or are sticky and therefore stick to plants or rocks. In some species (such as tilapia) the eggs may be collected by the adult fish and held in the mouth by the female after fertilization. The eggs hatch in the parent's mouth and the young develop there until they are large enough to be released. These fish practice a high degree of parental care, which means that large numbers of young can be successfully reared and protected without being eaten by other fish. Female livebearers (such as guppies) may store sperm for months, which they can use to fertilize their eggs when males are not available. The baby fish develop inside the mother and when she gives birth to the babies they are able to feed and look after themselves.

Before fish will breed they must be in good condition. They should be in an environment that is beneficial for spawning (e.g. the correct temperature, plants for egg attachment, etc.). They should also have been eating the correct food which helps make good-quality eggs and sperm.

### **Buoyancy**

Most fish are essentially 'weightless' in their medium, water, and don't need energy to stand up like land animals. Fish need to be able to remain and hover at their preferred position in the water using the minimum amount of energy. They do this by controlling their buoyancy which is the ability to alter whether they float or sink in the water. Most fish have a swimbladder, which is an organ to contain air inside the fish. The fish is able to regulate how much air enters or leaves the swimbladder, thus allowing the fish to float or sink as it needs to. Sometimes fish may get an infection of the swimbladder; this may cause it to swell, resulting in the fish floating on the surface, unable to swim down.



The study of fish informs us about how to best grow fish under aquaculture conditions. The faster we can get fish to grow, by providing them with the correct feeds and water conditions, the more money a fish farmer will make.



## Frequently asked questions

Q: *Do fish get sick like land animals?*

A: Yes, all animals get sick, but fish usually only get sick in large numbers when their environmental conditions are not to their liking, such as the result of polluted water or temperature stress. Because fish are so dependant on their environment, being cold-blooded, diseases are very difficult to cure if these environmental conditions are not suitable for the fish.

Q: *Why are fish more efficient at converting feed into mass than land animals?*

A: Fish need food only for movement, not for staying warm or for 'fighting' gravity. For example: a fish can move upwards in the water for 100 m for the same energy that it takes to horizontally move 100 m at the same depth. A land animal like a cow will consume far more energy walking up a steep hill than along the same distance on flat ground.

Q: *Since a fish is surrounded by water, how does it protect itself from water-borne diseases and parasites?*

A: A fish has an immune system, just like any other animal, that if healthy, will protect it from most diseases. Fish also have either scales or a mucus coating (or both) that protects them from physical damage and some parasites.

Q: *How does a fish swim?*

A: A fish swims by contracting its lateral (side) muscles and then flexing the body muscles along its length, which basically pushes the water behind the animal. Fins are mainly used for directional stability. A fish can only move its body one way, so when you see a fish apparently thrashing about on land after harvesting, it is only flexing its body muscles in an attempt to swim away.

Q: *Can fish see colour, and do they have good eyesight?*

A: Yes, many fish have excellent eyesight and can see a wide variety of colours very efficiently. Many fish, like tilapia, recognize their mates by colour differences during the breeding season. Some species, such as the catfish *Clarias gariepinus*, have small eyes and poor eyesight, but use their barbels as taste organs in muddy water or in darkness to find their position and food.

Q: *How do fish feel their environment?*

A: Fish have a sensory organ called the lateral line which lies along the mid flanks of the fish. This organ is very sensitive and can pick up vibrations in the water, warning the fish of other species or predators in the water or on the bank. Using the lateral line organ, most fish can detect your footsteps on the bank from far away. Other fish have weak electric organs to aid their navigation and to detect prey and predators. Fish have an acute sense of smell and can detect the smell of food and other substances underwater, sometimes at great distances.

Q: *How many eggs do fish produce, and how often do they breed?*

A: This varies greatly between species. Carp and catfish may breed once a year and produce in excess of 100 000 tiny eggs per female. Tilapia may breed three to four times each summer and may produce 500-1000 eggs per spawning. Guppies may give birth to 50-150 live young every six to eight weeks throughout the year. Eels will never breed in freshwater, but go into the sea to breed in a manner still poorly understood even by scientists.

Q: *Can fish be artificially induced to breed?*

A: To some extent, yes, with hormone injections, but they must still be in a near-ready state for reproduction. Trout, carp and catfish are often stripped of their eggs and milt and artificially spawned. Tilapia are usually bred naturally, which they seem to be capable of doing under even the most stressful conditions, which means that when you prefer them to be putting their energy into growing rather than breeding, they will still breed and overpopulate their environment in the absence of natural predators.





## Chapter 3 Aquaculture species

### Selection of species

The choice of what species should be cultured in a particular region depends on a number of factors, as discussed below.

### Location

Several introduced (exotic) species have caused or threaten conservation problems to indigenous species due to their hybridisation, the introduction of parasites, or by out-competing naturally occurring species for food or other resources. The reasons for culturing exotic species are:

- Some exotic fish grow better and faster than local species.
- Some exotic fish are preferred by people for eating (over local fish).
- The offspring of a cross between a local fish and an exotic fish sometimes grow faster and taste better than either of the parent fish (this is called hybrid vigor).
- Each species has a preferred range of water-quality and temperature parameters. It is important that only species whose water-quality requirements are within the range of those found in the region are considered.
- Availability: If there is a problem with fingerling supply, the farmer may need to build a hatchery, which is both expensive and requires highly technical expertise.

### Biology of the species

- Growth rate – Species that grow quickly reach market size in a shorter time. However, under

similar conditions, higher-valued species may sometimes be more cost-effective to culture as compared to cheap, fast-growing species.

- Feeding habits – The species being cultured must have dietary requirements that can be met by the pond and the farmer. Producing fish at a low cost relies on the fish using as much of the pond's natural food as possible. If greater production is wanted, additional feeding will be required, but this adds to the expense of fish farming. For example, catfish require a high-protein diet which cannot alone be provided from the natural food in the pond.
- Reproductive biology – It is usually best to choose a species that breeds easily and therefore produces many young.
- Hardiness – The commonly cultured species are popular around the world mainly because they adapt well to being cultured.
- Market – Many aquaculture businesses that fail, do so because they did not check properly that there was an economic market for their fish.
- Profitability – It is very important that a careful cost analysis is done concerning the costs of maintaining the ponds, buying the young fish, feeding them, and any other costs incurred while they grow. Once all the costs have been worked out it is possible to calculate the minimum price that each fish can be sold for.

If at all possible, farmers should be encouraged to start their ponds using a tested pond fish that

### Examples of successfully cultured warmwater aquaculture species

Country	Species	System used	Tonnage/year
China	Tilapia	Ponds	706 000
Philippines	Tilapia	Ponds/Cages	122 000
Brazil	Tilapia	Ponds	110 000
Europe	Tilapia/Catfish	Intensive	n/a
West Africa	Catfish	Ponds/Tanks	Cottage industry
Zimbabwe	Tilapia	Ponds/Cages	n/a

### Some cooler regions in the world

UK, USA, Chile, NZ, Canada	Trout	Intensive/Cages	n/a
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is locally available and well-liked by people in the area. If the fish can grow in ponds and the farmer is able to sell the fish or use them for his/her family, more or larger ponds could be built.

To decide which fish species are suitable for aquaculture in South Africa, we should look at case studies from other countries.

**Sharptooth catfish (*Clarias gariepinus*)**

The sharptooth catfish or barbel is a freshwater species and is distributed throughout southern Africa. This is a warmwater species that prefers temperatures between 20-30°C. Unlike most other fish, catfish do not have scales but rather a naked skin; this makes handling them easier as scales are not lost causing damage to the skin. *Clarias* species possess a breathing apparatus that allows them to breathe air as well as 'breathe' in the water. As long as the skin of the fish remains moist, the fish is capable of moving across land in search of water. Although they will actively prey on smaller fish, rodents, birds and frogs, they are omnivorous bottom feeders and can be fed a variety of feeds.

*Clarias gariepinus* can be identified by the following anatomical features: Head large and bony with small eyes and a terminal large mouth. Dorsal and anal fins long. No adipose fin. Pectoral fin with thick serrated spine used for defense or 'walking' on land. Four pairs of barbels. Colour varies from sandy-yellow through gray to olive with dark greenish-brown markings, and white belly (see photograph).

**Spawning**

Maturation of the gonads begins in winter and is associated with increasing water temperatures. Spawning normally takes place in spring and summer at water temperatures above 18°C, and usually above 22°C. These catfish reach sexual maturity between 150-750 mm total length, at an age of 1-4 years; however, there is a highly significant correlation between female size and fecundity, with the average relative fecundity in the region of 20 000-25 000 eggs/kg fish.

In the wild, spawning usually takes place in shallow water, where the fertilized eggs stick to the leaves and stems of plants. Spawning generally takes place at night in recently inundated marginal areas, typically between 20h00 and 02h30 hours and usually after heavy rain. Artificial spawning techniques are detailed in Chapter 10 on broodstock and breeding techniques.

Once the larvae have developed into juveniles (usually after a 10- to 15-day intensive hatchery period), they are transferred outdoors or to



Sharptooth catfish is favored by many fish farmers as it grows well, is easy to breed and can be kept in high stocking conditions. However, there is some work to be done to develop the market for this fish in South Africa.

indoor tunnel nursery ponds at a density of 2000 fry per m<sup>2</sup> or more. The juvenile fish are fed every four hours, with a 38% protein diet, and must be graded into three size classes at least two times during the following 4-6 weeks. When the fish reach an average weight of 4-5 g they are either sold to producers or put into the farm's production ponds. The average survival rate from hatching to the end of the nursery phase is approximately 40%.

**Grow-out**

Ponds with no water circulation stocked at a density of 10 fingerlings/m<sup>2</sup>, reached 10 000



**Considerations for catfish *Clarias gariepinus* as a candidate species for aquaculture:**

**Advantages**

- Robust
- Fast-growing
- Wide tolerance of temperatures and water quality
- Can breathe air
- Wide eating habits, but needs substantial protein
- Can be grown in high densities

**Disadvantages**

- Specialized breeding techniques required
- Can easily escape from ponds
- Requires high-protein feed
- Market resistance in some places
- Larger specimens (>2kg) taste poor
- Cannibalism by juveniles

kg/ha at an average weight of 200 g after 6 months. Higher stocking densities are not used because the poor water-quality conditions at the end of the production cycle are difficult to manage.

Crops of 40 000-100 000 kg/ha have been attained in ponds with a 25%/day water exchange. The daily water exchange is essential to maintain water quality as this otherwise



An example of how catfish can be grown in high densities. Their ability to breathe air is a contributing factor to this.

rapidly deteriorates due to the build-up of uneaten food and excreta, stressing the fish and possibly leading to an outbreak of disease. Due to these potential problems, it is recommended to initially stock the ponds at a maximum density of 10 fingerlings/m<sup>2</sup> and to thin the population out at regular intervals, maintaining a maximum standing crop of 40 000 kg/ha with a constant daily water exchange rate of 25%.

One of the main problems encountered with growing catfish is related to water quality. For instance, overfeeding leads to poor environmental conditions, including low oxygen, high ammonia, and high suspended solids. Adverse water conditions are also linked with dense algae concentrations followed by scum from algae appearing on the water surface. This causes low oxygen levels at night and pre-dawn. By flushing the pond with fresh water and reducing the dietary feeding level, the water quality will start to improve.

### **Feeding**

Catfish has a high dietary protein requirement and therefore feeding with a formulated feed is a prerequisite for intensive culture of the species. Optimal growth rates and food conversions are achieved with diets containing 35-42% crude protein. The artificially formulated diets are composed of vegetable and animal

### **INFO BOX: CATFISH**

- Feed needs to contain 35-42% crude protein.
- Adequate water quality control can be difficult due to high fish density.
- Can be cultured semi-intensively or intensively.
- Production of 40-100 tons/ha have been achieved.
- Management input is high due to the need for size sorting.

feedstuffs that are supplemented with vitamins and minerals.

It is difficult to give a standard formulation for a balanced diet for catfish as the composition of the formulated diets depends on the availability and prices of locally available feedstuffs. In order to help acclimatize the fish to the feed and feeding place in static ponds, slightly higher feeding levels may be applied during the first three months. However, due to deteriorating water quality, lower feeding levels should be applied during the last three months of culture. After about six months the pond can be harvested, with a net production of 4-8 tons/ha.

### **Common carp (*Cyprinus carpio*)**

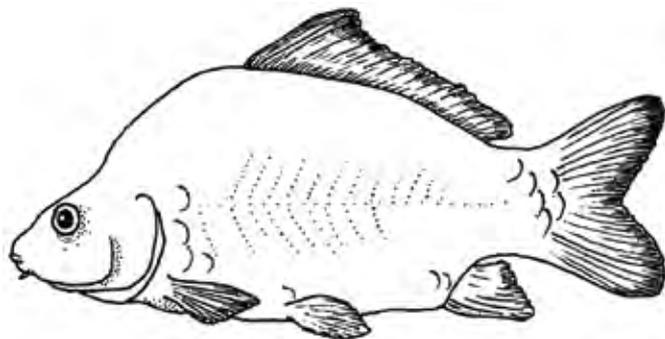
Common carp is the most commonly cultured aquaculture species in the world, with more than 10 million tons being produced in 1995. Like cattle, it is domesticated as it is very different to its wild form, both physically (e.g. its shape and scale types) and in its biology (spawning, growth and feeding habits).

In Europe and Asia, carp is popular as an aquaculture species as it feeds mainly on plant material (which is cheaper than animal feed) and the small insects that live in ponds. This makes the production of carp much cheaper than catfish, for example, as the expense of the feed is reduced. Carp grow quickly and can reach a length of 80 cm and weight of 10-15 kg. They are tolerant of a wide range of temperatures, from 1-40°C. They grow best at temperatures above 13°C and spawn at temperatures above 20°C. Another good characteristic of carp is that they do not get sick easily. While carp may be a good species to use by farmers who are fish farming for the first time, their commercial production must be market-driven.

### **Spawning**

Carp mature after three years and in the wild, and spawn every year in the spring, releasing up to 100 000 eggs per kg of fish body weight.

In captivity, male and female fish are placed in spawning ponds or tanks during the spawning season. To make captive broodstock breed, fish can be injected with hormones that stimulate the production of eggs and sperm. The hormones can be obtained from the pituitary gland (part of the brain), from other adult fish, or from a commercial source.



Common carp (*Cyprinus carpio*)

### Grow-out

The most suitable ponds for growing out juvenile carp should be shallow, weed-free and drainable (about 0.5 to 1.0 ha in size). The nursery ponds should be prepared prior to stocking to encourage the development of a rotifer population as this provides the fry with their first food. The ponds should be inoculated with other livefood (such as daphnia, see glossary) after stocking, and then supplementary feeds, such as

soybean meal, cereals, meat meal or mixtures of these materials, should be provided. Fry should be stocked at a density of 100-400 fry/m<sup>2</sup> for 3 to 4 weeks. Final fish weight is 0.2-0.5 g, with a survival rate of around 50-70%.

Tanks of 5-100 m<sup>2</sup> surface area, made of concrete, bricks or plastic, can be used for nursing fry up to 1-2 cm in size. By adding compost and manure, dense populations of zooplankton can be established in these tanks. Large ponds (bigger than 2 ha) have been shown to be better for growing fry. Fry grown under optimal temperature conditions (around 25°C) can reach 500 g in six months. Cooler temperatures result in slower growth.

In extensive aquaculture ponds, a crop of 600-700 kg/ha of market-size fish can be obtained when stocked at 120-200 kg/ha one year earlier.



### INFO BOX: CARP

- Easy to breed and grow
- Fast-growing
- Some marketing and conservation resistance to their use.

### Advantages and disadvantages of common carp (*Cyprinus carpio*) as a candidate species:

#### Advantages

Successfully cultured around the world  
 Survives a wide range of water quality  
 Disease resistant  
 Easily bred  
 Can be grown at high densities  
 Grows fast

#### Disadvantages

An alien and often invasive species  
 Flesh has many fine bones  
 Some cultural resistance in marketing

### Yield of carp in extensive type ponds (from Horvath et al., 2002)

	Stocking		Survival		Yield
	fish/ha	kg/ha	fish/ha	%	kg/ha
From larvae to 1st summer	100 000-200 000	1	10 000-40 000	5-30	200-400
From fry nursed to 1st summer	40 000-60 000	8-15	20 000-35 000	50-60	300-700
From 1st summer to 2nd summer	5 000-7 000	100-200	3 000-4 000	50-70	600-800
From 2nd summer to market size	600-800	120-200	400-500	50-70	600-700

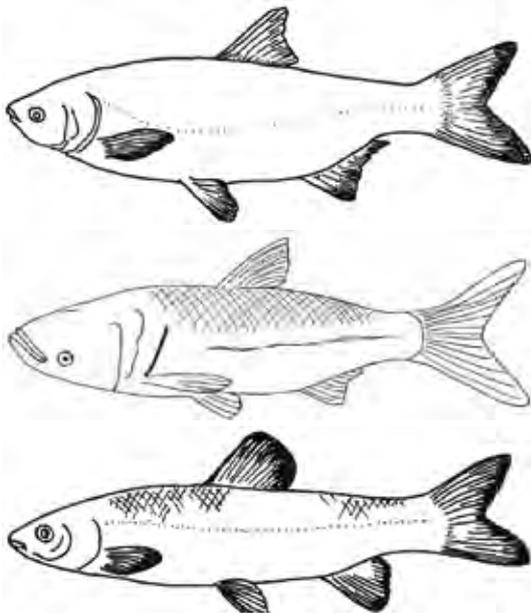
### Feeding

Common carp are omnivorous, preferring to feed on aquatic insect larvae. In poor conditions, artificial feed is added to improve growth rates. To maximize growth, the feed should be of high quality.

### Other carp species

Other kinds of carp, besides the common carp, are grown in ponds. Most commonly used are the Chinese carps. Some of these are –

- Silver carp (*Hypophthalmichthys molitrix*). This fish eats phytoplankton, but will accept rice bran and bread crumbs. The silver carp gets its name from its silver color. It has very small scales.
- Bighead carp (*Aristichthys nobilis*). This fish feeds mainly on zooplankton. It is a dusky green color on top, fading to a pale green color on the abdomen. It has small scales.
- Grass carp (*Ctenopharyngodon idella*). This fish is a herbivore and eats water vegetation (but will eat almost anything). The grass carp is also silver-colored, but has a darker grey area running along the top of the body. It grows larger and has larger scales than a silver carp.
- Other Chinese carps, like the black carp (*Mylopharyngodon piceus*) and mud carp (*Cirrhinus molitorella*), are bottom feeders. This difference in eating habits is very important in fish pond culture. It is the reason why polyculture, or growing a number of different fish species in one pond, can be successful. When one kind of fish is stocked alone (monoculture), the foods in the water that are not eaten by that type of fish are



Silver carp (*Hypophthalmichthys molitrix*); Bighead carp (*Aristichthys nobilis*); and Grass carp (*Ctenopharyngodon idella*).

wasted. In a polyculture of three species of Chinese carp, for example, three kinds of food are being eaten.

### Tilapia

Tilapia are often referred to as the 'aquatic chicken'. This is because tilapia are cultured so widely and successfully around the world that they now occur on every continent apart from Antarctica. Tilapia are even grown in cold climates, such as in the UK, where tilapia farms exist in huge heated warehouses.

Whereas tilapia farming took off just after the Second World War, with *Oreochromis mossambicus* (then called *Tilapia mossambica*) and a few other hybridized species being used, the main species now used for its better growth rates are genetically improved strains of the Nile tilapia *Oreochromis niloticus*.

Tilapia are herbivores, with some species eating plants and others eating phytoplankton. The Nile tilapia do well in very enriched waters (enriched by organic fertilisers). All tilapia have slightly different eating habits, depending on the species.

Tilapia species have many possibilities for pond culture. Their fast growth rates, ease of breeding, good taste and hardy bodies make them a good choice, particularly for the first-time fish farmer.

### Spawning

Once they become sexually mature, tilapia reproduce once every few months. The adults take very good care of their own eggs and fry. If the farmer plans to breed and raise fry, this fish

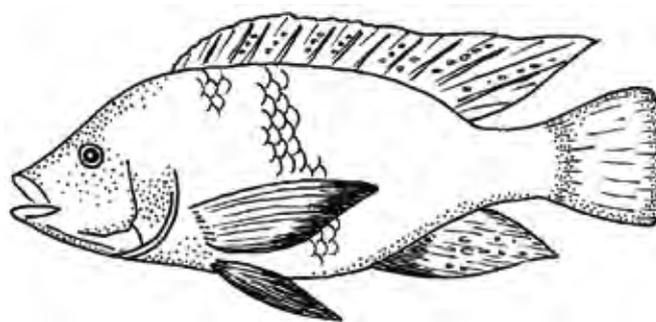


Women in a rural town selling tilapia. This fish has a lot of potential in South Africa as many people prefer eating this species.

**Species of tilapia widely used in aquaculture**

Tilapia species	Years used for culture	Attributes
<i>Oreochromis mossambicus</i>	From 1938 to the 1970s, especially in the Far East and southern Africa	Readily available, but poor growth and over-populates easily
<i>O. hornorum</i> , <i>O. macrochir</i> , <i>O. shiranus</i> , <i>O. aureus</i>	From 1960s to 1980s, especially hybrids in the Philippines and Indonesia	Near all-male offspring produced with better growth
<i>O. niloticus</i>	From the 1960s in Israel, to the present day worldwide	Better growth than other species
'GIFT tilapia' ( <i>O. niloticus</i> in genetically improved strains)	From the late 1980s to the present day; developed in the Philippines	Better growth and colour enhancement to include red colour strains.

is a good choice because the fish themselves take care of the fry at a stage where many fish of other species die easily. However, the wild spawning of tilapia in ponds is an inefficient way to produce fingerlings as no control is possible over production, and variable quantities of mixed-size fingerlings of unknown parentage are produced. The use of circular concrete tilapia spawning tanks, with a central arena for the adults and a peripheral shallow area to attract the juveniles, is preferred (see later section on broodstock and breeding). Another problem with raising tilapia in fish ponds is that they become sexually mature at a small size and begin to reproduce instead of growing. It may therefore be necessary to separate the tilapia by sex before they are old enough to reproduce. Another simple but not very efficient way of controlling unwanted spawning is to introduce a few catfish into the pond to eat the small fish.



Tilapia (*Oreochromis mossambicus*)

**Feeding**

*Oreochromis mossambicus* are used to control filamentous algae, which is a habitat for mosquito larvae, thus the tilapia is used to help with malaria control. Tilapia are omnivorous and will feed on an artificial diet in addition to the zooplankton in the pond.

**Grow-out**

Under monoculture conditions, fry (about 1 g) are stocked into nursery ponds and once they reach 30 g are stocked into grow-out ponds. Stocking density is usually at 1 to 2 fingerlings per m<sup>2</sup>. The pond is then fertilized to maintain high levels of plankton. Supplemental feeding of an artificial diet will improve production. With fertilizing and supplemental feeding, the pond

**INFO BOX: TILAPIA**

- High-potential aquaculture species
- Suitable for pond culture
- Wide market acceptance

**Advantages and disadvantages of tilapia (*O. mossambicus*) as a candidate species:**

**Advantages**

Feed at a low trophic level (they can eat a wide variety of feeds)  
 Are excellent table fish  
 Fast-growing, robust, disease resistant  
 Genetically improved strains have been developed for better growth

**Disadvantages**

Mature early and over-reproduce in ponds, leading to stunting  
 Do not grow well at temperatures below 20°C  
 Lack of local access to better strains

can be harvested after six months and will yield between 1500 and 4000 kg of fish per hectare per year (750-2000 kg per harvest).

At harvest, the percentage of the total pond fish weight is around 70%, with the remaining 30% made up of fry and fingerlings. These smaller fish can be kept back from harvest and added to the pond during the next production cycle.

A yearly production of 15-40 kg of fish in a 100 m<sup>2</sup> pond may not seem like much; however, if it feeds a fish farmer and his/her family, this extra protein is of great nutritional benefit.

### **Rainbow trout (*Oncorhynchus mykiss*)**

Trout is the most well-established aquaculture species in South Africa. It is very popular as a fishing species as well as a high-value food fish. Trout is not native to South Africa and was introduced over 100 years ago by people who wanted to catch them on a rod and line. Since then they have become established in many of our rivers where they have destroyed the local fish species. This is a good example of how important it is to ensure that an aquaculture species that is not local never has the chance of getting into the environment. There are laws to protect this from happening by not allowing trout (and some other species) to be cultured in areas where they are not currently found.

Trout prefer cooler temperatures (12-18°C) and begin to show signs of stress at temperatures above 21°C. The successful culture of trout requires culture systems with plenty of clean, oxygen-rich water. They cannot be cultured in stagnant ponds or those with a slow water-exchange rate.

### **Spawning**

Rainbow trout is easy to spawn and the large fry can be easily weaned onto an artificial diet (they usually feed on zooplankton). However, the hand-stripping of trout to breed them is a demanding job that requires careful planning and considerable equipment to hatch the eggs and rear the fry successfully (see section on broodstock and breeding). Temperature

and food availability influence growth and maturation, causing age at maturity to vary (usually age 3-4 years).

Females produce up to 2000 eggs/kg of body weight and the eggs are relatively large (3-7 mm). In nature, most fish only spawn once, in spring (January-May), although in captivity they can spawn all year round. Trout will not spawn naturally in culture systems; thus juveniles must



Trout need cold water and are commercially grown in South Africa. There is a very good market for this fish. Trout can be processed for added value, e.g. smoked and trout paté.

be obtained either by artificial spawning in a hatchery or by collecting eggs from wild stocks. Trout larvae are well developed at time of hatching.

### **Feeding**

In the wild, trout feed on aquatic and terrestrial insects, molluscs, crustaceans, fish eggs and other small fishes. The natural diet is rich in pigment and this is responsible for the orange-pink colour in the flesh. In aquaculture, the addition of pigments in the fish food causes this pink colouration.

Trout feeds have been modified over the years, with a variety of compact nutritious pelleted diets for all life stages. The pellets are high in

### **Advantages and disadvantages of trout as an aquaculture species:**

#### **Advantages**

- Popular angling, recreational and table fish
- Fast-growing
- Can be cultured at high densities
- Suitable for pond, tank or cage culture
- An established species with good markets

#### **Disadvantages**

- Not tolerant to low oxygen or high temperatures, restricting their distribution
- Susceptible to disease
- Regarded as an alien invasive species by conservation agencies
- Fingerlings only obtainable from hatcheries



fish oil, with over 16% fat. The feed uses fish meal, fish oil, grains and other ingredients, with the amount of fish meal being reduced to less than 50% using alternative protein sources, such as soybean meal. These diets are efficiently converted by the rainbow trout, often at food conversion ratios of around 1:1. Hand-feeding is best when feeding small pellets to small fish. Larger fish are usually fed using mechanical feeders; these can provide set amounts at regular intervals depending on temperature, fish size and season.

#### INFO BOX: TROUT

- A well-established aquaculture species with proven markets
- Can be cultured at high densities
- Has both culinary and recreational attributes
- Obtains high prices at market.

#### Grow-out

Trout eggs are relatively large compared to most other fish eggs. After the fry have hatched and used up their egg sac, they can be fed on an artificial diet. The fry are usually reared in circular fibre-glass or concrete tanks to maintain a regular current and uniform distribution of the fry. Water is sprayed in from the side of the tank to create a circular flow of water. The drain is placed in the centre of the tank and protected by a mesh screen.

Specially prepared starter feeds are fed using automatic feeders when about 50% have reached the swim-up stage. To ensure overfeeding does not occur, hand-feeding is recommended for the early stages, although demand feeders may be more efficient for larger fish. Dissolved oxygen must be monitored as growth continues, with the fish moved to larger tanks to reduce density.

When the fry are 8-10 cm in length they are moved outdoors. (The detailed method of cage-rearing of trout is described in Chapter 11). Typically, individual raceways and ponds are used (2-3 m wide, 12-30 m long, 1-1.2 m deep). Raceways provide well-oxygenated water. The water quality can be improved by increasing flow rates. Fry are stocked at 25-50 fry/m<sup>2</sup> to produce up to 30 kg/m<sup>2</sup> with proper feeding and water supply.

Within nine months, fish are grown to marketable size (30-40 cm), although some fish are grown to larger sizes over 20 months. The

fish are graded (at 2-5 g, 10-20 g, 50-60 g and >100 g) during the first year. Fish quantity and size sampling (twice a month) allows estimations of growth rates, feed conversions, production costs, and closeness to carrying capacity to be calculated; these are all essential considerations for proper trout-farm management.

Another method for growing trout is the use of cages (6m x 6m and 4-5m deep) where fish are held in floating cages to ensure good water supply and sufficient dissolved oxygen. This is a simple method as it uses existing waterbodies rather than flow-through systems. Stocking densities are high (30-40 kg/m<sup>2</sup>). However, the fish are vulnerable to external water-quality problems and predators (rats, otters and birds). In less than 18 months, trout fry of about 70 g can attain 3 kg.

#### Ornamental species

Fish bred for the aquarium (pet-shop) trade are known as ornamental species (as they are pretty to look at, like an ornament). They are not bred as food and are sold per fish rather than by the kilogram. The fish tend to be small (2-15 cm) and therefore the farm areas are small. Although ornamental fish farms are small, they require more technical equipment and knowledge to operate than a pond culture system. However, as ornamental species are sold live, no further processing or storage is required.

The farming of ornamental fish has an advantage over that of food fish in that it can be a very small-scale but still profitable enterprise, and these can operate at the family business level. In the Far East, numerous family-run farms using only one or two ponds and a number of tanks may raise one or more species of ornamental fish to sell live to cooperatives, which then distribute them worldwide. This can be a low-tech industry ideally suited to Africa, where both water availability and specific fish-husbandry skills may be lacking. There is a huge scope for satellite farms to produce both warmwater and coolwater species for the ornamental fish trade. At present, hundreds of boxes of ornamental fish are imported weekly to Johannesburg airport, mainly from the Far East, and opportunities lie in import-replacement for these by local producers.

There are many species of ornamental fish and their culture techniques and methods depend on the species being bred. It is important that fish are of high quality as the pet-shop trade is very fussy about the quality of the fish and will not pay a good price for average or poor-quality fish.



There are hundreds of species that can be farmed in the ornamental sector. Farmers need to know the market before deciding what species to select. Here are two farms, one in Gauteng (far left) and the other in the Northern Cape (left).

The species discussed in detail in this manual are livebearers: guppies, mollies, swordtails and platies. These species are all relatively hardy and easy to keep, all preferring warm water around 24°C. All these species are small compared to the other fish mentioned in this manual, reaching only 5-10 cm depending on the species. These are species that although fairly easy to produce, do not fetch a high price, as they are mass-reared in the Far East and thus imported at relatively low prices. In some circumstances, a better return could be made by culturing higher-value fish, which then need to be sold to specialized outlets that trade in these species.

### Spawning

The males and females are placed in a fish tank where they mate. As their name suggests, livebearers give birth to live young, which means no problems with trying to incubate eggs. As the young are born they are able to swim, feed and fend for themselves. However, if there is nowhere for the babies to hide, the adults will eat them as they are born. It is therefore very important to provide cover, such as weed or artificial shelter, for the babies to swim into. Daily inspection of the tanks will reveal the presence of babies which can be netted out and moved to another grow-out tank or pond. The pond should be inside a greenhouse to help raise temperature and control predators.

### Feeding

Juveniles will feed on an artificial diet (33-35% protein) or homemade diets using fishmeal, beef heart, and liver. The fish will also feed on the

natural zooplankton in the pond. Adults are fed a formulated diet or flake at a ration of 3-10%, depending on size and species. The food should contain pigments to enhance the bright colours of the fish.

### Grow-out

Size grading should be performed often to remove stunted individuals. Sex-sorting should be done when the fish start maturing in order to prevent uncontrolled spawnings which not only reduce the quality of the fish (due to inbreeding) but also slow down the growth rate (as the fish put energy into reproduction rather than growth).

In indoor ponds stocked with juveniles, survival up to market size is greater than 70%. If fed regularly and maintained at their optimal temperature, livebearers reach market size in three months. Care must be taken during harvesting as the fins and scales are easily damaged, reducing the quality of the fish. Before selling it is necessary to grade the fish and assign them to different levels of quality (colour, shape, size) such as high, medium and poor. A better price can be obtained for high-quality fish compared to medium-quality fish. Poor-quality fish should be culled (killed).

Before packing, the fish should be starved for 48 hours. This is to reduce the excretion of feces into the water during transportation. The fish should be packaged in sealed plastic bags with added oxygen and shipped in insulated boxes (to reduce the change in temperature). If packed properly the fish can survive for up to 48 hours.



Examples of higher-value ornamental fish: cichlids from Lake Victoria (far left) and Koi (left).

### INFO BOX: ORNAMENTAL FISH

- Numerous species
- Marketing established
- Small-scale ventures can be viable
- Relatively sophisticated infrastructure required
- Requires lower volume of water than food-fish aquaculture.

### A summary of good candidate fish species for local aquaculture:

Algae-eaters	Silver carp <i>Hypophthalmichthys molitrix</i> ; milkfish <i>Chanos chanos</i> ; mullet <i>Mugil cephalus</i>
Zooplanktivores	Bighead carp <i>Aristichthys nobilis</i>
Plant-eaters	Grass carp <i>Ctenopharyngodon idella</i> ; tilapia, <i>Tilapia rendalli</i>
Carnivores (predatory fish that eat other fish)	Sharptooth catfish <i>Clarias gariepinus</i> ; rainbow trout <i>Oncorhynchus mykiss</i>
Omnivores (eat small animals and plants)	Catfish species, <i>Clarius</i> spp.; common carp <i>Cyprinus carpio</i> ; Crucian carp <i>Carassius carassius</i> ; <i>Oreochromis</i> spp.; <i>Tilapia</i> spp.
Ornamental species	<i>Poecilia</i> spp.; <i>Xiphophorus</i> spp.; numerous cichlid species, livebearers and egg-layers



## Frequently asked questions

Q: *Can I grow tilapia on the Highveld?*

A: In summer all parts of South Africa are suitable for growing tilapia if the water is over 20°C. However, winter water temperatures that fall below 13°C will kill farmed tilapia, and they will not grow well at temperatures below 18°C. Thus, only a summer 'crop' can be harvested on the Highveld. The use of hot-house tunnels make tilapia farming more geographically widespread, however.

Q: *Where can I grow trout in South Africa?*

A: Trout need abundant cool running water to thrive, thus the higher, well-water regions of the Mpumalanga escarpment, KwaZulu-Natal Drakensberg mountains, Eastern Cape Amatola and Drakensberg highlands, and the upland regions of the Western Cape are the best regions for trout. Other more localized regions suitable for trout are the Magaliesberg hills in Gauteng and parts of the southern Cape.

Q: *Are barbel *Clarias gariepinus* really an attractive aquaculture species?*

A: Yes, and no. They have good culture potential in that the techniques have been well documented, but market acceptance still remains a challenge. Be cautious of this species at present until potential markets become more reliable.

Q: *Is ornamental fish culture highly specialized and complicated?*

A: No, if this was the case how is it that in the far East thousands of rural farmers make a living from it? Ornamental fish culture can be done in simple small earth ponds, in the warmer parts of the country. Coldwater ornamental fish (goldfish and koi) can be cultured almost anywhere in South Africa.

Q: *How can I get into ornamental fish culture?*

A: It is the marketing that has to be well-organised and the cooperative approach works best. Ornamental aquaculture is well-suited to the concept of 'aquaculture zones' where numerous small-scale fish farmers pool their resources and market their product collectively to a central buyer who will help with technical advice and may even help with the harvesting and collection of the product.

Q: *What is the potential for other species?*

A: Any fish species not indigenous or present in this country has to pass a 'conservation risk assessment' with the various nature conservation departments. The protocols for this have not yet been worked out; therefore, it is unlikely that other exotic species have realistic potential at this stage.

Q: *Is the production of fingerlings for sale to others a realistic aquaculture option?*

A: If they can be proven to be of superior quality, available in sufficient quantity and at an affordable price, yes. There is a need for the production of quality fingerlings, and the aquaculture industry cannot start without this reliable source of 'seed'. There is considerable potential for the production of mono-sex tilapia, red-colour forms of tilapia and even possibly Nile tilapia and catfish fingerlings; however, this form of aquaculture is technically demanding.





## Chapter 4

# Types of fish farms: ponds, cages and tank systems

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### **Pond design and construction**

The design and construction of ponds is very important if a fish farm is to operate properly. Ponds are earthen impoundments for holding aquatic species and have been used for thousands of years. Ponds can be holes in the ground (sunken pond), a dammed-off valley or stream bed (barrage pond), or constructed above ground (embankment pond).

Before constructing a pond, the questions in Annexure A should be answered. If a farmer can answer positively to the questions relevant to him, he will have a good chance of having a successful fish pond.

A number of factors need to be considered when designing a successful pond –

- The type of soil;
- A reliable source of good-quality water (ideally gravity-fed and gravity drained);
- The size, type, number and shape of ponds;
- The species to be cultured and the stages of its lifecycle.

How these factors affect the choice of pond construction will be discussed next.

### **Type of soil**

The type of soil available to construct the pond is of the utmost importance if the pond is to hold water, maintain water quality and not fall apart. The soil properties that must be considered for pond construction include:

- Physical – The texture, strength, stability and water-holding ability (such as clay) of the soil.
- Biological – There must be sufficient organic matter (some topsoil) to provide nutrients to the pond ecosystem.
- Physicochemical – The chemical reactions that take place in the soil must be beneficial to the organisms and fish in the pond.

The most important ability of soil is its ability to hold water. Clay soil is the best for a pond as it holds water the best. A farmer can tell a lot about the soil simply by feeling it. If it feels gritty or rough, it probably contains a lot of sand. If

it feels smooth and slippery, it probably means there is a lot of clay in it. Smooth soil is best for a fish pond.

A good way to tell if the soil is right for a fish pond is to wet a handful of soil with just enough water to make a ball in your hand. Then squeeze the soil and if it holds its shape when you open your hand, it will be good for constructing a pond. The more clay in the soil, the better it is for building a pond. If the soil is sandy, or does not contain much clay, the farmer can still build a pond but should seek advice. If the soil is rocky or has shifting sand, etc., only small ponds should be built.

The soil also helps the pond to remain fertile. The fertility of the pond is a measure of its nutrients and basically means how much natural food there is available in the pond for the fish to eat. A very fertile pond is one that contains a lot of natural food. Soil contains some of these necessary nutrients, such as iron, calcium and magnesium. Soil also contains acids that are often harmful to fish. Whatever a soil has in it will seep into the water and thus come in contact with the fish. Sometimes after a heavy rainstorm, there are big fish kills in new ponds. This is because the heavy rain carries larger amounts of acids from the soil into the pond. So the farmer who is aware of the kind of soil he has for his fish pond can prevent this problem before it happens.

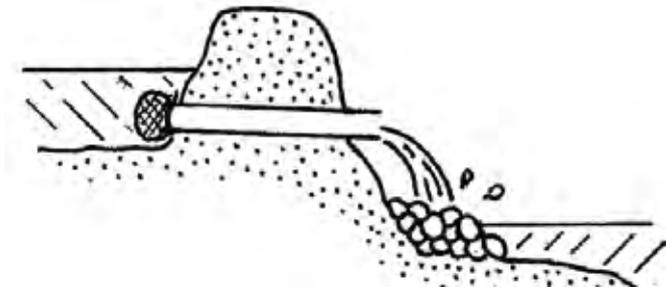
A good indicator of the quality of the soil is whether it can or has been used for growing crops. If crops grow well in that location, the soil will probably be good for the fish pond. If crops were grown before the nutrients were used up, then it will probably still be free of harmful substances.

If small ponds are to be constructed in an area where the soil is unsuitable, plastic-lined ponds can be used in which suitable soil substrates are added to provide the function of soil.

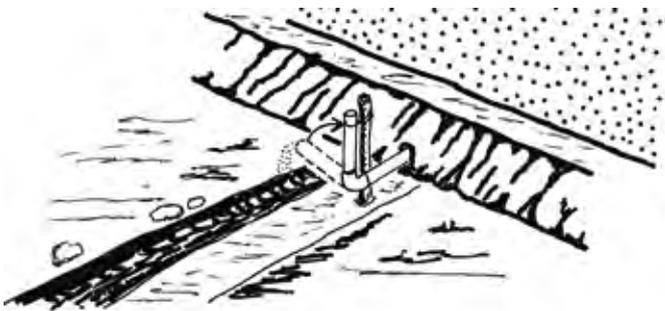
### **Water availability and quality**

There must be sufficient water available to





Pond inlet with screen and rocks to prevent erosion of the pond wall



Pond outlet using an up-stand pipe that is swiveled down to drain the water. The opening of the pipe should be covered with a screen to prevent fish from escaping when draining.

ensure the ponds are always full when holding fish. If water is only available for part of the year, production should be restricted to fall within the same period. As the fish grow they will require more food and in turn will produce more waste. This will change the biological load on the pond and more water may be required to maintain good water quality. As a result, more water may be needed for water changes at the end of the production cycle than at the start. It is important not to build a pond in an area where flooding occurs, otherwise the fish may escape during the flood and the pond walls may be damaged due to the fast-moving water.

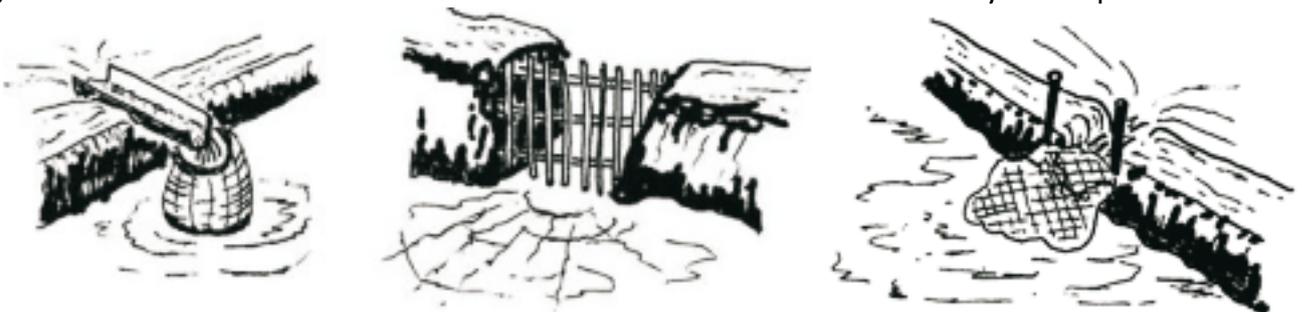
The quality of the water must be good enough to keep fish and it may need to be treated before being used. If water is obtained from a river or

stream it is important to check that there is no one upstream who uses the water for washing and/or that no pollution is added to the water before reaching the pond. One should also check that anyone using the river below the pond will not suffer due to a lesser amount of water being available to them once the pond is filled. Suspended solids should be filtered or allowed to settle out using a settling tank; this slows the water down and allows the small particles in the water to sink before they reach the pond. The design of filters and settling ponds is beyond the scope of this manual; however, information is available in the list of useful reading resources.

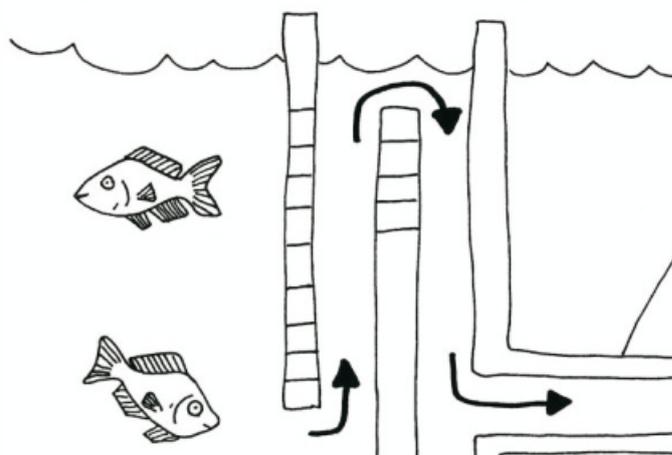
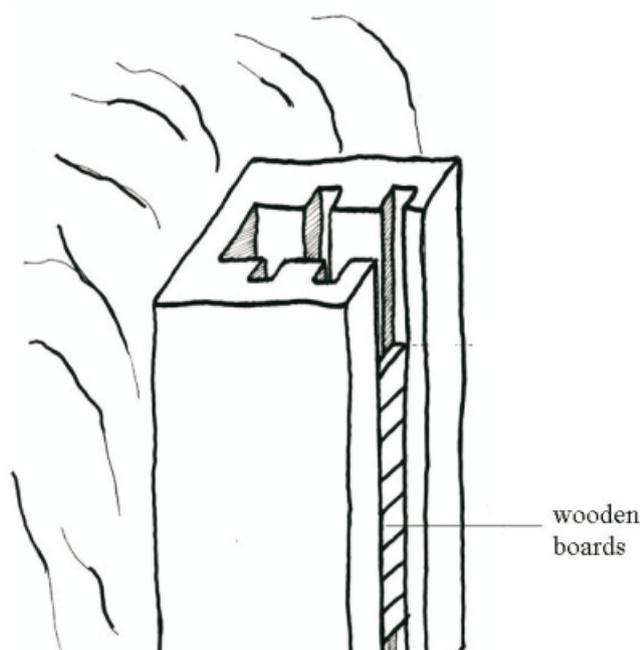
Supplying the water to the ponds is best performed using gravity, meaning the natural movement of water from a high point to a lower point without the need for pumping. The ponds should therefore be designed to have the water supplied from the higher ground and allow for drainage to the lower ground. The way the water is supplied to the ponds needs to be carefully considered as it is best to use the shortest route possible to save on pipes and channeling. It is best if the water supply can be controlled from a single source (such as a dam). The amount of water entering each pond can be individually controlled using valves, boards or pumps (in non-gravity fed ponds). Water entering ponds should be filtered to prevent predators (such as platanna frogs, or other fish), competitors, or vectors for disease (such as snails) from entering. This can be achieved by placing a nylon sock (stocking) over the inlet pipe or building a screen/filter box into the water channel.

The bottom or side of the pond where the water enters should have stones, bricks or concrete placed below the inlet to reduce pond erosion by the water entering the pond.

Outlets usually consist of upstand pipes or weir gates (monks). Monks are vertical control boxes made of concrete or wood. The level of the water in the pond is controlled by adding or removing wooden boards that slot into the monk. The weir gate should be constructed from concrete to ensure stability of the pond. Water



Variety of screens placed at pond inlets: basket, sticks and mesh bag.



Pond outlet using a monk. The level of the water is determined by the height of the wooden boards, which can be added or removed.

should always be removed from the bottom of the pond in order to remove the oxygen-poor, nitrate-rich water. Both upstand pipes and weir gates allow water to be removed from the bottom of the pond.

### Pond designs

Depending on the desired use, ponds differ in their size, shape and layout. Ponds may be of any size or shape, although embankment ponds are usually rectangular as they minimize the space between adjacent ponds by having a common wall. Typically, the length to width ratio is 2-3:1. The advantages of small and large ponds are outlined in the box below.

Fish grow bigger in larger ponds even when the stocking densities are the same as in small ponds and the management of the ponds is identical. This means that the weight of fish produced per hectare in a 0.5-ha pond may be almost double than that produced in a 0.1-ha pond. The reason for this is that large ponds have a larger surface

area and are more often subjected to wind action, which results in more oxygen entering the water and the water being mixed better.

Although large ponds are preferable, they are more difficult to fill, drain, harvest and maintain. Therefore, the optimal size and shape



### INFO BOX: HOW TO CALCULATE POND AREA IN HECTARES

- Pace out two sides of the pond, using fairly long paces of approximately 1 m;
- Multiply the one side by the other to get the number of square metres in surface area (assuming the pond is roughly rectangular);
- Divide your result by 10 000 m<sup>2</sup> (one hectare) to calculate the area in hectares.

Example: 50 x 40 paces = 2 000 m<sup>2</sup>.  
2 000 divided by 10 000 = 0.2 hectare

### Advantages of small and large ponds:

#### Small ponds

Easier to net and harvest fish;  
Easier to manage, maintain and treat for disease;  
Not eroded by the wind easily.

#### Large ponds

Cost less to build per hectare of water;  
Better production possible per hectare;  
More stable – less prone to temperature fluctuations;  
Have more oxygen available for fish.

### INFO BOX: EXAMPLE OF HIGHER GROWTH RATES USING LARGER PONDS

**Example 1:** 1-ha pond (1 000 m<sup>2</sup>) is stocked with 1000 fish fingerlings that are harvested after 6 months at an average mass of 250 g each. A total of 250 kg of fish is harvested (assuming 100% survival), amounting to 2.5 tons/ha production.

**Example 2:** A much larger pond of 0.5 hectare is also stocked at the same stocking rate, with 5 000 fingerlings, and harvested after 6 months at an average mass of 320 g each. A total of 1 600 kg of fish is harvested, amounting to 3.2 tons/ha production.

**Example 3:** A 1-ha pond is stocked with 10 000 fingerlings and harvested after 6 months at an average mass of 450 g each. A total of 4 500 kg of fish is harvested, amounting to 4.5 tons/ha production, nearly twice that of the first example.

of the pond will depend on the practicality and management available to make it large enough to grow fish but small enough to manage properly. The recommended maximum size for ponds for edible fish like tilapia or catfish is 1 ha. Quarter-hectare ponds (50 m x 50 m) are very effective and manageable in small-scale farms. For ornamental fish, ponds can be as small as 5 m x 5 m and only 0.5 m deep.

The design of the walls of the pond should be done with the help of an engineer. The wall design needs to consider the height and the slope of the wall. Because the pond is not filled to the top, the height of the wall must consider the desired depth of water plus the freeboard (the additional height above the water to the top of the wall). Ponds are generally between 0.8 m to 1.8 m deep as this –

- allows for light to penetrate the water thereby allowing the growth of plants and algae;
- reduces temperature fluctuations; and
- reduces the chances of thermal and oxygen layering of the water.

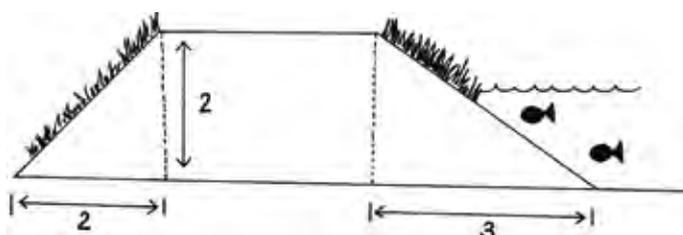
The penetration of light depends on the clarity of the water. Therefore, ponds with clean water can generally be deeper than those with dirty water. If plants are to be grown on the bottom of the pond, it should be shallow enough to allow for the penetration of light to the bottom.

Stratification (layering) occurs when the water is too deep and mixing cannot occur properly. This results in warm water on the top (heated by the sun) and cold water near the bottom. The levels of oxygen may also be high near the top and low (or even zero) near the bottom. It is obvious that low or zero oxygen levels are not good for the fish in the pond as many species prefer to live near the bottom and so this may result in large fish kills. Another problem that may occur when the oxygen level drops too low is that the bottom of the pond may start to rot. As it rots, it will release hydrogen sulfide (H<sub>2</sub>S) (which smells like rotten eggs), poisoning the water above it,

thereby killing all the fish. Therefore, it is not a good idea to build ponds deeper than 1.8 m unless sufficient mixing of the water through aerators or uplift pipes is used.

The soil in new ponds will settle by up to 10% depending on the soil type. Therefore, the wall should be built an extra 10% higher to account for soil settlement. The walls of embankment ponds need to be strong enough to hold the water. As it is expensive to move large amounts of earth, the dimensions of the walls should ensure the pond is strong enough without taking up unnecessary space. When building the walls, the dimension ratio should be 1:1 (vertical-horizontal) on the inside pond wall and 2:3 on the outside wall, as illustrated below. Erosion protection should be introduced (such as plants above and stones below the waterline). Grass should be planted on the outside embankment wall to reduce erosion. Ponds that are to be used for growing small fish should have a small wall or plastic (smooth) fence (50 cm high and 10 cm buried) built all the way around the pond to prevent predators from entering. Above this should be wire netting to keep out larger predators such as otters and leguaans. If platanna frogs get into the pond they will quickly eat many of the baby fish.

The top width of the wall should be wide enough to allow access along the length of the pond. Depending on the size of the pond, vehicles may be required to drive around the edge, and equipment may need to be installed. The walls must therefore be wide and strong enough to carry the load.



Suggested ratios of pond walls.



The bottom of the pond should be cleared of any trees and bushes, which may snag on nets during harvesting. The surface should be smooth and graded at a slope of around 5% (5 cm vertical per 1 m horizontal). Channels can also be dug (30-50 cm wide, 10-20 cm deep) to help drain the pond when emptying it. The water can be channeled and collected in a harvest sump, usually about 10-20 cm deep with an area of around 1% of the pond.

The pond should be built to suit the requirements of the species to be cultured. For example, shallow ponds are better for grass carp as the growth of plants on the bottom will only occur if the light can reach the bottom of the pond. If ponds are used for holding cages of tilapia broodstock, they should also be shallow enough to allow the breeding cages to be easily staked into the soil. Ponds used for the later stages of carp or tilapia grow-out can be deeper



A channel through the middle of the pond can help with draining the pond and harvesting fish.

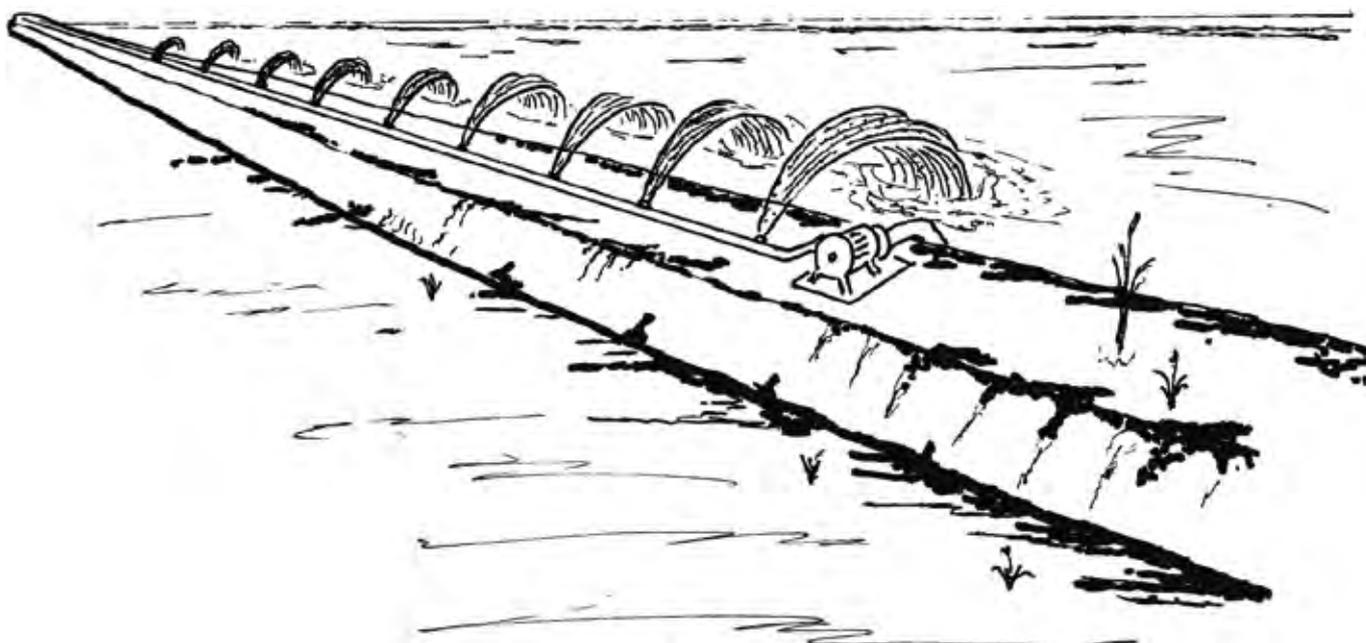
(max 1.8 m) as this increases the amount of water available to grow fish, thereby increasing production.

If the pond is to be stocked with high densities of fish, it is important that additional aeration is provided as the dissolved oxygen levels are likely to drop below the minimum level required for the fish to survive. Aeration can be increased using paddlewheels, spray-bars or aerators. If possible, these should operate all the time to maximize the amount of dissolved oxygen available to the fish, although the critical time is usually in the early hours of the morning up till sunrise when oxygen levels are at their lowest.

### **Predator control**

Predators such as birds, frogs, otters, snakes and lizards may eat many small fish, thereby reducing the number of fish available at harvest. If predators are found in the pond they should be removed and released far away from it. Fences may need to be installed around the edge of the ponds to prevent predators from entering. The screens over the inlet and outlet should also be checked to see that they are not damaged and thereby allowing predators to get through.

It is more difficult to prevent birds from eating the fish as they can fly over fences. One method is to cover the pond with bird- or hail-net, however this can be expensive and is sometimes not practical over larger ponds. Another option is to stretch fishing-line or wires across the pond by tying it to poles along the edge of the bank. The lines shine in the sun and some birds are scared that they will fly into it.



Spray bar for increasing the amount of dissolved oxygen in the pond. The water is pumped from the pond and sprayed back in.

Birds can also be chased using hooters or sirens. It is important that these noise devices are set to go off at random times and for varied durations otherwise the birds will get used to the noise and it will have no effect on chasing them away. The shooting of all birds that may prey on fish is not a realistic option.

### ***Pond construction by cooperatives***

Often fish ponds are built by a number of people who work together and share the benefits of the pond. A cooperative is an organization of people who come together to do something they could not or would not be able to do alone. For instance, this could allow four or five people or families to pool their resources and build a fish pond operation together. Sometimes an entire village may form a cooperative to build and operate a pond or group of ponds. This kind of cooperation makes better pond construction and management possible. A fish pond cooperative may be a good way for a village to improve the diet or income of the community and also to sell enough fish to maintain the enterprise. If the farmers in your area are not interested in, or are concerned about, building ponds individually, a cooperative may be an acceptable idea.

### **Tanks and raceways**

Tanks are generally smaller than ponds and are constructed above the ground. They are not in contact with the soil and tend to have a solid base (usually concrete) making them usable both indoors and outdoors. Tanks vary in size and shape depending on their use (e.g. culturing phytoplankton or larval fish) and can range in size from a few liters to hundreds of cubic meters.

Raceways are simply long tanks that are continuously supplied with water. They are usually long and narrow and allow for a high exchange of water. A common use of raceways is to hold large numbers of juvenile fish which require good water quality.

Tanks and raceways are typically constructed from either brick or concrete and are long-lasting and durable. More recently, circular tanks are made of various types of plastic, often

supported by a steel-mesh galvanized frame. Some of these tanks are made for domestic water storage and are black in colour. This makes the fish impossible to see and thus is not desirable, and these tanks are often too deep. Many of the pale blue-coloured tanks contain a fungicide in the vinyl to prevent algae and mould, and this is toxic to the fish. Plastic tanks should ideally be a pale colour, and not deeper than 1.2 m.

As tanks are relatively small waterbodies with none of the self-purifying water qualities of earth ponds, they can produce only small quantities of fish without filtration of the water. For example, a plastic water tank of 10 000 litres (the largest domestic water tank typically sold on the market) can only produce about 10-15 kg fish per year without filtration or exchange of water.

Raceways are usually used for the production of trout, although now tilapia and catfish are also grown in raceways in some countries using sophisticated management systems. These systems require large volumes of clean water to pass through the system continuously to sustain the high density of fish held therein. Raceway aquaculture is generally high-tech and high risk, although the production per unit area is also very high.

### **Cages**

Cages can either float in the water or be staked into the ground of the pond (in shallow areas of water). They are usually used between tank and pond culture as they make use of the pond water while still maintaining the control of a small area. There is therefore no control of the water quality when using cages and the water in which they are placed must be suitable for the species cultured. The mesh of the cage should be small enough to prevent the fish from escaping yet large enough to allow water and waste to pass through to the outside.

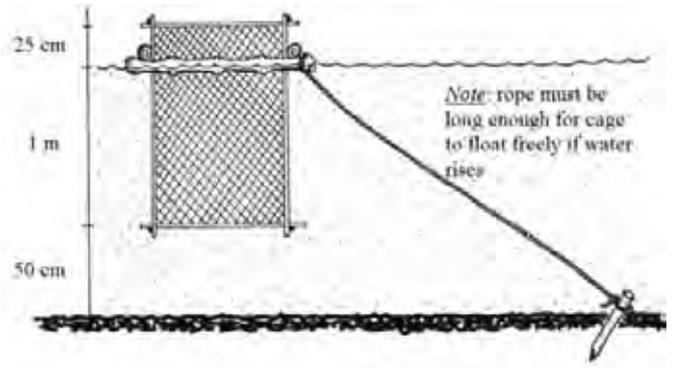
Small cages (such as those illustrated below) are often used in the Far East for ornamental fish culture as many different species of fish can be housed separately in one waterbody without



Bird netting protecting ponds (far left), and platanna frog and otter protection surrounding ponds (left).

becoming inter-mixed. These cages are called 'hapas' and may be as small as 1 cubic metre.

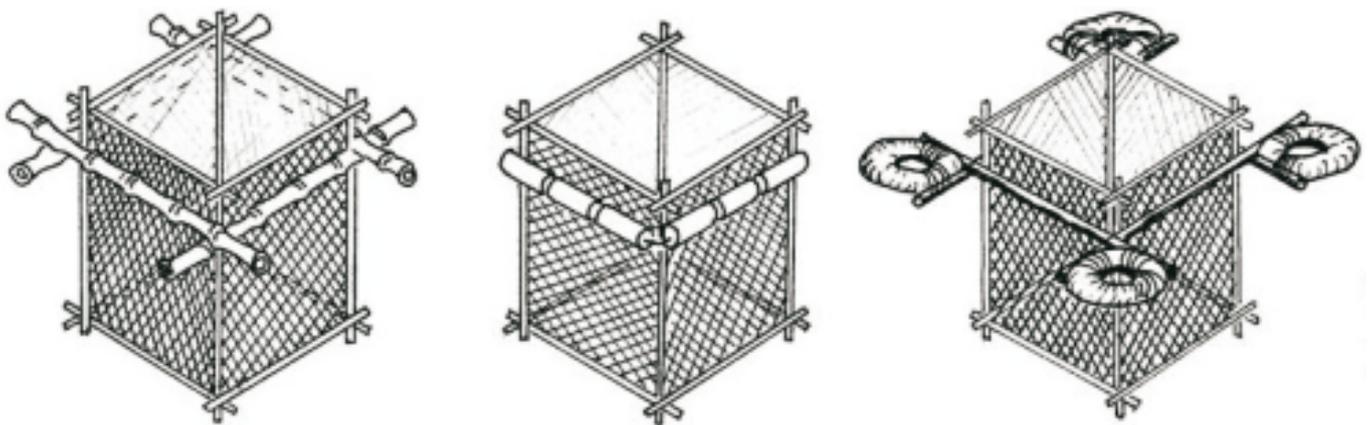
Cages used in large open waters such as in dams, lakes or the sea must be strong enough to handle rough weather and be easy to access, clean and harvest from. Floating cages should be secured to the bottom or side of the pond to prevent them from drifting away in rough weather. Predators (e.g. otters, leguaans, other large fish) may be a problem as they make holes in the cages and allow the fish to escape.



Attachment of a floating cage to the bottom of a pond.

**INFO BOX: EXAMPLE OF WATER REQUIRED TO REAR 1 TON OF 500 g TILAPIA**

- 1000 kg fish at 0.5 kg each = 2000 fish needed.
- 2000 fingerlings stocked at 1 m<sup>2</sup> need 2000 m<sup>2</sup> surface area of pond.
- A 2000 m<sup>2</sup> pond is required, measuring approximately 45 m x 45 m.
- The depth is on average 1 m deep.
- The pond takes 2000 cubic metres (2 million litres) of water to fill it.
- Evaporation and seepage may double this over the growth period.



Examples of floatation devices for cages: wood (or sealed pipes), polystyrene, and car-tire tubes.

## Frequently asked questions

Q: *Can I grow fish in a concrete or plastic water-storage tank?*

A: Not economically; fish tanks are best purpose-built, as they must be shallow, drainable, have clean water (preferably filtered) and be large enough to produce economically viable quantities of fish. One tank does not make a fish farm!

Q: *Can I do aquaculture in a farm dam?*

A: Not unless the dam can be drained and managed like a farm pond. However, you can utilize a dam for cage-culture.

Q: *Does one need heavy machinery to make earth ponds?*

A: Small ponds of 10-50 square meters can be made with hand labour, however a tractor with a blade or a dam-scoop can make ponds of up to 0.25 hectare in area or larger. For large ponds, and major earthmoving, a bulldozer may be required.

Q: *Is a filtration system necessary?*

A: Extensive or semi-intensive earth ponds are generally unfiltered. Many raceway systems are flow-through with no filter. Where water volume is limited, or the fish are cultured intensively, a filter becomes vital to maintain water quality. Fish cannot be grown in small tanks (<5000 l) of stagnant water without filtration or flow-through.

Q: *How much water does one need?*

A: This is a function of stocking density, food input, fish density, water quality, water replacement rate and filtration (if any). In semi-intensive ponds, a stocking density of 1 fish per m<sup>2</sup> water surface area is a rough guide (see Info box on page 25).

Q: *Is predator protection vital or a luxury?*

A: It is essential to have protection against animal predators as they can reduce stocks to almost nil if allowed unlimited access to the ponds or tanks. Fish farms in areas near human habitation also need protection against theft of the stock (fencing and alarms) if the fish stock can be easily stolen, which usually happens at night.





## Chapter 5 Water quality

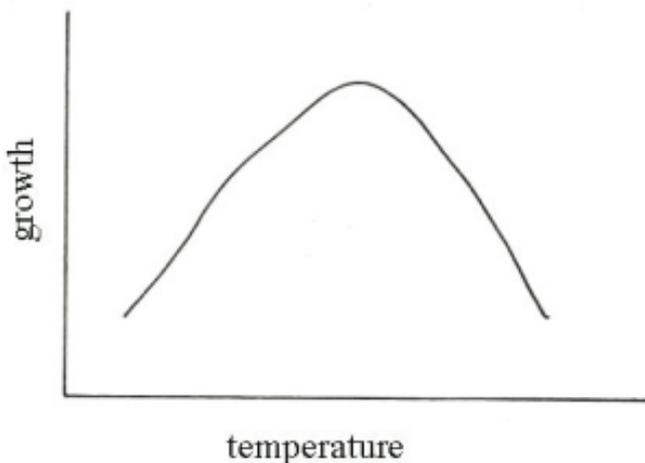
### The parameters of good water quality

Good water quality is essential to the health of fish at all stages of development. Water-quality requirements differ between species and between the different life stages as the fish develop. Many of the water-quality parameters are interlinked and a change in one feature can have an effect on another. Therefore, it is important to understand the various parameters that may affect the health of cultured fish.

#### Temperature

Temperature is the hotness or coldness of something and is probably the most important water-quality variable. Unlike mammals, fish are not able to regulate their own body temperature and therefore have a body temperature similar to that of the water around them. Therefore, all fish have a minimum and maximum lethal temperature limit. Temperature affects growth rate and feed conversion rate, with each species having an optimal temperature for growth (see box on page 28). Temperature also affects the metabolism and reproductive ability of fish.

Because temperature is difficult to change or control in large ponds, it is important to know what the annual average water temperature is for the region. Species that have a temperature range within that of the region's average water temperature are suitable for culture in that



The effect of temperature on fish growth.

region. If fish are moved between ponds they should never be moved without checking that the two ponds are the same temperature. If they are different, it is important that they are allowed to get used to the new temperature by floating the container holding the fish in the new pond until the two temperatures are the same. When new water is being pumped into a pond it is important to check whether the temperature

#### INFO BOX: TEMPERATURE CHANGES ACCEPTABLE TO MOST FISH

- It is safer not to move fish into water more than 2°C different from that which they came from.
- It is safer to move fish to slightly cooler water rather than warmer water, as it contains more oxygen which will assist the fish in overcoming the stress of handling.

of the new water is similar to that of the pond water. If not, the new water should be added slowly to allow the fish to get used to the new temperature over a long period of time. If this is not done, the fish may suffer from temperature shock, which can stress them and result in the death or sickness of all the fish in the pond.

Pond water temperature can be managed by using simple methods, such as covering the ponds with shade-cloth or allowing cooler water to enter when the temperature gets too warm. In South Africa, it is only trout that are often killed or stressed by temperatures that are too high (>23-25°C) in open pond or tank conditions. Tilapia, carp and catfish thrive in warm ponds of up to 33°C. Tilapia are more adversely affected by too low temperatures, and usually die if the water goes below 12-13°C for lengthy periods. Carp and catfish are tolerant of a wide range in temperature.

#### Dissolved oxygen

Like humans, fish also use oxygen; however, the oxygen available to them is that which is dissolved in the water and is measured in mg/l. Naturally, oxygen enters the water through the surface of the water and the amount that



### Water-quality variables for optimal growth of local aquaculture species:

Species	Optimal temperature range	Minimum dissolved oxygen per pH range
Catfish	25–33°C	3 mg/ℓ at pH 6–8
Tilapia	20–35°C	3 mg/ℓ at pH 6–8
Carp	23–30°C	3 mg/ℓ at pH 6.5–8.5
Trout	12–18°C	5 mg/ℓ at pH 6.5–8.5

is capable of entering the water can also be expressed as the percentage of saturation (% saturation), where 100% would be found in clean water with no fish. The level of dissolved oxygen and % saturation can be measured using a digital probe.

As the fish and other organisms (bacteria, plants, etc.) in the water use the oxygen, the % saturation decreases as the oxygen in the water is used at a rate faster than it can enter from the air. Generally, the surface layers of the water have higher levels of oxygen compared to deeper water. In cases where there is little mixing of water in ponds, the water in the bottom of a pond can have no oxygen. This can be very dangerous as fish cannot live in these waters and may die if the concentration of dissolved oxygen in the remaining water also drops. Therefore, in an effort to increase the amount of dissolved oxygen available throughout the pond's water we try to increase the surface area of the water across which the oxygen can enter from the air. This can be done using aerators, paddlewheels and air-stones and, in cases where none of these are available, by beating the water by hand.

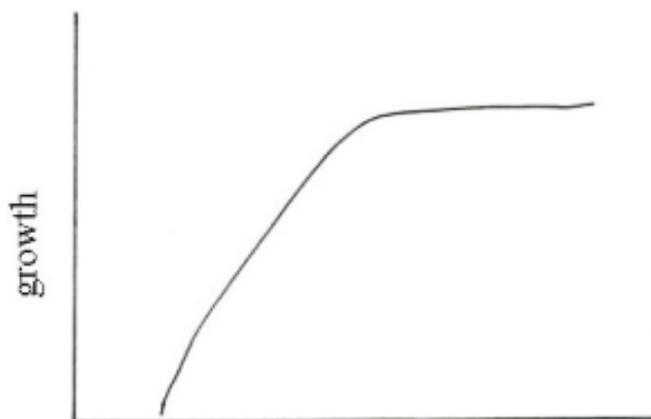
The amount of dissolved oxygen available to the fish depends on:

- water temperature,
- the height above sea level of the pond (with higher oxygen levels at lower altitudes), and
- the amount of salts dissolved in the water (with the highest oxygen levels having no dissolved salts).

A normal dissolved oxygen level is approximately 7-9 mg/ℓ in 25°C freshwater at sea level. Most fish prefer a minimum dissolved oxygen level of 5 mg/ℓ; however, some, like catfish, are capable of breathing air and can be maintained (for short periods) at low oxygen levels. It must be mentioned that although many fish species can tolerate low levels of dissolved oxygen (down to 3 mg/ℓ), they will not grow at their fastest growth rate as they need the extra oxygen to convert their food into body tissue.

An extremely important thing to remember regarding water quality is the relationship

between dissolved oxygen concentration and temperature. The amount of oxygen in the water is closely linked to temperature, with lower oxygen levels occurring at higher temperatures. When the temperature of the water increases past the temperature best for the species, the fish will use more energy and thereby create more waste. Bacteria grow quickly in the water, using the waste, which makes the situation even worse as the bacteria also require oxygen from the water. Therefore, when temperature increases beyond the normal range of the species, it is better to reduce (or even stop for a few days) the feeding levels, as this will reduce the amount of waste produced, thereby reducing the amount of oxygen required by bacteria, making more oxygen available to the fish. The amount of oxygen a particular species of fish requires is related to how much energy it uses. For example, trout are active, fast-swimming fish and therefore require higher levels of dissolved oxygen as compared to carp which are slower and more sluggish.

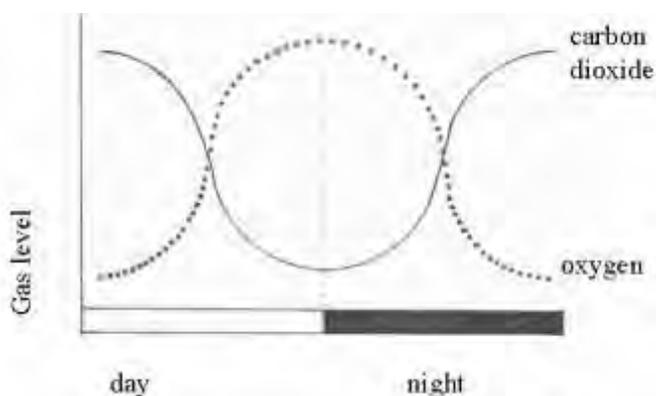


The effect of dissolved oxygen on fish growth.

Plants and algae in the pond will produce oxygen during the day, and then this can be used by the fish. However, at night, the plants, along with the fish, use the oxygen and the levels drop to a minimum by sunrise as no oxygen has been produced overnight by the plants. It is therefore important to check what the level of dissolved oxygen is just before sunrise if fish are found to be stressed in the early morning. If levels

are very low at night then additional oxygen should be introduced at night using aerators and paddlewheels.

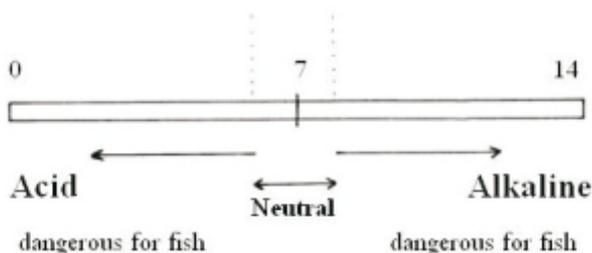
Algae and plants produce less oxygen in cloudy weather as less sunlight falls on the water. Oxygen levels increase during windy conditions as there is more mixing of the air with the water at the water surface. The application of fertilizer to ponds will greatly affect the amount of available oxygen to the fish, particularly during the night. This is because the plants and algae will increase in number due to the extra nutrients and therefore need more oxygen at night. Therefore, good fertilizer practice is very important as too much fertilizer can lead to a shortage of oxygen which may result in the death of the fish.



Dissolved oxygen level changes in the pond during the day and night.

### pH

The degree to which water is acid or alkaline is described by the pH scale, which ranges from 0-14. Acid substances have a pH from 0-7; 7 is neutral (neither acidic or alkaline), and alkaline is between 7-14. A change in one pH unit represents a large change in water quality and fish generally prefer water that is neither too acidic or alkaline and should be maintained within one unit from neutral (pH 6-8). pH can be measured using simple pH test-strips, chemical test kits or digital probes. pH levels can change depending on the amount of oxygen available in the water. At night, plants and algae in the pond use carbon dioxide and make oxygen. Carbon dioxide is acidic and causes the pH of



The pH scale



Water quality



There are a number of different factors that can cause problems for a fish farmer with regard to water quality. In the first case, high levels of nutrients from human activity entered the dam and caused the algae to bloom, causing depletion of oxygen in the water. In the second case, low water temperatures during the night caused the tilapia to die.

the water to decrease. If not carefully monitored and possibly controlled, the pH may drop to levels that are dangerous to the fish. Excess carbon dioxide can be removed from the water by agitating the water using aerators or paddlewheels. Water with low pH affects the fish's gills, making it difficult for them to remove oxygen from the water.

The pH of a pond can change quickly. Heavy rain can carry acid from the soil in the area around the pond into the pond inlet water. This will cause the pH of the pond water to drop. The best way to get the pH back to neutral is to add limestone (calcium carbonate) to the water by spreading it on the surface of the water. Tilapia can tolerate a pH from 3.7 to 10.5, but below pH 5, they are stressed and will not eat.

The percentage of poisonous waste-products (such as ammonia) that is toxic to fish is also dependant on the pH. As pH increases, the percentage of toxic ammonia increases.

**Nitrogenous compounds (waste products)**

Ammonia is probably the next most important water-quality factor after dissolved oxygen. Ammonia comes from decomposing material, such as plants and dead fish. It also comes from the fish as part of their normal metabolism and is excreted through the gills. If large numbers of fish are kept together the levels of ammonia can quickly build to levels that are dangerous to the fish. Ammonia is present in two forms: ionized ( $\text{NH}_4^+$ ) and un-ionized or free ammonia ( $\text{NH}_3$ ). Only  $\text{NH}_3$  is directly toxic and its toxicity increases with an increase in temperature and/or pH, with pH being the most important factor. Ammonia is measured using a water test-kit and is measured in mg/l. In systems where the pH is relatively neutral (around pH 7), ammonia is converted to nitrite then nitrate.

The formation of nitrite ( $\text{NO}_2$ ) is the step between the conversion of ammonia to nitrate. In systems where ammonia levels are high, high levels of nitrite may be found. Like ammonia, nitrite is measured using water test-kits and is measured in mg/l. High levels of nitrite can reduce the oxygen-carrying ability of the fish's blood. This causes the gills to change from red to brown. The problem can normally be corrected by replacing the water or moving the fish.

The final stage of the breakdown of ammonia is the formation of nitrate ( $\text{NO}_3$ ). Nitrate also comes from farming fertilizers that run off the land into the water. Nitrate is generally non-toxic to fish at low levels. Like ammonia and

nitrite, nitrate is also measured using a water test-kit in mg/l. Care must be taken when adding fertilizer to a pond that has low levels of nitrate as the sudden increase may result in the sudden growth of plants and algae. This will cause a bigger drop in the level of dissolved oxygen during the night. To further complicate the problem, if the nitrate supply is not maintained, the plants may die off which will result in a further reduction in the levels of dissolved oxygen due to the activity of bacteria.

**Phosphorus**

Phosphorus is necessary for the pond organisms to survive and is often important in the regulation of algal growth and subsequent food webs in the pond. The level of phosphorus in ponds is usually around 0.05 mg/l. If a large amount of phosphorus is added in the form of fertilizers, sudden algal and plant blooms may occur as well as some phosphorus being absorbed by the mud.

**Pesticides**

Like fertilizers with nitrates, chemicals used by farmers to treat plants against pests may find their way into the water. Care must be taken to ensure that the water running off land farms near to aquaculture farms doesn't have pesticides. Even low levels of pesticides are toxic to fish and many of the other pond organisms upon which the fish feed. Pesticides may be difficult to detect and treat.

## Frequently asked questions

Q: *Do the fish eat the manure or other fertilizer added to a pond, and will this affect their taste when harvested?*

A: No, the fish do not eat the various fertilizers added to the pond. These fertilizers break down to form the food source for microscopic animals (i.e. zooplankton, like daphnia and copepods) and microscopic plants (phytoplankton, like algae) that are eaten by the fish. These are the natural foods that wild fish eat and do not affect the flavour of the fish flesh when eaten by humans.

Q: *Is it possible to over-fertilize a pond?*

A: Yes, if too much is added the pond water becomes anoxic (lacking in oxygen) and the fish will die.

Q: *Do I still have to artificially feed the fish if the pond is fertilized with compost or manure?*

A: To obtain maximum production, yes. Fertilizing a pond may increase production by 30-40% over non-fertilized ponds, but feeding the fish an artificial diet will further increase production by another 30-40% or more. However, if feed is very expensive or unobtainable, then it may be more economic to just fertilize the pond only, and make do with a lower production, but at lower input costs. Each situation is different.





## Chapter 6 Production and shipping

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### **Pond management and maintenance**

The care of the cultured fish (fish husbandry) is one of the most basic aspects of fish farming, yet one which is often almost ignored in many manuals on fish farming. In all aspects of their lives, fish need to be maintained in conditions that allow them to thrive and grow, or to reproduce well. This chapter focuses on how to achieve these conditions.

### **Fertilizing ponds with compost**

Once the pond is full of water there are a few things that need to be done to ensure that the fish will have a place where they will be unstressed and will grow well. Making sure that there is an abundance of suitable food in the water is an important aspect. With tilapia, carp or catfish, making a compost heap can be done while the pond is being built so that it is ready when the pond is ready. Compost is then added to the pond to produce a bloom of zooplankton and phytoplankton, which serves as a food source for the fish.

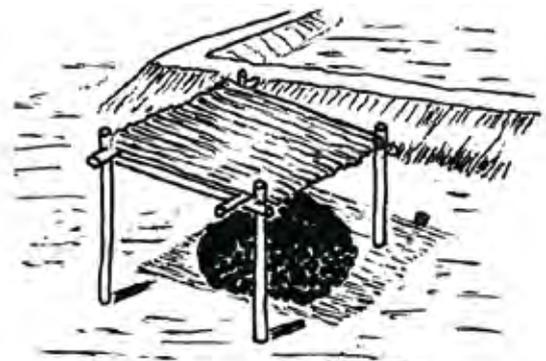
You will need to make a compost heap from where you can remove compost to fertilize the pond. To make a compost heap, find an area near the pond in a shady place protected from the rain. First make a layer of plant material, like cut grass or leaves mixed with a few spades of topsoil. Water it to make it rot faster. Add another layer of animal manure (pig, sheep, cow, goat, chicken or duck) mixed with some soil. Again, add water to speed up the rotting process. Make another layer of plant

material then another one of animal manure, remembering to water as you go. Build many layers until you have a large compost heap to use for fertilizing your pond as well as your fields. If you do not have any animal manure then just use layers of plant material, which can also include waste from home (spoilt fruit, potato skins, cold ash from the fire).

Keep the compost heap damp by watering it every few days. After about a month the compost will have rotted and you can remove the best compost from the bottom or oldest part of the pile. Remember to add new layers to your compost every week otherwise you will run out. If you have too much compost you can use it to fertilize your vegetables in your fields.

A compost cage then needs to be built in one of the shallow corners of the pond to hold the compost. This can be made using sticks and should sit about 60 cm under the water and 1 m from the edge of the water enclosing the corner of the pond. If the pond is bigger than 500 m<sup>2</sup>, two cages should be built, one in each of the two shallow corners or halfway on opposite sides of the bank.

To start, put enough compost in the cages and pack it down well to fill them up to the water level (50-60 kg per 100 m<sup>2</sup> pond area). Be careful not to pack it too hard as you may break the sticks holding the compost in the cage. Afterwards you will need to add 10 kg of compost per week for every 100 m<sup>2</sup> of pond. If



Compost is made from successive layers of chopped leaves, grass, animal manure and a little topsoil. Add water to keep it damp. Keep the compost heap in the shade and near the pond.

you only have animal manure to fertilize your pond you only need 2-3 kg of chicken droppings, or 8-10 kg of pig dung, or 10-15 kg cow dung per week per 100 m<sup>2</sup>. This is because manure is much stronger than compost, so less is needed.

Once you have added the compost or manure the water will start turning green within a week. When it starts turning green it means that the food is growing in the pond and that it should be ready in about a week. To test if the water is ready for fish, put your arm in the water up to your elbow. The water is ready for fish if you can just see the ends of your fingers, as shown below. Putting fish into the pond before it is ready may result in poor growth of the fish due to inadequate food being available.

**INFO BOX: NATURAL FERTILIZERS REQUIRED TO ENRICH A POND PER WEEK**

- 10 kg compost per 100 m<sup>2</sup> pond area
- or 2-3 kg chicken droppings
- or 8-10 kg pig dung
- or 10-15 kg cattle dung.

**Pond maintenance**

Like a farm field, the bottom of a pond must be looked after. Between harvests, pond preparation involves the following steps:

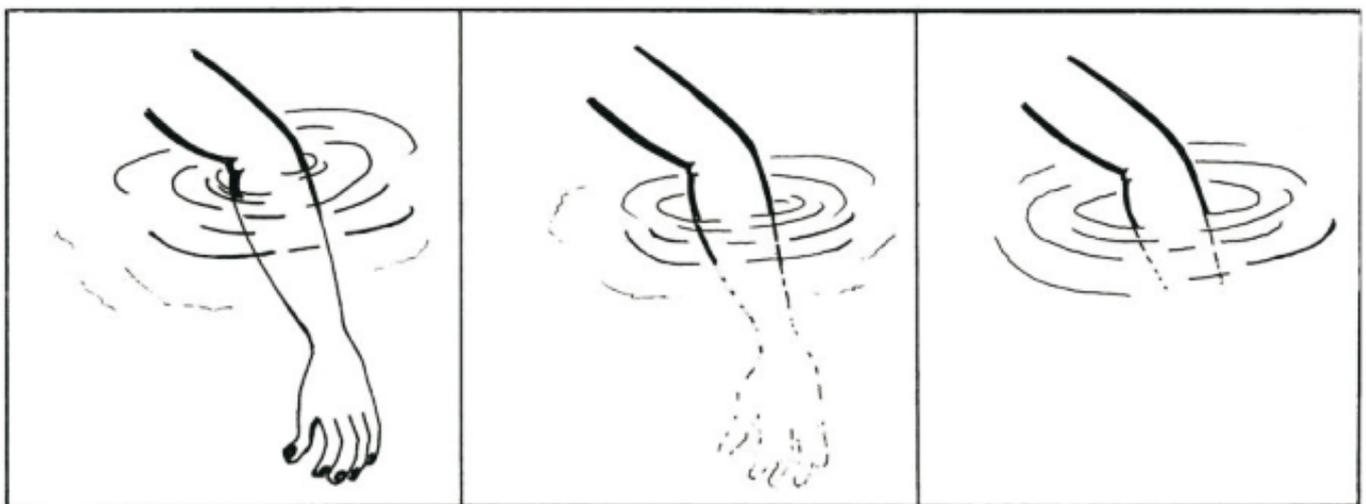
- Draining and drying the pond
- Turning the soil
- Disinfection and liming
- Fertilizing.

The bottom of the pond should be allowed to dry out for 2-4 weeks between harvest cycles. This is to help the bacteria break down the soil. Drying the pond also kills any pathogens and parasites as well as undesirable filamentous algae. Any weeds or plants that are not eaten by the fish should be removed. Removal of the weeds reduces the number of breeding areas for mosquitoes and snails, both carriers of human disease (malaria and bilharzia, respectively).

The soil should then be ploughed, and depending on the health of the soil, compost and chemicals such as lime can be added. The compost provides nutrients for the algae and plants in the next production cycle. Lime is required as it –

- conditions the soil and makes it suitable for keeping fish;
- corrects the pH of the soil (if applied properly);
- prevents the build-up of chemicals that are poisonous to the fish;
- speeds up the breakdown of compost and fish waste;
- reduces the chance of fish disease, especially gill-rot.

Lime is available in various forms and so the most cost-effective method should be used, with agricultural lime or limestone (CaCO<sub>3</sub> or MgCO<sub>3</sub>) being the cheapest and most popular. Other forms of lime are slaked lime (Ca(OH)<sup>2</sup>) and quicklime (CaO). The amount of lime required for the pond depends on the pH of the pond soil. Soil with a pH less than 4 requires around 4000 kg CaCO<sub>3</sub> per hectare while soil with a pH around 6 requires around 1000 kg/ha. Quicklime should be spread evenly over the bottom of the pond at a concentration of 100-200 kg per hectare.



Insufficient fertilizer

Correct fertilizer

Too much fertilizer

Testing for the correct amount of fertilizer in your pond before adding fish.

## **Fertilizers**

To ensure pond phytoplankton productivity, various nutrients such as nitrogen, phosphorus, potassium, carbon and calcium need to be added regularly. Fertilizers can be inorganic fertilizers or mineral fertilizers, or else organic fertilizers or manures of plant and animal origin.

### *Organic fertilizers*

Organic manures have been used for a long time. They can be obtained from a number of places: dung of cows, sheep, goat and pig, and poultry and duck droppings. They can also be found in farmyard manure, compost, green manures, sewage, etc. Of these, cow dung is the most widely used in undrainable pond culture systems. As most of the organic manures are waste products of local agriculture they are generally cheap and easily obtainable. They provide all the basic nutrients required for biological production. Several of these manures are quickly used by the pond organisms, especially by the zooplankton and even by some species of carp. By improving the quality of the pond's bottom mud they encourage the growth of bacteria, which leads to more zooplankton. Though the major elements are present in manures, their levels are generally low, which means that large amounts may be required. Unless proper care is taken in using manure, the level of dissolved oxygen in the pond water is likely to drop.

### *Inorganic fertilizers*

Commercially available inorganic compounds containing major nutrients (nitrogen, phosphorus and potassium) are known as inorganic or chemical fertilizers. They contain a high and fixed percentage of the three basic kinds of nutrients: nitrogenous, phosphatic and potassic, or mixed. As they can easily dissolve in water, these nutrients are quickly available to the pond.

Nitrogenous fertilizers usually contain nitrogen as the main element and are commercially available as ammonium sulphate, ammonium nitrate, or urea. Most of these fertilizers make the pond soil acidic and it is therefore important to select a fertilizer based on the soil of the pond. Nitrogenous fertilizers are essential for newly constructed ponds poor in nitrogen and without sufficient organic matter on its bottom. Older ponds tend to have a good layer of organic mud which is able to produce nitrogen by itself. To further complicate matters, the strength of nitrogenous fertilizers depends on how much phosphorous is available. It is best to maintain the phosphorous : nitrogen ratio at 1 : 4.

Phosphatic fertilizers are the best fertilizers for fish culture. This is important because almost all fish ponds do not have enough phosphorus. The most common phosphatic fertilizers are the orthophosphates. Superphosphates are the most soluble in water, and single superphosphate is the most widely used and is easily available. The more concentrated triple superphosphate is also used. Phosphatic fertilizers are released slowly over a number of years depending on the nature of the pond bottom.

### **Tank and cage management**

Tanks, raceways and cages are all artificial enclosures that need daily management to work efficiently. The life of the fish contained in these structures is entirely dependent on the lifesupport systems installed (pumps, blowers, water flow and climate control in the case of tanks and raceways; feeding and water quality in the case of cages).

Inlets and outlets, water temperature and other water-quality parameters need regular checking. Maintenance of predator proofing, pumps and plumbing, tunnel plastic coverings, cage integrity, growth recording and size-sorting of fish are all daily demands on the fish culturist's time. The more intensive the management and the greater the amount of care in fish husbandry, the better will be the results in terms of fish yields and quality. Slack management will result in system failures, which may happen over weekends or at night, when heavy fish mortalities can occur in the absence of anyone to fix the problem.

While a regime of regular fish feeding is indeed essential, there is far more to fish husbandry than just providing the fish with food. It only takes a failed pump to wipe out all the stock in an intensive system, or a damaged cage to lose most of the stock from cage culture, thus regular servicing and checking of such fish-farm hardware is essential. Where possible, pumps and blowers should have a back-up, or if this is too expensive, stocking rates must be kept at a low-enough level whereby an electrical failure does not cause immediate stock loss.

As a cattle or sheep farmer gathers his herd together to do daily checks, with regular dipping against ticks, so should a fish farmer check the health and growth of his/her stock at regular intervals. This means sampling the ponds with a throw-net or other least-disturbing collecting method, and checking for health, growth, or any signs of stress. Several times after the initial

stocking, the ponds, tanks or cages may need to be drained and emptied of fish to size-sort them, such that growth of the slower-growing individuals is not affected by the fastest-growing ones. At the same time predators can be eliminated, and the pond bottom remodeled or fertilized accordingly. The fish can be size-sorted and distributed to other ponds that have been

prepared. All this activity requires equipment, planning and manpower such that the whole operation does not overly stress or kill the fish. A rough schedule of essential activities is illustrated in the table below. These activities are not all that the farmer needs to do, but he will soon acquire a sense of how well his stock is doing by regular observations of feeding or shoaling behaviour of the fish, in just the same way as a cattle, sheep or goat farmer can tell the state of his animals by regularly observing them.

**INFO BOX: CHECKING FISH HEALTH AND CONDITION**

A common way to check on the condition, size and health of your fish is to observe them at feeding time when they rise to the surface. Healthy fish will rise actively to the surface and feed voraciously. Unhealthy or stressed fish will be lethargic and will hardly rise to take the feed from the surface.

An essential ingredient to successful fish husbandry is to prepare well in advance for any operation that involves catching or moving any of the fish stock, to reduce stress to a minimum.

Attention to such details as sufficient buckets or containers, water temperature differences between waterbodies, adequate and suitable



**Regular activities that are essential to efficient fish production**

FREQUENCY	ACTIVITY
Twice daily	<ul style="list-style-type: none"> <li>Feed fish, twice daily for juveniles</li> <li>Check inlets and outlets, or pond levels</li> <li>Observe fish for signs of ill-health or unusual behaviour</li> <li>Remove any dead fish</li> </ul>
Daily	<ul style="list-style-type: none"> <li>Check water temperature</li> <li>Check pumps or other electrical equipment</li> <li>Check predator or anti-theft protection</li> </ul>
Weekly	<ul style="list-style-type: none"> <li>Check water quality and recording parameters</li> <li>Estimate use and replacement of feeds and other consumables</li> </ul>
Monthly	<ul style="list-style-type: none"> <li>Sample and estimating growth of fish</li> <li>Drain of ponds to size-sort stock</li> <li>Remodel and fertilizing of ponds</li> <li>Redistribute stock according to size and growth stage</li> <li>Maintain plumbing and other equipment</li> <li>Breeding and preparation of fingerlings for restocking</li> </ul>
3-month intervals	<ul style="list-style-type: none"> <li>Draining and harvesting from ponds or tanks, or cages</li> <li>Processing of catch</li> <li>Marketing of processed harvest</li> <li>Remodeling and fertilizing of ponds; make repairs to tanks or cages</li> <li>Restocking with fingerlings</li> <li>Clean and dry nets used in harvesting</li> </ul>
Yearly	<ul style="list-style-type: none"> <li>Building of new structures, additional ponds, tanks or cages</li> <li>Make improvements to storage or processing facilities</li> <li>Accounting and annual record-keeping</li> <li>Plan for improvements</li> <li>Replace broodstock</li> <li>Replacement of equipment such as nets, buckets, vehicles</li> <li>Maintenance of serviceable equipment (pumps, plumbing, etc.)</li> <li>Maintenance and upgrade of anti-theft and predator protection.</li> </ul>

nets for the job, enough staff to carry all the equipment, prepared tanks to put the fish in that are to be moved, and many other factors, are all vital components of good fish husbandry.

### Transporting live fish

One of the most frequent activities on any fish farm is the moving of fish around from one tank to another, or from pond to pond, or even the collection of broodstock from elsewhere. Sorting stock, stocking grow-out tanks, moving broodstock, harvesting fingerlings, sampling growth rates, and catching adult fish for selling are all examples of why you would need to move fish. There are three important considerations to remember when moving fish:

- Crowded fish soon die of oxygen starvation in buckets or small containers.
- Fish should not be moved to water of a different temperature.
- Moving fish stresses them by the simple act of catching them and confining them under crowded conditions. Stress makes them more susceptible to disease.

### Short distances

When moving fish short distances within the hatchery itself, they can be transported in buckets. Remember that certain fish almost invariably try to leap out of buckets (*Tilapia rendalli* and catfish) so the buckets need lids or netting covers. Fish that leap out of buckets and fall into dust or earth lose their protective coating of slime, and will often die some days thereafter.

### Long distances

A particular procedure is required when moving fish over longer distances, such as when stocking ponds with fingerlings or obtaining broodstock. These fish should never be fed for at least 24 hours (preferably 48 hours with tilapia, due to their long gut length) before transporting them as they will foul the packing water and poison themselves and the other fish in the packing container. To purge or 'starve' fish prior to packaging and transporting them, they should be held unfed in clean algae-free water in containers or tanks like plastic or concrete pools, with clean through-flowing water. This also allows for them to be size-sorted as different size classes of fish should never be packed together (the larger ones will damage the smaller ones).

### Packing small fish or fingerlings

Small fish the size of fingerlings (3-8 cm) can be packed in double plastic bags which are then placed in boxes for transport. Packing water must be prepared in advance and should be absolutely clean and of the same temperature and quality as what the fish are used to. Never pack fish using water from the containment that the fish are in as ammonia concentrations may be high and the oxygen level low. Use new water. Plastic bags should be of minimum 40 micron thickness for small fish and preferably 60-80 microns for fish like tilapia with fin spines. The inner bag is filled one-third with water and inflated with oxygen. The neck is twisted several times, then bent over and tied tightly with strong rubber bands. This is then placed upside-down inside the outer bag, to prevent

### Transporting juvenile fish



(1) Do not feed fish for 2 days prior to packing them.



(2) Prepare clean water for packing and keep it at the same temperature.



(3) Assemble all nets, buckets and essential equipment.



(4) Pack small fish in plastic bags that are 1/3rd filled with clean water.



(5) Invert the inner bag in the outer one.



(6) Place bags in boxes.

small fish becoming trapped in the corners. This is essential and an often overlooked procedure; if a few fish become trapped in the corners and die, they will rapidly decompose in warm weather and poison many of the others. The bags are then placed within a cardboard box, bucket or polystyrene box to prevent them being punctured. The polystyrene boxes will help insulate the fish from rapid temperature changes.

When transporting the boxes they should not be placed in the back of an open bakkie, exposed to the sun or cold, as the small volumes of water will rapidly either overheat or cool down, so a canopy is essential. On arrival at the destination the fish will be considerably stressed, and the bags should be carefully floated in the water for 15 minutes to equalize the temperature differences. Once this is done the bags can be cut open and the fish released.

### **Packing large fish**

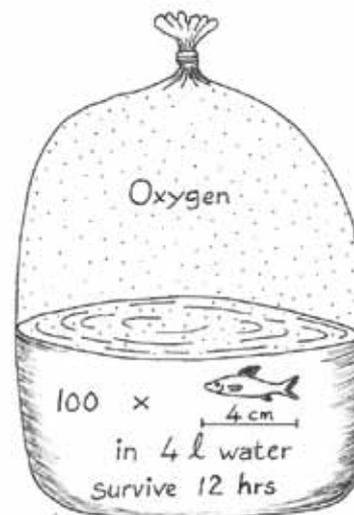
For large fish over 10-12 cm, plastic bags puncture too easily and other containers are used. The best are the blue or green plastic 50-200 l drums with an open top that can be clamped on. For short time intervals (<15 minutes) large fish can be moved around the farm in these drums without oxygenation, if not over-packed (not more than 20 adult-sized fish per 100 l drum). If the fish are likely to be in the drum for longer periods, portable battery-operated air-blowers can be used to oxygenate the water using an air line and airstone in each drum. These are both inexpensive and very useful pieces of equipment in any fish-moving exercise and well-worth obtaining. Alternatively, the type of air pump used to inflate car tyres and that plugs into the cigarette lighter can be used for short periods. The fitting that usually clamps over the tyre-valve fits well over an aquarium air line!

Drums should be filled to about 30% full when packing the fish, then lifted into the vehicle, and then topped up to 80% full with clean water to

prevent too much sloshing and damage to the fish on rough roads. All this must be done in the cool shade to prevent the water warming up to the point where oxygen levels decrease to the point where the fish die from suffocation. If road transport is to be long (2 hours or more), then consideration must be given to providing the fish with oxygen. A small air pump working off the vehicle battery is adequate, and actual oxygen bubbled through the water is not essential, except for trout or if the densities are very high.

At the destination, the drums should be first partially emptied using buckets, then the drums lifted down and the fish emptied into the dam, pond or other container. If the receiving water is different to the drum-water temperature, then some of this water should be added to the drum-water slowly, over half an hour, to equalize temperatures.

While this is being done, the flow of air or oxygen to the tanks must be kept operating.



Packing small fish for transport.

### **Packing un-purged fish taken from a dam or pond**

It is unwise to pack fish that have been caught from ponds or tanks where they have recently eaten. This is because they have a gut full of food that will be expelled in the packing water, thus polluting it. Tilapia are especially difficult in this respect due to their long gut length and their continuous eating habits. Tilapia caught and packed directly after capture will quickly foul the water to such an extent that it will be black



Tilapia fingerlings transported in oxygen-inflated plastic bags (far left). Another method of transporting the fish is to place them in one large tank (left). In this case, trout are being transported from Cape Town to Lesotho, a 24-hr journey. As such the water in the tank is filtered and oxygenated, and at regular intervals fresh water and ice are placed in the tank.



and filthy within half an hour, and all the fish will soon die thereafter. Only very short journeys are possible without in some way purging the fish prior to packing them. One solution is to hold them in a portable plastic pool, at the pond-side in the shade, with clean water, for some hours after netting them to attempt to purge them of most of the gut contents.



Packing larger fish for transport.

Use of one or more portable air-blowers can assist in keeping this holding water well oxygenated. If purging is not possible, the maximum packing density recommended for tilapia is no more than 6-10 adult fish per 100l drum for travel that is not more than 4-6 hours. Aeration will be essential.

**Size-sorting the fish**

After the fish have been collected in buckets, they should be sorted by sizes or species. If sorting is done quickly, small fish can be returned to the pond to allow them to grow further. If size-sorting is needed, it is recommended that one or more portable fish pools be erected in a shady area near the pond to be harvested. All undersized fish can be immediately placed in these pools to rid them of the mud and other plant debris that invariably clogs their gills and fins while being netted. If large quantities of fish are to be caught, a flow of fresh water from a pipe may be required to keep the water in the portable pools satisfactory for the fish. Fish will die very quickly in over-warm or mud-polluted water after the stresses of being netted. Avoid mixing very large fish with juveniles in the same pool.

## Frequently asked questions

Q: *Can I use ponds that are not drainable?*

A: Basically, all fish ponds must be drained to manage them efficiently because netting can never be 100% efficient. Some fish will remain in the pond after harvest; these will either prey on or compete with newly stocked fingerlings. Also, the pond basin will need remodeling, scraping out and possibly repairs, to operate well. Undrainable ponds are the equivalent of fields that cannot be ploughed before planting crops.

Q: *Do I have to be at the fish farm every day?*

A: Someone who is totally competent at running the day-to-day activities outlined in the table on page 35 must be present every day of the year, including weekends and public holidays. Fish die easily if the wrong environmental conditions develop, and mass-mortality can quickly result from inattention to apparently small problems, such as plumbing failures or water-quality changes, therefore it is essential that staff are always on hand to check the farm.

Q: *How many fingerlings can I pack in a plastic bag?*

A: You should be able to pack 100 x 4 cm purged tilapia fingerlings in 3-4 ℓ of water in an oxygenated double plastic bag, and expect them to survive well for up to 12 hours.

Q: *How many adult-sized fish can I pack in a drum?*

A: You can pack about 20 purged adult tilapia of 500-550 g (or 20 x 250 g trout) in a 200 ℓ drum with a blower bubbling air through an airstone in it, for a journey of around 4-6 hours, and expect them to survive well.

Q: *How long will fish survive in a bucket?*

A: Fingerling-sized fish of 4-6 cm will survive at a stocking density of 20-30 fish in a 10 ℓ bucket for 20-30 minutes; 100 such fish will only last 5-10 minutes before they start gasping at the surface.





## Chapter 7 Feeds and feeding

### Why feed the cultured fish?

A fish farmer may wonder why he needs to add extra feed to his pond when he already adds fertilizer to provide food for the fish. Since food is expensive, the farmer may not be willing to provide the fish with extra food and must therefore be taught why additional feeding is necessary. By correctly feeding the fish the farmer will be able to improve production and increase his profit.

This section, together with Appendix 1, gives information on energy, nutritional requirements and the feeding habits of fish. First, the types of food available to them and the ways one can provide the fish with these nutrients are described. Finally, some notes on the economic effects of feeding are included.

### Energy requirements

Fish (and other animals) require food to supply energy for movement and other activities as well as for growth. As fish are 'cold-blooded', their body temperature is the same as the water in which they are living. They therefore do not have to use energy to maintain a stable body temperature and therefore tend to be more efficient users of food than other animals. The optimum temperature for growth is different for each species. Within a species' preferred range of temperatures, the metabolic rate, and the need for food, increases as the optimum temperature is reached. This explains why in areas where there is a wide temperature range during the year, the fish eat much more food during the summer than in winter.

Energy can be defined as the capacity to do work. Free energy is that which is left for biological activity and growth after the energy requirements for maintaining body temperature are satisfied. Excess energy is dissipated as heat. This is important to fish farmers as the most economically important outcome is the quantity and cost of the energy available for the growth of the animal being cultured. This energy is supplied by food. The food requirements of fish vary in quantity and quality according to the species, its size, its feeding habits, its environment, etc.

The gross energy (GE), also known as gross calorific value of a food, is the total energy contained in it. Not all of the energy is available to the fish. Different parts of the diet have different amounts of energy available. The digestible energy (DE) of a food is the GE of the food less the energy of the feces. The energy available for the 'building blocks' of growth is what remains after the energy for metabolism, reproduction, etc., has been supplied.

Metabolism is the sum of all chemical and energy processes of the body. Metabolism includes the storage of food energy as fat, protein and carbohydrate, and its conversion into free energy for work and growth. The metabolic rate of small fish is greater than that of large fish. Small fish grow faster than large ones in terms of percentage increase in weight per day. Therefore, the feed requirements of small fish are different to those of larger fish, with smaller fish requiring a higher feeding

### Nutritional requirements of the juvenile stages of local aquaculture species:

Nutrient	Species			
	Tilapia	Common carp	Trout	Catfish
Protein	35%	25–38%	40%	40–42%
Lipid (fat)	8%	Up to 18%	12%	10–12%
Energy (Kcal/kg)	2500–4300	2700–3100	2800–3000	2800–3100



Fish feed is about 50% of the cost to produce the fish. Therefore, the farmer needs to ensure that the feed is not wasted and that the correct feed is being given to the fish. There are many different types of feeds, so speak to your local feed supplier for the appropriate ones for your fish.

food source. Some fish prefer only one kind of food while others will eat a few kinds of food.

The farmer should encourage the growth of these natural foods by maintaining the quality of the water, proper fertilization of the pond bottom and the water, etc. Sometimes, however, the farmer must add food to the pond because the pond is not producing enough food for good fish growth. The best supplementary foods a farmer can put into the pond are extra natural foods. But there are a great number of other foods that fish will eat.

ration. At a certain body size, growth rate starts to decline rapidly. The optimum marketable size normally occurs around this point. A summary of the essential components of feeds is given in Appendix A.

### Nutritional requirements of particular fish

As each species eats a different diet, each species of fish has its own nutritional requirements. Carnivorous fish (such as catfish and trout) require a high protein diet (around 40%) which has a high proportion of fishmeal. Herbivorous species require a lower protein content (around 30%) and can be fed a higher proportion of plant meal (such as soybean or maize) as part of their diet. An example of the nutritional requirements of a few species is shown in the table on page 40.

### Feeding habits

It is important to know the feeding preferences of the species being cultured so the correct food can be provided at all times in order to maximize growth. The feeding preferences are determined by observing the fish as well as by examining the gut of naturally occurring fish.

Fish (and other animals) can be divided into different feeding classes:

**Herbivores** – feed only on plants (e.g. *Tilapia rendalli*, grass carp)

**Carnivores** – feed only on other animals or meat (e.g. trout, bass)

**Omnivores** – feed on both animals and plants (e.g. common carp)

**Planktivores** – feed on the very small plants and animals in water (e.g. mullet, silver carp)

**Detritivores** – feed dead plant or animal material on the bottom (e.g. *Oreochromis mossambicus*).

Natural foods are the best foods for fish and include algae (phytoplankton), zooplankton, detritus, snails, worms, insects and insect larvae, small plants like duckweeds and various other weeds and grasses that are found in a fish pond. If the fish is carnivorous, smaller fish can be a

Depending on the type of fish in the pond, almost anything can be used as a supplementary food. Common supplementary foods are: bread crumbs, rice bran, fish meal, ground-up maize, oats, barley, rye, potatoes, broken rice, soy bean cakes, peanut cakes, corn meal, cottonseed oil cakes, coconut cakes, sweet potatoes, guinea grass, napier grass, water hyacinth, wheat, and leftover animal feeds and some animal manures.

Raw materials containing high amounts of animal protein, such as fishmeal and blood meal, are scarce and expensive. It is therefore easier to obtain the relatively high protein requirements for catfish by using feedstuffs that contain higher quantities of vegetable protein such as plant oilseed cakes and meals. These by-products from the agriculture industry are more common, cheaper and generally available in large quantities.

### INFO BOX: STORAGE OF DRY FEED

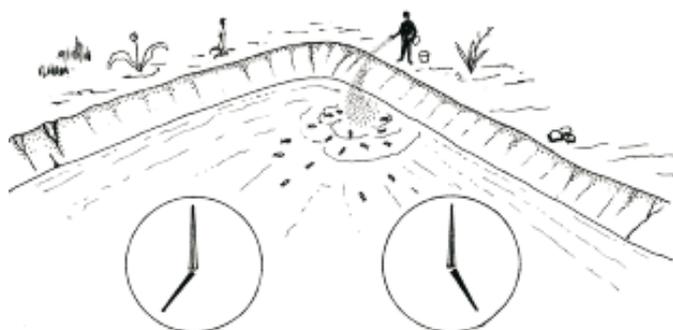
- Feed deteriorates rapidly unless stored in cool, dry conditions.
- Feed bags should be stored in rat-proof indoor conditions, and raised above the ground to prevent moisture contamination.
- Feed should never be stored in humid places such as net equipment stores or tunnels.
- Feed should not be stored for more than 6 months.

As there is little large-scale intensive aquaculture in most African countries, the present demand for raw materials comes mainly from domestic poultry and livestock industries. Consequently, there are generally no specific vitamin and mineral supplements available for aquaculture species.



The type of extra food supplied depends on the kind of fish. For example, tilapia will eat many vegetable or grain-sourced waste products, including the supplementary foods listed above, which is why they are such good pond fish. The silver carp, on the other hand, will eat only phytoplankton, even when it is a fish of marketable size. It is therefore important that the farmer knows what the fish will accept before putting extra food into the pond.

When the stocking density of fish is increased to levels beyond those capable of surviving on



Fish should be fed in the same place and at the same times every day, preferably in the early morning (7am) and late afternoon (5pm).

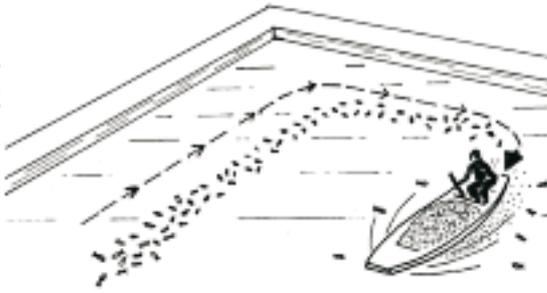
the natural food in the pond, the growth of the fish can only be maintained by supplementing the natural food with some artificial feed. This is the single most important management element to increase the pond's fish production. The type and quantity of food fed must be carefully considered as it may negatively affect the health

#### INFO BOX: FLOATING AND SINKING FEEDS

- Floating pellets have an advantage in that you can observe the fish feeding, which provides information both on the condition and size of the fish as well as the amount of feed that they will eat at one feeding. Once they stop taking the feed no more pellets should be given.
- Sinking pellets are better designed for fish that prefer to feed off the bottom of the pond and that do not rise to the surface for floating pellets. The disadvantage is that it is difficult to know when the fish have eaten their fill, with the subsequent risk of over-feeding the pond, thus polluting it.

#### Various types of artificial feeds and their uses:

FEED TYPE	SIZE	ATTRIBUTES
Artemia or brine shrimp	Microscopic	Artificially newly-hatched livefood for fish fry. Contains all the feed requirements for swim-up fry. Dried eggs are available in cans that are easily stored until used.
Specialised dry micro-sized fry and larval feeds	Several microns only	In powder form for swim-up fry and very small juveniles. Can be laced with hormones or other treatments, such as to produce mono-sex tilapia.
Flakes	Thin, easily crumbled	Ideal high-protein feed for small fish and ornamental species.
Spirulina flakes or pellets	1–5 mm	Spirulina-based dry foods for vegetarian fish, like some tilapia and ornamental species.
Crumbles	0.1–1 mm	Residue of pellets, ideal for juvenile fish.
Pellets	0.5–1 mm	Fishmeal-based balanced diet for juveniles and fingerlings.
	1–3 mm	Used to stimulate growth of juveniles and sub-adult fish, with high protein content.
	3–5 mm	Reduced protein content for adult fish.
Floating	1–5 mm	For surface-feeding fish like trout.
Sinking	1–5 mm	For bottom-feeding fish like tilapia, carp and catfish.
Chicken or rabbit pellets	3–5 mm	Not designed for fish, but acceptable to most tilapia, carp or catfish species. May be more readily available than actual fish pellets.



Methods of adding supplemental feeds to a pond. Adding food at wooden stakes (far left) and from an open-bottomed boat (left).

**Recommended feeding levels (% of body weight/day) for catfish at different temperatures (Hogendoorn *et al.*, 1983).**

Temperature (°C)	Fish body weight (g)					
	1	5	25	50	100	200
21	3.6	2.5	1.7	1.4	1.2	1
23	5.1	3.7	2.6	2.3	2.0	1.7
25	6.5	4.7	3.4	3.0	2.6	2.3
27	7.4	5.4	3.9	3.4	3.0	2.6
29	7.9	5.6	4.0	3.5	3.0	2.6
31	8.0	5.5	3.8	3.2	2.7	2.3
33	7.8	5.1	3.4	2.8		

of the fish in the pond (i.e. by causing a drop in oxygen levels, possible pollution, etc.). Feeding should be performed at the same times (early morning and late afternoon) to improve food consumption and to teach the fish to come to the same area of the pond.

Food should be fed in the shallow end of the pond or around wooden stakes, which encourages the fish to come to the same place in the pond to feed. This allows the fish farmer to check the health of his fish at each feeding. If ponds are too big to feed by hand, an open-

**INFO BOX: WHEN AND HOW TO FEED FISH IN PONDS**

- Fish should be fed at the same place and same time each day. This makes monitoring of fish stocks much easier as the fish get used to these routines.
- Watch the fish: when they stop eating, stop feeding.

Feeds & feeding

**INFO BOX: HOW TO CALCULATE THE AMOUNT TO FEED THE FISH**

- Juvenile fish should be fed 6-8% of their body mass per day, distributed over 3-4 times per day.
- Medium-sized fish should be fed at about 4-5% of their body mass per day.
- Adults of near harvest-sized fish should be fed at about 1-2% of their body mass per day.

To calculate how much feed would be required for a two-week period:

Food for 2 weeks = Average fish weight (g) x number of fish in pond x % fish bodyweight x 14 days. Example: 4000 x 100 g (medium-sized) tilapia with a total mass of 400 kg will need 5% body mass feed/day = 20 kg/day, over 14 days = 280 kg fee

bottomed boat can be used to supply a stream of feed around the pond. The build-up of waste on the bottom of the pond depends to a large degree on the amount of artificial food fed. It is therefore important that any excess or uneaten food is removed if the fish are not feeding. If the waste builds up, it will lead to high levels of ammonia and nitrate, which will cause a drop in dissolved oxygen levels, all of which are dangerous to the fish.



The amount of feed used per day is generally calculated for a two-week period and adjusted every four to six weeks after catching a few fish with a cast net and recording their average body weight. The biomass of the fish and the daily quantity of feed are then calculated according to the recorded average body weight (see example for catfish, in table above) and estimated survival rate. It may be difficult to predict growth and survival rates as they depend on many factors (such as fish density, feed quality, temperature, predation, etc.). If the temperature changes by 4°C (up or down)

from the preferred range of the species, the feeding rate should be reduced by 25%. If the temperature changes by 8°C, the rate should be half (50%) of normal. It is very important that the fish are not fed more food than they can eat. Not only is this a waste of money but it also leads to poor water quality and possible death of all of the pond's fish.

If the level of dissolved oxygen drops between 3-5 mg/l, the amount of food added to the pond should be halved. No feed should be given if the dissolved oxygen falls below levels of 2 mg/l. Every effort should be made to bring the oxygen level up to an acceptable level before feeding resumes.

If the fish should stop feeding, the cause of this should be determined immediately. The illustration below depicts various reasons why fish may stop feeding. All of these possibilities should be considered and investigated, otherwise the fish in the pond may die.

As in any business, it is important to reduce costs while trying to increase production. In aquaculture, fish farmers try to feed just the right amount and type of food to allow the fish to grow but not waste food as it is expensive. Some foods, such as those with a higher protein level (e.g. fishmeal) may produce better growth than plant-protein diets. However, the high protein content may be more expensive and therefore the cost of the diet must be carefully considered in relation to its contribution to improving fish growth. The concept of food conversion ratio (FCR) is important to

**EXAMPLE 1**

A 20 kg bag (costing R8/kg) of a diet containing mostly plant proteins was fed to fish newly stocked into a pond. When they were stocked, all the fish weighed about 5 kg. After the food was finished, the fish were caught and weighed again (none had died), weighing in at about 15 kg each.

$$\begin{aligned} \text{Feed conversion ratio (FCR)} &= \\ &= \text{Feed fed to pond} / \text{Increase in fish mass} \\ &= 20 \text{ kg} / (15 \text{ kg} - 5 \text{ kg} = 10 \text{ kg}) \\ &= 20/10 \\ &= 2 \end{aligned}$$

**EXAMPLE 2**

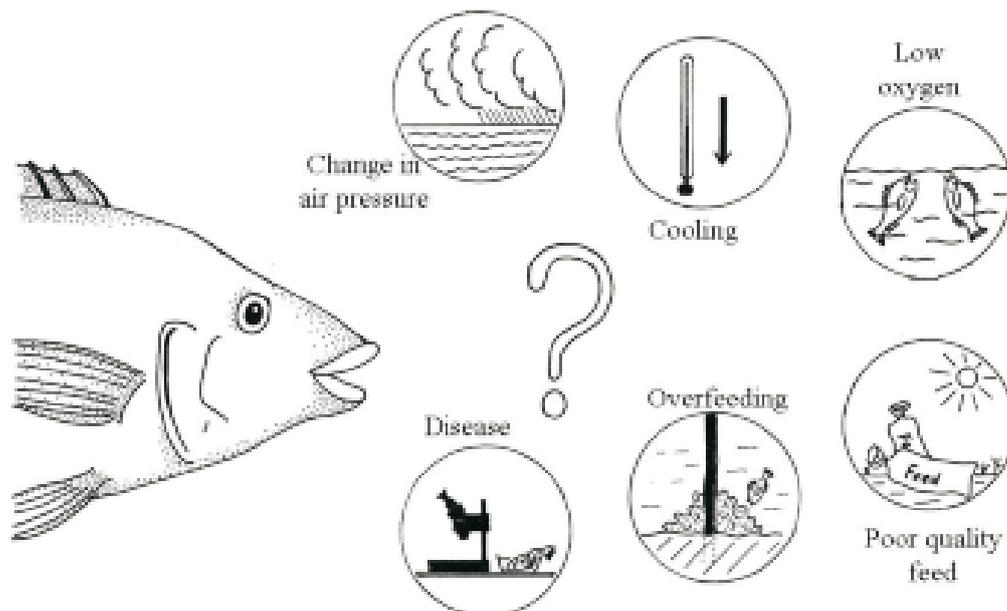
Another pond was fed 10 kg (costing R20/kg) of a higher protein diet, containing more fishmeal, and the fish also grew from 5 to 15 kg.

The feed conversion ratio for this pond is:

$$\begin{aligned} \text{FCR} &= 10 \text{ kg} / 10 \text{ kg} \\ &= 1 \end{aligned}$$

understand as it helps describe how well a diet is used by the fish to grow. FCR is defined as the mass of food consumed divided by the mass of fish produced (see examples in the boxes, above).

If the cost of the feeds were the same per kg, the diet with the lower FCR (of 1) would be



A few reasons why fish may stop feeding. The exact reasons should be determined immediately and the appropriate steps taken to correct them.

cheaper to use as you only use 1 kg feed instead of 2 kg of feed to produce 1 kg of fish. However, the cost of the plant-based diet in this example is R8/kg, and therefore:

The cost of producing 1 kg of fish =  $R8/\text{kg} \times 2$  (FCR) = R16/kg produced.

Similarly, the cost of the fishmeal diet =  $R20/\text{kg} \times 1$  (FCR) = R20/kg fish produced.

Therefore, although the fishmeal diet has a better FCR than the plant-based diet, the cost of the plant-based diet is cheaper per kg of fish produced and is therefore the more cost-effective diet to use.



## Frequently asked questions

Q: *When do fish first need feeding?*

A: In artificial containments such as tanks, raceways or cages there is no or very little natural food, so all the fish's diet must come from artificial feeds. Fry born into this near sterile environment will need feed as soon as their yolk sac is used up (typically three days after hatching for many species).

Q: *How often do fish need feeding?*

A: Juvenile fish should ideally be fed three or more times per day, but in reality this is often impossible to do; so two feedings per day is the norm, with one per day for sub-adult fish.

Q: *How much should fish be fed?*

A: Artificial feeds deteriorate very quickly in water, so any feeds not eaten immediately will quickly spoil and become little more than expensive pond 'fertilizer'. The general rule is to feed what the fish will consume in five minutes.

Q: *Can I feed the fish with kitchen waste?*

A: Yes, most tilapia, carp and catfish will readily consume kitchen waste, especially vegetable, meat and grain waste. If introduced in reasonable quantities, what is not immediately eaten will break down to fertilize the pond. Fish reared in tanks or raceways are not usually fed such wastes due to the threat of water pollution.

Q: *How do I know that the fish are eating the expensive feed I am throwing in?*

A: Always feed the fish at the same time and place each day: fish soon become used to this and you should be able to see the increased activity in the water when fish are feeding. To check, you can inspect the tank or pond bottom afterwards to see whether uneaten or rotting feed is present; this will reveal that you are either feeding excess feed or the fish are not eating it at all.

Q: *Are all dry fish pellets equal in terms of quality and palatability to the fish?*

A: No, definitely not; there are some very poor-quality feeds available that have very little food value at all, so only purchase from a recommended source. Some of these feeds clearly taste unpleasant to the fish too, and so they will not eat them.

Q: *Do I need to feed my fish fry with expensive, carefully formulated fry diets?*

A: No, in general most fry and fingerlings can be reared quite successfully on ordinary crumbles and small pellets, if specifically designed for trout, carp or catfish, combined with some natural foods where possible (like green water full of phytoplankton). Specialist diets are generally only used for higher-value fry like ornamentals or for mono-sex tilapia production. Juvenile catfish *Clarias gariepinus* require a yeast-based artificial diet to achieve high survival and even growth.

Q: *How do I know that the fish are profiting from eating an artificial pelleted ration?*

A: As the fish grow you will need to take regular samples from the pond, tank or cage, to assess the growth rate. These growth figures can then be compared to available growth patterns for unfed fish under similar environmental conditions to see whether the use of supplemental feeding is working well and makes good sense economically.





## Chapter 8 Harvesting

### Harvesting and preserving fish

Harvesting is the collection of fish from a pond, for selling at market or for cooking and preservation for family use. Harvesting can refer to collecting all the fish or to taking out only some of the fish (this happens often in tilapia ponds which have both young and adult fish).

### Harvesting from ponds

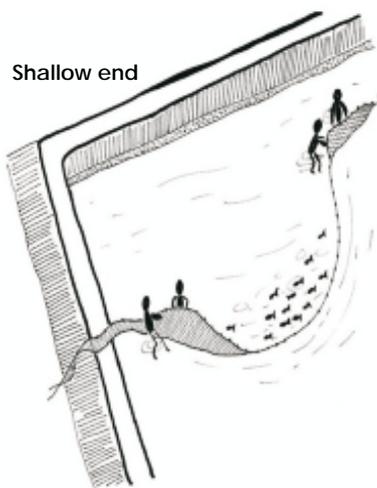
If the pond can be drained, harvest the fish by draining the pond into the catch basin and collecting the fish with a scoop net. If the pond cannot be drained, drain out as much water as possible and use seine nets to catch the fish. It must be remembered that, in practice, the catching of fish in ponds with seine nets can only ever be partially successful. After two or more pulls the fish become wise to the effort. Certain species such as *Tilapia rendalli* will invariably

#### Methods to harvest fish from ponds:

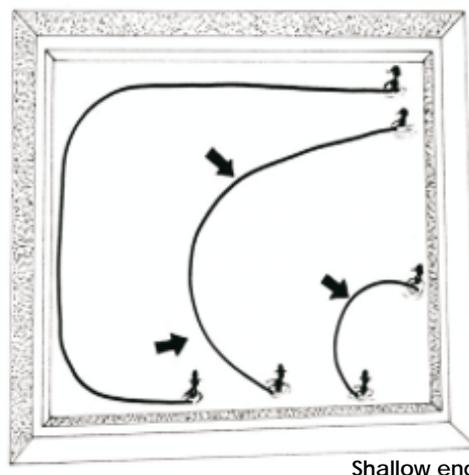
- Assemble equipment
- Set up holding tanks for the catch
- Seine net the pond and sort the catch
- As water level drops, clear catching basin of sludge
- Catch remaining fish from basin
- Once purged in holding tanks, pack into drums.

#### Equipment list for draining and harvesting ponds:

- Seine nets
- Large dip nets
- Small dip nets
- Throw net, fishing rods, bait, hooks, etc.
- Drums (several)
- Buckets (several, small and large)
- Tanks or porta-pools (2 or more), or
- Large keep-net that can float in dam
- Air blower or pipe with flowing water
- Air line, airstones, air-line valves, gang-valve for pipes
- Crocodile-clips or cigarette-lighter battery connection
- Nets to cover tanks (to stop fish jumping out)
- Shade cloth
- Bakkie with canopy
- Rope or strapping to secure drums in bakkie
- Some short lengths of piping (2 m x 20 mm pipe)
- Long lengths of piping (40-50 mm diameter) for through-flow of fresh water.



Deep end



Shallow end

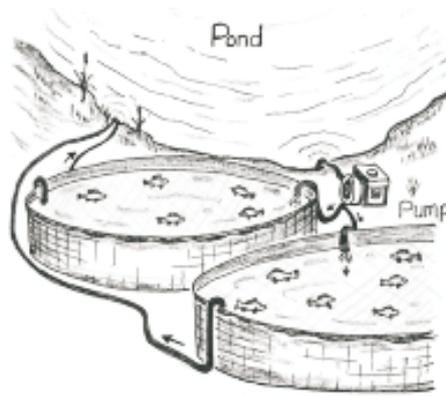
Seine nets can be used to harvest fish from shallow (or partially drained) ponds. The net should be pulled from the deep end to the shallow end. Hand-nets are then used to catch the fish and put them in buckets for sorting.



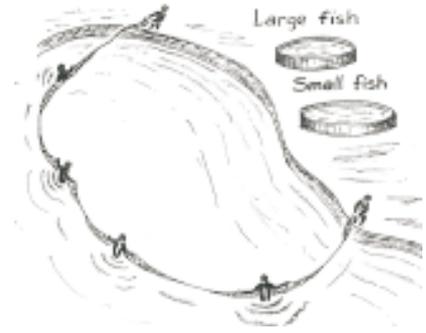
Sequence of events illustrating how fish could be harvested from ponds.



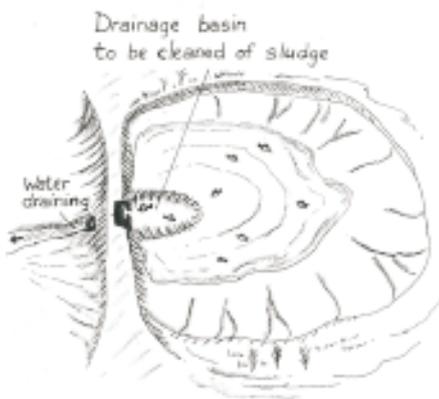
(1) Assemble equipment.



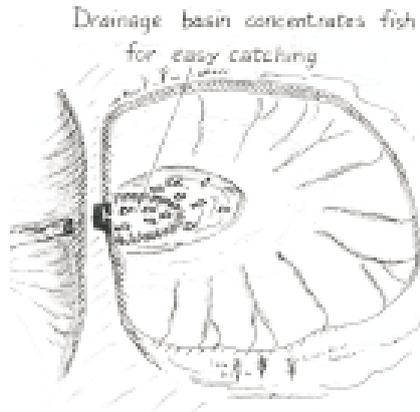
(2) Set up holding tanks for catch.



(3) Seine net the pond and sort the catch.



(4) As water level drops, clear the catching basin of sludge.



(5) Catch remaining fish from basin.



(6) Once purged in holding tanks, pack into drums.

jump over the top rope of the seine net, and catfish often slide under the bottom rope. Seine nets are therefore only an interim solution to harvesting until the pond can be drained.

Harvesting is one of the most important jobs in the work of fish farmers, therefore considerable planning needs to be done in advance to prevent the fish caught being spoiled after harvest, and to prevent stressing those fish being returned

alive to the ponds. If bad planning results in loss or spoiling of the fish harvested, all those months of work and the expense of feeding and taking care of the growing fish will have been wasted.

**Harvesting from tanks or cages**

Catching fish from either tanks or cages is somewhat easier than from large earth ponds. Tanks are drainable and the fish can therefore be caught progressively as the water drops, as opposed to all-at-once in a large seine net. However, the quantity of fish held in large tanks or cages may be very considerable (tonnes); thus careful planning is needed to determine



A net full of fish is a reward for any fish farmer.



A sorting table to sort the different species and sizes of fish obtained from the pond after harvest.



Harvesting trout from cages placed in dams. This is a cost-effective method of growing fish as there is no need for the expensive equipment related to growing fish intensively.

what to do with the catch immediately after harvesting. Cages may pose distinct problems during harvesting as the volume of each cage can be large and the working space confined and difficult. Again, partial catches of the fish in a single cage can be done progressively using nets, but care has to be taken that the fish do not panic in attempting to flee the net and so damage themselves against the cage sides. Precautions also have to be taken against loss of fish over the sides of the cage. For trout cages the fish can be crowded to one end of the cage using screens then dip-netted out into a floating keep-net. This net has a top to prevent fish from jumping out. The keep-net can be towed back to shore and then removed from the water and the contents emptied into ice-filled rectangular plastic holding boxes. The fish should be immediately taken by vehicle to the processing factory.

Once fish are harvested, they must be marketed. Marketing includes the transportation and sale of fish. As the introduction to the manual pointed out, one very important thing to consider before building a pond is the availability of a market. If a market is far away, the farmer must have transportation to it over passable roads. If the market is very near, the farmer may want to advertise the date of the harvest by word-of-mouth so that people will come directly to the pond to buy the fish. If he wants to sell his fish to a shop he should make a written agreement with the tradesman at the market



When harvesting fish from the dam ensure that all necessary equipment and services are ready— for example, a scale to weigh the fish (far left) and ice to keep the fish fresh. It is always recommended to initially talk to your customers to make sure that the fish is harvested and packaged in a way that is desired.

to be sure that he has a buyer for his fish when they are harvested. If there is no market, or if the farmer is going to use all the fish himself, then he probably will want to preserve some of the fish.

### Collecting broodstock:

- Start draining pond (overnight)
- Assemble equipment
- Set up tanks or porta-pools with clean water
- Cover to keep cool
- Pull seine nets, sort catch to large and small
- As pond drains, clean catching basin
- Dip net fish from catching basin
- Keep flow of fresh water through tanks or porta-pools
- Once all fish collected, fill drums 1/3rd full with clean water
- Sort broodstock into drums using dip nets, keep in shade if hot
- Load drums into bakkie and fill to 80% full
- Cover drums and fit air lines and blower
- Secure drums with rope
- Take to destination
- Try to equalize temperatures before releasing fish to new habitat.

### Preserving methods

#### Salting fish

Salting is one of the oldest methods of preserving fish. Salting allows a farmer to keep fish for long periods so that they can be used when fresh fish are not available. Salting depends on the species, the size of the fish, and on the amount and quality of the salt used. Fish that have been well salted last a long time without going rotten.

One of the most important things when salting fish is the quality of the fish. Only fresh fish should be used – fish that have been left dead





Salted catfish from the Northern Cape. This product is popular among the local community. Farmers may need to try different methods to sell their fish.

for a few hours are not good for salting. The fish and all equipment used for salting should be clean.

There are four major steps to salting fish:

1. gutting and cleaning
2. salting
3. washing and drying to remove excess salt
4. air drying.

#### *Gutting and cleaning*

- Gut the fish by cutting along the belly from the gills to the anal vent.
- Remove the guts and the black membrane in the gut cavity.
- If preferred, cut off the head.
- Remove the gills and all blood vessels after cutting open the throat.
- Cut the fish into the right shape for salting: small fish may be left whole; larger fish should be split in half from head to tail, so that all the fish flesh will be exposed to the salt.

#### *Salt the fish*

- Place a layer of salt on the bottom of the container that will hold the fish.
- Place a layer of fish, flesh side up, on the salt. Do not let the fish touch each other.
- Cover the fish with a thin layer of salt.
- Continue to place fish, then salt, stacking them almost to the top of the container.
- Place the last fish layer with the skin side up.
- Sprinkle with salt — the last layer must be salt.
- Place boards and weights on top of the fish in the container to press them down.
- Leave the fish in the container for 15 days.

Add salt as necessary, until the fish are thoroughly full of salt. As the fish lie in the salt, the salt draws out all the water in their flesh. The moisture from their flesh forms a solution (brine) with the salt as the salt dissolves. It is necessary to add more salt as the salt is diluted in the solution. As the moisture is removed from the fish by the salt, the level of fish in the container falls.

#### *Wash and dry the fish*

Remove the fish from the container when they are fully salted. The fish are properly salted

when they are firm and have a whitish salt layer on their flesh.

Wash the fish in clear, clean, sea water or brine:

- Brine can be made by dissolving one large cup of salt (about 300 g) in a bucket of clean fresh water (10 liters).
- Place the fish on a flat surface and press them down with boards and weights to make them as flat as possible before drying.

#### *Air dry the fish*

Dry the fish in the sun and open air, or use heating and fans. Usually fish are dried outside in an area that is exposed to sun and wind and is very clean.

Dry the fish under a shelter of leaves or branches for the first few days, so that they do not dry too quickly. After the first few days put the fish into as much sunlight as possible. Lay the fish on triangular slats or hang the fish by their tails from lines strung between trees. Cover the fish if it rains. Any moisture at all, at this stage in the salting process, will cause the fish to go rotten. Dry the fish for about one week. Pack and store the fish in dry, waterproof containers.

#### *How to use salted fish*

Soak salted fish in fresh water for 12 hours. Change the water at least once during this time. Soaking removes the salt; the longer the fish is soaked, the more salt removed. After the fish has been soaked, it can be used in any way that fresh fish is used.

#### *Smoking fish*

Smoked fish do not last as long as salted fish. This is because they need to be refrigerated, frozen, or canned if they are to be kept for long periods. A smokehouse is used to make smoked fish. A simple smokehouse is a shed or box built over a (controlled) fire so that it produces smoke instead of flames. Fish are hung inside the smokehouse so that they are surrounded by smoke.

Smoked fish are cleaned the same way as fish for salting. After they are bled and gutted, they are split from head to tail. They are then washed in freshwater and placed in a saltwater brine made by dissolving 1kg of salt in one liter of water for one hour. Then the fish are removed from the brine and washed in clean, fresh water again. The fish are then drained and hung in a cool breezy place for about an hour.

At this point, the fire can be built in the smokehouse. When it is smoking properly, place the fish on hooks and hang (or tie) the fish in





Frozen catfish (far left) and tilapia (left) ready for sale. The catfish has already been priced. It is important to make the fish look presentable to the customers.

the top of the smokehouse, away from the fire. Make sure the fish are placed securely so they will not fall. Watch the fire carefully to make sure it is smoking, and not cooking or burning the fish. It takes about six hours to smoke fish so that they can be eaten or stored.

After the fish are smoked for six hours, they can be eaten immediately, stored frozen or refrigerated until they are eaten. Smoked fish do not last as long as salted fish, so do not smoke all of the fish, unless they will be eaten soon after harvesting.

### **Freezing**

Often fish are preserved by freezing. Freezing requires a constant supply of electricity, something many farmers do not have. However, if electricity is available, freezing is one of the easiest and safest ways to preserve fish. In this method, fish are gutted, cleaned, cut up (if desired), placed into packets or containers, and put into freezers. Frozen fish can last for a very long time if they are not allowed to thaw (become unfrozen). Once frozen fish are thawed, they must be used immediately, or they will spoil. You CANNOT refreeze fish that has thawed – if you do, you risk getting anyone who eats it very sick.

### **Air drying**

Fish can also be preserved by simple air drying. Air drying involves only cleaning and washing the fish and drying them in the sun and wind until they are a clear white color.

#### **INFO BOX: FISH PREPARATION**

- Fresh fish is fish that has been cleaned of scales, gills and guts, but not frozen (although it may be chilled).
- Frozen fish is that which has been deep-frozen and packed in some way.
- Dressed fish is that which has been further prepared or value-added.
- Filleted fish is where boneless portions are removed from either flank of the fish; this is sold fresh, smoked or even dressed with breadcrumbs or spices.
- In-the-round fish is fish that has been cross-cut into circular portions with the central vertebra still in place.
- Freezer burn is when unpackaged fish becomes discoloured and damaged by freezing.
- Refreezing of previously frozen and then thawed fish is dangerous because bacteria that have entered the flesh when unfrozen can remain active and toxic.

## Frequently asked questions

Q: *What aspect is most important to prepare before the actual harvesting of fish?*

A: It is important to be mindful of the harvested fish as a product and to remember its market value when preparing for this stage of the operation. You must be organized as to what is going to happen with the catch. Newly harvested fish spoil quickly, and months of investment in time, money and labour can be wasted if they do not arrive at the market in excellent condition. It is important therefore to have all collecting gear and procedures well-prepared and thought-out beforehand.

Q: *What size should fish be harvested at?*

A: This aspect depends on the market that you have targeted in your operational plan. If the market is prepared to accept smaller fish, this will make harvesting and handling easier. Rural markets tend to accept fish at smaller sizes (150-300 g) while urban markets often prefer fish that can be filleted (350-500 g).

Q: *What does harvesting involve?*

A: In a nutshell, harvesting involves the entire or partial collection of the fish from the water-body, be it a dam, pond, tank, cage or raceway. Harvesting will require specific equipment (such as nets and portable tanks, trays, etc.) to be readily at hand.

Q: *Does one harvest the entire crop of fish?*

A: You can decide to harvest all the fish at one time only if you are able to handle the logistical possibilities for delivering the harvested catch to the market in good condition. If fish are to be harvested live, then adequate holding facilities need to be prepared in advance. You may also wish to separate the broodstock from the harvested fish so that you ensure continuation of your aquacultural activities.

Q: *What equipment is required for harvesting?*

A: Harvesting is impossible with equipment that is in poor condition, such as nets with holes in them, insufficient buckets or holding containers for the catch, etc. All equipment must be prepared well before, as the fish will be stressed by activities such as emptying the water or by handling or netting. A valuable exercise may be to have a 'mock run' with your staff before harvesting to check that you have all the necessary equipment.

Q: *How long does harvesting take?*

A: Always longer than you think! Even the draining of a small 0.25-ha pond can take several hours. It is advisable to start draining the pond beforehand to allow more time to catch, clean, and package the fish the following day, and to get them to market that same day. This will ensure that the catch is fresh and that a better product is delivered. It is often better to harvest only partially, especially if time is limited. It is important to ensure that the remainder of the fish (those not harvested) have suitable living conditions (e.g. adequate oxygen, clean water, adequate space to prevent physical damage) to enable them to survive in good conditions until another harvest.





## Chapter 9 Fish health and diseases

### Managing fish health and diseases

Under culture conditions fish are more likely to encounter disease as many fish are kept close together, sometimes under stressful conditions. It is therefore very important that farmers carefully watch their fish for any strange behaviour. If disease is detected early it can be treated accordingly; disease treated too late may result in the loss of all the fish in the pond or cage.

There are two basic types of disease – non-infectious and infectious. Non-infectious includes nutritional, environmental and genetic problems. Nutritional problems include not providing the correct diet or vitamins to the fish. An environmental problem, such as high ammonia levels, can also cause the fish to get sick. Genetic problems usually occur when there is inbreeding among the broodstock. As these three things (nutrition, environmental, genetics) can be easily controlled, it is clear that non-infectious diseases only occur when there are poor management practices.

For an infectious disease to occur there needs to be an imbalance between two or more of these components: 1) the host (the fish), 2) the pathogen (the bacteria, fungus, parasite, etc.), and 3) the environment (e.g. water quality). When all three are in balance, the chance of disease is small. However, when one of the

components is compromised, the opportunity for disease opens up. Infectious diseases are generally more difficult to control than non-infectious diseases and may therefore result in losing many or all of the fish. It is therefore very important to identify and treat the disease early – before it is allowed to develop beyond the point where it cannot possibly be treated.

One of the most sensitive fish organs prone to disease and parasitic infestation are the gills. If the gills are damaged or infected, the fish is unable to obtain the oxygen it needs. Fish that are having difficulty breathing tend to gather at water inlets, near the surface of the pond, or along the edges. They may 'gasp' at the surface as they try to obtain extra oxygen from the air even if the dissolved oxygen in the pond appears normal. Generally these fish are easier to catch as they have less energy and cannot escape as easily as healthy fish. In addition to treating the disease, extra oxygen should be supplied in the form of paddlewheels, aerators or sprayers.

Diseases of pond fish are usually caused by fungi, bacteria, protozoans, worms or crustaceans. Most often, diseases can be controlled with proper pond management. This includes draining the pond, drying it, and liming it regularly, and also by preventing wild fish or unfiltered water from entering the pond. Some diseases will inevitably kill the fish, while others

can be controlled by treating the pond or the fish with chemicals.

Some diseases attack fish in ponds because the fish are stressed due to some environmental factor, such as overcrowding, low oxygen levels, or insufficient or poor-quality food. All of these conditions weaken the fish thereby allowing them to get diseases more easily. The farmer should watch the fish for signs of stress and disease. A change in normal behavior

State vet dissecting a fish to determine the disease affecting it. Farmers should contact their local state vet and consult them should they need their services.



may be a sign of disease (e.g. gasping at the surface for air, rubbing the body or head against the sides of the pond, or ragged fins and sores on the body). Something is wrong when a fish population stops eating suddenly. The farmer must check the fish daily, especially in very hot weather.

If fish are thought to be sick or are dying for unknown reasons, a few of the fish should be removed from the pond and examined for disease. The fish should ideally be kept alive and immediately transported to a specialist who can identify the disease and provide the appropriate treatment. If the fish cannot be kept alive, it should be sealed in a packet and placed on ice (but not frozen); this is to ensure that any parasites remain attached to the fish so they can be seen on examination.

During harvesting it is possible to check the health of the fish. Harvested fish can be quickly treated using short chemical baths. These baths may also be useful as preventative control against disease and parasites and to reduce the incidence of fungal infections, which may occur due to handling during sorting.

Details of specific diseases and their treatment are summarized in Appendix 3.

#### **INFO BOX: WHEN FISH ARE SICK**

- Speak to your state vet about the problem. Keep his or her telephone number at hand.
- Treat one pond or tank for a start. If it looks as though this is working, then apply the treatment to the other containments.

#### **Disease treatments**

Reality must prevail in the treatment of diseases: there is little point in spending large amounts of money to administer expensive drugs to a pond-full of sick fish when the cash value of the fish is little more than the cost of the treatment. Most diseases are caused by poor environmental factors and it is far more cost-effective to remedy the root cause of the problem than to medicate for the symptoms. When disease gets to a magnitude that all the fish in a large pond are suffering from it, the best solution is to sacrifice those fish, disinfect the pond with lime, and start over again, making sure that the poor environmental conditions that led to the initial stress are identified and remedied.

If medication in smaller containments is both practical and desirable, the actual diagnosis and treatment of disease should only be done by suitably trained personnel. A small mistake in dosage or adding an incorrect chemical can kill all the fish in the tank or cage, so if in doubt ask!

## Frequently asked questions

Q: *What medicines should be kept on a fish farm?*

A: In reality very few. Disinfectants such as acriflavine, permanganate of potash or formalin are valuable for sterilizing tanks. Salt is a useful and benign substance that can reduce stress in fish under certain circumstances. Malachite green or methylene blue crystals are useful in eradicating external parasites. For trout farms, Furanace® is valuable against bacterial diseases.

Q: *What do I do when the fish seem to be sick?*

A: The golden rule is to cease feeding as most diseases are a result of poor water quality made worse by excessive feeding, resulting in uneaten feed breaking down into toxic ammonia. Increasing the water flow to dilute toxins or poor water quality is also essential. Try to isolate the fish pond or container from other ponds or tanks that are not showing the symptoms.

Q: *What do I do when all the fish are seen gasping at the surface?*

A: This is usually a sign of low oxygen content, often seen early in the morning. The water quality is probably low, or the fish containment overstocked. Carry out a partial water change and reduce the stocking load immediately, and cease feeding for several days until the water quality improves. Use some form of blower to increase oxygen content if the stocking rate remains high. If the ponds are enriched with fertilizers, reduce the amount used for a while and try to flush out the ponds with clean water.

Q: *What do I do when the fish stay on the bottom with clamped fins, are skittish, and refuse feed?*

A: This is usually a sign of high ammonia content. Do a water test to confirm this (anything over 0.1 ppm ammonia is high and can be lethal to some species). Carry out a water change, cease feeding, and take steps to improve the water quality either by filtration (in the case of tanks) or by through-flowing clean water in the case of ponds.

Q: *How can I prevent disease from spreading from pond to pond?*

A: If fish in a particular pond or cage are infected do not use any equipment such as nets or buckets from the infected pond or cage in the other ponds or cages. Try to sterilize all such equipment in acriflavine or permanganate after use. Water should not flow from the infected to the uninfected containment or else the disease will spread rapidly and total mortality may result.





## Chapter 10

# Fish husbandry

### Broodstock selection

A classic mistake made in fish farming is assuming that all fish of one species are the same. In any type of farming, be it stock (cattle, sheep, goats, chickens, pigs) or crops (maize, cotton, sorghum, fruit), selection of the founder stock is highly important. So it is with fish. Too often people have assumed that any tilapia, barbel or carp from the local dam or hatchery are suitable. The reality is that while stock selection with animals such as cows is highly developed in southern Africa, this is not the case with fish. For example, no one would consider starting off commercial ranching with poor-quality cattle purchased cheaply at a backyard sale, and great efforts and high prices are paid for quality founder stock such as stud bulls, disease-resistant seed, and fast-growing hybrids. Likewise, the production of tilapia greatly improved in the Far East with the development of genetically improved farmed tilapia, which was developed in the Philippines in the late 1990s. This is a highly developed strain of the Nile tilapia (*Oreochromis niloticus*) which was selected for its rapid growth, good body form and red colouration.

When buying fish fingerlings, consult your local aquaculture officer to assist you in identifying a hatchery that produces quality fish. It is an unfortunate reality that the freshwater fish stocks offered by many hatcheries in South Africa at present, with the exception of trout, are of worse quality than wild-origin fish!

What are the essentials in identifying good founder stock to breed from?

- The population must have a wide genetic base and not be inbred. Unless the hatchery of origin advertises a program of stock selection, and specializes in quality fingerlings, avoid mass-production hatcheries, especially those who cannot show any quality control. Also avoid obtaining fingerlings from the 'guy next door' who probably also has inbred stock.
- The fish must show good growth characteristics. How can you ascertain this? There have been numerous scientific studies done by universities and other research

institutions on wild or other populations of tilapia, barbel and carp. Researching these can lead you to wild stocks of good quality with a wide genetic base.

- In the case of tilapia (*O. mossambicus*), use a founder stock from the cooler parts of the natural geographic range of the species (such as the Eastern Cape), where the fish will have developed a natural tolerance to cooler conditions and will grow at lower temperatures than the local strains. Tilapia from the Eastern Cape are more cold tolerant than those found in Limpopo, Mpumalanga and KwaZulu-Natal. Here temperatures of down to 9.5°C are tolerated and the fish may grow up 2.4 kg, reaching >400 g in mass during the first year of growth under wild conditions at temperatures in the mid-teens to low 20s°C.
- Inbred fish (e.g. barbel and carp) often have reduced tolerance to disease. In the case of barbel, the best fish probably come from the lower Vaal and Orange River systems. Carp have been highly developed and selected for improvements by aquaculturalists over the years and deep-body fast-growing forms are available that give better performance than wild strains.
- Trout produced by hatcheries in South Africa are often of good quality, and may have some improved tolerance to higher temperatures than imported strains from Europe or the USA.



Rural farmers in Egypt buying *O. mossambicus* fingerlings from a reputable farm. This is important as fish from good genetic stock will grow faster.



Farmers in Egypt breed tilapia using simple techniques. They net ponds where tilapia have dug 'nests' (far left). The female tilapia swims around the nest with fertilized eggs in her mouth. The eggs are collected from the fish and placed in glass bowls. When the eggs hatch, the larvae swim out of the bowls and into a larger tank where they are collected.

### Maintenance of broodstock

One of the essentials of good animal husbandry is the high-quality care taken of broodstock year round. Emaciated or diseased stock can hardly be expected to perform well when called upon to breed, so the conditions under which breeder fish are kept is paramount to their performance. Generally, with the exception of trout which will not breed under culture conditions (but have to be stripped of their eggs and milt), it is best to keep males and females separately to prevent wild-spawning. Tilapia, barbel and carp should be kept in as large a pond as possible, at low density (less than 1 fish per 5 square meters pond area), and be well fed. If year-round spawning is desired then some form of heating will be necessary, such as by enclosing the pond under tunnels to elevate the temperature to 20°C or more. Ponds should be protected against predators such as birds by using bird-netting and by low walls to keep out otters, leguans and platanna frogs. Also, wild fish should not be able to gain access to the ponds and all inlets should be screened. The fish should be supplementally fed, and the pond enriched on a regular basis to encourage plankton growth. Broodstock should be replaced at regular intervals and a breeding span of not more than 3-4 years is considered the maximum for most fish from southern Africa (except carp which can be used for up to 10 years). Trout are usually ineffective breeders after 2-3 years as they are a short-lived species.

### Breeding techniques:

#### Barbel (*Clarias gariepinus*)

Barbel are spawned artificially in aquaculture as natural spawning is haphazard and uncontrollable. Ripe fish of 2-4 kg are used and kept under prime conditions until the water temperatures reach the mid 20s°C. Females will be noticeably swollen in the belly with thousands of ripened eggs, and the ovipositor will look swollen and apparently inflamed. As male barbel do not easily release their milt and females their ripe eggs simultaneously, an injection of pituitary extract is required for both sexes. This can be achieved by injecting either with commercially available hormone treatments or homogenized pituitary glands

from another mature catfish. This is a skilled procedure and best left to competent hatchery technicians who will remove the pituitary gland from sacrificed males and inject the pituitary extract into fish of both sexes. The pituitary glands can be stored in ethanol for up to 18 months before being mashed up and mixed with sterile water or pure rainwater before being injected intramuscularly into the fish at a dose of 1.5:1 (donor : recipient weight basis).

Injected females should be separated to eliminate aggression. After approximately 20 hours at 22°C (sooner for warmer temperatures), the females should be fat and full of eggs and therefore ready for stripping. If the female can be held in a head-up position while the eggs flow freely from the genital pore, the eggs are ready for fertilization. The testis from two to three sacrificed males should be used for fertilisation as it will increase genetic variability and reduce the risk of one male being infertile. The sperm should be diluted in physiological saline (2% NaCl) before being mixed with the eggs. If fertilization is performed by squeezing sperm from the testis directly into the eggs in a bowl, some water should be added (as it activates the sperm) and then mixed in thoroughly.

When added to water, the fertilized eggs become sticky on contact; these can be spread onto screens made from mosquito mesh, using running water to keep them well-oxygenated, and they will hatch after 24 hours. Egg development time is temperature dependent (24 hours at 26°C; 18 hours at 28°C). When hatching occurs the free embryos will fall to the bottom of the tank. Once a few larvae have hatched the rest will hatch soon after. The larvae feed on their yolk sac for the first few days but require additional livefood three times a day (such as *Artemia*) from days 3-5 before they are weaned onto an artificial diet. Larval rearing is restricted to a 10-15 day period during which the fish are kept indoors and fed on a dry feed every few hours.

The juveniles should be fed a yeast-based diet and regularly size sorted to prevent cannibalism



of the smaller ones by the frequent 'shoots' which outgrow the rest. High mortalities can be experienced at this stage because the young are fragile. Once they have reached about 50 mm they become far more robust and can be stocked into plankton dams for on-growing, before stocking into grow-out ponds.

Barbel need efficient hatchery conditions to be spawned successfully in large numbers, with large well-covered holding tanks for the adults, and numerous small, clean tanks with filtered water for the fry.

### Tilapia (*Oreochromis mossambicus*)

One of the inherent disadvantages of tilapia as an aquaculture species is its tendency to breed at an early age and small size, and thus overpopulate ponds with small fish. However, the availability and quality of tilapia fingerlings

#### INFO BOX: CANNIBALISM IN CATFISH

- One of the essentials in culturing catfish is the need to frequently size-sort the juveniles as they grow, due to the prevalence of cannibalism.
- For example, juvenile *Clarias gariepinus* of 50 mm can eat their smaller siblings of 30 mm and must be removed to containers holding only similar-sized fish. These fish are called 'shoots'.
- Once shoots are removed, others will then become shoots in turn, and these need to be sorted out at daily or at 2-day intervals to reduce cannibalism.

is not always certain, so breeding should be done in a controlled manner to produce quality even-sized fingerlings for stocking ponds. Tilapia start growing when water temperatures reach about 18-20°C (16-17°C in the Eastern Cape), which is usually during late September in South Africa. At this time fingerlings for onward growth should be available to take full advantage of the growing season of warm summer months. To

achieve this, tilapia can be bred during winter in indoor tunnel-covered tanks where the water is kept 4-6 degrees warmer than outdoors. A method used is the 'Baobab Farm' type circular breeding arena (developed at the farm of that name near Mombasa, Kenya) which can be enclosed in a tunnel. Here the natural spawning behaviour of tilapia is exploited whereby the centre of the circular tank becomes the territory of male tilapia, with females attracted to their nests dug in the sandy substrate. Once they have bred, the mouth-brooding females retreat to the tank margins and eventually release their fry into an extremely shallow marginal area that is warmer and has inflowing water, attracting the fry, and from which they are easily collected. The females may then spawn again after a few weeks. The collecting process for the fry does not disturb the adults and relies on the natural instinct of the fry to seek shallow warm water, often of up to 35°C at the tank margins, from where they can be 'channeled off' into other containments.

Using such breeding arenas means that selected high-quality males and females can be used for breeding, and fry of a very young age, just post-release can be obtained. This leads to the possibility of using them for all-male production by sex-reversal processes using a feed laced with methyltestosterone for the first 10 days of their life. Use of such all-male stocks will then lead to more even production without all the inherent problems of precocious breeding, reduced growth rates, and over-population of the ponds with juvenile fish.

### Sex-reversal in tilapia

The sex of tilapia appears only to be fixed during the first two weeks of exogenous feeding (feeding through the mouth after absorption of the yolk sac). This means that if juvenile tilapia are fed with methyltestosterone-laced feed for the first 21 days of their lives, the sex of the fish will become over 95% males. This has two advantages: first, male tilapia grow faster than females; second, if reproduction is halted in



There are many different ways to grow fish, even of the same species. For example, tilapia can be grown in tunnels or in large earthen ponds. Each system has its advantages and disadvantages.

ponds then all energy is diverted to body growth rather than egg production in the females, and a more evenly sized crop can be harvested instead of the typical stunted crop of undersized and largely juvenile fish so typical of mixed-sex tilapia culture.

To ensure that all the juvenile fish feed only on the hormone-treated feed, a high measure of control is required. Female fish are usually stocked for breeding at a ratio of 5 females per male and kept in small breeding containers like hapas, concrete tanks, small ponds or aquaria. When the females are seen to be mouth-brooding, the hatched eggs are removed and placed into well-oxygenated tanks. Once the yolk sac has been absorbed and the juveniles are ready to feed from the mouth, they swim-up, as a shoal, and can be fed solely on a prepared diet for 21 days. At this stage the tanks will require filtration, as the young fish will need to be fed at least three times per day, and the water quality must be kept at an optimum level. After the 21-day period, the fry may be about 15-18 mm in length, and at this stage the development of the gonads is fixed. Microscopic examination has confirmed that 95-98% of the fish will be sexually male, while the rest may show signs of both male and female gonad development. However, these apparently bisexual fish are usually unable to reproduce.

The actual manufacture of the feed is done by experienced feed-companies to ensure the correct mix of hormone and its stability in the feed. Micro-encapsulation is sometimes used to prevent the hormone from leaching out in the water before being consumed by the juvenile fish.

### ***Tilapia rendalli***

*Tilapia rendalli* are not mouth-brooders, yet are best spawned in the same way, as *O. mossambicus*. This species has much larger individual broods and can be successfully bred in simple earth ponds with a shallow end that can be partitioned off to collect the fry.



### **Carp (*Cyprinus carpio*)**

Female adult carp are kept separately during winter, after which time their eggs will ripen. Once water temperatures rise above 20°C in spring, shallow breeding ponds (<1 m deep) can be prepared; these usually include a crop of grass or other vegetation that the carp can fix their spawn onto when introduced. Males and females are introduced and will often spawn within a few days, during which much activity will be noticed as the males pursue the females into the vegetation onto which they will lay their eggs. The eggs hatch after four days and the larvae are about 5 mm in length. The pond is then partially drained to remove the adults, which would otherwise consume part or all of the hatching eggs. For this to be successful, part of the pond edge must have a deeper channel section to allow for easier catching of the adults without disturbing the eggs on the vegetation. The ponds are then fertilized with manure to produce a plankton bloom that provides the fry with food for the first few weeks of their life. After the juveniles reach about 40 mm in length they can be collected and stocked into grow-out ponds.

Another method of spawning carp is by stripping and artificially incubating the fertilized eggs in large jars with through-flowing clean water in a similar way to the method of spawning barbel. However, male carp do not need to be sacrificed for their milt after injection (or sometimes even without injection) as this is free-flowing when the male is ripe and ready.

### **Trout (*Oncorhynchus mykiss*)**

The spawning of trout is done by artificial methods in a way very similar to that for carp, whereby the males are stripped of their milt and this mixed with stripped eggs from ripe females. Trout eggs are relatively large and robust (in the wild the adults bury them under fine gravel in 'redds') but the eggs need high levels of dissolved oxygen to survive. Fertilized eggs are placed on screens in single layers in tanks, with cool flowing water (13-16°C). The eyed ova are



Trout ova hatching trays (far left) and tanks with fry (left). Trout hatcheries require very good water quality.



often sold at this stage to other hatcheries, and hatched out elsewhere as they travel well in crushed ice. Trout will grow well from first feeding on artificial diets of finely crushed trout pellets, with a protein content of about 48%. Above all, trout need cool, clean water to prosper and will suffer numerous ailments if the water quality is not high.

## Frequently asked questions

Q: *Can I breed tilapia (O. mossambicus) in a pond?*

A: Yes, but you will have little control over production, and collection of the fry will be difficult as you will not be able to separate the fry from the adults if you drain the pond, and many will likely be lost in the mud. Netting juvenile tilapia from the pond margins is more difficult than it looks as they soon flee to deeper water as they perceive you to be a predator and their natural instincts compel them to flee. Pond-breeding is very much a second-best option. If a shallow-end can be closed off from the main pond, this helps in collecting fry.

Q: *Will barbel (C. gariepinus) breed naturally in ponds, and will I get lots of fingerlings from them?*

A: Barbel will sometimes spawn wild in ponds, but production will be very low and most will be lost to predators and cannibalism. Cultured barbel need to be spawned artificially.

Q: *Can I mix the juveniles of tilapia, carp and barbel together in a pond?*

A: Yes, to some extent this is polyculture and their slightly different feeding habits can give a higher overall production from the pond (in theory). However, barbel tend to produce 'shoots' which rapidly outgrow the others, and cannibalism may cause heavy losses of the tilapia and carp juveniles.

Q: *Will trout breed naturally in dams or tanks?*

A: No, in South Africa, only rare wild populations of trout, in certain rivers where environmental conditions are perfect, breed naturally. Most farmed trout are stripped and then artificially reared from the fertilized egg stage.

Q: *How many fingerlings can I get from one spawning?*

A: A mouth-brooding *O. mossambicus* of around 500 g may spawn up to 500 eggs, a substrate-spawning *Tilapia rendalli* may produce up to 3000 fry. Barbel and carp can produce several hundred thousand fry per spawning from a 3-4 kg female. Trout may produce around 500-1000 eggs per 2-kg female.





## Chapter 11 Cage culture

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### Cage culture of fish

Cages are widely used around the world to culture fish in natural or artificial water bodies. The use of cages in aquaculture has several advantages which are summarized below. Cages have some disadvantages, such as not allowing the fish access to the substratum from which they can feed or seek refuge, with the ever-present risk of losing the entire stock within a cage should the fish be able to escape. Cages also suffer from fouling of the mesh in certain waterbodies; this prevents water free-flow through the cage, resulting in poor water quality at times within the cage. Cages may also pollute some waterbodies due to the accumulation of uneaten feed and fish waste below the cage. Another disadvantage is that the fish only receive the feed ration actually fed to them and little nutrition is derived from natural sources, especially in clear, sterile water situations. This means that the feed supplied has to fulfill all the nutritional requirements of the species cultured. Fish kept in cages are vulnerable to existing diseases in the waterbody, and they may introduce other diseases to wild fish in that waterbody, over which there is little control.

### Types of cages

#### *Small cages*

Most people assume that fish cages are all very large and expensive. This is not true. In the Far East, many ornamental fish are cultured in small

mesh cages called pen-nets or 'hapas' which are often set together in groups in fertilized ponds or small dams. Pen-nets are staked out using mesh for the sides and the natural pond bottom for the base. Sometimes these cages are made of locally available materials, such as bamboo, although today the wide availability of plastic mesh of various types makes for more secure cages. Some of these cages may be as small as 1 m x 1 m and only 0.5 m deep. They are either staked out in shallow ponds, or floated using bottles, inflated tubes, or closed-PVC piping for buoyancy. Hapas are strictly small cages whose mesh-base is on the bottom of the pond or dam, allowing the fish some access to benthic feeding. Often hapas have light mesh over their tops to prevent predatory birds from gaining access and eating the fish. Simple hapas can be made of plastic mosquito mesh, shade cloth or semi-rigid plastic mesh (such as oyster mesh). It is important to ensure that the cage is escape-proof, and that all seams and joins are robust and will not break open after prolonged use or when the cage is lifted up to remove the fish at harvesting. Needless to say, cages with weak or gaping seams and joins are useless, and the fish will be lost to the larger waterbody from where they cannot be harvested.

Small cages in ponds or small dams have the advantage that the waterbody can be enriched with manure or fertilizers to create a bloom of zooplankton or phytoplankton, which provides

### The advantages of fish cages

- Cages are less expensive than building ponds, dams and other infrastructure.
- Cages can make use of existing water bodies (such as lakes, dams or the sea) that have good water quality.
- Cages do not require land-ownership and can be moved to the most suitable area.
- Cages protect fish from predators and theft.
- Cages are versatile in that they can be small and easily maintained for low volumes of fish such as ornamental species, where many different individual species are kept by one producer in groups of cages.
- Fish can easily be harvested from cages by simply pulling up the netting to crowd the fish, and then dip-netting out the required number.
- Cages can be kept in groups which facilitates the size-sorting of fish.
- Cages prevent unwanted reproduction of some species (such as tilapia) as the fish are unable to establish nesting territories in the confines of a cage.

a large proportion of the feed needed for the growth of the fish. This is widely done in the Far East where millions of gouramies, livebearers, cichlids and other fish species are reared in small cages in enriched ponds for the ornamental fish trade.

### **Large cages**

Many people have seen pictures of the large marine sea-cages in the Northern Hemisphere (used to grow fish such as salmon, in Norway, the UK, Chile and Canada). These cages are built to withstand the storms and rough seas of their environment and are very expensive to construct. They are also very large, some being more than 20 m or more across. Some of these cages are circular, others are rectangular, and they may contain several tonnes of fish each. Stocking, feeding, monitoring and harvesting are all highly mechanized due to the heavy equipment and large volumes required. Such operations are run by large companies that usually have their own hatcheries to produce the juveniles, and their own factories to make the fish-feed and process the catch after harvest. A local example of such a fish farm is the Lake Harvest tilapia farm on Lake Kariba, Zimbabwe. Here, juvenile fish are produced in ponds on the lake side and then stocked into large cages in the main lake for growth up to marketable size. The tilapia are then harvested and processed in the farm's own factory, into value-added form (fillets, smoked fish, etc.) and then air-freighted to markets in Europe.

In South Africa, smaller-scale cage-culture enterprises that still use relatively large cages are found in the Western Cape. Here the many coolwater dams provide suitable habitat for culturing trout in cages. Often the water quality is very good, yet the use of the dams without cages would be difficult due to factors such as the impossibility of draining them, problems with harvesting the fish, loss through predation and theft, and conflict with other water-users such as anglers and farmers, etc. The use of cages to confine the trout into a manageable area, where they can be monitored, fed, and ultimately easily harvested, has proved to be a success.

### **The Western Cape cage culture of trout**

This province's success with cage culture of trout over the last few years serves as an example of what potentially could be done in other regions of cooler water (temperatures <23°C) such as the Mpumalanga escarpment, the KwaZulu-Natal Drakensberg region and the highland regions of the eastern and southern Cape. Trout are an established, highly marketable product

and fetch a good price. However, the quality must be very high and there is no room for error in the cultivation of the fish. The essentials in achieving a successful cage-culture venture with trout are:

- Good water quality suitable for trout all year round.
- A ready and affordable source of fingerlings.
- Properly designed and built cages that are escape-proof and predator-proof, yet which can be managed efficiently and without difficulty.
- An installation that is easily accessible and can be monitored on a daily basis, which requires that someone check on and feed the fish usually twice daily.
- A source of suitable feed at an affordable price, with a place to store it nearby so that it retains good condition.
- Sufficient help at hand to assist with harvesting the fish.
- A pre-identified market to accept and process the fish, at an agreed price that makes the venture profitable.
- A business plan that details the responsibilities and potential rewards for all those involved in the project.

As with most fish-farming ventures, such a project should be run as a business that will incur capital costs, running expenditures and then income through sales of the product. This is then shared out between the members of the project according to a pre-agreed formula. Experience in the Western Cape has shown that each project should not involve too many participants, otherwise the rewards are too diluted and each member of the project will not receive enough cash at the end of the day to make him/her feel that it was worthwhile. Several established projects, each with one cage, have only two members, yet each partner receives a worthwhile income from the sale of the fish. Many of the workers on these projects are part-time in that they have fulltime jobs working on the farms where the cages are situated, and they feed and monitor the fish before and after work each day. Harvest usually takes place over a weekend or on a public holiday when other people are available to assist in the day's work and earn extra cash.

### **Technical aspects**

#### **Cage types**

The design of the cage is a function of:

- The scale of the operation
- The fish species
- Environmental considerations such as aesthetics





A floating trout cage as used in the W. Cape, showing the raised blue-netting predator protection surrounded by the walk-ways. The cages are anchored away from the edge of the dam but can be pulled to the edge to stock with fish. Juvenile fish are transported to the dam in a tank and flushed into the cage through a pipe.

- The local availability of materials and skills to assemble suitable cages.

The cage bag has several requirements: it must hold the fish such that they cannot escape, even as juveniles, yet it must allow the maximum possible exchange of water to maintain water quality at a high standard inside the cage. Cage bags can be any shape, from rectangular to circular. Circular bags are cheaper to make, but harder to work with in terms of catching the fish, although some fish such as trout seem to prefer circular bags which allow them to shoal in a circular manner. The mesh should be rot-resistant, light yet non-abrasive, easily repaired, foul-resistant, and affordable. There are many materials available, from artificial fibre netting to semi-rigid extruded plastics. The cage bag should retain its shape by means of supports, weights or attachments, such that the fish are not crowded or crushed by collapse of the bag due to water currents or foul weather.

The cage frame must have several attributes built into its design. It should be durable and rigid such that its lifespan is in proportion to its cost. Wooden frames may last one or more years but will eventually rot under water. Metal frames are heavy and will rapidly corrode. Plastic components are best if sufficiently strong enough, and these have the advantage that they are usually lighter than other materials (a cage frame of 10m x 10m x 3m can be heavy and bulky to move!).

#### ***Access and ease of management***

Clearly, large cages will hold large numbers of fish, which need to be fed, monitored and eventually harvested. Such cages need to be designed such that the persons doing these tasks can operate easily and safely. Large cages should have a stable walkway around them and should also project above the water surface by at least one meter to prevent the fish from jumping out. Supporting the cage, as well as the people working on them, requires floatation, and this should be sufficient to provide a stable working platform. Usually for larger cages in

freshwater dams in South Africa, plastic drums are used. The entire structure needs to be rigid and should not partially sink or bend when being worked upon.

To prevent theft, and to increase water circulation through the cage body, cages are often moored offshore such that access is only by boat. These cages need to be securely anchored to resist strong winds and wave action in larger impoundments. If cages are grouped together then the grouping should take into account the prevailing winds and currents to ensure the best water exchange possible through the cages.

Where cages are installed in dams with deep water close to the shore, access can be by walkways or floating pontoons, but then consideration must be given to the equal ease of access by predators and the risk of theft.

#### ***Ancillary equipment needed***

When cages hold fish at high densities, especially with high numbers of trout shortly prior to harvest, the oxygen content of the water may reach critically low levels at times of warm weather. To ensure that massive losses are not experienced, supplementary aeration may be necessary, and this can be done using mechanical surface agitators and air or water pumps. Alternatively, injection of either pure oxygen or compressed air to the cage may be a solution if electricity is not available.

In some situations the build-up of wastes under fish cages can reach a point where the proximate water oxygen content can decline to near lethal levels for the fish. The simplest solution is to then move the cage from site to site to disperse this build-up of wastes over a wider area.

Fish harvested from cages can be both individually quite large (250-500 g for trout) and also bulky in terms of overall mass. A range of dip-nets, screens, containers and other equipment is needed to efficiently harvest the fish. One successful method used by Western

Cape fish farmers is to use a floating rectangular keep-net of approximately 1m x 2m x 1m deep to place the caught fish into; this is then towed ashore, and the fish are emptied into large

plastic tubs partially filled with crushed ice. These tubs are then sealed and taken by vehicle directly to the processing plant.



## Frequently asked questions

Q: *When/why should cage culture be considered?*

A: Cage culture is an alternative to building containments for fish aquaculture (ponds, tanks, etc.). Pre-existing water bodies such as dams, lakes, estuaries or the sea are used for cage culture. This means that no capital is required for additional building containment (such as plumbing or filtration) other than the cages themselves.

Q: *What species of fish are suitable for cage culture?*

A: Species that grow well on artificial manmade diets are some of the best candidates for cage culture. This is because many of the health and growth requirements of the fish have been experimentally determined and the feed formulation can be optimized for variable conditions. An example is trout, which can receive their entire nutritional requirements from a high-protein pelletized diet. Fish at the bottom of the food chain (such as detritivores, zooplankton- or phytoplankton-feeders) will be more expensive and slower-growing species to raise in cages, and are therefore not good candidates.

Q: *Can ornamental fish be reared in cages?*

A: Yes, very successfully. Simple netting 'hapas' are widely used in the Far East to separate numerous species raised in nutrient-rich ponds for ornamental fish, and this reduces the number of expensive containments required to separate the many species often raised by ornamental fish farms.

Q: *What are the disadvantages of cages?*

A: The set-up costs can be high initially; these include the costs of building large robust cages that can withstand rough weather. Cage culture can be prone to damage and there is a risk of escape of the entire stock should the cage break or be damaged by predators or thieves.





## Chapter 12 Increasing production

### Increasing the production from ponds

To increase the production of a pond, a fish farmer has a number of options available. These include combining different species of fish (polyculture) or growing fish along with other domestic animals (integrated aquaculture).

### Monoculture

The most commonly farmed fish in Africa is tilapia. The most frequently used species is *Oreochromis niloticus* stocked at 1-2 fingerlings per m<sup>2</sup>, with an average stocking size of 5-10 g each. The ponds are fertilized with manure or compost and the fish are fed irregularly using locally available ingredients. The production cycle lasts around 5-6 months and harvest yields 750-2000 kg of fish per hectare (15-50 kg/year in a 100-m<sup>2</sup> pond). This can be doubled for the year if the ponds are used twice.

### Polyculture

Polyculture is culturing two different species at the same time. The two species use the same space but because they have different habits and diets, they do not negatively affect each other. In many cases the growth of the different fish is better than when they are grown alone in the same pond. This is because one species cannot completely use the nutrients in the pond, and thus two species make better use of them. For example, ponds with Nile tilapia on its own produced 35% less kg/ha/year than ponds stocked with Nile tilapia and catfish.

The most common polyculture species are:

- Common carp (omnivore) and *Oreochromis* species (planktivores)
- Common carp (omnivore) and grass carp (herbivore)
- Common carp (omnivore) and silver carp

- *Oreochromis* species (planktivores) and catfish (carnivore).

It is important that the size of the two species are similar when stocking the pond, otherwise the larger species could end up eating the other.

### INFO BOX: POLYCULTURE

Polyculture (two or more species grown together) —

- In Israel, yields of up to 11 tons/ha/year achieved.
- World average is 3.4 tons/ha/year.
- In South Africa with just fertilization of ponds, can achieve 1.25-2.25 tons/ha/year
- In South Africa with supplementary feeding, can achieve 3-6 tons/ha/year.

### Integrated aquaculture

In other parts of the world, polyculture aquaculture has become more important as it improves the recycling of organic wastes.

### Irrigation of farmlands and fish farming

If the ponds are built so that the water level is higher than the crop fields, it is possible to drain the water to irrigate the farmlands. This has a number of benefits. First, the water is reused, which is important in southern Africa due to the limited supply of freshwater. Second, the water coming from the pond is likely to have a higher nutrient load due to excretion by the fish. This extra nutrient is beneficial to the plants and will save the farmer fertilizer and manure. Design and placement of the irrigation canals should be considered before building the pond as the relative position of the pond and fields is important.

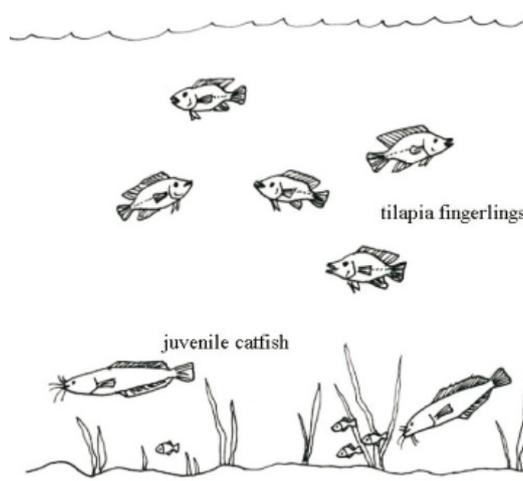
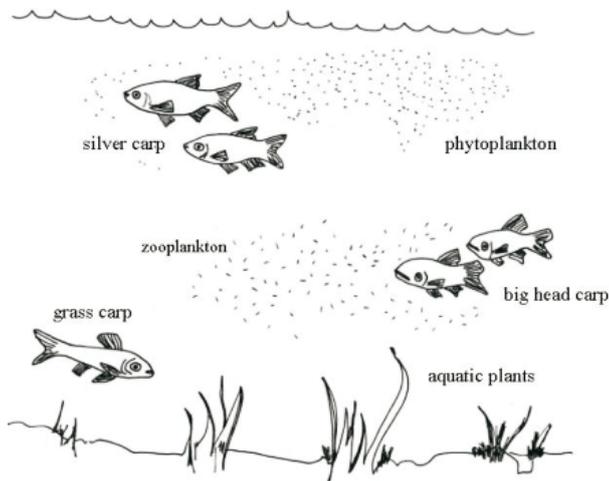
### Mixed-sex *Oreochromis mossambicus* production

- Stocked at 1-2 fish/m<sup>2</sup>
- Fingerlings of 5-10 g (5-8 cm length)
- Growing period 6 months
- Ponds fertilized with organic manures
- Harvest size 50-400 g, many juveniles
- Harvest yield 0.75-2.0 tons/ha.

### Single-sex (all-male) *O. mossambicus* production

- Stocked at 5-10 g fingerlings per 1-2 m<sup>2</sup>
- Fingerlings of 5-10 g (5-8 cm length)
- Pond fertilized with organic manures
- After 6 months fish grow to 350-400 g
- Expect to harvest 5 tons/ha
- With supplementary feeding expect up to 8 tons/ha.





Combinations of species used in polyculture: three carp species, and catfish with tilapia.

### **Integrated fish/pig farming**

Pig sties are constructed on the pond embankment or near the pond to allow for easy runoff of waste directly into the pond. The recommended number of piglets is 100 per hectare of pond (1 piglet per 100 m<sup>2</sup>). Two-month-old weaned piglets are fattened for six months until they attain market size (70 kg). The waste acts as pond fertilizer and encourages the growth of natural fish food organisms. The fish also feed directly on the pig waste and no other feed or fertilizer is required.

In this manner, after six months, monoculture ponds stocked with *Oreochromis niloticus* at 2 fingerlings per m<sup>2</sup> can yield 4000 kg/ha and 3000-4500 kg of live pig.

### **Integrated fish/duck farming**

A duck hut is built on the pond embankment or on a floating platform. Erosion damage may be caused by the ducks pecking at the soil on the sides of the pond in search of insects. Therefore, a fence should be placed around the inside wall to prevent the walls from collapsing. Peking and Muscovy ducks are the most popular, with Peking ducks being preferable as they spend more time on the water. The ducks will feed

on aquatic organisms such as insect larvae, tadpoles, snails and weeds, but they should also be provided with duck feed at 100 g/bird/day. As with pigs, the duck droppings act as fertilizer for the pond water. About 10-15 ducklings per 100 m<sup>2</sup> (2-3 months old) are suitable for starting with. Ponds can be stocked with tilapia, common carp or catfish, at 2-3 fingerlings per m<sup>2</sup>. The fish require no additional feeding and the pond can produce 1250-2250 kg of fish/ha and 750 kg/ha of duck per six-month cycle. Additional food (or ducklings) can be obtained when the ducks start to lay eggs after 5-6 months.

### **Integrated fish/chicken farming**

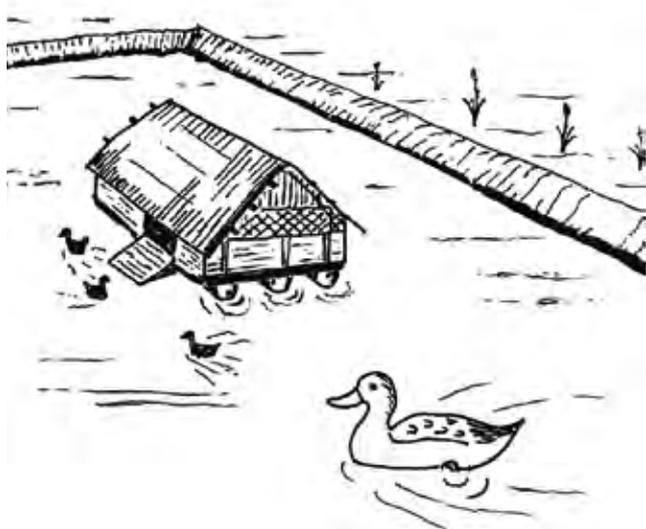
Like integrated duck farming, the chickens are raised in cages under a hut constructed over the pond, on the side of the pond or nearby. About 20-50 chickens can be used per 100 m<sup>2</sup>. If the hut is not built over the pond, the chicken droppings fall on the floor, from where they are collected and applied to the pond. No extra feed or fertilizer is added to the pond. Polyculture of tilapia (2 fingerlings per m<sup>2</sup>) and catfish (1 fingerling per m<sup>2</sup>) or common carp will yield 1700-2500 kg/ha after six months. At each harvest, the live weight of the chickens will be between 40-60 kg per 100 m<sup>2</sup> of pond, depending on the number raised and breed

#### **INFO BOX: INTEGRATED AQUACULTURE**

- With irrigated crops, water is used twice and enriched by fish waste.
- With crops, vegetable farmers can feed vegetable waste to herbivorous fish species (lettuce, cabbage, spinach, beetroot leaves, carrot tops) can all be added directly or as compost.
- With livestock, chicken, cattle, sheep, goat or pig manures used to fertilize ponds.
- With fowls, ducks or geese can directly fertilize ponds, increasing productivity.

#### **Annual production through integrated carp and livestock farming:**

Animals	Fish production	Animal production (live weight)
Fish + pig farming	6-7 ton/ha	4 000-5 000 kg pig meat
Fish + duck farming	3-4 ton/ha	500 kg duck meat + 17 000-20 000 eggs
Fish + chicken farming	4-5 ton/ha	60 000-70 000 eggs + 1 500-2 000 kg meat



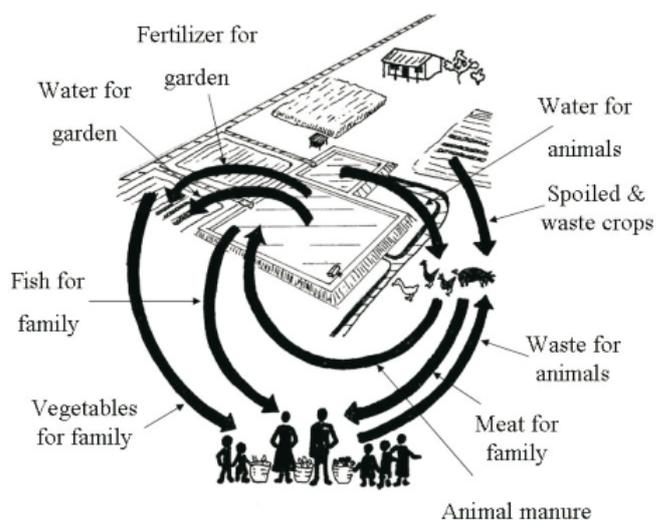
Integrated fish/duck farming. The duck hut can float on the pond or be built on the side of the pond embankment.



Integrated fish/chicken farming. The chicken hut can be built on poles over the pond or on the side of the pond embankment. In South Africa, where land is less at a premium than in China, for example, it is best to place the chicken houses adjacent to the pond to make netting the pond easier.<sup>2</sup>

used. Egg production can help provide additional income (and chicks), with approximately 120-200 eggs produced per chicken per year.

A successful pond can help the farmer by providing fish and water for his/her family, garden and livestock. In turn, the livestock and vegetable garden can provide the pond and fish with food (via feces and waste plant materials).



The benefits of integrated aquaculture: using a pond, livestock and vegetable garden can improve the farmer's livelihood.<sup>3</sup>

## Frequently asked questions

Q: *How can production be increased in ponds?*

A: In general, production is increased by improving water quality, so that fish can be held more intensively, and by increasing food quality and quantity. This has to be balanced against input and running costs such that the venture is not over-capitalized in terms of expensive technology.

Q: *When should increased production (intensification) be considered?*

A: When the risks of losing the stock due to poor water quality or technical failure is safe-guarded by back-up systems such as stand-by generators, clean water supplies or 24-hour monitoring. The cost of installing these systems must be justified by the increased productivity in terms of fish harvested per unit area or unit volume of water.

Q: *When should increased production not be considered?*

A: A good rule is to hold back when intensification runs the risk of destroying your stock, and when you cannot support the upgrade with technical back-up systems. If markets cannot absorb increased production, or if inadequate finance is available to make systems technically reliable, then increased production should not be considered.

Q: *How can pond aquaculture production be increased simply, without high-tech input?*

A: By using fertilizers to increase natural food productivity, and by using polyculture of species that feed on different organisms. Integrated aquaculture using farm wastes such as manure, vegetable clippings or edible by-products of other farming activities (such as brewery waste), can also increase production at little extra cost.





## Chapter 13 Business and financial planning



### Business planning

You may have read many magazine or newspaper articles that promise a bright future for aquaculture. The technology, growth processes, challenges and potential rewards are exciting. At the same time you must remember that aquaculture is a risky business, so inadequate preparation of a business plan will hurt in two fundamental ways. First, starting in aquaculture without a good business plan will result in mistakes that could have been solved on paper. Second, those providing the financial resources for building up the project demand a business plan, unless you yourself are the sole source of funding. A demonstration that the project is viable will be essential if you are asking for funding.

Farmers have to possess more skills than most other occupations, and this is also true for aquaculturalists. You must have a practical bent and be good at building, repairing equipment, working with pumps and nets, and handling fish. You have to understand fish biology, run an office, keep books, hire and fire, and do the marketing of the final product.



Fish being sold along the roadside in Limpopo Province. Farmers can establish a considerable number of customers by selling fish informally.

All these responsibilities are overshadowed by three fundamental concerns:

- Who will buy the product?
- How will you produce the product?
- Will the income you make exceed the costs?

There are many different types of fish-farm business, from the micro level, where one person grows fish in one or more ponds and sells or barter these to people in his community, to the complex high-investment company-run business that moves large volumes of fish competitively into the formal market at regular intervals. The business plan for these extremes

### Examples of businesses and their requirements for a business plan:

Ownership of business	Typical investment	Facility used	Typical monthly income	Typical business plan and accounting type
One person	R500-R1000	Single pond, no buildings	R20-R200	Simple one-page plan. No accounts or records kept.
Group or partnership	R250 000-R750 000	6 ponds, feed and net store, office	R1000-R5000	5-page plan with start-up, running costs and expected income; bank account required.
Company	R1–10 M	10-50 ponds, hatchery outbuildings and office, lab and stores.	R10 000-R250 000	Complex professional plan indicating strengths and weaknesses, market opportunities and cash-flows; uses professional accounting and auditing.

would look very different, but each needs a plan to show that the activity is worth doing.

For each type of business an examination of the following aspects needs to be done:

- Expectations (see Annexure A)
- Market potential (see Annexure B)
- Production feasibility (see Annexure C)
- Financial feasibility (see Annexure D).

**Basics of business planning: key questions**

Aquaculture is no different from agriculture when considering whether or not a proposed venture is worth doing. Just as a farmer is not going to buy cattle if grazing is unavailable, nor plant crops if suitable arable land is not available, nor should he/she consider aquaculture if sufficient water is unavailable. The basis of aquaculture is water: water is fundamental in its importance to aquaculture, just as good land is for classic crop-agriculture, and water quality and quantity are the most essential starting points in any business plan.

Before considering an aquaculture project the people undertaking the proposed venture need to ask themselves certain key questions. These questions vary in importance: from those that may be answered “No”, making the project unviable from the outset (e.g. “No” to the question “Is there sufficient water?”, making aquaculture impossible), to those that require some form of compromise to make the project viable (e.g.: “Is there a market for the product?” Answer: “No, there is no local market, therefore transport to a market further away is required, incurring additional transport costs”). A list of key questions is given in Annexure A, and the types of question are summarized in the table below. Some negative answers to these questions are considered to be ‘fatal flaws’, and if these fail to give satisfactory responses,

no further investigation into the viability of the project should be considered, as these are fundamental faults that rule out the project (see page 73).

Some reasons why some aquaculture ventures and projects have failed:

- Pond-type aquaculture ventures started in rural areas where input and running costs were too high in comparison to the financial yields of the project.
- Community-run ventures where too many people expected to be supported by the venture.
- Projects using waste water from purification schemes but that resulted in marketing difficulties due to perceived ‘pollution’ of the edible product.
- Climatic problems, either too hot or too cold, that made the culture of certain species unviable.
- Disputes over the use of either water or land.
- Excessively heavy investments in technically complex facilities and unsecured markets for the end product.

This list is by no means exhaustive but serves to illustrate the degree of planning that must be considered before undertaking a venture.

**Components of a business plan**

In compiling a business plan and anticipating the costs of starting-up a business, a simple business plan must cover the following aspects:

1. A project overview that concisely describes the project concept.
2. The reason for initiating the project: what advantages the project has, describing its overall design and method of operation.
3. A costing exercise for the project, divided into

***Key questions can be divided into groups, each with their own reason for asking them.***

**Type of question**

Socio-economic questions, e.g.  
*Why do you want to start an aquaculture venture?*

Site-related questions, e.g.  
*Is the site suitable for ponds?*

Biological questions, e.g.  
*Are the water temperatures suitable for tilapia growth?*

Market-related questions, e.g.  
*Is there a market at a realistic price for the species you have chosen?*

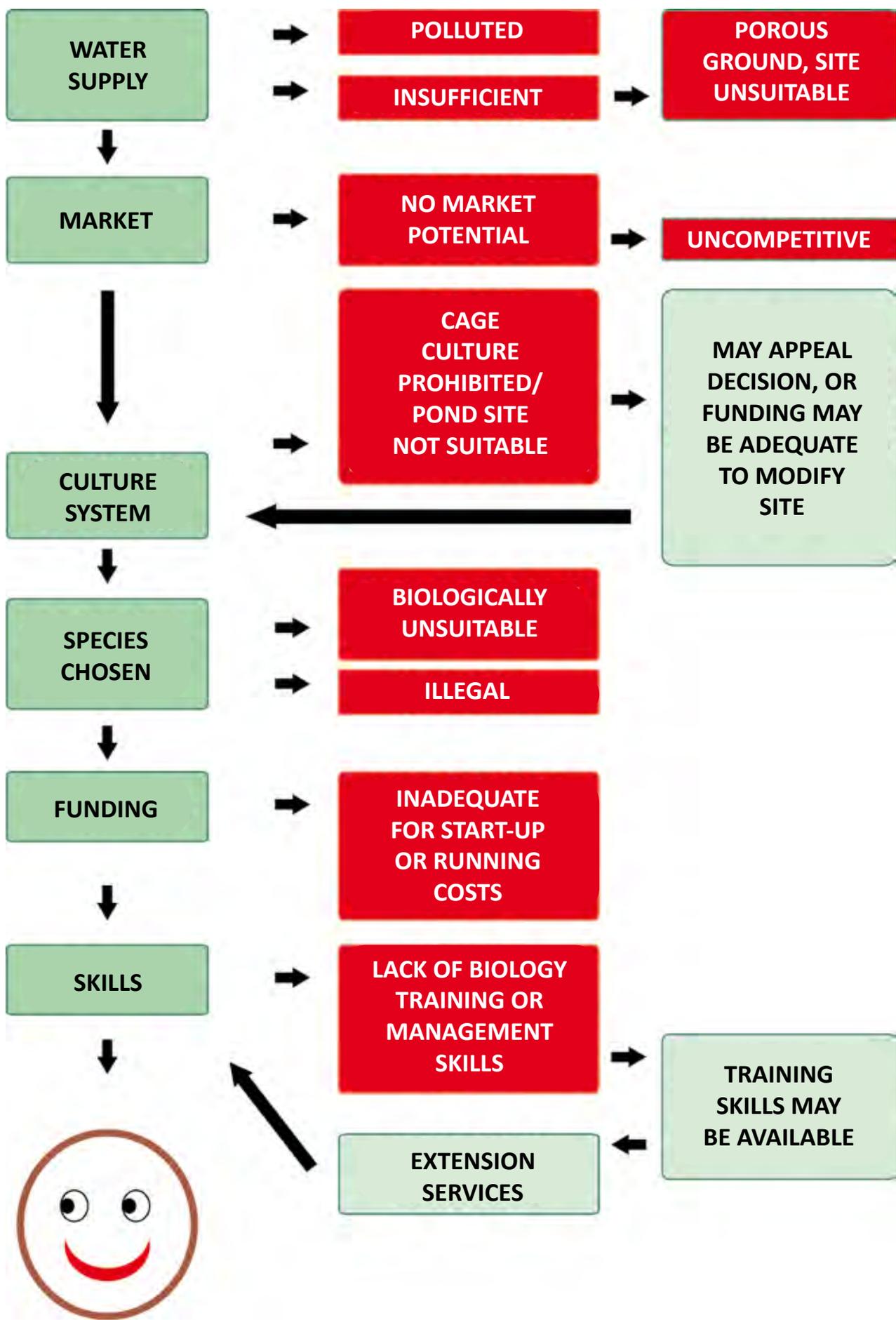
**Reason for asking this question**

To assess whether or not you: see a financially viable prospect, have skills working with fish, or have a facility that may have potential for aquaculture.

To assess the financial cost and technical suitability of developing that site.

To assess correct species choice.

To assess whether or not you can sell the fish profitably (even if you can grow the species successfully).



Examples of 'fatal flaws' that make projects unviable.  
Green = go/continue; Red = stop/no go

the following aspects:

- **Initiation costs:** the costs of obtaining permits, surveys, water rights, business partnerships and other legal aspects in setting up a business.
- **Construction costs:** all the anticipated material and labour costs, including capital items such as land, vehicles and machinery.
- **Start-up costs:** these include obtaining broodstock, stationary and office equipment, feeds and medications, electrical and telephone connections, etc.
- **Running costs:** these include all expenses incurred before the project provides a return that equals or exceeds the running costs (profit). Examples are electricity, telephone, staff salaries, feed, fuel, transport, etc.

4. A description of how the venture would be run, including staff hierarchy and duties, stocking plan, anticipated growth, and harvest schedules.

5. A description of marketing potential and techniques to penetrate local or other markets, including any potential prospects for value-adding to the product offered for sale.

6. Strengths and weaknesses of the project: these can be grouped under headings such as site, facilities, species, anticipated production volume, local markets, distant markets, and potential for expansion or diversification.

7. Future potential prospects for the project.

### Checklist in preparing a business plan

Are you prepared for an aquaculture business? The checklist of key questions on page 79 will help provide the farmer with what needs to be considered before starting. The three most important decisions are site selection, species choice and market potential. However, ignoring socio-economic factors has led to the failure of many otherwise potentially good projects.

### INFO BOX: THE THREE MOST IMPORTANT CONSIDERATIONS IN BUSINESS PLANNING

- Site selection
- Species choice
- Market potential

### Site selection

The suitability of the site is extremely important and the following checklist will help determine whether it has good aquaculture potential.

1. Is the proposed site in a region zoned suitable for aquaculture?
2. Is the site well drained and above flood-prone areas?
3. Who owns the land where the fish farm will be built?
4. If you are considering ponds, is the land a good shape for a fish pond?
5. Is the soil suitable for pond construction and will it hold water?
6. If you are considering putting cages in dams, is there sufficient water turn-over to dilute pollution from feed and waste?
7. Is there a sufficient and acceptable water supply?
8. Would you be able to use this water?
9. Is the water polluted by any chemicals, fertilizers, pesticides, toilets or other pollutants?
10. Is the pond or cage site close to your home?
11. Are there enough people to help build and harvest the pond, cage, or other system that you build?
12. Is there enough food available for the fish?
13. Are there fertilizers available for ponds?
14. Can the equipment for building a pond be borrowed, hired or bought?
15. Is it possible to get made-up cage components to the site, or will they have to be assembled on-site?
16. Does the site have acceptable potential for the disposal of waste water?
17. Is there easy access to services and technical assistance?
18. Is there adequate room for the proposed ponds or cages, plus possible future expansion?



It is important to decide where your market realistically lies.



### Species selection

1. Do the people in the area like to eat the fish species that is to be cultured?
2. Do you and your family eat the farmed freshwater fish?
3. Can the people in the area afford to buy the fish produced in the pond, cage or tanks?
4. Is the cultured fish suited to the local climate, and is it native to the area?
5. If the species is not indigenous, is it an acceptable species for aquaculture in that catchment in terms of conservation legislation?
6. Are established and reliable rearing techniques known and readily available for the intended species?
7. Can the basic biological needs of the culture species be met?
8. Have you chosen a species for culture, and are you familiar with its biology?
9. Have you investigated the production strategies available and chosen the best for you?
10. If you do not have the necessary technical experience, are you prepared to employ someone who does?
11. What food would you feed the pond fish and where would you get it from?
12. Are dependable sources of juvenile fish available locally?

### Socio-economic factors

1. Is the development acceptable to neighbours and others who may use the area?
2. What competition is there for the use of water?
3. If people drink the water downstream of your proposed fish farm, will they still be happy with the fact that you may add fertilizers to the water or are feeding the fish?
4. Have the plans been discussed with the appropriate state agencies and extension officers?
5. Have you identified what permits are required for the construction and operation of the facility?
6. Can the required permits be obtained without excessive investment in time, money and effort?
7. Can you obtain permits for an extended period of time, or do they have to be renewed frequently?
8. If it is a community project, is the local chief involved or aware of this project?
9. Is your project large enough to be economically viable?
10. If you are proposing a cage-culture project, has the owner of the dam given approval?
11. Does the owner of the dam (or waterbody) want a share of your income or profits, and have you

### Important aspects in planning an aquaculture business

- Skills: Aquaculture, like agriculture, requires knowledge of the biology of the species cultured. A project started by unskilled or untrained staff is unlikely to have any chance of success.
- Formal organization: Any business needs formal organization and division of labour. Some people have technical skills, others know office or business management, and others are labourers. These skills should be recognized in the planning of the business. No business can be operated by managers only; there has to be a hierarchy of jobs and rewards accordingly. Community-run projects run the risk of no clear demarcation of people's roles, resulting in either stagnation of the project or conflict between the parties.

### Market potential

Marketing the product is very important and often overlooked. Not only is it important to identify your market, but also to make sure that you can supply it at the right time, in the right form, and at the right price. Ask yourself:

1. Is there a market for your fish (can you sell your fish at a profit)?
2. Are there any competitors selling the same fish as you in your area?
3. If people are going to buy fish from you, what protein were they eating before the fish became available, and thus will be 'displaced' by your product?
4. Is the market big enough for you and your competitors?
5. Is there a good (and easy) way to get the fish to the market?
6. Is the market accessible year round from the site?
7. How will you get the perishable harvest to the market without spoiling it?
8. Are the roads passable even in the rainy season?
9. If there is no market nearby, or if it is hard to get to the market, can the fish be kept by drying, smoking, or salting them?
10. Is there a vehicle available for transportation if necessary?
11. Can you produce what the market demands, at the right time and in the right amount?
12. What form will you market your product in (i.e. fresh, filleted, salted)?
13. Are you able to harvest, handle, hold and transport the product to market or will you require additional help?
14. Are there already established marketing outlets that you can tap into?

- **Water use:** Just because water appears to be available or on site does not mean that it is free for use in an aquaculture venture. Water is often jealously guarded by its users, be they a community, private individuals or government controlled. Many projects have foundered through inadequate planning for the use of water, or over its consumption, diversion or pollution by fish farms.
- **Disease:** While in theory there are cures to many of the diseases that affect fish, the reality is that a major disease in the fish-farm environment usually means very high mortalities and major loss of stock as there is very little that one can do about it in practical terms. Thus, the risk factor is always high, more so in intensive systems.
- **Partnerships and joint ventures:** Partnerships and joint ventures need to be covered by legal agreements that detail the 'exit plan arrangements' under certain circumstances, such as if one or more party wishes to leave the project. Many projects have failed due to the departure of either skilled personnel or the end of running capital, leaving the rest with either a burden of debt or lack of skills to run the venture.
- **Lack of motivation:** Motivation comes from knowing that the rewards for your achievement are directly related to how hard you work at the project. If the project is funded such that all beneficiary parties reap the same reward irrespective of how hard they work, it will probably fail and conflicts will arise. Also, if a project guarantees basic income to those working on it, irrespective of the output success of the project, there is little incentive to work harder at making it a productive success.
- **Costing:** It is easy to underestimate costing for construction and running costs of a project. There are always unforeseen expenses (for example: the high costs of security fencing the fish farm after stock was stolen). Unforeseen costs can be as much as 25% of the total budget.

### Financial planning

Starting an aquaculture business can be an expensive exercise. It is important that you first acknowledge that starting an aquaculture business is a big decision and requires serious commitment. Like any other business venture, some research needs to be done before money is invested. Depending on what you intend to use the fish for (i.e. only to feed you and your family, or to sell and eat a few) will also influence the size, scale and expense of the fish-farming operation.

It is important that the prospective fish farmer is aware of the following –

- Aquaculture is a farming/business enterprise that requires money, time and labour.
- It is easy to under-capitalise, which may mean that there is not enough money to get the business running.
- A good understanding of the cultured animal is necessary, particularly regarding water-quality requirements.

Starting a fish farm has the potential for good returns on your money. However, it also has an element of risk: fish can die in large numbers very easily, and once they are killed-off, they have no sale value. It is most important to realistically evaluate the prospects of good financial return and the feasibility of the operation. Depending on the nature of the fish farm, there are some opportunities for financial support and it a good idea to investigate these options.



Balancing the potential sales and expenses in aquaculture can be difficult without expert advice and planning.



### **Economic considerations**

1. Do you own or have access to an appropriate site?
2. Have you determined what your financial responsibilities will be to start your fish farm?
3. How much money would you need?
4. When would you need the money?
5. What would the money be used for?
6. Would you require financial assistance and if so, how would you repay it?
7. If you need a loan, can you secure sufficient money at a reasonable interest rate?
8. Have you made a realistic assessment of the timing and scale of expected returns on your investment?
9. Are there adequate cash reserves for unanticipated costs, such as equipment and/or unexpected loss of the fish?

Once all of the above questions can be answered, the money required to build and operate a fish farm needs to be worked out. Costs need to be determined for these aspects as well as for what the running costs will be to maintain the ponds or cages and to feed and harvest the fish.

What expenses are there in operating your fish farm? These things need to be carefully costed-out so that you do not end up under-budgeting. Possible expenses are:

1. Pond or cage construction
  - Labour
  - Equipment and machinery (pumps, paddlewheels, aerators, etc.)
  - Materials (concrete, bricks, wood, etc.)
  - Security (fences, alarm systems).
2. Water
3. Electricity
4. Telephone
5. Fish
  - Cost per fish from the hatchery
  - Transport from hatchery and to market.
6. Pond, cage or tank maintenance
  - Fish food
  - General hardware (nets, buckets, etc.)
  - Chemicals (lime, fertilisers, disease treatments, etc.)
  - Harvesting equipment (sorting tables, scales, freezers, smokers)
  - Labour.

After the above costs have been determined, it is necessary to determine what the fish in the farm will cost you to produce. You cannot afford to sell the fish cheaper than this amount otherwise you will be losing money. Bear in mind that you will probably lose some fish and therefore the price per fish should take this potential loss into account.

When the fish are eaten by the farmer or his family, the value of the fish should be determined according to market prices and not cost prices (e.g. the farmer would have to pay the retail price for the goods at the market if he were to choose to buy them himself, so their value to him must be determined in terms of this price and not in terms of costs of production).

If the fish are to be used to feed a family and provide a small additional household income, it is important that the fish farmer uses the cheapest (but good quality) dietary ingredients for his fish. Commercially formulated feed pellets may be too expensive for a small-scale farmer. The farmer may have access to cheaper ingredients (i.e. maize, grass, brewery waste or waste vegetables from the vegetable garden) that can be fed to his fish. The number of fish stocked in the pond or cage is determined by the size of the containment and how much food you are able to provide.

To help explain what the costs and potential returns of a small-scale pond system are likely to be in a rural setting, the results of a survey of smallholdings in the southern region of Malawi are presented. The survey estimated the input rate, yields, input costs and income associated with a variety of plant materials that were being used as inputs in small-scale farms (around 200 m<sup>2</sup> ponds). Yearly farm income was estimated to range from approximately SA R76.30 to R578.90. Although these figures may appear low, they must be seen in perspective and compared to the overall low annual incomes earned by smallholder farmers in Malawi (approximately R1050-1400 in 1991). In some cases, the presence of a fish pond also leads to an increase in the production and cash earnings from vegetable farming using integrated farming systems.

**Fish yields, costs and incomes associated with the use of various smallholder resources in integrated agriculture-aquaculture in southern Malawi (adapted from Noble & Chimatiro, 1991)**

Input	Input rate	Mean fish yield (kg/ha/yr)	Range (kg/ha/yr)	Cost of input (SA Rand)	Income (SA Rand)
Napier grass	100kg/ha/day	1 405	647–2 195	102.06	238.00
Maize bran	3% MBWD	1 726	406–2 368	18.55	292.39
Napier grass/maize bran	as above	3 013	2 726–3 299	120.61	578.90
Waste pumpkin leaves <sup>a</sup>	50 kg/ha/day	1 444	1 372–1 616	88.20	245.42
Maize stover compost/FWA + AL <sup>b</sup>	3% MBWD; 2.5 t/ha	750	710–790	51.66	127.40
Smallholder farmers using maize bran	When available	951	241–3 336	18.55	161.07

*a Cost of waste pumpkin leaves based on labour input to harvest waste leaf*

*b FWA + AL: Fuel-wood ash and agricultural limestone combination*

*MBWD: Mean body weight per day*

**Notes:**

1. Cost of fresh fish, 1991 retail prices @ R8.47/kg.
2. Cost of maize bran @ R0.28/kg dry matter @10% moisture.
3. FWA - no cost; a waste resource from household cooking fires.
4. AL - Agricultural limestone @ R0.28/kg.
5. Cost of maize compost based on labour input @ R5.67/day.
6. Napier grass cost based on labour input to cut grass @ R5.67/day.
7. Costs of inputs are: kg/yr/200 m<sup>2</sup> pond (2 fish crops/year; 1-ha pond).
8. Income is per 200 m<sup>2</sup> pond (2 fish crops/year; 1-ha pond).



## Checklist for compiling a simple business plan

- Compose a 'concept description' of your project.
- Suggest a legal business framework or organization that you intend to run the project under, such as a partnership, company, or CC.
- Describe what legal processes you need to complete to initiate and then run the project.
- Describe the site and situation of the proposed project.
- Describe the technical processes to be used to grow the product.
- Describe the harvesting and processing procedures to be used.
- Detail the marketing approach you will use, and say why your product should be competitive with other products already available.
- List the range of prices you expect to receive for the product in various forms from raw to value-added, if applicable.
- Strengths and weaknesses: Why is this project likely to succeed, and what are its weaknesses? Look at all aspects, from financial to technical, including marketing.
- Financial planning: What will the project cost (a) to set-up, (b) to run until profitable? Draw cash-flow diagrams of best- and worst-case scenarios.
- Sequence of events: Detail in terms of days/months or years how you see the anticipated progress of events from initiation of the project until it is running profitably.
- Detail your expected source of funding, and how these amounts will be made available to you for your use, including any interest payments.
- Describe any conditions-of-funding required by the funding organization.

## Frequently asked questions

Q: *What is the minimum cost of a fish farm venture?*

A: This is determined by the quantity of basic equipment required to make the venture a viable enterprise. Items like containments and associated plumbing, feed and storage, harvesting equipment, and the means to transport the product to market (a vehicle) are all essential items that can make a micro enterprise uneconomic.

Q: *What are the benefits of planning and drafting a business plan?*

A: Planning is an exercise that allows for mapping out all the project activities, and when well thought out can reveal constraints and challenges that need attention. Often these may be otherwise overlooked and may incur additional costs. In compiling a plan, even the unseen and unexpected costs can be estimated. It is advisable to have the plan reviewed by experts who have practical experience in similar ventures.

Q: *What are the dangers of business plans?*

A: Too many ventures start out with unrealistic business plans that are computer-generated, and often designed to show a projected profitable business on the basis of 'scaling up' a micro enterprise or pilot project. Beware of business plans that use spread-sheets that automatically make a venture look profitable by simply altering the capital, input or running costs. The hidden costs and unexpected expenses have caused many seemingly viable ventures to fail. A practical plan, drafted and planned on paper, although less appealing than computer-generated spreadsheets of projected costs and profits, is a better option. We advise you to be cautious and conservative in estimating yields and expenses.

Q: *What are the basic pillars of a sound aquaculture venture?*

A: The market for the product that you are developing must be assured, or in the least must have been researched (estimated) in terms of demand. The technology for culturing the fish must be available and affordable. The venture must be based on a sound business plan. And the people who run the venture must have the relevant expertise.

Q: *What is the 'bottom line' in any business plan?*

A: The ultimate goal is to make a profitable business! Therefore, the most fundamental aspect must be that the venture be market oriented. If you cannot be certain of selling the product at a good return, it does not matter how successful you are at producing it. Too many aquaculture ventures start out based on the primary question 'How to produce the product?' rather than considering 'Is there a demand for it?'

Q: *In planning an aquaculture venture, can it be a part-time or side-line activity to other occupations?*

A: In practice this occurs very rarely! Like any other intensive livestock production, fish culture is dependent on the care that the fish receive in terms of the environmental conditions in which they are grown. But, unlike most terrestrial-based farming of sheep, goats, cattle, etc., the 'housing' facilities have to provide all the fish's environmental needs, including the maintenance of good conditions in terms of ponds, tanks and the water quality within them. If these conditions are sub-optimal you may run the risk of losing the entire stock, especially towards harvest time when crowding and fish size create the highest density. Constant supervision and care and a degree of technical expertise are required to manage a facility. For example, fish suffering from lack of oxygen due to overcrowding or poor water quality will die within a few hours. Conditions need to be monitored and follow-up action needs to be prioritized to ensure that problems are dealt with, urgently.



## Annexure A

### *Questions regarding your expectations of an aquaculture venture:*

**1. Which type(s) of aquaculture interest you?**

- Species
- Production method

**2. Describe your product(s):**

- Product form (live, fresh, fillets, smoked, etc.)
- How marketed (wholesale, retail, informal gate sales, etc.)
- What makes your product desirable (a) to produce, (b) to market?

**3. How will the business be organized?**

- Sole proprietorship
- Partnership
- Close-corporation or company
- Other

**4. Why will you be successful?**

- Who will buy your product?
- What will set you apart from existing or future competition?
- What skills and abilities will make you successful?

**5. How much money do you expect to make?**

- What can you survive on?
- What would be a comfortable amount?
- How much would you really like to make?

**6. How will the venture affect your family?**

- Are they willing to relocate?
- Are they willing to live on a reduced income, and for how long?
- Will they support you in taking the risk?
- Will family members work in the business?

**7. What impact will the new venture have on your present job?**

- Provide supplementary income
- Replace current job

**8. How long do you expect it will take for the venture to —**

- Become operational?
- Become profitable?
- Achieve your financial goals?



## Annexure B

### *Assessing the market feasibility of your aquaculture venture:*

#### **1. Market area**

- Determine time available for deliveries (i.e consider the time required to harvest, process, package, ice, etc.)
- What is the longest distance you can travel to your market (in terms of how quickly the product may spoil)? This distance includes how many towns/villages? Population?

#### **2. Market segments**

- Within the market area, who will buy your product? Possibilities are: Individuals, small shops and stores, cooperatives, businesses (like butcheries), restaurants, supermarkets, wholesalers, mines, schools, farms or other institutions.

#### **3. Buyers' needs**

- Which product form is preferred? Options are: Live, fresh, frozen, whole, headed, scaled and gutted, fillets/steaks/cutlets, value-added (smoked, dried, salted).
- What is the preferred quantity of each product per unit time? (i.e. kg/week)
- Are there seasonal price differences for each product?
- Can you provide consistent supplies? If not, do buyers see this as a problem?
- What are the preferred payment practices? (immediate cash, cheque, terms, etc.)

#### **4. Market potential**

- What is the average quantity that each buyer will purchase per year?
- What is the total quantity that the market area will take from you each year?
- What competition is there from other similar products?
- Are these products more expensive or cheaper than your price per unit mass?

#### **5. General conclusions**

- Did you modify your original product concept? Why?
- What are the most attractive market segments? Why?
- Are there enough potential buyers in your market segment who may purchase the anticipated product at the appropriate time?
- What are your market options for (a) excess production or (b) undersized fish?
- How much will marketing add to your production costs (in terms of cleaning the fish, packaging, chilling or refrigeration, transportation, advertising and promotion costs, billing and recording)?

## Annexure C

### *Assessing the production feasibility of your aquaculture venture:*

#### **1. Compile information on the culture potential and biological needs of the species.**

- Make a list of your most valuable resource materials (e.g. personal contacts, books, etc.) for culture of your species.
- List permits and regulations that apply to use of the species, water use, land use, waste water and other legal aspects pertaining to starting your venture.

#### **2. Biological factors**

- What are the water-quality requirements of the species?
- Does your system meet these requirements?
- What diseases and predators can affect the species?
- What parameters need to be controlled and how will they be controlled?

#### **3. Factors affecting profitability**

- How many fish will you need to stock your system?
- What percentage of the original stock do you expect to lose?
- What is the potential yield of your system?
- How long will it take to produce a marketable product?
- What could cause losses (e.g. water quality, predation, theft, disease, competition)?
- How and at what cost can losses be controlled?

#### **4. Production costs**

- What are the initial construction or facility costs?
- List equipment needs for the following culture operations:
  - water-quality maintenance
  - harvesting
  - storage (product)
  - loading and transport
  - processing
  - electricity
- List and estimate variable costs for the system:
  - feed (price per kg and per year)
  - labour (cost to feed, harvest, process, etc.)
  - electricity
- Do you have adequate environmental information on water temperature, water quality and flow?
- Are you able to extract water legally, and at what rate and cost?

#### **5. Emergency plans**

- What are the production risks?
- How can these risks be reduced?
- What will risk-reduction methods cost?



## Annexure D

### Assessing the financial feasibility of your aquaculture venture:

#### Cash flow statement, Year One

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	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
<b>Beginning cash balance</b>												
<b>Add:</b>												
Cash sales												
Collection of receivable												
Loans												
Additional investment												
Total cash receipt												
<b>Deduct start-up costs:</b>												
Seed or juvenile fish												
Feed												
Chemicals												
On-site fuel and oil												
Electricity/utilities												
Variable labour												
Advertising												
Insurance												
Legal and accounting												
Delivery expense												
Fixed cash disbursements**												
Loan payment												
Mortgage or rent												
Taxes												
<b>Total cash disbursements</b>												
<b>Net Cash Flow</b>												
<b>Cumulative Cash Flow</b>												
<b>Ending Cash Balance</b>												

\*Start-up costs include:

- Site development
- Buildings
- Production facilities
- Equipment
- Vehicles.

\*\*Fixed cash disbursements include items such as:

- Salaries
- Payroll taxes and benefits
- Office supplies
- Boxes and packaging
- Licenses and renewable permits
- Telephone
- Miscellaneous
- Total per month.



## Glossary

- Acclimate** – to adjust to a change from the normal environment (acclimatise).
- Acidic** – pH values less than 7.
- Aeration** – adding oxygen to water by spraying or bubbling air through the water.
- Algae** – photosynthetic organisms, ranging from single-celled to large forms.
- Alkaline** – a substance with a pH more than 7.
- Amino acids** – the building blocks of proteins.
- Aquaculture** – the cultivation of animal or plant life in water.
- Area** – the length and width of a surface.
- Artemia** – very small shrimp-like creatures used as livefood for juvenile fish.
- Barbels** – whisker-like sense organs near the mouth in some fish (e.g. catfish).
- Basic** – (see Alkaline).
- Biomass** – the total weight of all animals in a pond, for example.
- Bloom** – a sudden growth of algae in a waterbody, giving it a strong green color.
- Bottom feeders** – an aquatic animal that feeds on or near the bottom of a waterbody.
- Breeding** – the cycle of reproduction in animals.
- Broodstock** – adult fish used for breeding in the hatchery.
- Cage** – an enclosure to hold fish in the water.
- Captivity** – the state of being held in a confined place (fish in ponds are captive).
- Carbohydrate** – a source of energy in animal diets.
- Carnivore** – an organism that eats animal protein.
- Cold-blooded** – animals (like fish) that do not regulate their body temperature and therefore have a temperature similar to that of their surroundings.
- Compete** – to fight for something against someone or something.
- Contaminant** – something that makes something else impure; a pollutant.
- Cooperative** – an organization of people working together for a common purpose.
- Dam** – an artificial embankment or dyke that holds back water.
- Daphnia** – a kind of zooplankton, commonly used as food for fish.
- Debris** – rubbish, garbage, anything that is not supposed to be in a certain area (pond).
- Density** – the number of fish in a particular volume (or area) of water (e.g. per m<sup>3</sup> or per ha).
- Detritus** – rotting plant or animal material on the pond bottom.
- Dike** – the wall of a fish pond.
- Diversion channel** – a ditch that takes water from a stream or river to a fish pond.
- Emaciated** – starved and thin.
- Exotic species** – species not native to the area.
- Extension** – the actions necessary to promote, propagate and spread the practice of aquaculture.
- FCR** – feed conversion ratio: measure of an animal's efficiency in converting food mass to body mass.
- Fertilizer** – anything added to water or soil to enrich it, thereby making it more productive.
- Fingerling** – a fish that is about as long as a person's finger (6-10 cm).
- Fishmeal** – cooked, dried and ground up fish; used as a diet protein source.
- Fry** – fish that have just hatched until they reach fingerling size.

**Genital opening** – the body opening where the eggs or sperm are released.

**Gills** – the respiratory organ that allows a fish to breathe in the water.

**Gonads** – organs that produce reproductive cells in fish (ovary or testis).

**Gravity** – the natural force causing things to fall downwards.

**Hapa** – simple mesh enclosure suspended in ponds, where fish can be spawned or cultured.

**Hardy** – ability to survive under conditions considered more difficult for other species.

**Herbivore** – an animal that eats only plant materials.

**Hormones** – substances secreted by glands or organs, causing certain changes in the body's functions.

**Impermeable** – a substance through which nothing can leak.

**Induced spawning** – causing a fish to spawn by injecting it with hormones.

**Introduced species** – animals or plants not native to an area but released or escaped there.

**Lipids** – fats.

**Metabolic rate** – the rate at which organisms convert food into energy.

**Mortality rate** – the rate of death in a population.

**Natural food** – food that an animal eats in nature.

**Niche** – what an organism does; for example, its position in the food web.

**Nutrient** – a source of nourishment; a food ingredient that is healthful.

**Omnivore** – an animal that eats both plants and animals.

**Operculum** – the gill covering of fish.

**Optimum** – best.

**Oxygen** – a gas that is necessary for all life.

**Pens** – enclosures for fish culture on large bodies of water.

**Phytoplankton** – minute, free-floating plants in water, sometimes used by fish as food.

**Photosynthesis** – the process whereby green plants produce food for themselves and release oxygen as a result.

**Pituitary gland** – a gland attached to the base of the brain which releases hormones controlling body processes, such as growth and the reproductive cycle.

**Plankton** – tiny plants and animals that drift in a body of water and are sometimes eaten by fish.

**Ponds** – any enclosure that holds water so that fish can be grown inside it.

**Predators** – animals that prey on other animals.

**Productivity** – the growth of live organisms in a pond, for example, from the plankton to fish.

**Rancid** – the deterioration of feed to a state of unpalatability.

**Ration** – the amount of food fed; determined as a percentage of bodyweight (about 2-5% in fish).

**Reproduction** – producing offspring.

**Respiration** – breathing.

**Slope** – the slant of land.

**Spawning** – the release and fertilization of eggs and sperm.

**Stress** – any change that is not normal in the environment that creates physical problems.

**Trash fish** – fish not wanted in the pond, or fish that are too small to eat, or spoiled fish.

**Watertight** – impermeable to water.

**Zooplankton** – small animals that can barely be seen with the naked eye, swimming or floating in a body of water.



### **Units of measurement**

ha — Hectare: 100m x 100m = 10 000 m<sup>2</sup> (unit of area)

m<sup>2</sup> — Square meters: 1m x 1m = 1 m<sup>2</sup>

m<sup>3</sup> — Cubic meters: unit of volume = 1000 liters

kg — equivalent to 1 liter of freshwater

g — equivalent to 1 ml of freshwater

mt — metric tons (= 1000 kg)

ℓ — liter

### **Useful reading resources**

- Brink, D. (2004) *Trout Farming Reference Guide – Aquaculture Technical Training Course for Small-scale Farmer Division of Aquaculture*. Stellenbosch University, Stellenbosch, South Africa.
- Chakroff, M. (1976) *Freshwater Fish Pond Culture and Management*. United States Peace Corps and Volunteers in Technical Assistance, Washington D.C.
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Additional information for start-up aquaculture ventures is provided in Appendices 1–4.

### **Regulations for South African Aquacultural Initiatives – New Developments**

To support and strengthen aquaculture development in South Africa, DEAT/MCM in partnership with key stakeholders produced a “Draft policy for the development of sustainable aquaculture in South Africa”. The policy and guidelines are available for comment and will eventually be promulgated into law for national-level implementation. Developers and investors are urged to refer to these documents to guide their planning and attend to the environmental requirements of their aquaculture projects. The document contains such information as the nearest provincial and regional contact office and other administrative and infrastructural information that start-up projects may find useful. The document can be downloaded from:

[http://www.environment.gov.za/Branches/MarineCoastal/AreasWork/mariculture/Aquaculture\\_Policy\\_21Sept20061.pdf](http://www.environment.gov.za/Branches/MarineCoastal/AreasWork/mariculture/Aquaculture_Policy_21Sept20061.pdf).

## **Appendix 1**

### ***Nutritional requirements for artificial feeds:***

#### **Protein**

All animals need protein to grow. Inside the fish, protein is broken down into amino acids which are used by the organs and tissues to make new proteins (for growth) or to replace existing proteins (for maintenance). Any excess protein can be converted into energy which fuels the activity of the fish. Amino acids are the building blocks of proteins. There are 20 naturally occurring amino acids, 10 of which cannot be made by the fish and must be provided in the diet. These 10 amino acids are known as essential amino acids.

The quality of proteins depends on the composition of the amino acids as well as their digestibility (how easy it is digested and used by the animal). Protein is the most expensive part of the formulated diet, and animal proteins (e.g. fishmeal, bonemeal, bloodmeal) are easy to digest compared to proteins from plants (e.g. soybean meal). If any of the essential amino acids are not available in large-enough quantities, growth will be reduced. Plant proteins are low in certain essential amino acids, and therefore a combination of animal and plant proteins is required to provide the essential amino acids needed in the diet.

#### **Lipids**

Lipids or fats are important components of an animal's cell membranes as well as a good source of energy. Like proteins, fish require the correct balance of fats or else they will not grow. Fish larvae have particularly strict requirements for certain fats at particular stages of their development, and failing to provide these fats results in large-scale deformities and death. Common sources of fats are fish-liver oil and soybean and sunflower oil. For optimal growth, fish usually require a combination of animal and plant fats.

#### **Carbohydrates**

Carbohydrates are a cheap source of energy for the fish and are used to provide energy in place of more expensive proteins. Starch is easily digested by fish and is composed of glucose. Complex carbohydrates such as cellulose can only be digested by bacteria (which live in the fish's gut) so it is important not to supply more than can be digested. Carnivorous species can be fed diets with lower carbohydrate levels compared to herbivorous species. Carbohydrates are also important in the making of artificial diets as they help to bind (glue) the food together. Since carbohydrates are the cheapest part of the diet it is best to use as much carbohydrate as the fish can use and in that way reduce the amount of protein required.

#### **Vitamins**

Vitamins are complex compounds required for things such as energy production, blood clotting and cell repair. Vitamins occur in trace (very small) amounts in most natural foods; however, because the fish cannot make them themselves, they must be provided in the feed. Low levels of vitamins (vitamin deficiency) results in poor growth.

#### **Minerals**

These dietary ingredients (particularly calcium, phosphorus, magnesium, sodium, potassium and chlorine) are required for the formation of many parts of the fish. Fishmeal is considered an adequate source of necessary minerals; however, additional amounts may be added to the diet to maximize fish growth, survival and health.

#### **Feed additives**

Feed additives are usually added in small amounts to the dietary ingredients when the diet is being made. They are added to: a) preserve the food and stop it from spoiling; b) help make the pellets stick together during manufacture; and c) improve digestion of the feed.

## Appendix 2

### *The process of beginning a freshwater aquaculture business in South Africa:*

- STEP 1** Application must be made to local authorities in terms of compliance with local bylaws, land-use planning ordinances, existing resource utilisation, and other local government provisions. This includes compliance with tribal or traditional legal systems where applicable.
- STEP 2** Where new exotic species are being considered for use in aquaculture, applications must be made to the relevant sections of the Department of Agriculture in terms of the Agricultural Pests Act (Act 36 of 1983) and the Animal Diseases Act (Act 35 of 1984).
- STEP 3** Application must be made to the to the Department of Water Affairs and Forestry in terms of the National Water Act (Act 36 of 1998) for water-usage rights, effluent discharge rights, and other potential impacts on the water resource (including pollution, but also physical and biodiversity impacts that could affect water resources). Note that these applications will need to be made to Catchment Management Agencies as these are implemented into various catchments over the next few years.
- STEP 4** Application must be made to provincial custodians of conservation and environmental ordinances in areas under their jurisdiction. In a few instances this jurisdiction is shared or in the hands of a national body such as the Department of Environmental Affairs and Tourism.
- STEP 5** Application must be made to the relevant provincial custodians of the EIA regulations in the Environmental Conservation Act (Act 73 of 1989), which is nationally administered by the Department of Environmental Affairs and Tourism. Such an application must encompass the provisions of the National Environmental Management Act (Act 107 of 1998) and include public participation.
- STEP 6** Application must be made to the provincial Department of Agriculture (as representative of the national department in its capacity as lead agency in freshwater aquaculture).



## Appendix 3

### *Diseases and their treatments:*

#### Fungal diseases

Gill rot — This is a disease caused by the filamentous fungus, *Branchiomyces sanguinis*.

**Signs:** Red spotting on the gills which later turns the gills a greyish-white. The gills then stop working and the fish suffocate and die. Gill rot is most common during the hot part of the year.

**Treatment:** Remove the dead fish from the pond and treat the remaining fish in a salt bath. Drain the pond and allow the bottom of the pond to dry. Treat the pond with quicklime or copper sulphate to kill the fungus spores. Fill the pond with water. Add quicklime every few weeks until there is no more sign of the disease.

*Saprolegnia* — This aquatic fungus is often associated with gill rot. It attacks weakened places on the fish's body (e.g., bruises from handling). Since it hits already sick fish, *Saprolegnia* attacks fish already trying to fight other diseases.

**Signs:** *Saprolegnia* looks like fuzzy, white cotton wool, often growing in tufts on the body of the fish. The fungus can kill eggs and fry, but does not usually kill adult fish.

**Treatment:** Use the same treatment as outlined for gill rot.

#### Bacterial diseases

Furunculosis — This is the most common bacterial disease.

**Signs:** Causes ulcers or sores on the skin. It then breaks through the skin, and, eventually, becomes a site for fungus infections, like *Saprolegnia*. The disease usually attacks in the spring, and is most often found in coolwater species (such as trout).

**Treatment:** Disinfect everything used in the pond or used for maintaining the pond (nets, feeding rings, etc.). Drain the pond and treat it with lime.

Infectious dropsy — This is caused by the bacterium *Pseudomonas punctata*.

**Signs:** Swelling of the fishes' belly with water, ulcers on the skin, lengthening of the fins, and deformation of the backbone.

**Treatment:** Prevent diseased fish from entering the pond. Bury and burn the dead fish.

Columnaris — This bacterial disease is caused by the bacteria *Chondrococcus columnaris* and *Cytophaga columnaris* and is often associated with low oxygen levels in the water.

**Signs:** Discolored patches on the body, loss of scales, and, often, death. This disease can look like a fungal disease, but it is not. If possible, it should be examined under the microscope for positive identification.

**Treatment:** Give fish a feed that has the antibiotic terramycin in it, for two weeks. If the infection is very bad, place the infected fish in a dip (bath) of copper sulfate (2 minutes in a solution of 1 g for every 2 liters of water) or a dip of malachite green (20 seconds in a solution of 1 g for every 15 liters of water). Also treat the pond with 1 g of copper sulfate per m<sup>3</sup> of pond water.

## Parasites

*Ichthyophthirius multifiliis* or “ich” — This is the worst protozoan disease and is caused by a ciliate. Each parasite produces thousands of spores, which can then infect other fish in the pond.

**Signs:** White spots or pimples on the skin and fins of the fish.

**Treatment:** Drain the pond and lime it. Or treat the fish with chemicals as follows:

Formalin	20 ml per 100 liters daily bath and 15 ml per m <sup>3</sup> in the pond
Malachite green	1.25 g per m <sup>3</sup> daily bath/30 minutes and 0.5 g per m <sup>3</sup> pond
Methylene blue	2 g per m <sup>3</sup> daily bath
Salt	7 kg per m <sup>3</sup> water; administer several baths daily.

*Costia* and *Trichodina* — These are two other ciliate diseases. They are caused by microscopic organisms that attack the skin of fish and cause lesions.

**Signs:** These ciliates cannot be seen by the naked eye, but the lesions and sores that they cause can be seen by looking closely at the fish.

**Treatment:** Add 3 g of potassium permanganate per m<sup>3</sup> to pond. Or dip the fish in baths of 10% salt for 5 to 20 minutes daily, for up to one week.

*Lernea* — The anchor worm is the most common disease of this type (a copepod). This worm attacks the gills or any other part of the body.

**Signs:** It burrows into the fish, leaving its two egg cases protruding on the outside of the fish. *Lernea* causes red sores and makes the fish thin.

**Treatment:** Add castor oil in a thin film over the surface of the pond. Treat fish infected with young *Lernea* in a formalin bath, or remove each parasite by hand.

*Argulus* — *Argulus* is a fish louse. It sucks blood with a piercing organ that also injects poisons. Young fish may die.

**Signs:** Occurs as a pinkish-red disc that attaches to the fish’s mouth, gills, skin or fins.

**Treatment:** Drain and lime the pond. If this cannot be done, put the fish in a bath of 3-5% salt or 250 ml formalin per m<sup>3</sup>, for one hour.

*Dactylogyrus* — The fish are exposed to this worm (gill fluke) when they are between 2 and 5 cm long.

**Signs:** Attacks the gills of young fish.

**Treatment:** Manage the pond well so that fingerlings quickly grow past the stage when they would normally be attacked by *Dactylogyrus*.

*Gyrodactylus* — This worm (skin fluke) can cause fish to die from hunger.

**Signs:** Burrows through the skin into the blood vessels of the fish, causing the fish to appear reddish with sores.

**Treatment:** Treat ponds with 5 ml formalin per m<sup>3</sup> pond water. Alternatively, bathe the fish in 25 ml formalin per m<sup>3</sup> for one hour.



## **Diseases and their treatments (continued):**

### **Chemical treatments**

#### **Salt water**

When moving fish between ponds or prior to transport, it is recommended to bathe the juveniles in a 2% salt solution (20 g of salt per ℓ water) for 2-3 minutes to reduce the number of parasites. Industrial-grade, coarse salt can be used.

#### **Malachite green**

Used against whitespot disease (*Ichthyophthiriasis*) of fish and fungus (*Saprolegnia*) of eggs. It is normally used at 0.1-0.2 mg/ℓ in ponds where there is little or no water exchange. In ponds where the water can be changed within 15 minutes, an initial concentration of 1-3 mg/ℓ can be used.

#### **Copper sulphate (CuSO<sub>4</sub>)**

Used mainly to treat fish infected with external fungus (*Saprolegnia*) and gill-rot (caused by the fungus *Branchyomyces*). The infected fish must be caught from the ponds and maintained in a solution of 500 mg/ℓ until they show signs of distress.

#### **Potassium permanganate (KMnO<sub>4</sub>)**

Used to control external parasites such as fungus (*Saprolegnia*) or to disinfect hatchery tanks. Treatment consists of a 20-50 mg/ℓ bath for 30-60 minutes. To increase the effectiveness of KMnO<sub>4</sub> treatment, an organophosphate such as Dipterex can be added at 100 mg/ℓ (active ingredient).

#### **Formalin (formaldehyde)**

Used for the treatment of the parasite *Costia*, administered at a concentration of 200-400 mg/ℓ over a period of 15-40 minutes. Gill-worm infections in fry can be treated by bathing at 250-500 mg/ℓ for 30 minutes. A 10% formalin solution is often used to sterilise nets, buckets, tanks, etc., but the items should be rinsed in freshwater before use. This is to remove traces of formalin, which is toxic to fish at this concentration.

#### **Organophosphates**

These products are used to kill insects, gill flukes and parasitic copepods. They are sold under various trade names (such as Dipterex, Dylox, etc.). The recommended dose is 0.25-1.0 mg/ℓ of the active ingredient, which should kill the parasites within 24 hours. The solution should be mixed in a bucket and poured around the edges of the pond, taking care to avoid skin contact as the chemical is poisonous.

To make a final concentration of 0.25 mg/ℓ Dipterex (which has 40% active ingredient), you first need to calculate how much you need to add because the active ingredient is only a part of the chemical. For example:

If you added 0.25 mg of Dipterex to 1 liter of water, you would only have 40% of 0.25 mg Dipterex = 0.1 mg/ℓ active ingredient (which is too diluted).

Thus, to account for the other 60% of non-active chemicals in the Dipterex we need to add:

Desired active concentration / percent fraction (%/100) = mg/ℓ chemical  $0.25 / 0.4$  (40%) = 0.625 mg/ℓ of Dipterex from the bottle.

## Appendix 4

### *Interactive spreadsheet for fish-farm start-up costs:*

#### **Instructions for use**

The interactive spreadsheet CD is designed to give basic guidelines as to the costs for setting up a small tilapia-production fish farm, together with running costs over three or more years, and the expected returns. The spreadsheet comes in two forms: Sheet 1 is for a small commercial tilapia farm built on purchased land, and company-run. Sheet 2 is for a similar farm but located on rural communal land.

The operation of the sheet is simple: input costs are accumulated and subtracted from income from sales, and either a positive or negative balance results (the pink Column S). These input costs are either capital or running costs. For simplicity, not all the likely expenses have been included, for example there are no input costs given for insurance or the purchase of broodstock or fingerlings, and therefore the final balance (in bold red) must be treated with caution. A common failing is for users of such spreadsheets to simply increase the expected returns (sales) in an attempt to show a profit on a proposed venture. This must be avoided; anticipated production and returns should always err on the side of caution rather than overestimate the likely productivity of the farm, especially over the first few years.

The vertical columns numbered D through R are some of the input costs that could be expected in setting up such a fish farm. These costs can be changed by the user to fit in with their own particular case study. If these figures are changed, the spreadsheet automatically adjusts the totals. Additional columns can be inserted as desired to include extra items, such as insurance or the purchase of broodstock. Likewise the units in Columns B and C can be changed to give different scenarios, according to the user's preference. For example, the sale price of fish (in Column B12) can be changed from R20/kg to an alternative sale price, and the total income and account balance will adjust accordingly.

Column T reflects an estimated and realistic production from a newly built fish farm growing tilapia. If the user wishes to adjust the expected production, either upwards or downwards, according to his/her expected returns, then the totals will again alter automatically to show profitability or otherwise.

Both sheets 1 and 2 cover four years of operation. After Year 1, capital costs are reduced and running costs stabilise; at the same time, anticipated production should increase considerably. In addition, certain input costs also increase, such as feed (Column L), but under certain circumstances the venture will show a profit (Column S). This is what any new venture strives to do: that is, to anticipate how long before it becomes profitable. A word of caution is needed here: no recurring costs, such as interest on loans, repayment of capital and other non-material expenses, have been included, although these must be taken into account when assessing whether a venture is likely to be economically viable.

