Agrodok 15

Small-scale freshwater fish farming

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Foreword

This Agrodok aims at providing basic information on how to set up a small-scale fish farm for subsistence purposes.

As fish farming practices are very diverse, we have chosen to limit ourselves to small-scale freshwater fish farming in the tropics. And, as pond fish farming is the most common form of fish cultivation in these areas, the information provided focuses on pond construction and pond management.

The first part of this Agrodok (Chapters 1 to 4) describes the principles of fish farming, types of fish farms, methods of fish farming, and pond maintenance and monitoring. Also included is a section on periphyton-based fish farming, a new and promising technology. The second part of the book gives basic guidelines for setting up a fish farm and covers the selection of a proper site, of farm type and of fish species to be cultured. Fish nutrition, health, reproduction, harvesting and post-harvesting aspects are briefly discussed.

Agromisa welcomes your comments on the contents of this book, or additional information in order to improve future editions.

Wageningen, 2008.

Eira Carballo

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Part I: Fish farming: basic principles

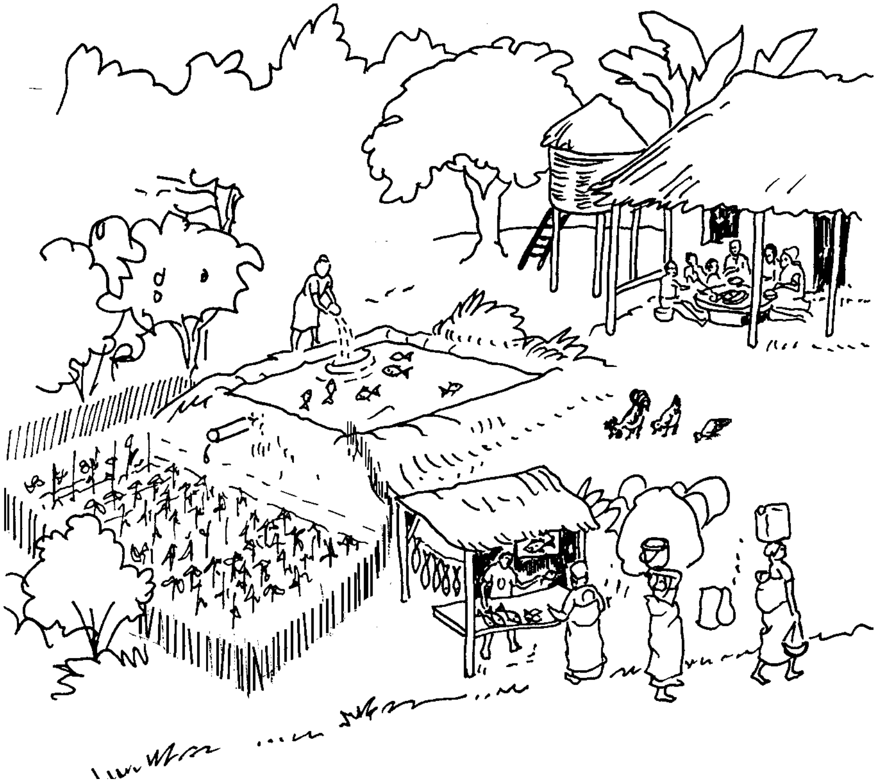

Figure 1: Advantages of fish farming

1 Introduction

Throughout the centuries fish has been an important component of the population's diet in many parts of the world. Fish catches increased rapidly over the past hundred years due to improved technology, which provided more powerful engines and sonar equipment. This led to over fishing and caused a worldwide decrease in wild stocks. As a result, the growth in fish catches stopped some 20 years ago. The need to increase fish production by farming became therefore an urgent matter.

The term 'aquaculture' covers all forms of cultivation of aquatic animals and plants in fresh-, brackish- and saltwater. Aquaculture has the same objective as agriculture, namely, to increase the production of food above the level that would be produced naturally. Today, aquaculture is responsible for an ever-increasing share of global aquatic food production, which has increased from 3.9 percent in 1970 to 31.9 percent in 2003 (FAO, 2005).

This book focuses on the small-scale cultivation of mainly freshwater fish species. As in agriculture, fish farming techniques include:
- Removal of unwanted plants and animals
- Replacement by desirable species of fish
- Improvement of these species by crossbreeding and selection
- Increase of nutrient availability by the use of fertilisers and feeds

Fish farming can be combined with agriculture, animal husbandry and irrigation practices, which can lead to better utilisation of local resources and ultimately to higher production and net profits. This practice is called 'integrated fish farming' and the subject is extensively dealt with in Agrodok No. 21.

The most important advantages of fish farming are summarised below and depicted in figure 1.

Advantages of fish farming

- Fish provides high quality animal protein for human consumption.
- A farmer can often integrate fish farming into the existing farm to create additional income and improve its water management.
- Fish growth in ponds can be controlled: the farmers themselves select the fish species they wish to raise.
- The fish produced in a pond are the owner's property; they are secure and can be harvested at will. Fish in wild waters are free for all and make an individual share in the common catch uncertain.
- Fish in a pond are usually close at hand.
- Effective land use: effective use of marginal land e.g. land that is too poor, or too costly to drain for agriculture can be profitably devoted to fish farming provided that it is suitably prepared.

2 Fish farming practices

2.1 Methods of fish farming

Fish farming may range from ‘backyard’ subsistence ponds to large-scale industrial enterprises. Farming systems can be expressed in terms of input levels (figure 2).

In **extensive** fish farming, economic and labour inputs are usually low. Natural food production plays a very important role, and the system’s productivity is relatively low. Fertiliser may be used to increase fertility and thus fish production.

Semi-intensive fish farming requires a moderate level of inputs and fish production is increased by the use of fertiliser and/or supplementary feeding. This means higher labour and feed costs, but higher fish yields usually more than compensate for this.

Intensive fish farming involves a high level of inputs and stocking the ponds with as many fish as possible. The fish are fed supplementary feed, while natural food production plays a minor role. In this system, difficult management problems can arise caused by high fish stocking densities (increased susceptibility to diseases and dissolved oxygen shortage). The high production costs force one to fetch a high market price in order to make the fish farm economically feasible.

The focus of this Agrodok is on extensive and semi-intensive fish farming practices.

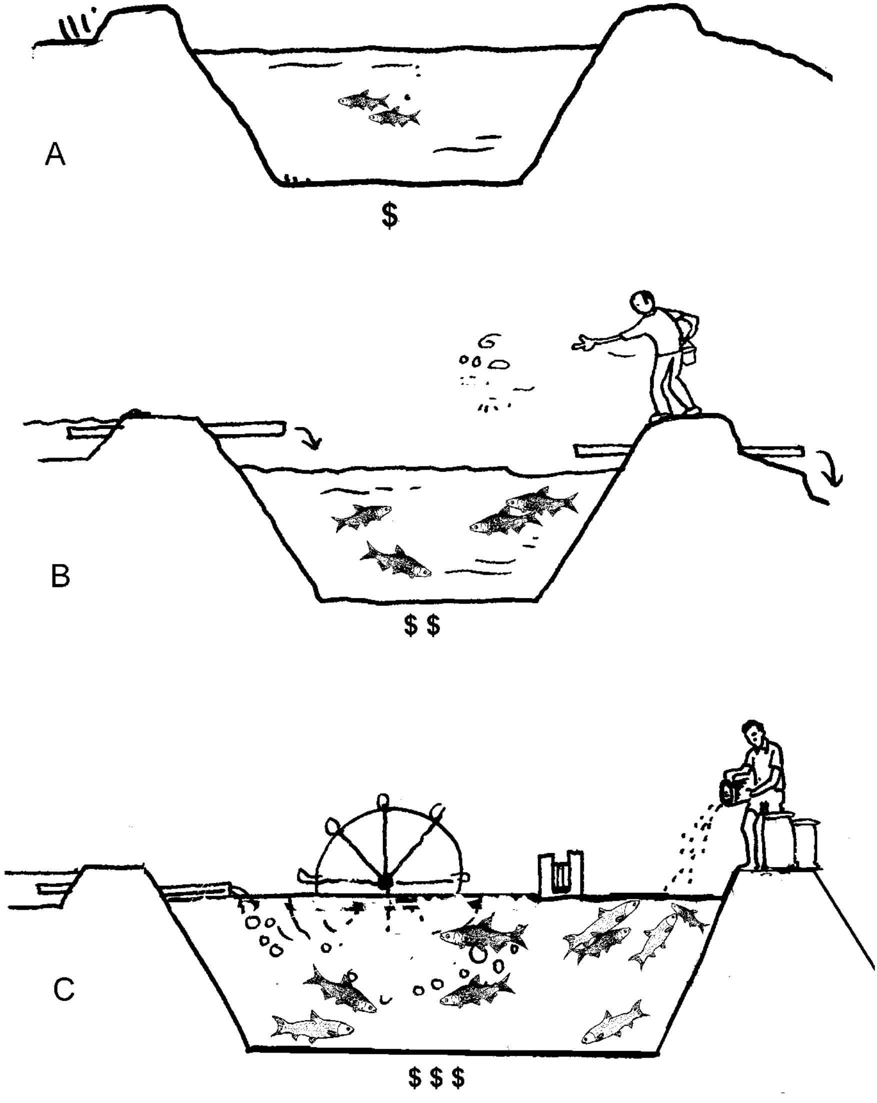

Figure 2: A: extensive, B: semi-intensive and C: intensive fish farming methods

2.2 Pond culture

The majority of freshwater fish are raised in ponds. Water taken from a lake, river, well or other natural source is channelled into the pond. The water either passes through the pond once and then it is discharged, or it may be partially replaced so that a certain percentage of the total water in a system is retained. Pond systems that yield the highest fish production only replace water lost through evaporation and seepage. Water flow generally reduces the production of pond systems in the tropics.

Fish farming ponds range in size from a few dozen square metres to several hectares (ha). Small ponds are normally used for spawning and baby fish production, while larger ponds are used for the grow-out period. Production ponds larger than 10 ha become difficult to manage and are not very popular with most producers. The ponds illustrated here serve only as examples. The kind of pond a farmer will build depends very much on local resources, equipment and conditions.

Ponds are usually located on land with a gentle slope. They are rectangular or square-shaped, have well-finished dikes and do not collect run-off water from the surrounding watershed (see figure 17). It is important that sufficient water is available to fill all the ponds within a reasonable period of time and to maintain the same pond water level. You should also be able to drain the pond completely when the fish are to be harvested. Side slopes should be 2:1 or 3:1 (each metre of height needs 2 or 3 metres of horizontal distance), which allows easy access to the pond and reduces the risk of erosion problems.

To prevent fish theft, try to locate the pond as close to your home as possible. Another method to keep thieves away from your fish pond is to place bamboo poles or branches in the water, which makes netting and rod-and-line fishing impossible. Apart from theft prevention, the poles and branches provide the fish with extra natural food. This practice is called periphyton-based fish farming and will be described in detail in chapter 3.

The main characteristics of a fish pond are presented in table 1.

Table 1: Characteristics of a good pond for fish farming

Location	Select land with a gentle slope, taking advantage of existing land contours.
Construction	Ponds may be dug into the ground; they may be partly above or below original ground level. Slopes and bottom should be well packed during construction to prevent erosion and seepage. Soil should contain a minimum of 25% clay. Rocks, grass, branches and other undesirable objects should be eliminated from the dikes.
Pond depth	Depth should be 0.5-1.0 m at shallow end, sloping to 1.5-2.0 m at the drain end.
Configuration	Best shape for ponds is rectangular or square.
Side slopes	Construct ponds with 2:1 or 3:1 slopes on all sides.
Drain	Gate valves, baffle boards or tilt-over standpipes should be provided. Draining should take no more than 3 days.
Inflow lines	Inflow lines should be of sufficient capacity to fill each pond within 3 days. If surface water is used, the incoming water should be filtered to remove undesirable plants or animals.
Total water volume	Sufficient water should be available to fill all ponds on the farm within a few weeks and to keep them full throughout the growing season.
Dikes	Dikes should be sufficiently wide enough to allow mowing. Dike roads should be made of gravel. Grass should be planted on all dikes.
Orientation	Locate ponds carefully to take advantage of water mixing by the wind. In areas where wind causes extensive wave erosion of dikes, place long sides of pond at right angles to the prevailing wind. Use hedge or tree wind breaks where necessary.

3 Fish farming ponds

3.1 Different pond types

Depending on the site, there are two different types of fish ponds to choose from: diversion or barrage ponds.

Diversion ponds

Diversion ponds (figure 3) are constructed by bringing water from another source to the pond.

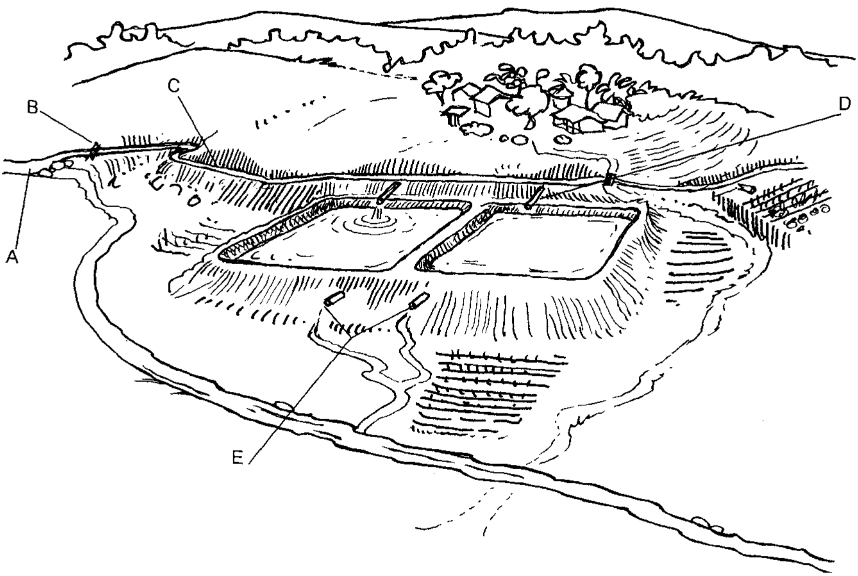

Figure 3: Diversion pond: A: stream, B: water intake, C: diversion canal, D: inlet, E: outlet (Bard et al., 1976)

Below are the different types of diversion ponds (figure 4):

A Embankment ponds:
The dikes of an embankment pond are built above ground level. A disadvantage of this type of pond is that you may need a pump to fill the pond.

B Excavated ponds:
An excavated pond is dug out of the soil. The disadvantage of this type is that you need a pump to drain the pond.

C Contour ponds:
Soil from digging out the pond is used to build the low dikes of the pond. The ideal site has a slight slope (1-2%) so the water supply channel can be constructed slightly above and the discharge channel slightly below the pond water level. Since natural gravity is used to fill and drain the ponds, no pump is needed.

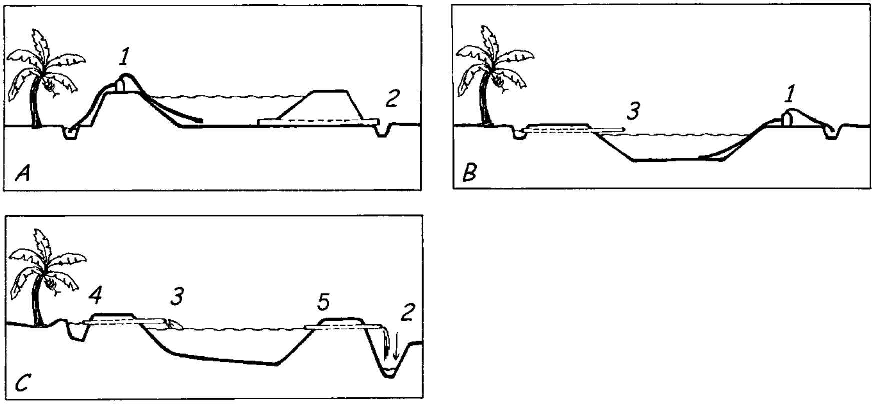

Figure 4: Different types of diversion ponds (Viveen et al., 1985) A: embankment pond B: excavated pond; C: contour pond.1. Pump, 2. Drainage canal, 3. Inlet pipe, 4.Diversion canal, 5. Overflow pipe

Barrage ponds

Barrage ponds (figure 5) are constructed by building a dike across a natural stream. The ponds are therefore like small conservation dams with the advantage that they are easy to construct. However, it is very difficult to control this system: it is difficult to keep wild fish out and a lot of feed added to the pond will be lost because of the current.

A properly built barrage pond overflows only under unusual circumstances.

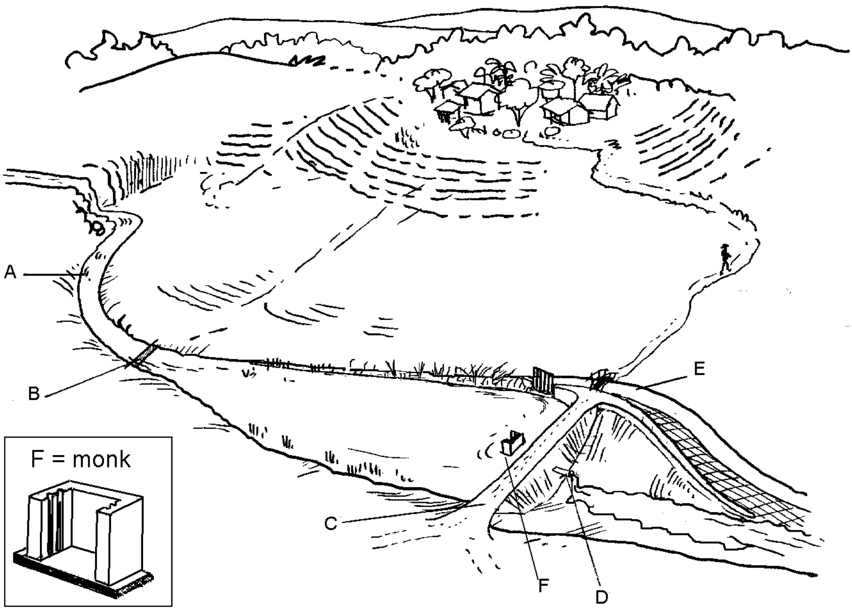

Figure 5: Barrage pond. A: stream, B: inlet, C: dam, D: outlet pipe, E: spillway and overflow, F: monk (One of the most common pond draining structures. It consists of a vertical tower with boards to regulate the water level; a pipeline to discharge the water; and a screen to prevent farmed fish from escaping the pond)

3.2 Guidelines for pond design and construction

Size and Shape

Square and rectangular shaped ponds are easiest to build, but your pond can have a different shape to fit the size and shape of the land. An area of 300 m² is a good size for a family pond, which you can build without the use of machinery. Ponds can be much larger than this, but for family use it is better to have several small ponds rather than one large one. Also, if you have more than one pond you will be able to harvest fish more often.

Depth

The water depth is usually 30 cm at the shallow end and 1 metre at the deep end (figure 6). The pond can be deeper than this if the pond is used as a water reservoir in the dry season. It is important that the water can be completely drained for harvesting.

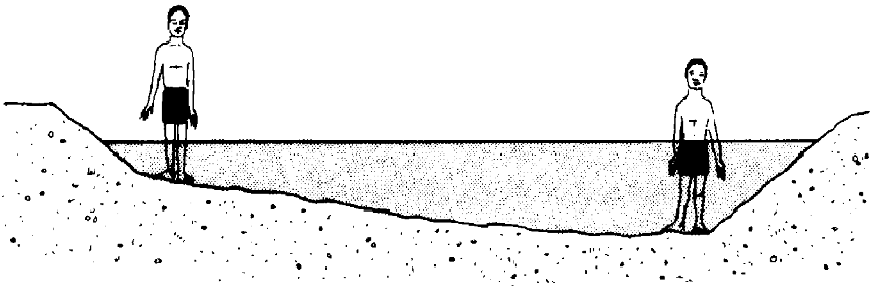

Figure 6: Cross-section of a pond (Murnyak and Murnyak, 1990)

Types

The type of pond you need to build depends on the land contours (topography). Different types of ponds are suitable for flat and hilly areas.

Excavated ponds are built in flat areas by digging out an area as big as needed for the pond. The water level will be below the original ground level (figure 7).

Figure 7: Excavated pond (Murnyak and Murnyak, 1990)

Contour ponds are built in hilly areas on a slope. The soil on the upper side of the pond is dug out and used to build up a dam on the lower side. The dam must be strong because the water level in the pond will be above the original ground level (figure 8).

Figure 8: Contour pond (Murnyak and Murnyak, 1990)

Building the fish pond

Building a pond can be the most difficult and most expensive part of fish farming. A well-built pond is a good investment that can be used for many years.

The steps in building a fish pond are:

1 Prepare the site
2 Build a clay core (in the case of contour ponds)
3 Dig the pond and build the dikes
4 Build the inlet and outlet
5 Protect the pond dikes
6 Fertilise the pond
7 Fence the pond
8 Fill the pond with water
9 Stock the fish

1 Prepare the site

First remove trees, bush and rocks, then cut the grass in the area where the pond will be made. Measure and stake out the length and width of the pond (figure 9).

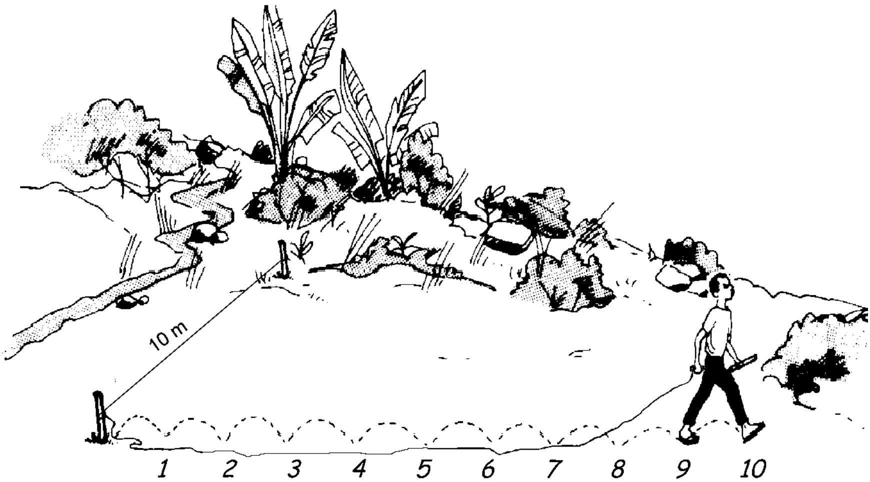

Figure 9: Staking out the pond (Murnyak and Murnyak, 1990)

Remove the top layer of soil containing roots, leaves and so forth and deposit this outside the pond area (figure 10). Save the topsoil for later use when grass is to be planted on the pond dikes.

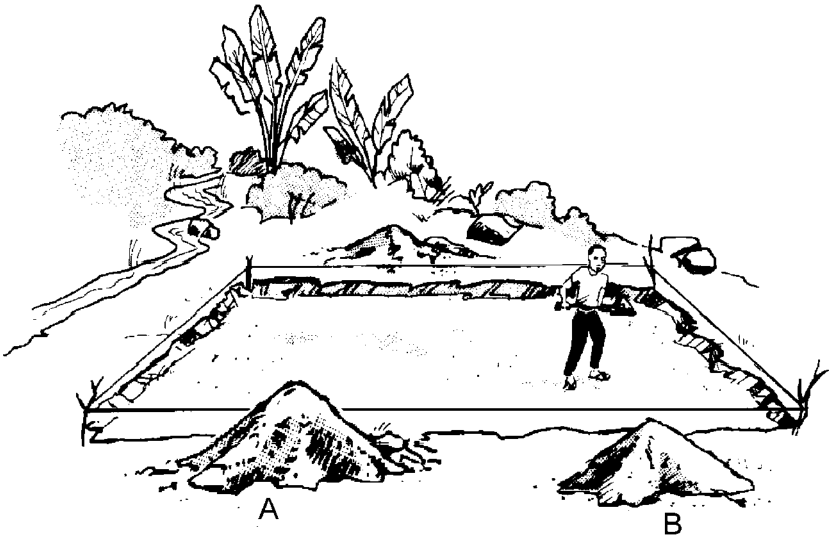

Figure 10: Remove the topsoil (A= Topsoil, B= Clay)

2 Build a clay core (in the case of contour ponds)
A clay core is the foundation for the pond dike, which makes it strong and prevents water leaks. A clay core is needed in contour ponds and is built under those parts of the dike where the water will be above the original ground level. A clay core is not needed in excavated ponds because there the water level is below the original ground level.

Remove all the topsoil in the area of the pond dikes and dig a 'core trench' in the same way as you would dig the foundation for a house. The trench needs to be dug out along the lower side of the pond and halfway along each short side of the pond (figure 11). Fill the trench with good clay. Add several centimetres of clay at a time and then compact it well. This will provide a strong foundation upon which the pond dikes can be built.

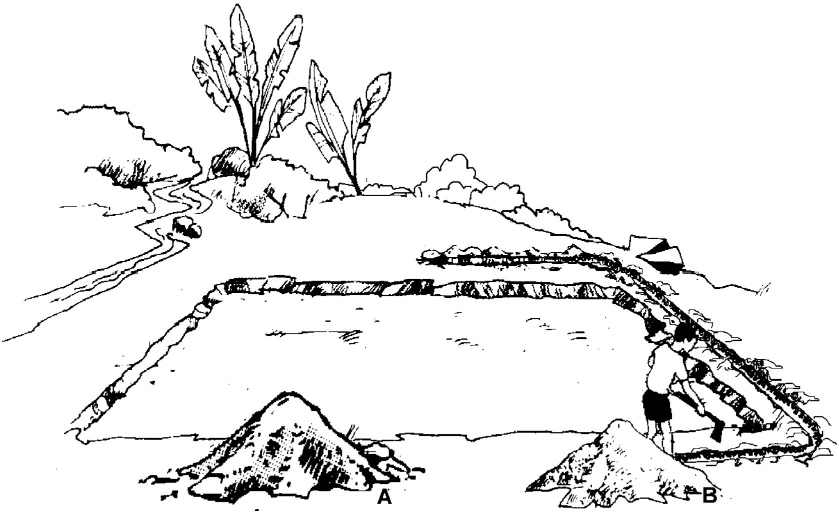

Figure 11: Digging a 'core trench' (A= Topsoil, B= Clay)

The drawing in figure 12 shows how a core trench helps to strengthen the pond dike and keep it from leaking. There is a tendency for water to seep away where the new soil joins the original ground layer. In the drawing on the left side, there is no clay core and water seeps out under the new dike. This leaking may eventually cause the entire dike to break down. In the drawing on the right side, the clay core stops the water from seeping under the newly built dike.

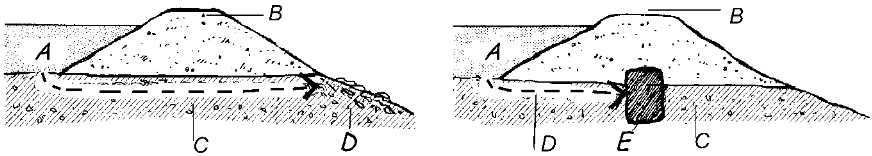

Figure 12: The function of the core (Murnyak and Murnyak, 1990). A: water; B: pond bank; C: ground; D: seepage; E: clay core

3 Dig the pond and build the dikes

Use the soil that you dug out when making the trench for the clay core to build up the dike on top of the core trench. Try not to use sandy/rocky soil or soil that contains any roots, grass, sticks or leaves. These will decay later and leave a weak spot in the dike through which the water can leak out.

Keep compacting the soil at regular intervals while you are building the dike. After adding each 30 cm of loose soil trample it well while spraying water on the dike. Then, pound it with your hoe, a heavy log, or a piece of wood attached to the end of a pole (figure 13). This will make the dike strong.

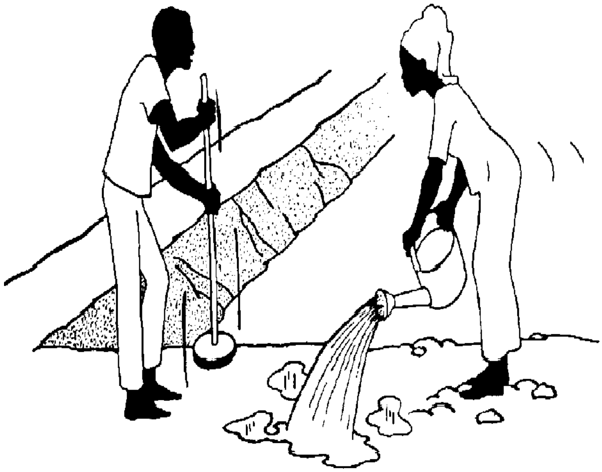

Figure 13: Compacting the dike (Viveen et al., 1985)

Pond dikes should be about 30 cm above the water level in the pond. If catfish are to be farmed in the pond, build the dike to 50 cm higher than the water level to prevent the catfish from jumping out. Once you have reached this height, add a little more soil to allow for settling and then refrain from adding any more soil on top of the dikes.

If you have not yet made the pond deep enough, continue digging, but take the soil away from the pond area. If you put the soil on top of the pond dikes they will become too high and unstable, and it will make working around the pond difficult.

The pond dikes should have a gentle slope, which will make them strong and prevent them from undercutting and collapsing into the pond. The easiest way to slope the dikes is AFTER digging out the main part of the pond.

The best slope for the pond dike is one that rises 1 metre in height for every 2 metres in length. It is easy to make a triangle as shown in 0 to help obtain this slope. A good way to determine whether the dikes are too steep is to try to walk slowly from the top of the dike to the pond bottom. If this is not possible then the dike is too steep!

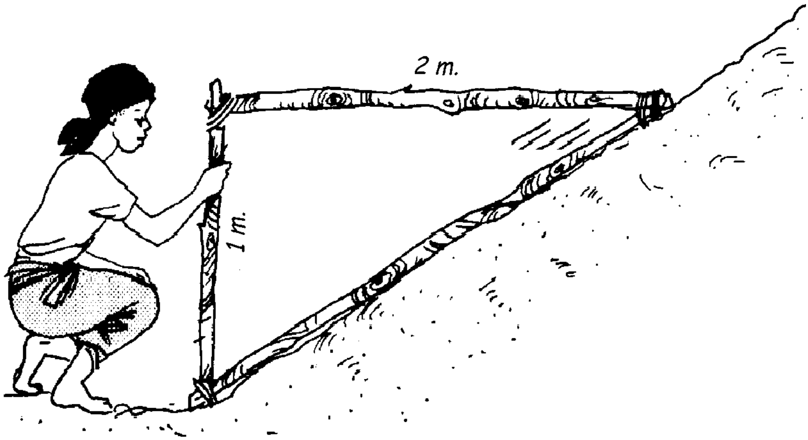

Figure 14: Measuring the slope of the dike (Murnyak, 1990)

The pond bottom should also slope so the water varies in depth along its length. Smooth out the pond bottom after reaching the required pond depth, which will make it easy for sliding the nets along the pond bottom when harvesting the fish.

4 Build the water inlet and outlet

The water **inlet** consists of a canal to bring in the water, a silt catchment basin, and a pipe to carry water into the pond (figure 15).

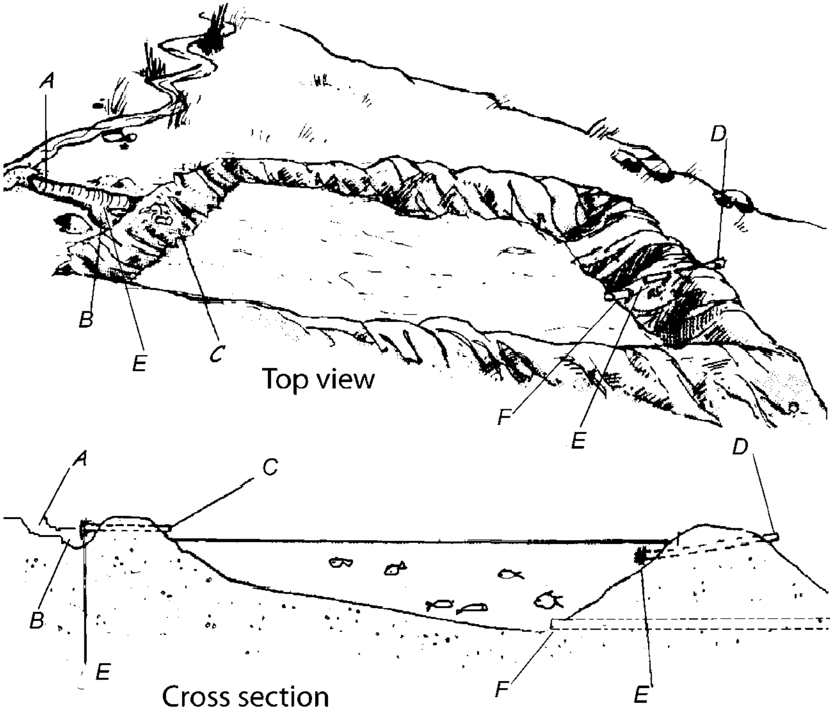

Figure 15: The water inlet and outlet of a pond (Murnyak, 1990). A: inlet canal; B: silt catchment basin; C: inlet pipe; D: overflow pipe; E: screen, F: outlet pipe. (Top view and Cross-section)

The water coming into the pond often contains a lot of soil and silt and will make the pond very muddy. A silt catchment basin will prevent this soil from entering the pond. By widening and deepening the inlet canal right outside of the pond dike, the soil will settle into this hole – called a silt catchment basin – instead of entering the pond.

The water inlet pipe runs from the catchment basin through the pond dike into the pond. It should be about 15 cm above the water level so that the incoming water splashes down into the pond. This will prevent fish from escaping by swimming into the inlet pipe. It also helps to mix air (and thus oxygen) into the water.

The water overflow pipe is used only in emergencies. Water should NOT flow out of the ponds on a daily basis. During heavy rains the overflow pipe takes excess rainwater and run-off water out of the pond. The overflow pipe can be installed at an angle as shown in figure 15. If you install it with the intake underwater as shown, this will prevent the screen (see below) from clogging with debris that may be floating on the pond surface.

The inlet, outlet and overflow pipes can be made of metal, plastic, bamboo, wood or other material. Install the pipes through the pond dike near the water surface.

Pipes should have screens to stop fish from entering or leaving the pond. The INLET pipe is screened at the edge, which is outside the pond to stop wild fish and objects like branches and leaves from entering. The OUTLET (also called drainage pipe) is screened inside the pond to stop fish from escaping.

Screens can be made from many types of materials. Anything will do that allows water but not small fish to pass through (figure 16):
A Piece of metal with holes punched in it
B Screen or wire mesh
C A clay pot with holes punched in it
D A loosely woven grass mat

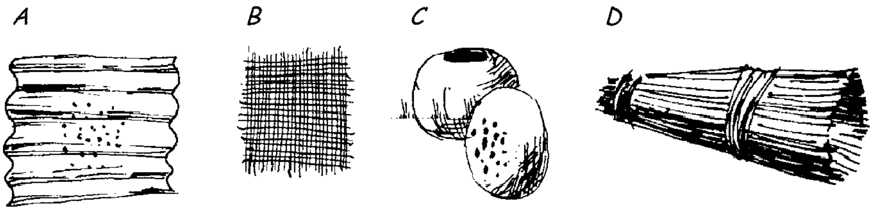

Figure 16: Materials for screens (Murnyak, 1990)

The screens should be cleaned daily.

5 Protect the pond dikes

When the pond dikes are finished, cover them with the topsoil that was saved when digging the pond. On the dikes, plant grass such as Rhodes grass (*Chloris gavana*) or star grass (*Cynodon dactylon*). Do not use plants with long roots or trees because these will weaken the dikes and may cause leaks. The fertile topsoil will help the new grass to grow, and the grass will help to protect the dikes from erosion.

Flooding during heavy rains can destroy pond dikes, if too much rainwater and run-off water flows directly into the pond. This problem is most common in contour ponds built on hillsides, but can be prevented by diverting the run-off water around the sides of the pond. You can do this by digging a ditch along the upper side of the pond. Use the soil from this ditch to build a small ridge below it. The ditch will carry run-off water away from the pond, which will prevent flooding and protect the pond dikes (figure 17).

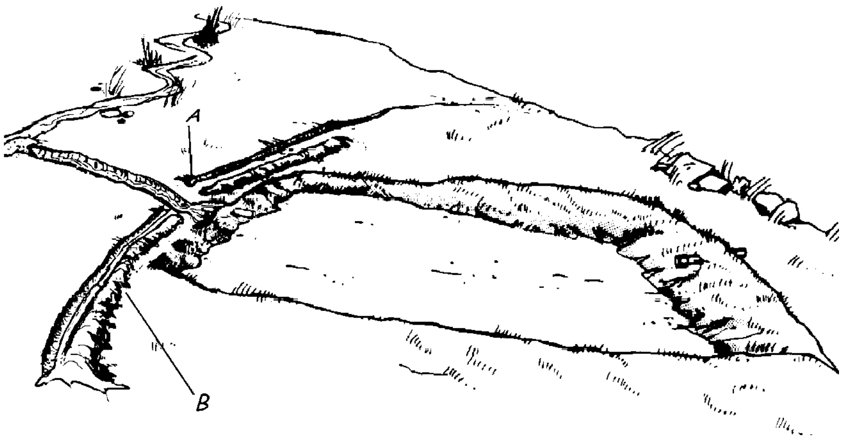

Figure 17: Dike protection by diverting run-off water (Murnyak, 1990) A: ditch, B: dike

6 Fertilising the pond

The natural fish food production in the pond can be increased by the use of fertilisers such as animal manure, compost or chemical fertilisers. Spread the fertiliser on the dry pond bottom before filling the pond with water. Add fertiliser to the pond water at regular time intervals, preferably each day in the late morning or early afternoon. This continuous adding of fertiliser will ensure a continuous production of natural fish food. For detailed information on the application rates of different fertilisers see Agrodok No. 21 on 'Integrated fish farming'.

If the soil is acid, add lime or wood ashes to the pond bottom in addition to fertiliser before filling the pond. Use 10-20 kg of lime or 20-40 kg of wood ashes for each 100 m^2 of pond bottom (see also the section on water acidity, alkalinity and hardness, chapter 4 and Appendix 2).

7 Fence the pond

Putting a fence around the pond will protect children from falling into the pond and it can help to keep out thieves and predatory animals. To make a low cost and sturdy fence, plant a thick hedge around the edge of the pond or build a fence using poles and thorn branches.

8 Fill the pond with water

Before filling the pond, put rocks on the pond bottom at the spot where the water lands when coming in from the inlet pipe. This will keep the incoming water from making a hole and eroding the pond bottom. Then open the inlet canal and fill the pond.

Fill the pond slowly so that the dikes do not subside due to uneven wetting. While the pond is filling, the water depth can be measured with a stick. Stop filling the pond when the required depth is reached.

To prevent overflowing, do not fill the pond too full. Water in the pond should not flow through (and should thus be stagnant), because water flowing through the pond will slow down fish growth by flushing away the naturally produced fish food. The only water added to the pond should be to compensate for water loss through evaporation and seepage. New ponds often seep when they are filled with water for the first time as the soil partly takes up the water. Keep adding new water for several weeks and gradually the pond should start to hold water.

9 Stock the fish

Wait 4-7 days before stocking the fish. This allows the natural food production in the pond to reach a sufficient level to sustain fish growth. In case you decide to introduce substrates in the pond, you will have to wait longer until the substrates are colonised by organisms that can be eaten by the fish (see the next section on periphyton-based fish farming).

Figure 18: Stocking the fish

Stock the baby fish (called fingerlings) gently, as indicated in 0. Note, the temperature of the water the fingerlings come from should be about the same as the water temperature in the pond.

From this point onwards it is important to maintain the pond in a good state and monitor water quality, as described in chapter 4.

3.3 Sticks in the mud: periphyton-based fish farming

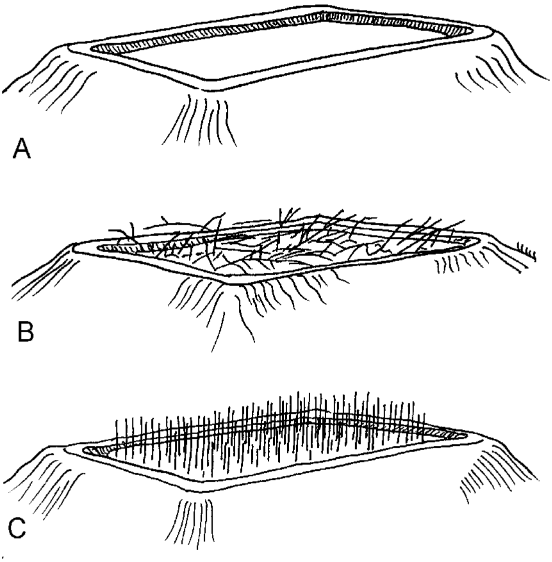

Figure 19: ponds with and without substrates: A: Pond with no substrates, B: pond with sticks and branches placed at random, C: pond used in scientific trials with bamboo poles placed at equal intervals

Periphyton is the group of algae, bacteria, fungi and other aquatic organisms that attach to substrates (= hard material) present in the water. The aggregate formed by these organisms, a sort of slimy layer, is called "periphyton mat". It has been observed that fish production is higher in ponds provided with substrates, such as branches or bamboo poles placed vertically across the pond, than in ponds without substrates (figure 19). This practice is known as 'periphyton-based fish farming' and was inspired by the traditional *brush park fisheries* in natural waters, where vegetation or branches are distributed through the water body with the purpose of attracting fish and other animals.

Additional food

One of the main advantages of placing substrates in the ponds is that the submerged poles or branches are soon colonised by a variety of tiny organisms that can be eaten by the fish (figure 20). In periphyton-based fish farming, food availability in the pond is increased in a natural way, thus reducing the need to fertilise the pond or provide the fish with supplementary feed.

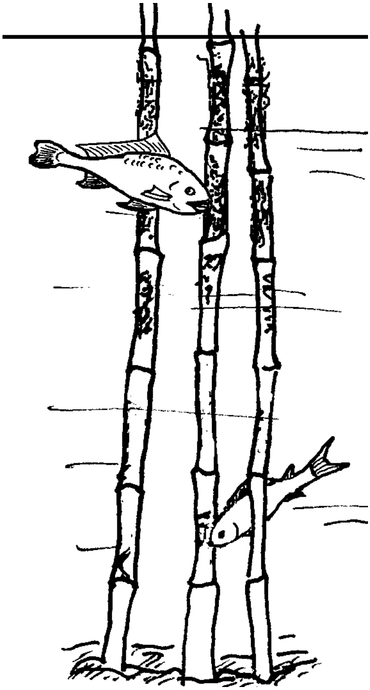

Figure 20: Bamboo pole colonised by periphyton

This is very important, both from an economic and environmental point of view: supplementary feed and fertilisers can be expensive, and this is an inefficient process anyway, as the majority of the nutrients are lost to the environment as waste. The advantage of periphyton is that the fraction of nutrients retained in harvested fish is increased considerably, compared to fish from ponds where artificial feed or fertilisers are added (inorganic fertiliser, compost, manure, etc.).

Fish use the resources more efficiently in periphyton-based ponds. The reason is that some species are more efficient at grazing from a three-dimensional structure such as a bamboo pole (periphyton) than at filter feeding from the water column (phytoplankton = tiny algae).

Shelter

Another important benefit from introducing substrates into the pond is to protect fish against predators such as birds, frogs or snakes. Although poles can also be used to perch on by fish-eating perching birds, you can take certain measures to prevent the birds from catching fish. For instance, birds that pick fish from their perching spot on the poles are dependent on the height of the pole above the water column. By making the poles a little longer, it will make it problematic for the bird. For diving birds, the density of sticks in the pond forms an obstacle and thus reduces the risk of predation. Apart from natural predators, theft by humans can be reduced when poles or branches are placed in the ponds.

Fish health

Fish survival is generally believed to be better in ponds where substrates are used than in ponds without substrates. There is growing evidence that periphyton can have a positive effect on fish health. It can act as an antibiotic against a variety of disease-causing bacteria present in ponds, or as a kind of vaccine for fish that feed on it. Furthermore, fish have been observed to rub against branches or poles to dislodge parasites.

The benefits of periphyton-based fish farming are summarised in figure 21.

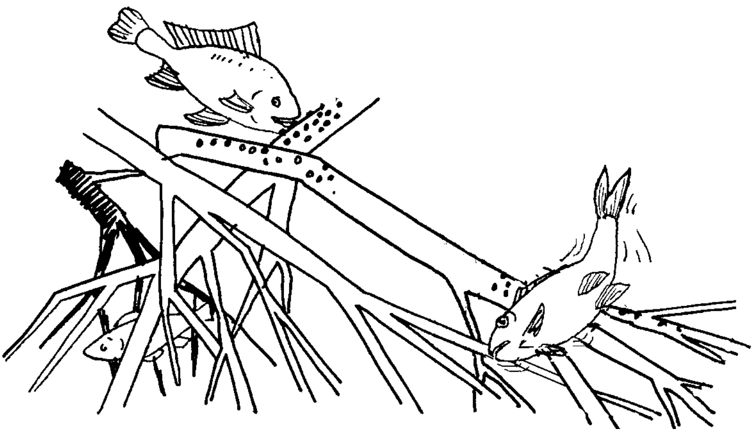

Figure 21: Benefits of periphyton-based fish farming: food, shelter and health

Case study:
The CARE-Bangladesh Locally Intensified Farming Enterprises (LIFE) project

Factors such as substrate type, substrate density, periphyton quantity and quality, fish species, fish density and water quality all influence the success of the system.

Substrates
For fish farmers in Bangladesh, the decision-making process on what kind of substrate to use was based on indigenous knowledge derived from brush park fisheries. The factors they considered before selecting the substrate were the flexibility of the different substrates after immersion in water, possible water quality problems and potential for periphyton growth.

In general, bamboo performs best but it is expensive. Substrate choice will depend on local availability and whether its use in the fish pond does not conflict with other household activities, for example, wood for fuel. Sugarcane bagasse, paddy straw and water hyacinth have also been used with some success.

Regarding substrate density, the approach tested by most farmers differed from that conducted in research stations. During the experiments, substrate poles were meant to be placed at regular intervals across the pond at a uniform density. In practice, however, most farmers used a mixture of bamboo poles, tops and branches at unknown densities. Poles were usually placed at intervals of 1-1.5 m, while branches were set randomly on the pond surface. Farmers were observed to position poles at an angle in order to increase the surface for periphyton growth, which often occurs in the upper 30-45 cm layer of the water column.

Based on experiments, a rough estimate on the appropriate amount of substrate to be used is a substrate surface area more or less equal to the pond area. For example, for a 100 m^2 pond, use roughly 6-10 poles per m^2.

The timing of substrate introduction into the ponds is important, as it takes several days or even weeks before enough periphyton has grown and can sustain fish growth. Most Bangladeshi farmers introduced the substrates about one month *after* stocking the fish, instead of doing that *before* stocking the fish.

Finally, it was observed that taking out the substrates from the pond (in order to enable harvest) damaged the periphyton mats due to drying. It took the periphyton 1-2 weeks to recover and delayed the next farming cycle. This was an important concern for the farmers.

Periphyton quantity and quality

The grazing pressure of the fish growing in the pond will affect the regeneration capacity of periphyton. This means that the stocking density of the fish should not exceed this regeneration speed. Little is known about grazing efficiencies of the different fish species, so more trials are needed on this subject.

A possible way to improve the nutritional quality of the periphyton mats is to ensure that enough nutrients are available in the water (mainly phosphorus and nitrogen, but also silicon). Adding compost to the pond may be useful.

Fish species and fish density

Experiments in India and Bangladesh were done to determine which fish species were good candidates for periphyton-based polyculture (the practice of raising more than one fish species in the same pond, see chapter 6). In these experiments bamboo was used as a substrate.

It was found that red tilapia and the Indian carp species rohu (*Labeo rohita*), and kalbaush (*L. calbasu*) ate periphyton. Moreover, the combination of rohu and a fish with complementary feeding habits, the carp catla (*Catla catla*) in the ratio 60%-40%, resulted in very high fish production, superior to monoculture of either species. When bottom-feeding kalbaush was added to the rohu-catla system, the overall production improved even more.

Experience has shown that most fish species, with the exception of pure carnivores, will benefit from periphyton. Therefore, farmers are advised to experiment to find the suitable substrates to encourage periphyton growth in their ponds, and to compare production increases with previous years.

Water quality

Different kinds of substrates have different effects on the water quality in the pond. For example, bamboo is more resistant and requires less dissolved oxygen than easily degradable organic substrates, such as sugarcane bagasse or paddy straw. Also, depending on the position of the substrate in the water column, periphyton mats are either oxygen producers (upper water layer) or consumers (bottom water layer). By controlling the distribution of substrates in the water column, one can help to prevent oxygen shortages in the pond. For further explanation on water quality see chapter 4.

The periphyton mat entraps suspended solids, which improves water transparency and thus the penetration of sunlight into the pond. The periphyton mat also takes up compounds that are toxic for the fish, like ammonia and nitrate.

Ammonia toxicity is an important constraint in the intensification of fish farming in pond systems. In periphyton-based ponds, bacteria that break down ammonia can colonise the surface of the substrates located in the well-oxygenated water column. These mats form a 'biofilter' that keeps ammonia levels low.

Costs and constraints of periphyton-based fish farming

Calculations of the costs and profits of a polyculture trial with carp were done in India in an attempt to estimate the economics of periphyton-based fish farming. The trial involved catla, rohu and common carp. The substrate used was sugarcane bagasse at different densities: 0, 7, 14 and 28 kg/100 m^2. Fish yield was increased in all trials where substrates were used, but the increase in the trials with 14 and 28 kg/100 m^2 was almost the same. Therefore, the costs associated to the trial with 14 kg/100 m^2 were used for comparison to the trial without substrates. The extra costs for transport, labour and materials for substrate installation totalled Rs 5,960 (Indian rupees), while increased income from fish sales was Rs 24,500.

Serious constraints of periphyton-based fish farming are:
- Additional labour required for substrate installation and removal before harvest
- Possible conflicts in the use of the substrate in the household (as fuel or in other more productive activities)

- Cost of the substrate if this is not available on-farm
- Potential local deforestation if demand for substrates increases
- Problems with water quality if the system is not managed properly
- Insufficient knowledge of the biology of the system: fish species or species combination to be used, fish density, substrate type, density and so forth.

Conclusion

Despite the constraints mentioned above, periphyton-based aquaculture offers many potential benefits to fish farmers around the world. First, fish yields increase and predation and poaching decrease. Second, it is a relatively simple technology that makes use of local resources (materials and manpower) and can be applied at different levels of intensity to most systems depending on the resources available. Finally, it improves sustainability by increasing the percentage of input nutrients retained in harvested products and decreases the discharge of waste and potential pollutants into the environment.

4 Maintenance and monitoring

To achieve a high production of fish in the pond, regular maintenance and monitoring is vital. Daily management includes:

- Checking the water quality (oxygen, pH, colour, transparency, temperature, etc.)
- Checking the pond for possible water leaks
- Cleaning the screen of the water inlet and outlet
- Observing the fish while they feed: Do they eat normally? Are they active? If not, and if they are gasping for air at the surface, the oxygen level in the water is too low. Stop feeding and fertilising and let water flow through the pond until the fish behave normally again. Otherwise, look for symptoms that could indicate a disease.
- Watching out for predators, or signs of predators such as footprints, and taking precautions if necessary
- Removing aquatic weeds growing in the pond

Water quality is a vital factor for good health and growth in fish. Some of the most important water characteristics are described below.

Oxygen

Oxygen is a gas that is produced by all plants in the pond (therefore also by phytoplankton) with the help of sunlight. The more sunlight falls on the pond and the larger the quantity of phytoplankton, the higher the oxygen-production will be. The oxygen produced partly dissolves in the water and the rest escapes to the air. The oxygen level of the water varies during a 24-hour period because the production and absorption of oxygen by the plants change with light and darkness. The phytoplankton in the pond only produce oxygen when there is light. At night they need oxygen like any other plant or animal in the pond, but because of the lack of sunlight no oxygen can be produced. Consequently, the quantity of dissolved oxygen in the water decreases after sunset (figure 22). Normally, the oxygen level is at the highest at the end of the afternoon (oxygen has been produced throughout the day) and at the lowest in the early morning (oxygen has been used up throughout the night). Shortage of oxygen is the most important cause of fish death when the pond has been fertilised with manure or fed too much. A sufficiently high oxygen level is important for good fish production.

If fish are gulping for oxygen at the water surface, you can solve this problem by flowing extra freshwater through the pond. Stirring up the water in the pond also helps to increase the amount of dissolved oxygen. Do not feed and fertilise the pond at this moment because this is often one of the reasons for the oxygen shortage. Over-stocking of fish in the pond could be another possible cause of oxygen shortage problems. This can cause oxygen stress for the fish, which can result in disease outbreaks and mortality.

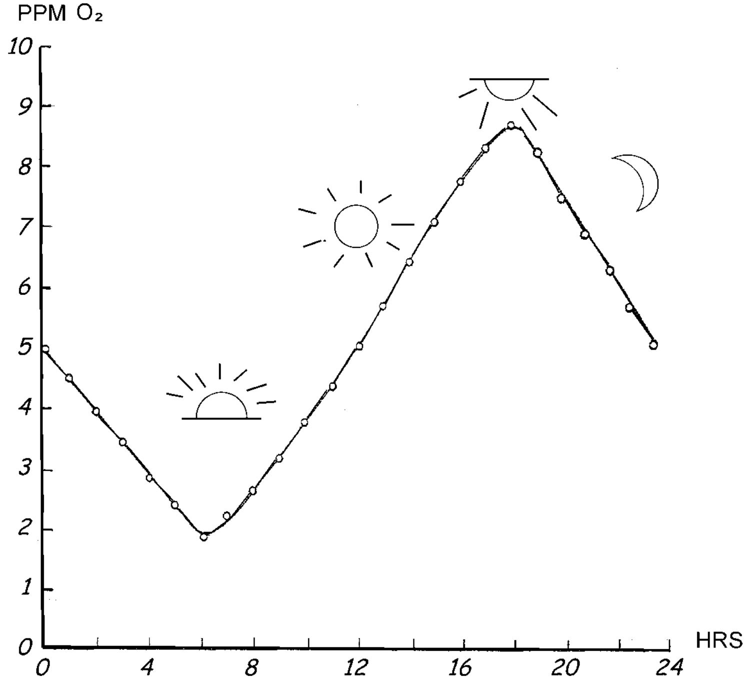

Figure 22: Oxygen level over the day

Water acidity, alkalinity and hardness

Water suitable for fish farming should have a certain degree of acidity, indicated by the water pH-value. This should preferably range between 6.7 and 8.6 (figure 23). Values above or below this range inhibit good fish growth and reproduction. Phytoplankton require a pH of about 7 and zooplankton (tiny animals in the pond water on which the fish feed) a slightly lower pH of 6.5.

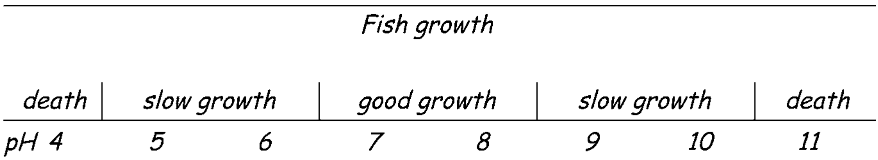

Figure 23: The effect of pH on fish growth (Viveen et al. 1985)

Sometimes the pH of the pond water can change quickly. For example, heavy rain may carry acid substances, dissolved from the soil into run-off water, into the pond. In this way, the pond water gets more acid and thus the pH-value decreases.

The best way to increase the pH-value of the water again to neutral (about 7) is to add lime to the pond (Appendix 2).

Water alkalinity is a measure of the acid-binding capacity of the water (buffering ability), and is the opposite of water acidity. This means that when pond water alkalinity is high, more acid substances are needed to decrease the water pH-value.

Water hardness is the measure of total water-soluble salts. Water that contains many salts is called ‘hard’ and water that contains few salts is called ‘soft’. One method of measuring hardness is to carefully examine the pond dikes. If a white line appears on the dike at the same height of the water level, this means that salts present in the water have dried on the pond dikes. Therefore the pond contains hard water. Hard water is important for good fish growth. If the water is too soft (i.e. the amount of water soluble salts is low), the farmer can increase the hardness by adding lime to the water. In this manner, water fertility will increase, so natural food production and ultimately fish production in the pond will also increase.

Water acidity, alkalinity and hardness can all be changed by adding lime to the pond as described above. These three water quality measurements are **NOT** the same but are usually related to each other in the following way:

Low alkalinity ≈ low pH ≈ low hardness

So, the aim of adding lime is to increase either water alkalinity, water hardness or pond water pH (to about 7). Ponds that have just been built need a different treatment than ponds that have already been limed before.

- Newly built ponds
  These should be treated with 20 to 150 kg agricultural lime per 100 m2 (Appendix 2). This is mixed with the upper (5 cm) layer of the pond bottom. The pond is subsequently filled with water to a depth of 30 cm. Within one week the pH of the pond water should have reached 7 and you can start fertilising.

- Ponds limed before
  These should be treated with 10 to 15 kg quicklime per 100 m^2, added to the damp pond bottom to get rid of fish pathogens, fish parasites and fish predators. After a period of 7 to 14 days the ponds should be refilled with water. After filling the pond to a depth of 30 cm, the pH of the water can be adjusted by adding agricultural lime (Appendix 2).

Turbidity

Turbidity is the term for the amount of dissolved, suspended dirt and other particles in the water, which give the water a brown colour. High turbidity of water can decrease fish productivity, as it will reduce light penetration into the water and thus oxygen production by the water plants. Dissolved, suspended solids will also clog filters and injure fish gills.

A method for measuring water transparency, and therefore an indirect way to estimate turbidity, is the Secchi disc shown in figure 36 (see chapter 8). A suitable method for reducing turbidity is using a silt catchment basin. This is a small reservoir at the inlet of the pond. The water flows into this reservoir and is kept there until the mud settles on the bottom. Then the clear water is let into the fish pond.

Another way of clearing muddy water is to place hay and/or manure in the pond and leave it there to decompose (resulting in sedimentation of mud particles). This method should not be used during very hot weather because the hay will begin to rot very quickly. This could lead to oxygen shortage in the pond.

In the case of water turbidity caused mainly by factors other than phytoplankton abundance (water colour is not greenish), there are some widely used practices to decrease this turbidity. For instance, before stocking the fish, place animal manure in the pond at a rate of 240 g/m^2. Do this three times with an interval of three to four days between the applications. Another method to decrease turbidity is to apply lime, gypsum, or preferably alum at 1 gram per 100 litres of water.

However, the only real long-term solution to turbidity is to divert muddy water away from the pond and ultimately protect dikes from erosion, which cause the high water turbidity.

Toxic substances

Toxic substances in the water supply of the pond can decrease fish production seriously, so it is wise to investigate any existing or potential sources of water pollution in the vicinity of the pond. Many chemicals used in animal husbandry and crop cultivation are poisonous to fish. Therefore, chemicals should never be used in the area around the pond, especially avoid spraying on windy days.

Part II: Planning a fish farm

Figure 24: Setting up a fish farm

5 Introduction

Land, water and climatic conditions are probably the most important natural factors that need to be assessed. When developing a site for fish farming you should consider the effect it may have on the environment. Important natural areas (e.g. fish nursery grounds like mangrove forests) *should not be used for fish farming*.

One of the most essential requirements is water availability, in terms of quality and quantity. The type of aquaculture farm and species of animals or plants that you will be able to culture will depend largely on the properties of the site.

The risks involved in fish farming should also be stressed. Fish need protein in order to grow and reproduce. This means they can become competitors for products, which could otherwise be used directly for human consumption. Furthermore, the cost of production is fairly high and therefore *fish grown in ponds are not always able to compete financially with fish caught in the wild*.

Setting up a fish farm involves high initial investment and high production costs as well as economic risks. Therefore, there are some very important factors a prospective fish farmer should consider before embarking on a fish farming venture (see figure 24). For example:

1 Gathering information:
Future fish farmers can often get assistance with starting up a fish farming enterprise in the form of technical advice from extension services. In some cases even financial support is provided.

2 Finance:
A cost estimate should include the cost of land as well as capital expenditures for fish stock, pond construction, labour, production and harvesting.

3 Site:
The soil must be able to retain water. Good water quality and sufficient quantity should be available at a reasonable cost. The site should be close to home and potential losses from stealing should be estimated. The ownership of the land, as well as the state or federal permits required, should be known and obtained. The site and roads should be passable and not subject to flooding.

4 Fish stock:
You need to decide whether to breed your own fish stock or purchase it from others. If you plan to buy from others you must have a reliable source of good quality fish stock. If you choose to breed on-site, then you must have adequate space for maintenance of brood stock and production of young fish.

5 Production:
Will the feed available for the selected fish species match this species preferences?

6 Harvesting:
Enough people should be available to harvest the fish. Find out what is the most economical method for harvesting. You may need storage facilities for harvested fish.

7 Consumption:
Will the fish be used for your own consumption or for selling?

6 Selecting the site and type of fish farm

Site selection

Proper selection of a site is probably the most important factor for success. However, if the ideal site is not available, you may have to compromise. There may also be conflicts concerning land and water use that need to be resolved. You should decide on which species to raise, based on the available feeds (e.g. agricultural by-products) and possible fertilisers (e.g. compost or animal manure).

Site selection will depend on the type of fish farm you plan to run. For pond construction you need to consider the following factors: soil type and quality and quantity of the water available.

Soil

The quality of soil influences both water quality and productivity in a pond. The soil must also be suitable for dike construction. To determine soil suitability the two most important properties to examine are soil texture (particle size composition), and porosity or permeability (ability to let water pass through). The pond bottom must be able to hold water (have a low porosity, like clay) and the soil should also contribute to the fertility of the water by providing nutrients. The best soil for pond construction should contain a lot of clay. The three methods one should follow to predict whether the soil will be suitable for pond construction are:

1 The 'squeeze method'
2 The ground water test
3 The water permeability test

1 Squeeze method (figure 25):

a Wet a handful of soil with just enough water to make it moist
b Squeeze the soil by closing your hand firmly
c If it holds its shape after opening the palm of your hand, the soil will be good for pond construction.

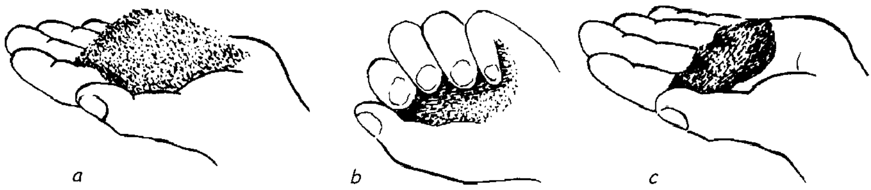

Figure 25: The 'squeeze method' (Chakroff, 1976)

2 Ground water test (figure 26)

This test should be performed during the dry period in order to get reliable results:

a Dig a hole to a depth of one metre
b Cover it with leaves for one night to limit evaporation
c If the hole is filled with ground water the next morning, a pond could be built but take into account that you will probably need more time to drain the pond. This is due to the high ground water levels that will refill the pond.
d If the hole is still empty the next morning, no problems will occur as a result of high ground water levels and the site will probably be suitable for pond fish farming. Now you should test the soil permeability to water.

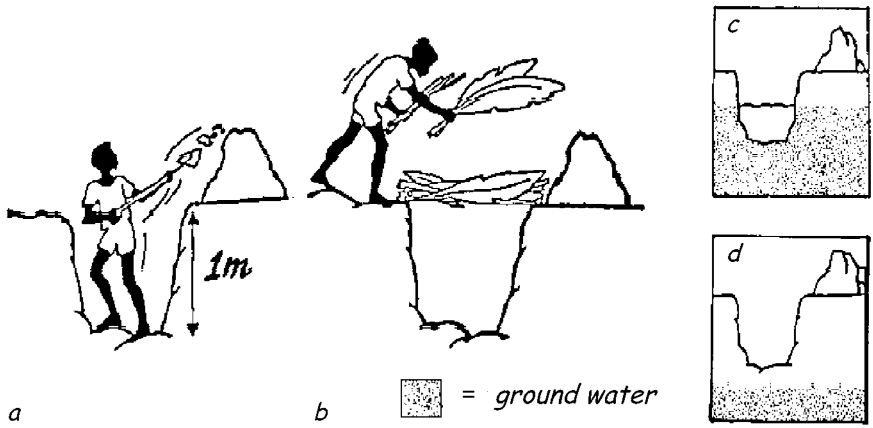

Figure 26: Ground water test (Viveen et al., 1985)

3 Water permeability test (figure 27):

a Fill the hole with water to the top

b Cover the hole with leaves

c The following day the water level will be lower due to seepage. The dikes of the hole have probably become saturated with water and might hold water better now.

d Refill the hole with water to the top

e Cover it once more with leaves. Check the water level the next day.

f If the water level is still high, the soil is impermeable enough and is suitable for pond construction.

g If the water has disappeared again, the site is not suitable for fish farming, unless the bottom is first covered with plastic or heavy clays.

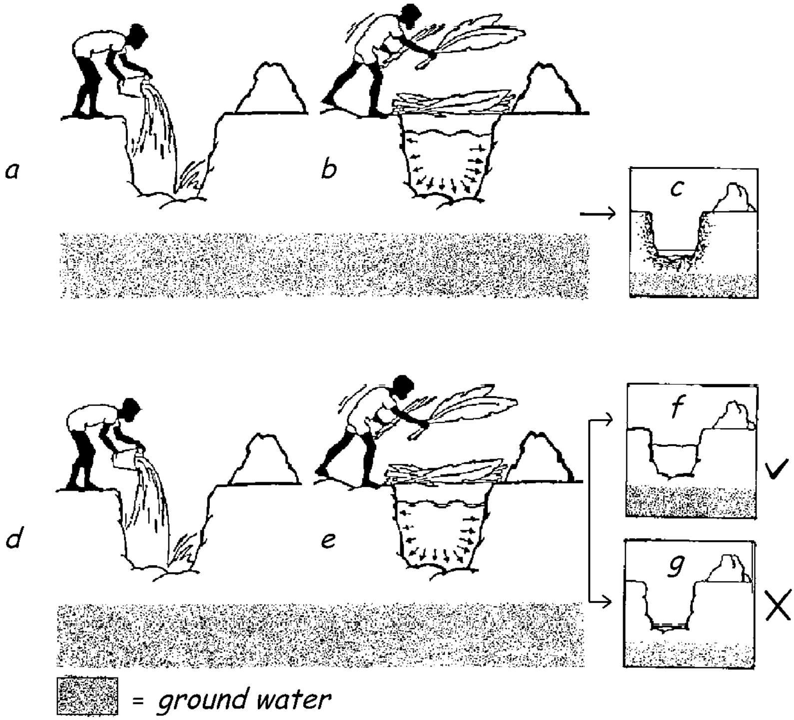

Figure 27: Water permeability test (Viveen et al., 1985)

The land contour and especially the land slope determine the way the pond should be built. The slope of the land can be used for the pond's drainage at harvest.

Totally flat land and a hilly terrain with a slope of more than 4% are unsuitable for pond construction. All slopes between 2% and 4% can be used for pond construction. A 2% land slope indicates a 2 cm drop in elevation for every metre of horizontal distance. If the slope is adequate, you can fill and drain by the simple means of gravity. However, you should take care to prevent erosion of the pond dikes.

Water

The availability of good water quality is significant for all fish farming systems but water quantity is of even greater importance for land-based fish farming systems. A constant water supply is needed, not only to fill the pond, but also to make up for the losses caused by seepage and evaporation (figure 28).

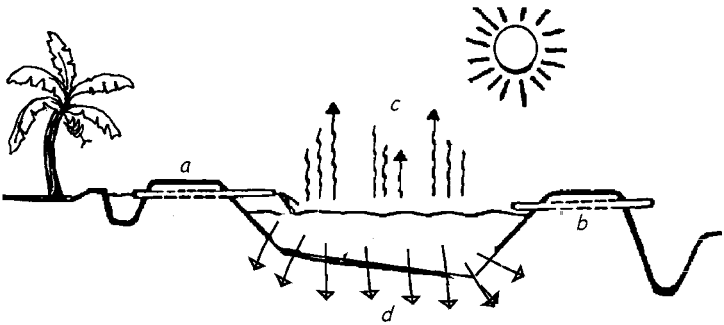

Figure 28: Water supply and water loss in a fish pond (Viveen et al. 1985) a: inlet, b: overflow, c: evaporation, d: seepage

Investigation of the water sources is very important:
1 How much water is available?
2 Is water available in all seasons, or is the availability different during the different the seasons?
3 What are the water sources? Are they likely to be polluted?

Ideally, water should be available all year round. Different water sources and their disadvantages are listed in table 2.

Water temperature

Water temperature is an important condition in assessing whether the fish species selected can be raised. A water temperature between 20 °C and 30 °C is generally good for fish farming.

Water salinity

Variation in water salinity (amount of dissolved salts in the water) is also an important factor to consider. Some fish species can withstand a wider salinity range than others: e.g. tilapia and catfish can withstand a wide range from freshwater to seawater, while carp can only withstand freshwater.

These are the most important water quality criteria for site selection. There are other important water quality characteristics, but these are more easily controlled by management measures (for example, dissolved oxygen, pH, etc., see chapter 4).

Table 2: Water sources and their main disadvantages

Water source	Main disadvantage
Rainfall 'Sky' ponds rely on rainfall only to supply water	**Dependency** The supply depends heavily on amount of rain and seasonal fluctuations
Run-off Ponds can be filled when water from the surrounding land area runs into them	**High turbidity** Turbidity is the amount of mud in the water. In case of run-off the water may be muddy. Danger of flooding and pesticides (or other pollutants) in the water
Natural waters Water can be diverted and brought in from streams, rivers or lakes	**Contamination** Animals, plants and rotting organisms can cause diseases. Danger of pesticides (or other pollutants) in the water
Springs Spring water is water under the ground that has found a way to get out. Spring water is good for fish ponds because it is usually clean.	**Low oxygen level and low temperature**
Wells Wells are places where ground water is pumped up	**Low oxygen level and low temperature**

7 Selecting the fish species

When selecting fish species suitable for farming, various important biological and economic factors need to be considered:

1 market price and demand (not when fish are produced for own consumption)
2 growth rate
3 ability to reproduce in captivity
4 simple culture of the young fish
5 match between available fish feeds and the food preference of the selected fish species

It will often be possible to choose from locally occurring species and to avoid the introduction of exotic ones for culture. The most important biological characteristics (growth rate, reproduction, size and age at first maturity, feeding habits, hardiness and susceptibility to diseases) determine the suitability of a species for culture under local conditions.

Although certain slow-growing species may be candidates for culture because of their market value, it is often difficult to make their culture profitable. It is better that they reach marketable size before they attain maturity, thus ensuring that most of the feed is used for muscle growth instead of reproduction. Early maturity, on the other hand, ensures easier availability of young fish.

In fish development, the following stages exist:

1 egg
2 larva: feed on own reserves, do not need external food yet
3 fry: reserves in yolk sac are depleted, external food is now necessary
4 fingerling: a young fish, older than fry but usually not more than one year old, and having the size of a finger
5 juvenile: fish not mature yet
6 adult: fish ready to reproduce

"Baby"or "young" fish are general terms generally referring to the fry or fingerling stage.

If you do not intend to breed fish yourself you may have to depend on fingerling supply from the wild. This is generally an unreliable source, as the fingerling quantities caught from the wild vary greatly from moment to moment. This is due to the fact that natural fish reproduction depends on unpredictable biological factors (water temperature, food availability, etc.). Furthermore, the collection of young fish from the wild could give rise to conflicts with commercial fishermen. It is better to select fish species that can be easily reproduced by yourself, or species that can be bought from the fish market or from a reliable fish supplier, fish culture station or fish culture extension service.

In fish farming, feeding costs are generally the most important in the total cost of production. Therefore, plant-eating (herbivorous) or plant- and animal-eating (omnivorous) fish species are preferable as they feed on natural food resources occurring in the pond. The cost of feeding these species will be relatively low. Carnivorous (predatory) fish species, on the other hand, need a high protein diet and are therefore more expensive to produce. To compensate for higher feeding costs, however, most carnivorous species fetch higher market prices.

Fish species that are hardy and can tolerate unfavourable culture conditions will survive better in relatively poor environmental conditions (e.g. tilapia). Besides the effect of the environment on the fish species, the influence of the species on the environment should also be considered when introducing a new fish species. The newly introduced fish species should:

1 fill a need which cannot be fulfilled by local species
2 not compete with local species
3 not cross with local species and produce undesirable hybrids
4 not introduce diseases and parasites
5 live and reproduce in balance with their environment

When introducing exotic species you should be aware of the fact that this activity is subject to strict national and international regulations.

Raising different fish species together in one pond (polyculture) will produce a higher fish production than from raising fish species separately (monoculture).

Monoculture

Only one fish species is raised in the pond. An advantage of monoculture is that, as there is only one fish species to consider with regard to food preference, it is easier to give certain supplementary feed to the fish. A disadvantage is the risk that a single disease may kill all the fish in the pond. Different fish species are usually susceptible to different diseases.

Polyculture

More than one fish species are raised in the fish pond. This way the various natural food resources in the pond are better utilised. Each fish species has a certain feed preference, which is related to the position of the fish in the pond (e.g. bottom-living or mid-water-living fish). For example, mud carp live mostly on the bottom of the pond and feed on mud and detritus (= dead material), which they find on the bottom. Tilapia, on the other hand, prefer the middle part of the pond. By combining different species in the same pond, the total fish production can be raised to a higher level than would be possible with only one species or even with the different species separately. An example of a Chinese polyculture fish farming system is the culture of silver carp, bighead carp and grass carp together in one pond (figure 29).

Silver carp feed mainly on phytoplankton, bighead carp mainly on zooplankton and grass carp mainly on water plants, so there will hardly be any food competition. Another often used example is the polyculture of tilapia and common carp as tilapia feed mainly on phytoplankton and common carp on zooplankton and pond bottom material. A special form is the concurrent culture of tilapia, and either catfish or snakehead (in general, a predatory fish) to control the excessive breeding of tilapia. The emphasis should be on fish species that can live on different kinds of feed.

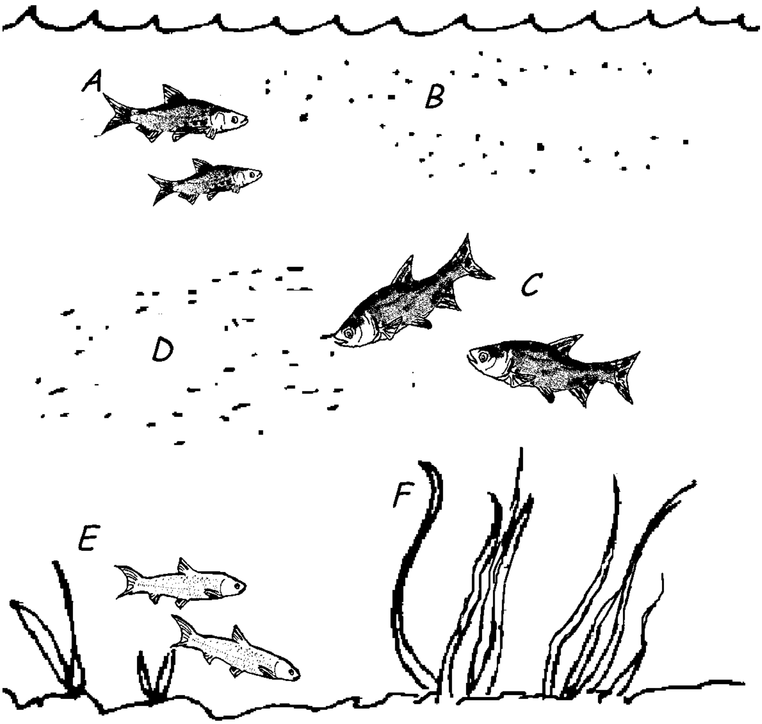

Figure 29: Carp polyculture. A: silver carp, B: phytoplankton, C: bighead carp, D: zooplankton, E: grass carp, F: water plants

7.1 Most widely cultured species

Tilapia, catfish and carp are the most commonly cultured fish species in the tropics.

Tilapia culture

Tilapias are a group of tropical freshwater fish species native to Africa and the Middle East. There are at least 77 known species of tilapia, of which Nile tilapia is the fastest growing one.

Tilapia is a fish that is ideally suited to polyculture under poor environmental conditions and/or when pond management is of low priority. They are hardy fish, able to withstand extreme water temperatures and low levels of dissolved oxygen. Natural spawning occurs in almost any type of water. The water temperature range for optimal growth and reproduction is between 20 - 30 °C. Tilapia can tolerate water temperatures as low as 12 °C and can survive in water temperatures below 10 °C for prolonged periods of time. Some species are also known to survive and grow in salt water. Being real omnivores, tilapia will eat almost anything and are therefore often called ‘aquatic chickens’. Because of the favourable culture characteristics mentioned above, tilapia is considered the most ideal species for small-scale fish farming.

However, one constraint to profitable fish farming is the continuous reproduction of tilapia. Tilapia become sexually mature at a size of about 10 cm (about 30 grams body weight). This early maturation and frequent breeding causes overpopulation of the ponds with young fish and will lead to fierce competition for food between the stocked tilapia and the newborn recruits. This will in turn decrease the growth rate of the originally stocked tilapia, resulting in high numbers of small-sized tilapia at harvest.

The most common and widely practised system of tilapia culture is in earth ponds of all sizes. In pond culture, attempts have been made to overcome the problem of early breeding, and thus overpopulation of the pond. Of the different control methods in existence, the simplest one is continuous harvesting. This involves removing the largest fish by using a selective net made from natural material or nylon. Thus, by removing the market-sized fish, the remaining young fish are allowed to continue their growth. Although this method extends the period before maturity is reached, it is labour intensive. There is also the risk of genetic deterioration of the stock when the large, fast-growing fish are sold. This means that the remaining slow-growing individuals become the breeders.

A slightly more complicated method is to remove the young from the pond when they hatch, rear them in fry ponds and then stock them into grow-out ponds. However, as mentioned above, the fish will tend to breed before they have reached market size and overpopulation can still be a problem.

Overpopulation can be controlled most economically by the small-scale subsistence farmer by stocking predatory fish together with the tilapia in the pond. These predators will eat the majority of the tilapia baby fish and will therefore prevent overpopulation of the pond. Various predators are used in different parts of the world: *Cichlasoma managuense* (El Salvador), *Hemichromis fasciatus* (Zaire), *Nile perch Lates niloticus* (Egypt), *Micropterus salmoides* (Madagascar), *Bagrus docmac* (Uganda). The predators usually fetch high market prices when sold.

When using this method of reproduction control of tilapia, the factors that should be considered include the size and stocking density of both tilapia and predator, and the time when predators are introduced into the pond. In general, tilapia start breeding immediately after they are stocked into the pond so the predatory fish can be stocked at the same moment.

The stocking density of tilapia is 2/m^2 and that of the predatory fish varies according to its voracity: 83 catfish of at least 30 cm in length per 100 m^2 or 7 snakeheads of at least 25 cm in length per 100 m^2.

When other predatory fish species are stocked one must also carefully consider the number and size of fish to be stocked. A general rule with respect to stocking size of the predatory fish is that a predator's maximum consumption of prey fish is 40% of its own length. This means that when stocking 10 cm tilapia, a predator should be smaller than 25 cm in length (10/0.40), otherwise the predator will eat the stock of tilapia!

The predator stocking density depends on its voracity. To estimate the voracity of the predator to be stocked you could make comparisons between those of the moderate voracious catfish and the highly voracious snakehead.

Tilapia males grow faster than females, so they are mostly bigger at the same age. Male tilapia can be distinguished from female tilapia by the absence of an extra opening on the genital papillae (figure 30).

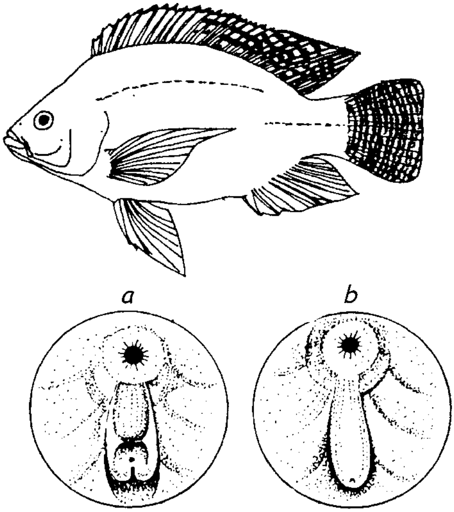

Figure 30: Genital papillae in (a) female, and (b) male tilapia

Spawning
Egg production presents no problem as the fish readily spawn in the ponds. The preferred water temperature during spawning is 20 to 30 °C.

Usually, tilapia females of about 700 g weight and males of 200 g are stocked in one pond at an average density of one fish per 2 m^2 in a sex ratio of one male to four or five females. Tilapia males will begin digging holes in the pond bottom immediately, attracting the female to the hole who will simply release her eggs. If the pond bottom is not loose, pottery jars or wooden boxes can be used as nesting material. Tilapia can then breed every 3 to 6 weeks.

The number of eggs produced per spawning depends on the size of the female: a 100 g female Nile tilapia spawns about 100 eggs while a 600-1,000 g fish will spawn 1,000-1,500 eggs. The fry are collected at monthly intervals and grown to fingerlings in nursery ponds. The average monthly production is about 1,500 fry/m^2.

During the early stages, the fry feed on the natural food produced by the pond. The fry are removed from the spawning ponds and transferred to nursery ponds or directly to grow-out ponds. Once they are transferred to the nursery ponds, supplementary feeding is provided at a rate of about 6 to 8% of body weight, depending on food type. When wheat bran is used, feeding levels can vary from 4% up to 11% of the fish body weight per day.

Grow-out ponds
Tilapia culture is generally focused on producing marketable-sized fish of at least 200-300 g. Ponds used for extensive or semi-intensive culture can vary in size from a few square metres to several thousands of square metres. Typical intensive cultivation units are about 800-1,000 m², which are easy for the farmer to manage.

A stocking density of 2 fingerlings/m² is recommended, and the application of fertilisers and/or additional feeding. Higher food availability leads to a larger size at maturity and a lower spawning frequency in females, thus the effect of overpopulation in the fish pond can be retarded artificially in this way. Two harvests can be obtained each year when the marketable size is around 200 g. The ponds may be fertilised with chicken manure and ammonium phosphate. Supplementary feed often used are rice bran, wheat bran and dried chicken manure.

Feed and fertiliser
Although tilapia can be divided into species that mainly eat water plants and species that mainly eat phytoplankton, under pond culture conditions, they have highly flexible feeding habits. This means that nearly any kind of food available will be eaten. Detritus found on the pond bottom also forms a large part of their diet. Fertilising tilapia ponds with manure and/or artificial fertilisers increases overall fish food production.

A variety of feeds can be used when culturing tilapia in ponds. Tilapia young rely mostly on the natural food production in the pond. Adult tilapia can be raised on the food produced in the pond if manure and/or artificial fertiliser are added. This natural food production can be supplemented, to a bigger or lesser extent, by the addition of other feeds. Tilapia can be fed plant materials like leaves, cassava, sweet potato, sugarcane, maize, papaya and various waste products like rice bran, fruit, brewery wastes, cotton seed cake, peanut cake and coffee pulp.

The type of feed used depends on its availability and local cost. In the majority of cases the feeds are prepared on the farm itself from all kinds of agricultural (by-) products. Some examples of simple feed formulations are presented in table 3. The amount needed to feed the fish depends on the fish size and feed type. Careful observation of the fish in the pond while feeding is the best way to determine the amount to be provided. Do not give the fish more than they will eat at one moment.

Table 3: Some tilapia fish feed formulations used in different countries (Pillay, 1990)

Philippines	Central Africa	Ivory Coast
65% rice bran 25% fish meal 10% copra meal	82% cotton seed oil cake 8% wheat flour 8% cattle blood meal 2% bicalcium phosphate	61-65% rice bran 12% wheat 18% peanut oil cake 4-8% fish meal 1% ground oyster shell

Polyculture systems of tilapia with common carp, and either mullet (*Mugil cephalus*) or silver carp can contribute to maximum utilisation of natural food in ponds. The fish yield in polyculture can reach 750-1,070 $g/m^2/year$.

Table 4: Typical production levels of tilapia obtained in different culture systems

System	Production Level
Unfertilised, unfed ponds without stocked predator	30-60 $g/m^2/year$
Unfertilised, fed ponds (agricultural waste), with stocked predator	250 $g/m^2/year$
Ponds fertilised with manure (pig, poultry, etc.)	300-500 $g/m^2/year$
Ponds fertilised and fed with commercial pellets	800 $g/m^2/year$

Catfish culture

Catfish belong to the order called *Siluriformes*, subdivided into various families, including the **Ictaluridae**, **Pangasidae** and **Clariidae**. This fish order consists of both marine and freshwater fish species found in most parts of the world. Over 2000 different species have been recorded, of which over half are present in South America. Some catfish families and the areas of farming are:

Ictaluridae; Channel catfish (*Ictalurus punctatus*) and blue catfish (*Ictalurus furcatus*) both farmed in the USA.

Pangasiidae; *Pangasius sutchi* farmed in Thailand, Cambodia, Vietnam, Laos and India and *Pangasius iarnaudi*.

Clariidae; Asian catfish (*Clarias batrachus*) and *Clarias microcephalus* farmed in Thailand and African catfish (*Clarias gariepinus*) farmed in Africa and Europe (figure 31).

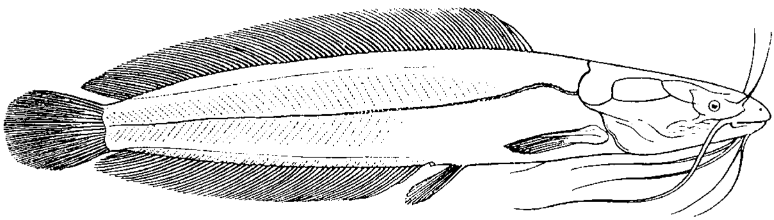

Figure 31: African catfish (Clarias gariepinus)

All farmed catfish are freshwater, warm water species with a temperature range of 16-30 °C. Catfish have either a naked skin or a skin covered with bony plates. This is useful to the farmer as it means that catfish can be handled easily without scales rubbing off, which can damage the skin. Their hardy nature and ability to remain alive out of the water for long periods of time is of special value in tropical countries. There, high water temperatures may cause practical problems, for example, during transportation.

Spawning

In catfish, the urogenital opening is situated just behind the anus in both sexes. The adult male can be distinguished from the female by the elongated, backwards-projecting form of its papilla. In the female, the papilla has an oval form. In figure 32, mature female (A) and male (B) catfish are shown lying on their backs. Catfish fingerlings do not have a papilla.

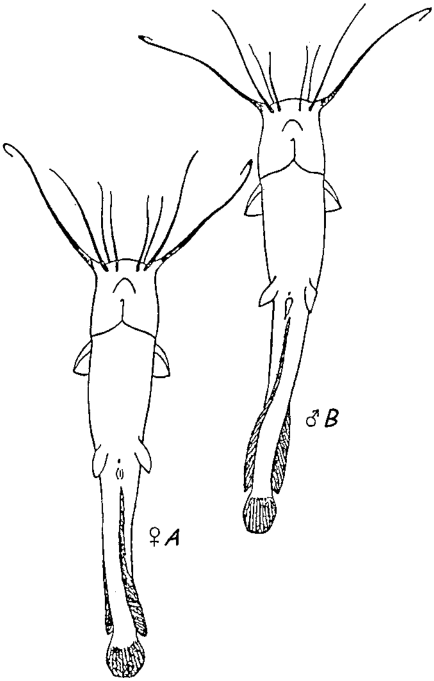

Figure 32: Genital papillae in female (A) and male (B) African catfish (Viveen et al., 1985)

Breeding behaviour differs between the different catfish species. Channel catfish spawn when they are 2 to 3 years old and weigh at least 1.5 kg. In natural spawning, a catfish pair is left in the pond, which contains a suitable nesting area. Spawning ponds are about 2,500 m² in area and are stocked at a density of 5 to 30 fish per 1,000 m². In pen spawning, each pair of fish is given a suitable spawning container in a wire mesh pen of 3 to 6 m² and 1 m deep. In both systems, the eggs may be left to hatch in the pond or may be removed for hatching in a hatchery. Females produce between 3,000 and 20,000 eggs per spawn; this number increases with increasing body weight.

In the case of the **Pangasiidae** and **Clariidae** catfish families, most of the seed is obtained from the wild in the form of small fish fry. Induced artificial spawning is now widely practised in Europe and Asia for all the **Pangasiidae** since the fish are not able to spawn naturally in captivity, and the same holds for some **Clariidae**. Both the Asian and the African catfish can spawn naturally in ponds when feeding is stopped and the water level is raised and kept high. Substrates for African catfish spawning include sisal fibres, palm leaves and stones.

Hatcheries

When the eggs of the channel catfish hatch in the spawning ponds, the fish fry are collected and transferred to nursing ponds for further rearing. In fish hatcheries, the eggs are hatched in simple aluminium troughs placed in running fresh water. In this way the eggs are kept in motion artificially, to imitate what the males do while guarding the eggs. The eggs of the **Ictaluridae** catfish family usually hatch in 5 to 10 days at a water temperature of 21- 24 °C while the eggs of the **Pangasiidae** catfish family hatch in 1 to 3 days at 25-28 °C.

Asian catfish eggs hatch in the spawning nests which are guarded by the males. Hatching takes place in 18 to 20 hours after spawning at a water temperature of 25-32 °C. The newly hatched catfish fry first remain in the nests and are removed to nursery ponds with a scoop net after 6 to 9 days. Each catfish female produces 2,000 to 5,000 fry, depending on its body weight. Under pond culture conditions, the African catfish spawns naturally but the brood stock does not show any parental care towards their young, resulting in a very low survival rate and fry production. Induced spawning and controlled fry production is therefore becoming more common.

Fry production

Catfish eggs are small and hatch into very small fish larvae. Channel catfish larvae hatch with a very small yolk gland, which contains some extra food for the fish after hatching and before they will have to search their own food. The fry are reared in nursery troughs until the yolk is completely consumed and the fry have started to feed on natural food sources in the pond. This moment is at about 4 days after hatching when the fish are transferred to fry ponds.

Fry ponds vary in size; the fry are stocked at a density of 50 fish fry per m^2 pond surface and start being fertilised when the Secchi depth is between 25 and 50 cm. Fertilising might be done by adding animal manure (5 kg cow manure or 3 kg chicken/pig manure per 100 m^2) and/or artificial fertilisers (50 g super phosphate and 100 g urea per 100 m^2). About two weeks after stocking, the phytoplankton and zooplankton production rate will no longer cover the food needs of the growing fry. They will start to eat organisms from the pond bottom (such as mosquito larvae) and cannibalism will frequently occur. Without supplementary feeding, a maximum survival rate of about 30% of the total numbers stocked can be reached within the 30 day nursing period. The fingerlings will have a mean weight of 1 to 3 grams (3 to 6 cm length).

Fry of the **Pangasiidae** catfish family are generally transferred directly into the fry ponds after hatching. The fry feed on food present naturally in the pond. Supplementary feeding is recommended since natural food production is not always adequate.

Grow-out ponds

These ponds vary in size between 5,000 and 20,000 m². Because of low winter temperatures which slow down growth, channel catfish are sometimes kept in the pond for 2 years until they have reached market size.

The fingerlings stocked should be of the same size, otherwise cannibalism will occur, as the largest ones will start eating the smallest ones when not enough food is present. During the first year the stocking density is about 20 fingerlings per 10 m², which is reduced to 4 during the second year.

Ponds for maturing **Clariidae** and **Pangasiidae** catfish families may vary in size between 1,000 and 20,000 m² and are usually1 to 3 metres deep. Fingerlings are stocked at a rate of 25 individuals per m². Catfish are also produced in floating cages, which can vary in size between 6 and 100 m².

Feed requirements

Catfish, just like tilapia, have a broad food preference and will eat almost anything present in the pond. They do show a slight preference for small fish (measuring up to 30% of their own body length) and pond bottom material like vegetable matter.

Besides their gills, which take up oxygen from the water, many catfish species have a pair of extra air-breathing organs that enable them to take up oxygen from the air. They are able to spend a considerable time out of the water, and sometimes crawl out of ponds to look for food (this is the reason why channel catfish are sometimes called ‘walking’ catfish). Because they can live under poor environmental conditions (such as in shallow ponds with oxygen shortages), they are sometimes stocked in rice fields together with carp and tilapia to use all available natural food. Catfish stocked in rice fields will eat almost anything but prefer worms, snails and other fish.

African catfish feed on the natural food sources present in the pond. Fertiliser is added to catfish ponds to increase overall food production. From past experience it has been shown that animal manure yields a higher fish production than artificial fertilisers (which are often also expensive).

Carp culture

Carp belong to the freshwater family Cyprinidae. The family consists of 1600 different species of which only very few are important for fish farming. Farmed carp are divided into three groups: common carp, farmed in Europe, Asia and the Far East; Indian carps; and Chinese carps.

Table 5 shows these different carp species and their different food preferences. As mentioned before, you can take advantage of this by keeping the different species together in one pond (polyculture).

Table 5: Different carp species and their food preferences

Common name	Scientific name	Food preference
Common carp		
Carp	*Cyprinus carpio*	Small plants and zooplankton
Indian carps		
Catla	*Catla catla*	Phytoplankton and dead plants
Rohu	*Labeo rohita*	Dead plant material
Calbasu	*Labeo calbasu*	Dead plant material
Mrigal	*Cirrhina mrigala*	Detritus on pond bottom

Common name	Scientific name	Food preference
Chinese carps		
Grass carp	*Ctenopharyngodon idella*	Water plants
Silver carp	*Hypophtalmichthys molitrix*	Phytoplankton
Bighead carp	*Aristichthys noblis*	Tiny animals
Black carp	*Mylopharyngodon piceus*	Molluscs
Mud carp	*Cirrhina molitorella*	Detritus on pond bottom

Common carp

The common carp is a widely cultured, strictly freshwater fish (figure 33), which can reach a length of some 80 cm and a weight of 10 to 15 kg. The temperature range in which common carp live is from 1 to 40 °C. The fish starts growing at water temperatures above 13 °C and reproduce at temperatures above 18 °C, when the water flow is increased suddenly. Carp are usually mature after about 2 years (weighing 2 to 3 kg).

In temperate zones, carp spawn each year in spring, while in the tropics spawning takes place every 3 months. The female carp can produce 100,000 to 150,000 eggs per kg body weight. Growth rate is high in the tropics, where the fish can reach a weight of 400 to 500 g in 6 months and 1.0 to 1.5 kg in one year.

The common carp (figure 33) is a hardy fish species and thus resistant to most diseases when environmental conditions are maintained properly.

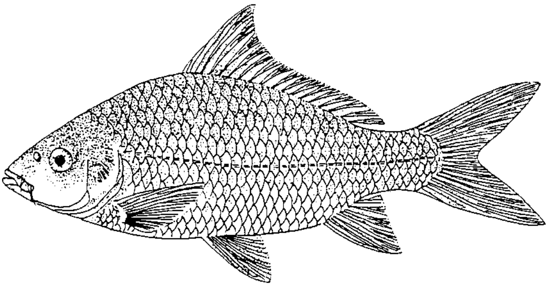

Figure 33: Common carp (Cyprinus carpio) (Hanks, 1985)

Spawning
Carp spawning can occur naturally in outdoor ponds or artificially in a fish hatchery using induced spawning methods. Induced spawning is a technique whereby hormones (substances that are produced by the fish itself to trigger spawning) are provided to the fish via the feed or injected into its muscles.

Common carp breeds throughout the year in tropical climates with two peak breeding periods: one during spring (January to April) and the other during autumn (July to October). The best results in natural breeding are obtained when broodfish are carefully chosen. Broodfish are fed rice bran, kitchen refuse, corn, etc.

The following points for recognising ready-to-spawn fish should be taken into account (figure 34):

1. A fully mature female has a rounded, soft, bulging belly with an obscured ridge.
2. A mature female will rest on her belly without falling sideways, and when held with belly upwards, shows slight sagging on the sides due to the weight of the eggs inside;
3. Mature males (just like in other fish species) produce sperm when gently pressed on their bellies.

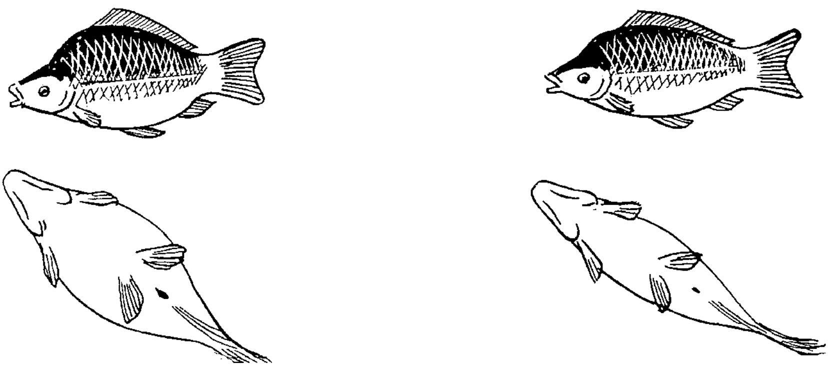

Figure 34: Ripe female (left) and male (right) common carp (Costa-Pierce et al., 1989b)

Under natural reproduction conditions, parent fish are allowed to spawn in special spawning ponds and are then removed. Spawning ponds are usually 20-25 m^2; they are dried for a few days before filling with clean water up to a depth of 50 cm. Water is released into the spawning pond on the morning of the breeding day, and broodfish as well as egg collectors are placed in the afternoon. The ponds are stocked with one, two or three sets of fish, each set consisting of 1 female (1 kg body weight) and 2 to 4 males (1 kg total weight).

There are many different techniques for collecting the eggs from the spawning pond. In some systems, branches of coniferous trees are placed in the pond. The eggs stick to the branches, which are removed and transferred to the nursery pond.

Another method is to place floating plants to act as egg collectors. In Indonesia, grass mats and fibre mats made of palm trees are used as egg collectors. The mat area needed is about 10 m^2 for every 2-3 kg female. After spawning, the mats are moved to nursery ponds. Another egg collector used in Indonesia, called a kakaban is made of dark horse-hair-like fibres of the *Indjuk* plant (*Arenga pinnata* and *Arenga saccharifera*). To make *kakabans*, the *Indjuk* fibres are washed clean, then arranged in layers of 1.2 to 1.5 metre-long strips. The long strips are lined lengthwise between two bamboo planks, 4 to 5 cm wide and 1.5 to 2 m long, and nailed together on two sides (figure 35).

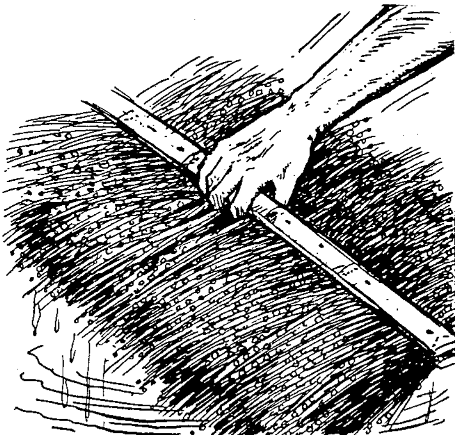

Figure 35: Taking out a carp egg collector after spawning (Costa-Pierce et al, 1989b)

Before the fish spawn, *kakabans* are kept in a floating position (like a raft) a little under the water surface, propped up on bamboo poles. Five to eight *kakabans* are required per kilogram weight of female stocked carp. A gentle flow of water is supplied in the spawning pond when the broodfish are released. The fish will tend to attach the eggs onto the underside of the *kakabans*.

When the entire underside is full of eggs, the *kakabans* ‘raft’ is turned over. When both sides of the *kakabans* are full of eggs (figure 35), they are transferred to the nursery ponds. These are 20 times bigger than the spawning pond. In the nursery ponds, the *kakabans* are placed vertically on floating bamboo poles leaving a gap of 5 to 8 cm between the fibres of the other *kakabans*. Care must be taken to ensure that the eggs always stay fully submerged under 8 cm water.

The eggs hatch in 2 to 8 days depending on the water temperature. At the most suitable water temperature (20 to 22 °C), hatching will take place within 4 days.

Nursery ponds

Nursery ponds are usually 2,500 to 20,000 m^2 in area depending on the size of the farm. These ponds are 0.5 to 1.5 m deep and the fish are stocked at a density determined by the water flow into the pond. In stagnant water ponds (no water flowing through), the fish stocking density is 5 larvae/m^2, while in flow-through ponds the stocking density can be increased up to 30 to 80 larvae/m^2. The fish larvae can be raised to fingerlings within a period of about one month. The most common practice is to rear fry in nursery ponds for about a month and transfer them to grow-out ponds where they will reach market size.

Regular application of worm castings and rice bran/coconut oil cake increase food availability in the pond, and thus fry survival and production. The worm castings have to be applied at a rate of 925 g/m^2 weekly and the rice bran/coconut oil at a rate of 0.5 g/m^2/day at the moment of fish hatching, gradually increasing to 20 g/m^2/day 20 days after hatching. In the last treatment, rice bran and coconut oil are completely mixed dry at a 1:1 ratio and then wetted until small 1-2 mm ‘balls’ can be made and fed to the fish. Worm castings can be obtained by composting chopped water hyacinths with rabbit manure for 2 weeks before adding earthworms, then harvested 2 months later.

Grow-out ponds

The type of grow-out system required for carp depends on climatic conditions and market requirements, but usually common carp is produced in monoculture. In tropical countries, a 500 g fish can be produced in six months and a 1.0 to 1.5 kg fish in one year.

In practice, 4 to 8 week-old-fish fingerlings are stocked in ponds of 70 cm depth. Using fertiliser can enhance natural fish food production. The best growth of common carp occurs when stocking densities are about 1 to 2 fish per m^2 of pond surface.

Production

Production levels achieved vary according to the type of fish farming, duration of culture, fish size at harvest, fish species stocked, level of fertilisation and water temperature. In the tropics, in supplementary fertilised and fed fish culture ponds with regular water exchange, yearly fish production rates vary from 30 g/m^2 in unfed and unfertilised ponds up to 800 g/m^2 in fed and fertilised ponds.

8 Fish nutrition, health and reproduction

8.1 Fish Nutrition

There are usually two types of food available to the fish: natural and supplementary. Natural fish food consists of phytoplankton, zooplankton, periphyton, water plants, etc. produced in the pond itself. Supplementary fish feed is produced outside the pond and supplied to the fish regularly to further increase the amount of nutrients in the pond.

Natural fish food

The natural fish food in the pond largely consists of phytoplankton. The amount of phytoplankton can be increased by the addition of fertiliser to the pond.

Water transparency as pond fertility indicator

The transparency of pond water varies from almost zero (in the case of very turbid water) to very clear water, and depends on the amount of water turbidity, which is caused by suspended matter such as phytoplankton, soil particles and so forth. Phytoplankton blooms generally change the colour of the water to green. Measuring the transparency of a green coloured pond will give an idea of how much phytoplankton there is in the pond water and thus an idea of pond fertility.

Water transparency can be measured using a Secchi disc, as mentioned in chapter 4. A Secchi disc is an all white or a black and white metal disc measuring 25-30 cm in diameter, which can easily be made by hand (figure 36). The disc is attached to a cord that is marked every 5 cm along its length.

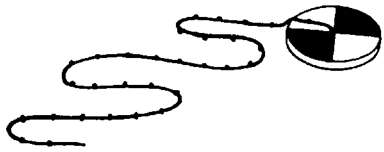

Figure 36: The Secchi disc (Viveen et al., 1985)

To measure water transparency, lower the disc into the water at a depth at which it just disappears from sight. Measure this depth by using the markers on the cord to which the disc is attached. The necessary action to be undertaken for the different water transparencies is given in table 6.

Table 6: Actions to be undertaken for different water transparencies

Water transparency	Action
1 - 25 cm	Density of phytoplankton is too high. Risk of oxygen shortages for fish at dawn. Stop adding feed and fertiliser. Observe fish behaviour regularly: if fish are gulping for air at the water surface, water exchange is necessary.
25 - 30 cm	Optimum abundance of phytoplankton for fish production. Continue with (routine) feeding and/or fertilising at the same rate.
> 30 cm	Density of phytoplankton is too low. Stimulate phytoplankton blooms by adding more feed and/or fertilisers until a water transparency of 25-30 cm is reached.

As described in chapter 3, fish can be stocked in the pond when natural food production is high enough to sustain their growth. This corresponds to a water transparency between 15 and 25 cm.

Supplementary fish feed

When supplementary feed is thrown into the pond, the fish immediately eat some of it. The uneaten feed will act as an additional fertiliser for the pond. But even in ponds receiving a high amount of supplementary feed, natural feed still plays a very important role in the growth of fish. In general, local organic waste products can be used as supplementary fish feed; the type depends on local availability, costs and the fish species being raised.

Typical examples of supplementary fish feed are rice bran, broken rice, breadcrumbs, cereals, cereal wastes, maize meal, Guinea grass, napier grass, fruits, vegetables, peanut cake, soybean cake and brewer's waste.

Some practical guidelines for feeding fish are the following:

1 Feed the fish at the same time everyday and in the same part of the pond. Fish will get used to this and they will come near the surface of the water. This also makes it easier to see if the fish are eating and growing well. Feeding should be done in the late morning or early afternoon when dissolved oxygen levels are high. Fish will have enough time to recover from the high oxygen-demanding feeding activity before nightfall.
2 Do not over feed the fish, as too much feed will decay and use up too much oxygen in the pond.
3 Stop feeding the fish for at least one day before breeding, harvesting or transporting them. The stress from these events causes the fish to excrete waste, which makes the water turbid. In general, fry can be starved for 24 hours, fingerlings for 48 hours and adult fish for about 72 hours. This enables the fish to digest the food completely before stressful events.

The feeding preferences of the most widely cultured fish species are summarised in Appendix 1.

8.2 Fish Health

Fish are vulnerable to diseases when environmental conditions, such as water quality and food availability, are poor. Once a disease has entered the fish pond it will be very difficult to eradicate it. This is because infected fish are difficult to pick out and treat separately. Water is a perfect agent for spreading diseases. The diseases from which fish may suffer are many and varied. Sick fish do not grow, so the farmer loses money as harvest is delayed. If fish are near market size when they die from disease, losses are very severe. The cost of treatment can be high and very often the use of medicines can become dangerous, not only for humans but also for other animals and plants. In the long run, the waste from the medicines will be released into the environment when the pond is drained. It is therefore much better to prevent diseases. Prevention is cheaper than disease treatment and it avoids losses due to poor growth and death.

Preventing fish diseases

Good nutrition and proper water quality (= plenty of dissolved oxygen) are the most important factors for good fish health.

Many of the potential pathogens (organisms which can cause disease) of fish species are normally present in the water waiting to 'attack' when environmental conditions become bad. Under such conditions the fish become stressed and their resistance to diseases is lowered. There are some basic rules to be observed in order to prevent, or control, disease outbreaks:

1 Ponds must have separate water supplies. It is not advisable to supply a pond with water from another pond, since this water may carry diseases and the level of dissolved oxygen may be low. It is therefore wise not to design ponds in series.

2 Fish must be kept in water with optimum conditions at all times: water with plenty of oxygen, with the correct pH and with a low ammonia content.

3 Fish must not get stressed. If you handle the fish, take great care so that you upset them as little as possible. Extreme stress can be the direct cause of fish death. Damage to their skin (rubbing off the scales and the protective slime layer), means pathogens can enter the fish more easily.

4 Great care must be taken that no sick fish are introduced when mixing fish from different ponds, or when introducing new fish into the farm. New fish to the farm site should be kept in a separate pond until it is certain that they do not carry a disease. Only then should they be brought into contact with on-farm fish stocks.

5 Any change in normal behaviour may be a sign of disease. Signs to look for include 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 fish stop eating suddenly*.

6 You must check the fish often, especially in very hot weather, as dissolved oxygen shortages occur often (in warm water less oxygen can be dissolved than in cold water).

7 Do not get discouraged if you occasionally find a dead fish in the pond. This also happens in nature. Watch out, however, for large numbers of dead fish. If large numbers of fish die, try to find out the cause.

Fish diseases

Diseases can be classified in infectious and nutritional ones. Infectious diseases can be carried from one pond to another by the introduction of new fish or by the farmer and his equipment, whereas nutritional diseases are caused by dietary shortages.

There are also diseases caused by pollutants and bad water quality.
The fish farmer should focus on the prevention of diseases as the treatment of fish diseases is often difficult, time consuming and expensive.

8.3 Fish Reproduction

The selection of fish species for culture depends, amongst other factors, on whether it would be easy for you to breed the fish yourself (or buy it from a local supplier), or whether it is easier to obtain young fish from the wild.

It is important to achieve controlled reproduction, even when culture can be started using young fish caught from the wild. With controlled reproduction, you will get a supply of eggs and young fish in adequate numbers for fish farming and will not have the problem of either collecting broodstock or harvesting young fish from the wild. Controlled reproduction will provide you with seed when you require it, and not just during the few months of the year when natural spawning occurs in the wild.

Most cultured fish species are seasonal breeders. The breeding season appears to coincide with environmental conditions most suitable for the survival of their young. Day length, temperature and rainfall are important factors in the regulation of the reproduction cycles. These stimuli trigger the release of hormones by the fish brain; the hormones act on the reproductive organs of the females and the males. These organs in turn produce sperm in the case of males and eggs in the case of females. If you know how the reproduction cycle functions, you can use this knowledge to provide the appropriate environmental stimuli to the fish (e.g. increase the water level) and induce fish spawning (see previous chapter for more details on the reproduction of tilapia, catfish and carp).

9 Harvesting and post-harvesting

9.1 Harvesting the fish

As in any other type of farming, the final phase in the fish farming cycle is the harvest and possible sale of the fish. When most of the fish are big enough to be eaten or sold, harvesting can start (usually after 5 to 6 months).

Harvest only the amount that can be eaten or sold within one day. To begin with, start emptying the pond a few hours before dawn while it is still cool. There are two ways to harvest fish: either take out all the fish in the pond at the same time, or selectively cull fish from the pond throughout the whole year. In the latter method, usually the larger fish are taken out and the smaller fish are left in the pond to keep growing. It is, of course, possible to combine these two methods by taking out large fish as required and finally removing all the remaining fish at once.

There are different kinds of nets for harvesting the fish from the pond as shown in figure 37.

The method used for continuous selective culling is to hang a net in a pond. A gillnet is often used in this method of harvesting (figure 37B). The fish trying to swim through the net get caught up behind their gills, hence the name. All fish smaller and larger will not be caught: those fish smaller than the mesh are able to swim through, while those which are too large to push their heads through the mesh as far as their gills are not trapped. In this way it is possible to harvest fish throughout the year without having to drain water from the pond or seriously disturb the remaining fish.

When all the fish in the pond are to be harvested at the same time, the water level should be lowered slowly to ensure that all the fish are caught. Make sure that the fish are harvested in good condition by avoiding any damage to their skin and try to harvest quickly so the fish stay fresh. To accomplish this it is common to use two different methods for catching fish as described below.

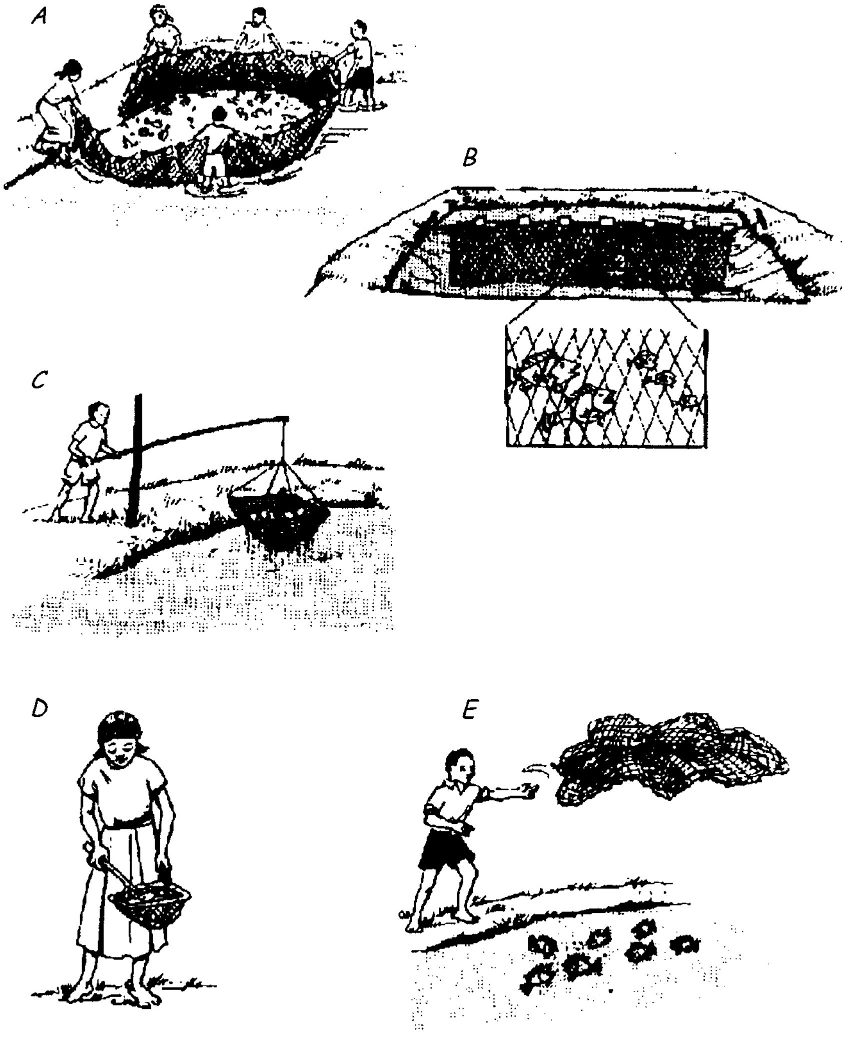

Figure 37: Different nets for fish harvesting (Murnyak, 1990) A: seine net, B: gill net, C: lift net, D: scoop net, E: cast net

First, most of the fish can be caught in a seine net with a mesh size of 1 cm when the water level is still high (figure 37A, figure 38 and the text box: How to make a seine net). The net is laid out on the pond dike and pulled in a half circle through the pond until it reaches the dike again; the net is then dragged towards the dike, thereby trapping the fish (figure 39).

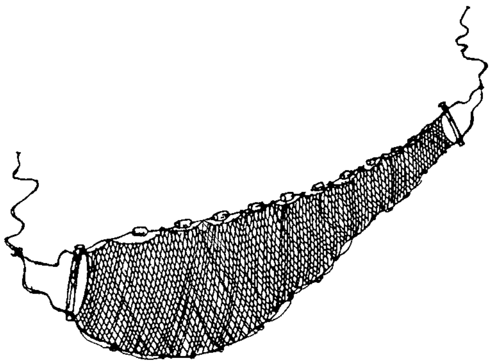

Figure 38: Seine net

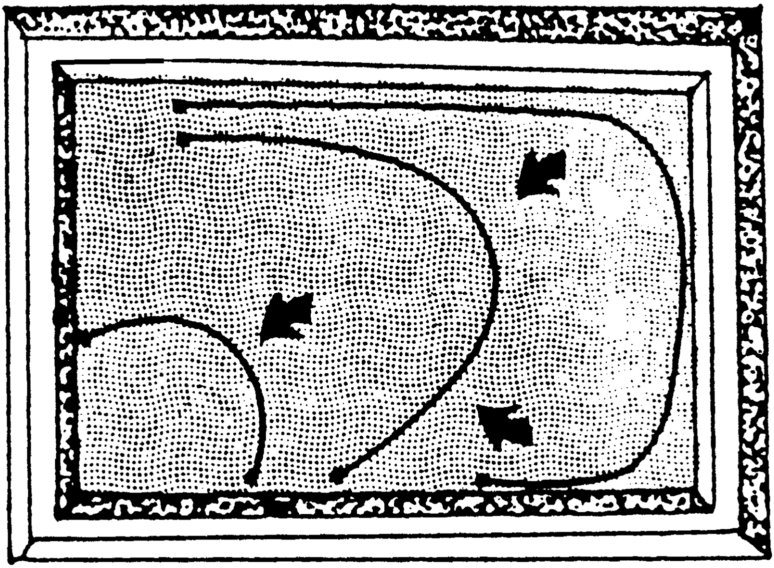

Figure 39: Harvesting technique with a seine net

The pond is then emptied. As the water flows out of the pond, large quantities of fish can be caught. Place slatted boxes or (scoop) nets (figure 37D) under the drain pipe to prevent fish from escaping as the pond is drained.

Finally, when the pond is completely drained, the remaining fish can be gathered by hand from the pond bottom. Try to catch as many fish as possible before the pond is completely empty as stranded fish can be lost or damaged. After harvesting, let the pond dry out until the pond bottom cracks, when it should be limed (reducing pond bottom acidity), thereby killing unwanted animals and plants on the pond bottom.

How to make a seine net

Materials:
Rope, cork floats, lead sinkers (or something heavy to let the net sink), netting, string and a sewing needle for repairing nets.

Methods:

1 Tie two ropes between two trees; these form the top and bottom lines.
2 Mark each rope at 15 cm intervals. Make sure these two ropes are a few metres longer than the desired length of the net.
3 Stretch the netting until the meshes close completely; then count the number of meshes in a 23 cm section. Good netting for a general seine will have 6 to 9 meshes in a 23 cm stretched section.
4 Use very strong nylon string. Wind a long section on a net needle. Tie the end onto the lead line rope (top rope) at the first marking. Pass the needle through the number of meshes counted in the 23 cm section of netting. Tie the string onto the rope at the second marking.
5 Repeat the process until the last marking on the top rope is reached.
6 Attach the sinkers onto the bottom rope at 15 cm intervals. Tie the cork floaters onto the top rope also at 15 cm intervals.
7 String the bottom line onto the netting in the same way as the top line.

After use, the net must be washed, repaired, dried in the shade, folded and put away in a cool, dry place. A net that is taken care of in this way will last much longer.

Some more simple, and therefore cheaper, nets are:

1 A lift net (figure 37C) made of seine netting material. It can be of any shape and size and is set on the pond bottom. When the fish swim over it, it is lifted up, capturing the fish.
2 A scoop net (figure 37D) is a small net with a handle that is held in one hand. It is often used when counting and weighing fish and fingerlings.
3 A cast net (figure 37E) is a round net that is thrown into the pond from the shore and pulled back to capture the fish.

9.2 Post-harvesting

Fresh fish spoils very quickly. In the tropics, fish spoils within 12 hours after being harvested. This is due to the high ambient temperature that is ideal for bacterial growth. To prevent contamination of the fish, proper hygiene must be ensured. Contamination can come from people, soil, dust, sewage, surface water, manure, or spoiled foods. Poorly cleaned equipment, domestic animals, pets, vermin or unhygienically slaughtered animals can also be the cause.

To prevent spoilage of the harvested fish, either the bacteria present in them must be killed, or their growth must be suppressed. Different methods exist to suppress bacterial growth. These methods are briefly mentioned here and described in detail in Agrodok No.12, entitled 'Preservation of fish and meat'.

Salting

This is an inexpensive method when salt is cheap, as no electricity is necessary and storage can be at room temperature. Fish quality and nutritional value are reasonable after salting. Storage life is long.

Drying

Also an inexpensive method as no electricity is required and little equipment is needed. Dry and/or airtight storage is required. Quality and nutritional value are reasonable if storage is good.

Smoking

Inexpensive, little equipment and energy needed, but fuel must be available. Quality and nutritional value are reasonable.

Fermentation

This method is often inexpensive, but the fish taste and odour are radically changed. Storage life varies depending on the product. Nutritional value is often high.

Canning

This is a fairly expensive method because it is labour intensive and requires plenty of energy, water and equipment, such as tins or jars with lids, sterilisers and canning machines. Packaging is expensive. Storage is easy and possible for long periods (below 25 °C/77 °F). Quality and nutritional value are good.

Cooling and freezing

This is a very expensive method because it involves high use of energy and large investments in equipment. Quality and nutritional value of the product are good, and storage life is long.

Appendix 1: Overview of widely cultured fish species and their food preferences

Phytoplankton-eaters
Chinese silver carp (*Hypophtalmichthys molitrix*)
Indian ‘catla’ carp (*Catla catla*)
Indian ‘rohu’ carp (*Labeo rohita*)
Milkfish (*Chanos chanos*)

Water plant-eaters
Chinese grass carp (*Ctenopharyngodon idella*)
Chinese ‘Wuchang’ bream (*Megalobrama amblycephala*)
Big gourami (*Osphronemus goramy*)
Tilapia (*Tilapia rendalli*)
Zill's tilapia (*Tilapia zillii*)

Zooplankton-eaters
Chinese ‘bighead’ carp (*Aristichthys nobilis*)

Snail-eaters
Chinese black carp (*Mylopharyngodon piceus*)

Predatory fish species (fish-eaters)
Snakehead species (*Channa* spp. = *Ophiocephalus* spp.)

Omnivores (eat everything available)
Barb species (*Puntius* spp.)
Crucian carp (*Carassius carassius*)
Chinese mud carp (*Cirrhinus molitorella*)
Common carp (*Cyprinus carpio*)
Catfish species (*Clarias* spp., *Pangasius* spp., *Ictalurus* spp.)
Indian ‘mrigala’ carp (*Cyprinus mrigala*)
Tilapia species (*Oreochromis* spp., *Sarotherodon* spp., *Tilapia* spp.)

Appendix 2: Characteristics of liming materials

The most important liming materials that can be used are agricultural lime, slaked lime and quicklime. Agricultural lime is often applied by fish farmers because it is safe, very effective and often less expensive.

The amounts of liming material needed when compared to 1 kg of agricultural lime ($CaCO_3$) are:
700 g slaked lime ($Ca(OH)_2$)
550 g quicklime (CaO)
2.25 kg basic slag ($CaCO_3 + P_2O_5$)
This means, for example, that 550 g quicklime has the same liming effect as 1,000 g agricultural lime.

The liming effect is better when the particle size of the liming material is decreased, so crushing the liming material before application gives better results. Best results with liming are obtained if the lime is equally distributed on a dry pond bottom. Quicklime, as disinfectant, however, needs moisture.

Application of liming materials

Ponds with acid soils or acid water and/or ponds with soft water of low alkalinity require an application of lime. Table 7 should serve as a guideline for estimating the required amount of lime, expressed as kg/ha of agricultural lime.

Table 7: The required amount of agricultural lime (kg/ha)

pH pond bottom	Heavy loams or clays	Sandy loam	Sand
5-5.5	5,400	3,600	1,800
5.5-6	3,600	1,800	900
6-6.5	1,800	1,800	0

If the chosen lime application rate is correct, the pH will be above 6.5 and total alkalinity above 20 mg/l in 2 to 4 weeks.

Further reading

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Raising fish in ponds: a farmer's guide to Tilapia culture, 1990. Murnyak, D. and M. Murnyak. Evangelical Lutheran Church of Tanzania. 75p.

Useful addresses

AASA, The Aquaculture Association of Southern Africa
AASA's objective is to contribute towards the development of aquaculture in Southern Africa through effective representation and dissemination of information.
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W: http://www.aasa-aqua.co.za/

AwF, Aquaculture without Frontiers
Independent non-profit organisation that promotes and supports responsible and sustainable aquaculture and the alleviation of poverty by improving livelihoods in developing countries.
W: http://www.aquaculturewithoutfrontiers.org

CIDC, Central Institute for Animal Disease Control, Lelystad
Independent veterinary research institute acting for the Dutch government. Responsible for the surveillance of notifiable infectious animal diseases of farmed livestock and fish.
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