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 with regard to daily protein needs.

Since fish farming practices are so diverse, this manual focuses on land based freshwater fish farming. In the tropics, pond fish farming is the most common form of fish farming in the tropics. Therefore, the information provided in this manual concerns pond construction and pond management.

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

Wageningen, 1996.

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1 Introduction

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

Since fish farming practices are so diverse, this manual focuses on land based freshwater fish farming. In the tropics, pond fish farming is the most common form of fish farming in the tropics. Therefore, the information provided in this manual concerns pond construction and pond management.

The first part of this Agrodok (Chapters 2 to 4) describes the principles of fish farming, including site selection and type of fish farm. In Chapter 4 fish farming practices are presented, including selection of species, nutrition, health aspects, reproduction, harvesting and pond maintenance.

The second part (Chapters 5 to 7) gives specific information about the culture of common carp, tilapia and catfish.

2 Fish farming: basic principles

In many parts of the world, fish have provided an important part of people's diets for centuries. During the last hundred years, fish catches have increased rapidly due to technological improvements including more powerful engines and sonar equipment. Despite the fact that growth in fish catches stopped some 15 years ago, overfishing had already caused the worldwide decrease in stocks to become a real problem. The need to increase fish production by fish farming is urgent.

The term 'aquaculture' involves all forms of culture of aquatic animals and plants in fresh-, brackish- and saltwater. Aquaculture has the same objective as agriculture: to increase the production of food above the level which would be produced naturally. As in agriculture, fish farming techniques include the removal of unwanted plants and animals, their replacement by desirable species, the improvement of these species by cross-breeding and selection, and the improvement of food availability by the use of fertilizers. Fish farming can be combined with agriculture, animal husbandry and irrigation practices which can lead to a better utilization of local resources and ultimately to higher production and net profits. This practice is called 'integrated fish farming' and this subject is extensively dealt with in Agrodok no. 21.

Advantages of fish farming

- Fish is a high quality animal protein provider for human consumption.
- A farmer can often integrate aquaculture into the existing farm to create additional income and improve water management on the farm.
- Fish growth in ponds can be controlled: the fish species raised are the ones the farmer selected.
- 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 if it is suitably prepared.

2.1 Planning an aquaculture enterprise

Land, water and climatic conditions are probably the most important natural factors which need to be assessed. When developing a site for aquaculture you should consider the effect it may have on the environment. Naturally important areas (e.g. fish nursery grounds like the mangrove forests) should not be used for aquaculture. One of the most important requirements is water availability in terms of quality and quantity. The type of aquaculture and species of animals or plants which 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 *pond grown fish are not always able to compete financially with fish caught in the wild*.

The high initial investment and production costs as well as the economic risks involved in setting up a fish farm, mean that there are some very important factors a prospective fish farmer should consider before embarking on a fish farming venture.

- *Finance*:
  You should make an estimate which includes the cost of land as well as capital expenditures for fish stock, pond construction, labour, production and harvesting.

- *Site*:
  The soil must be able to retain water. A good water quality and quantity should be available at 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 what state or federal permits are required, should be known and obtained. The site and roads should be passable and not subject to flooding.

- *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 be sure of a reliable source of good quality fish stock. If you choose to breed on site then you must have sufficient space for maintenance of brood stock and production of young fish (fingerlings).

- *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.

Most of these factors will be addressed in more detail in the following chapters.

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

3 Planning the site and type of fish farm

3.1 Site selection

Proper selection of a site is probably the most important factor in the success of a fish farm. However, the ideal site is often not available, so you may have to compromise. There may also be conflicts concerning land and water use which need to be resolved. Before this you should have decided which species to raise based on the available foods (e.g. agricultural by-products) and possible fertilizers (e.g. compost or animal manure).
Site selection will depend on the kind of fish farm you plan to use. For pond construction you need to consider the following factors: soil type, quality and quantity of the water available and the requirements for filling and drainage of the pond.

Soil

The quality of soil influences both productivity and water quality in a pond. However, it 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 (soil texture consists of a lot of clay particles) so the best soil for pond construction contains a lot of clay. The three ways 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 1):
  a wet a handful of soil with just enough water to make it moist,
  b squeeze the soil by closing your hand firmly, and

c if it holds its shape after opening the palm of your hand, the soil will be good for pond construction.

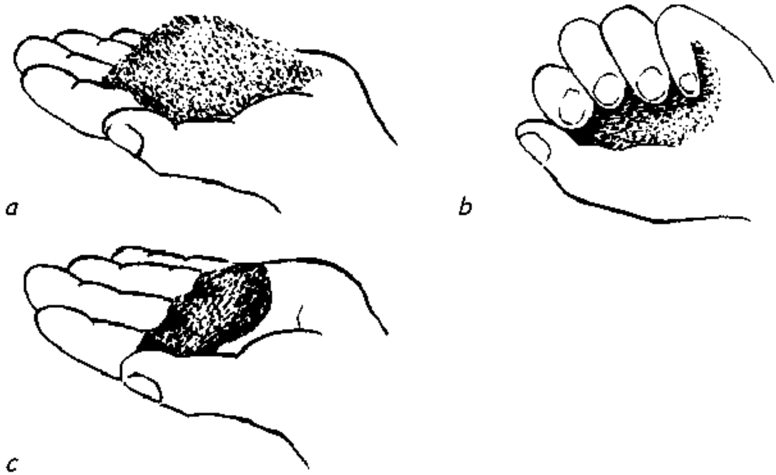

Figure 1: The "squeeze method" (Chakroff, 1976).

2 *Ground water test (figure 2)*

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

a Dig a hole with a depth of one meter.

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. Take into account that you will probably need more time to drain the pond due to the high ground water levels filling the pond again.

d If the hole is still empty the next morning, no problems will occur as a result of high ground water levels (figure 2) and the site will perhaps be suitable for pond fish farming. Now you should test the water permeability.

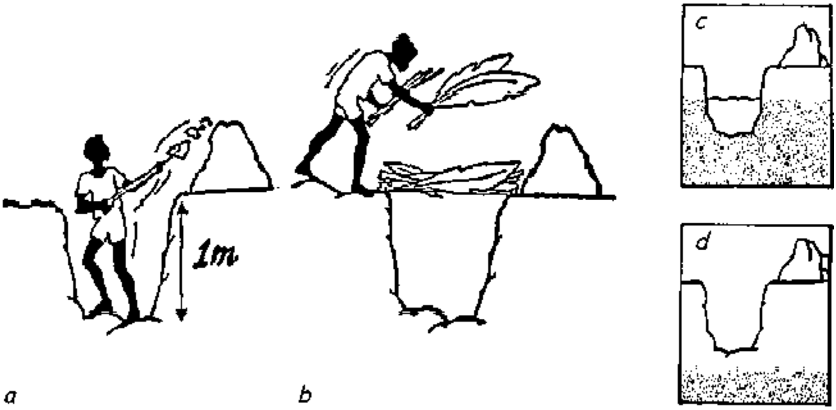

Figure 2: Ground water test (Viveen et al., 1985).

3 Water permeability test (figure 3):

a Fill the hole with water to the top.
b Cover the hole with leaves.
c The next 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.

The land contour, and especially the land slope, determine the way to build the pond. 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 2%-4% are unsuitable for pond construction. All slopes between 2% and 4% can be used for pond construction. A 2% land slope means 2 cm drop

in elevation for every meter of horizontal distance. If the slope is sufficient you can fill and drain by using gravity. However, you should take care to prevent erosion of the pond dikes.

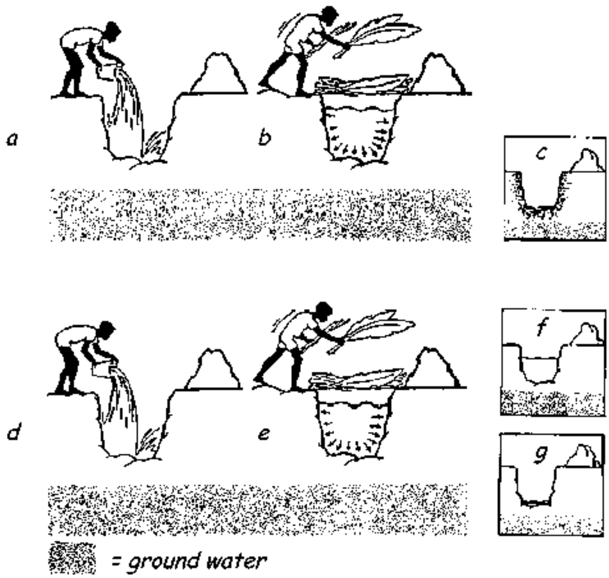

Figure 3: Water permeability test (Viveen et al., 1985).

Water

The availability of good water quality is important 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 4).

Investigation of the water sources is very important:

- What is the amount of water available?
- Is water available in all seasons, or is the availability different in the sequence of the seasons?
- Where are the water sources, are they likely to be polluted?

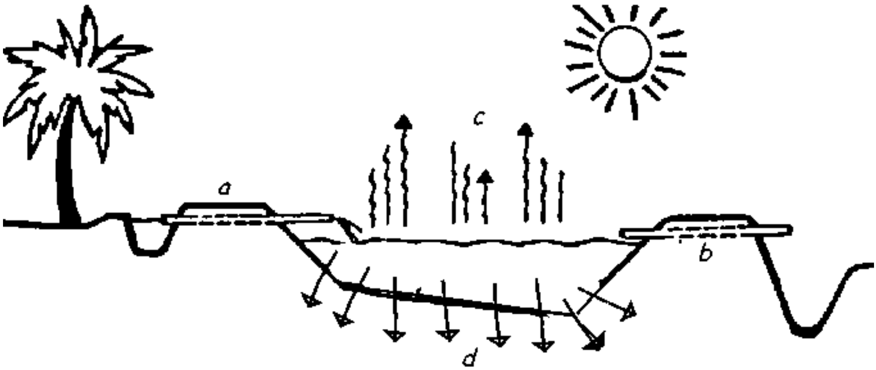

Figure 4: Water supply and water loss in a fish pond (Viveen et al., 1985). a: inlet; b: overflow; c: evaporation; d: seepage).

Ideally, water should be available all year round. Different water sources and their disadvantages are listed in table 1.

Water temperature
The 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 which must be considered. Some fish species can withstand a wider salinity range than others: e.g. tilapia and catfish can withstand a wide range from fresh- 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. These criteria are described in more detail in Chapter 4.

Table 1: 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**

3.2 Type of aquaculture farm

Fish farming may range from large scale industrial enterprises to 'backyard' subsistence ponds. Farming systems can be distinguished in terms of input levels.

In **extensive** fish farming, (economic) inputs are usually low. Natural food production plays a very important role, and pond productivity is relatively low. Fertilizer may be used to increase pond fertility and thus fish production.

In **semi-intensive** fish farming a moderate level of inputs is used and fish production is increased by the use of fertilizer and/or supplementary feeding. This means higher labour and food costs but higher fish yields more than compensate for this usually.

In **intensive** fish farming a high level of inputs is used and the ponds are stocked with as many fish as possible. The fish are fed supplementary food, and natural food production plays a minor role. In this system the high feeding costs and risks, due to high fish stocking densities and thus increased susceptibility to diseases and dissolved oxygen shortage, can become difficult management problems. Because of the high production costs you are forced to fetch a high market price in order to make the fish farming economically feasible.

Pond culture

The vast majority of freshwater fish are raised in ponds. Water is taken from a lake, bay, well or other natural source and is directed into the pond. The water either passes through the pond once and is discharged or it may be partially replaced so that a certain percentage of the total water in a system is retained and recirculated. However, the pond systems yielding the highest fish production, only replace water evaporation and seepage losses and do not flow through. In general, water flowing reduces the production of pond systems in the tropics.

Fish farming ponds range in size from a few hundred square meters to several hectares. In general, small ponds are used for spawning and fingerling production. Production ponds larger than 10 ha become difficult to manage and are not very popular with most producers. The ponds presented here are only examples and 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 bottom slopes and do not collect run-off water from the surrounding watershed. It is important that sufficient water is available to fill all 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 meter of height needs 2 or 3 meters of horizontal distance) which allow easy access, will not encourage vegetation to grow and helps to reduce erosion problems. To prevent fish theft, bamboo poles or branches might be put in the pond which make netting and rod-and-line fishing impossible. Another method to keep thieves away from your fish pond is locate the pond as close to your home as possible.

The main characteristics of a fish pond are presented in table 2.

Table 2: Characteristics of a good culture pond.

Location	**Select land with a gentle slope and layout ponds to take advantage of existing land contours.**
Construction	Ponds may be dug into the ground, they may be partly above and partly in the ground, or they may be 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; deeper ponds may be required in northern regions where the threat of winter-kill below deep ice cover exists.
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 to mow; road dikes should be made of gravel; grass should be planted on all dikes.
Orientation	Situate ponds properly to take advantage of water mixing by the wind, or 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 when necessary.

Depending on the site different fish ponds might be constructed: diversion or barrage ponds (figure 5).

1. Diversion ponds (figure 5A) are made by bringing water from another source to the pond.

There are different types of diversion ponds (figure 6):

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 (figure 6A).

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 (figure 6B).

C Partially excavated ponds with low dikes:
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 6C).

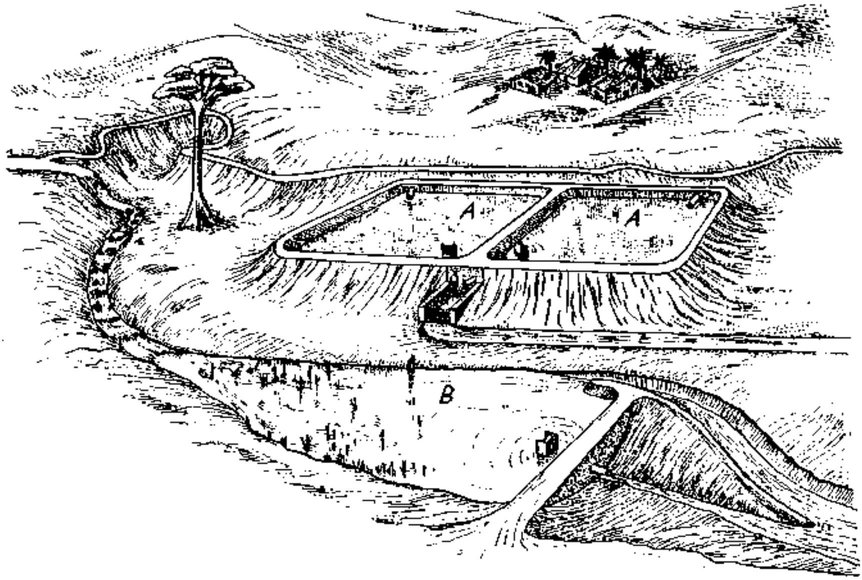

Figure 5: Different pond types (Bard et al., 1976) A: diversion pond; B: barrage pond.

2. Barrage ponds (figure 5B) are made by building a dike across a natural stream. The ponds are therefore like small conservation dams. The advantage of a barrage pond is that it is easy to construct. However, it is very difficult to control this system: it is difficult to keep

wild fish out and a lot of food added to the pond will be lost because of the current.
A properly built barrage pond (with overflow) overflows only under unusual circumstances.

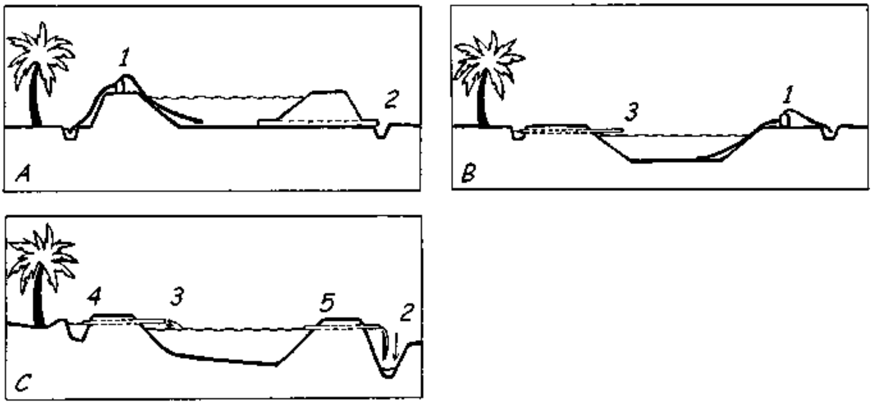

Figure 6: Different types of diversion ponds (Viveen et al., 1985) A: embankment pond B: excavated pond; C: partially excavated pond. See Appendix 1 for an example of how to construct a diversion pond.

3.3 Other methods of fish farming

Although fish farming in ponds is the most common method of fish farming in the tropics, there are some other methods used in places where it is not possible to construct ponds.

Dams and reservoirs

Water contained by dams and reservoirs is increasingly used for aquaculture. These waters can be stocked with fry or fingerlings and later be harvested with nets. This method of raising fish is more difficult than in ponds, because these waters can not be controlled: draining is impossible and removal of predators is difficult. It is nearly impossible to feed or fertilize the water completely so natural fish food production must be sufficient for the stocked fish to grow. Raising fish in reservoirs can be done more easily if the fish are placed in fish cages and pens. These are enclosures which confine the fish to a certain place in the water and enable more control over the fish.

Cage culture

In many parts of the world, the only water available is flowing water or large water bodies where it is difficult to divert water into a pond. In these waters, it is possible to grow fish in small cages. Cage culture can also be practised in swampy areas.

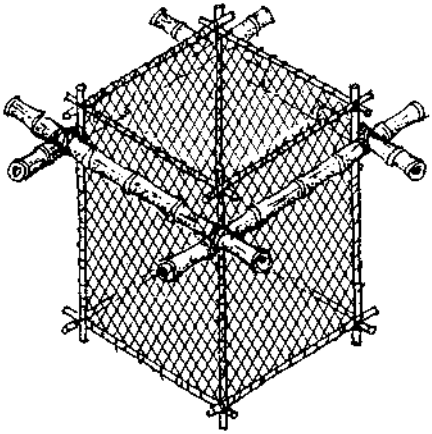

Figure 7: Floating cage (FAO, 1995).

Cages can be rectangular boxes, bamboo cylinders or anything which can be placed in a water current so the water passes through (figure 7). In addition to bamboo, cages can be made out of materials such as wire screen, nylon mesh and wood. All cages must be anchored so that they do not drift away.

The best place for a cage is a sunny place, near your home, in deep water where gentle water currents and winds bring clean water into the cage.

Cages are also used in ponds for keeping fish between harvest and selling time. Sometimes cages are used as breeding tanks.
Advantages of growing fish in cages are:

- cages are easy and cheap to build;
- cages can be owned and maintained in groups;
- fish in cages are easy to stock and feed;
- fish grow fast in cages;
- cages are easy to harvest.

Pens

Fish can also be grown in pens inside lakes or offshore areas (figure 8). Pens are constructed from bamboo or wooden poles that are forced down into the lake or shore bottom. Then nets are strung from pole to pole to form an enclosure. The nets are anchored into the lake bottom with weights or sinkers and the fish are stocked inside the pen.

Fish pens measuring the size of a fish pond and placed in fertile lakes can yield a high fish production. They do not require extra feeding or fertilization and need very little maintenance. The fish are stocked and harvested at the end of the growing season.

In less fertile waters, supplementary feed may be necessary to feed the fish inside the pens. The food should be provided to the fish by using feeding rings (a floating ring in which food can be supplied) so the food will stay inside the pen.

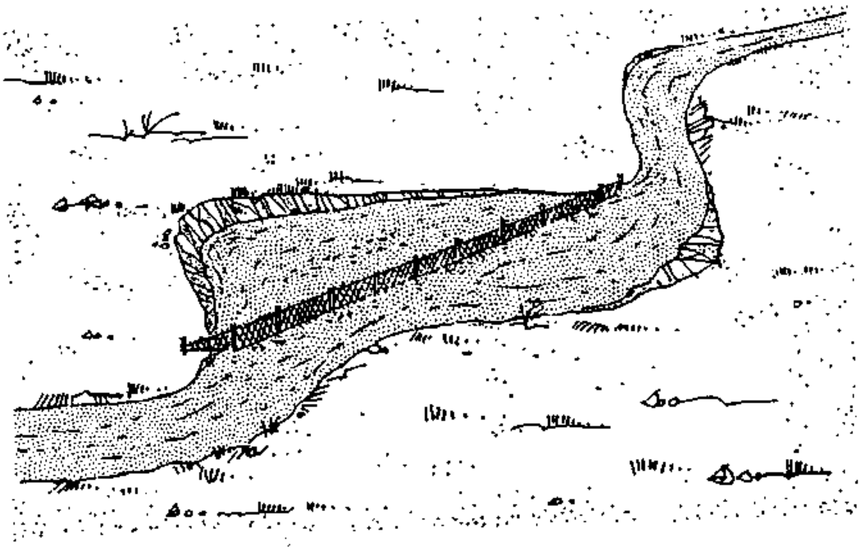

Figure 8: Fish pen (Costa-Pierce, 1989).

Some disadvantages of pens are:

- Pens are expensive to build; the netting must be nylon or plastic, and poles must be treated so they will not rot.

- A fish pen only lasts three to five years in the water.
- Pens are usually built in the shallow areas of a lake, where they use space which naturally occurring fish species need to feed and spawn. This reduces natural production in some lakes.
- Fishermen must go further out into the water when there are pens in the shallow areas.
- Fish excreta and uneaten feed may cause pollution (also true for cages).
- Fish are very easy to steal from pens (also true for cages).

4 Fish farming practices

4.1 Selection of fish species

When selecting fish species suitable for farming various biological and economic factors are important to pay attention to:

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 (larvae or fingerlings);
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 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 biological 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 to ensure 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 (larvae or fingerlings).

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 to big extent from one moment to another as natural fish reproduction depends on unpredictable biological factors (water temperature, food availability, etc.). Furthermore, the collection of fish young from the wild could give rise to conflicts with commercial fishermen. It is better to select fish species which can be easily reproduced by yourself or bought on the fish market or from a reliable fish supplier, fish culture station or fish culture extension service.

In aquaculture, 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 of these species will be relatively low. Carnivorous (predatory) fish species need a high protein diet and are therefore more expensive to produce. To compensate for higher feeding costs, most carnivorous species fetch higher market prices.

Fish species that are hardy and which 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. This newly introduced fish species should:

- fill a need which can not be fulfilled by local species;
- not compete with local species;
- not cross with local species and produce undesirable hybrids;
- not introduce diseases and parasites;
- live and reproduce in balance with their environment.

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

By raising different fish species together in one pond (polyculture) the fish production is higher then when the fish species are raised separately (monoculture).

Monoculture

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

Polyculture

In polyculture more than one fish species is raised in the fish pond. In this way the various natural food resources in the pond are better utilized. Each fish species has a certain food preference which are 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 dead material which they find on the bottom. Tilapia, on the other hand, live more in the deeper part or end of the pond; some species feed on plants and others on plankton. 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 9).

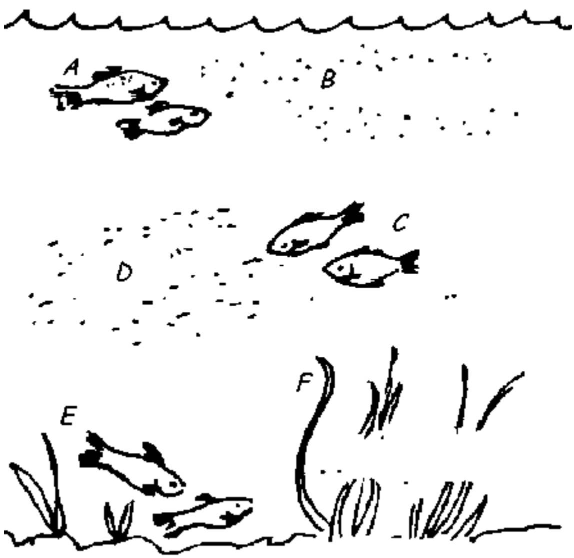

Figure 9: Carp polyculture. A: silver carp: B: algae; C: bighead carp; D: zooplankton; E: grass carp; F: water plants.

Silver carp feeds mainly on algae, bighead carp mainly on tiny animals (called zooplankton) and grass carp mainly on water plants so there will hardly be any food competition. Another much used example is the polyculture of tilapia and common carp as tilapia feed mainly on algae and common carp on zooplankton and pond bottom material. A special form is the concurrent culture of tilapia and catfish or snake-head (in general a predatory fish) to control the excessive breeding of tilapia (Chapter 6). But to obtain a production of fish that is as high as possible it is better to breed as few prey fish as possible in the pond. The emphasis should be on fish species that can live on different kinds of feed.

4.2 Fish nutrition

There are two types of food in the pond which the fish can eat to grow: naturally produced fish food inside the pond and supplemented fish food supplied from outside the pond to the fish. Natural fish food consists of algae (phytoplankton) and tiny animals (zooplankton) produced in the pond itself and which can be increased by fertilizing the pond. Supplementary fish food is produced outside the pond and supplied to the fish regularly to increase the amount of fish food in the pond further.

Natural fish food

The natural fish food in the pond consists for a big part out of algae. Oxygen is a gas that is produced by all plants in the pond (therefore also by algae) with the help of sunlight. The more sunlight falls on the pond and the larger the quantity of algae, the higher will be the oxygen-production in the fishpond. The oxygen produced solves partly in the water and the rest escapes to the air. The oxygen level of the water varies during the day because the production and absorption of oxygen by the plants changes with light and darkness (with or without sunlight in the fishpond). The algae in the pond only produce oxygen when there is light. At night they need oxygen like any other plant or animal in the pond, while no oxygen can be produced due to lack of sunlight. Due to this, the quantity of solved oxygen in the water decreases after sunset (figure 10). 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 death cause of fish in fisheries where the pond has been manured or fed too much. An oxygen level that is sufficiently high is important for a good fish production.

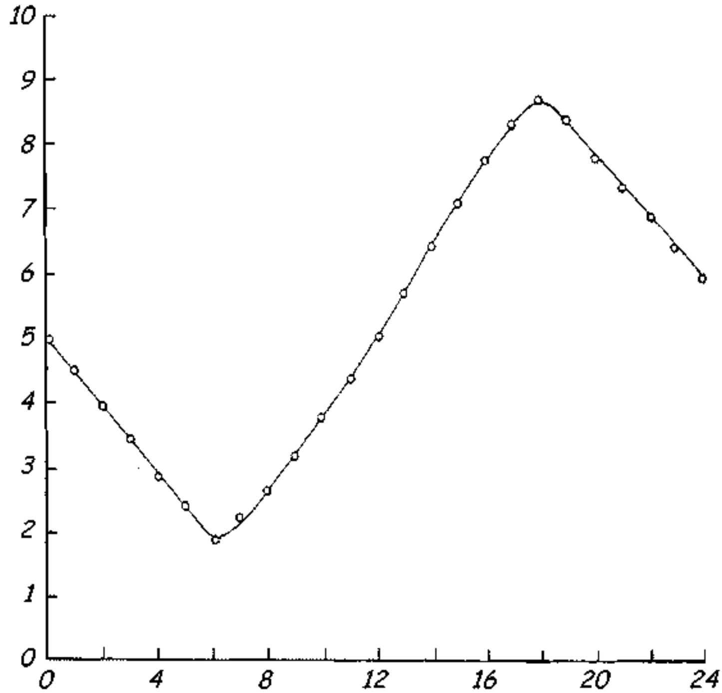

Figure 10: Oxygen level over the day.

Supplemented fish food

When supplementary food is given to the fish most of it is directly eaten by the fish. The uneaten food will act as an additional fertilizer for the pond. But even in ponds receiving a high amount of supplemented food, natural fish food still plays a very important role in the growth of fish. In general, local waste products can be used as supplementary fish food. The type of food to use depends on the local availability and costs and the fish species raised. Typical examples of supplementary fish feeds are rice bran, broken rice, bread crumbs, cereals, cereal wastes, maize meal, Guinea grass, napier grass, fruits and vegetables, peanut cake, soybean cake and brewer's waste.

Finally some practical guidelines for feeding fish:

- Feed the fish at the same time and in the same part of the pond. Fish will get used to this and come near the surface of the water so it is 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 so fish have enough time to recover from the high oxygen-demanding feeding activity before nightfall.
- Do not overfeed the fish by observing their behaviour while feeding as too much food will decay and use up too much oxygen in the pond.
- Stop feeding fish for at least one day before breeding, harvesting or transporting them. This enables the fish to digest the food completely. In general, fry can be starved for 24 hours, fingerlings for 48 hours and adult fish for about 72 hours. The stress from these events causes the fish to excrete waste making the water turbid.

The feeding characteristics of particular fish species are discussed in Chapters 5, 6 and 7 for carp, tilapia and catfish and summarized in Appendix 2 for other fish species.

4.3 Water transparency as water 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 water turbidity which is the amount of suspended matter (algae, soil particles, etc.) in the water. Algae blooms generally changes the colour of the water to green. Measuring the transparency of a green coloured pond will give an idea of the abundance of algae present in the pond water and thus of pond fertility.

Water transparency can be measured using a Secchi disc. 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 11). The disc is attached to a cord that is marked every 5 cm along its length.

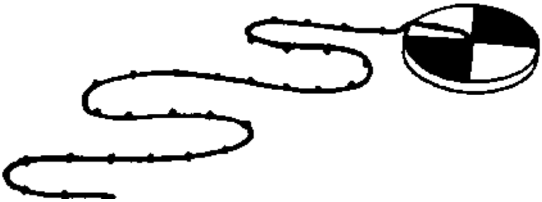

Figure 11: The Secchi disc (Viveen et al., 1985).

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 activity to be undertaken for the different water transparencies is given in table 3.

Table 3: Actions to be undertaken for different water transparencies.

Water transparency	Action
1 - 15 cm	Too much algae present in pond.
15 - 25 cm	Risk of oxygen shortages for fish at dawn. Stop adding food and fertilizer. Observe fish behaviour regularly and if fish are gulping for air at the water surface water exchange is necessary.Abundant algae present.
25 - 30 cm	Optimum abundance of algae for fish production. Continue with (routine) feeding and/or fertilizing at the same rate.
> 50 cm	Too low density of algae. Stimulate algae blooms by adding more food and/or fertilizers until a water transparency of 25-30 cm is reached.

When water transparency is in between 15 and 25 cm, the small baby fish (called fingerlings) can be stocked in the pond. When doing this you should do this gently as indicated in figure 12. Furthermore, the water temperature of the water the fingerlings come from should be about the same as the water temperature the fish are stocked in.

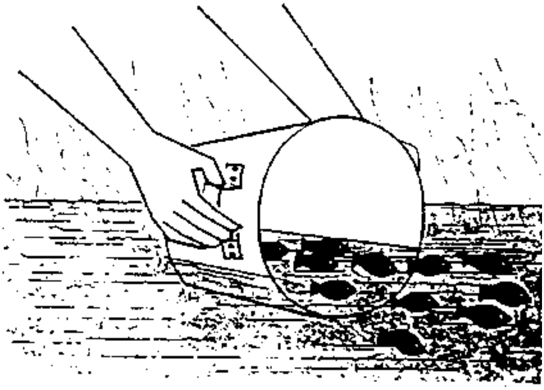

Figure 12: Stocking of fish into the pond (FAO, 1995).

4.4 Health and disease

Fish are vulnerable to diseases when environmental conditions (water quality and food availability) are poor and once a disease has entered the fish pond it will be very difficult to eradicate it. This is caused by the fact that infected fish are difficult to pick out and treat separately and water is a perfect agent for spreading diseases. The diseases from which fish could suffer are many and varied. Sick fish do not grow, so the farmer loses money as growth and thus harvest is delayed seriously. If fish are near market size when they die from disease, losses are most severe. The costs of treatment can be high and very often the use of these treatments can become dangerous, not only for humans but also for other animals and plants. In the long run, the waste from the treatment 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 (with plenty of dissolved oxygen) are the most important factors for good fish health needed to cope with diseases. Many of the potential pathogens (animals which can cause disease) of fish species are normally present in the water waiting to 'attack' when environmental conditions become bad and subsequently fish are stressed causing a decreased resistance to diseases.

There are some basic rules which must be observed if outbreaks of disease are to be prevented or, if they occur, to be controlled. Ponds must have separate water supplies. It is not recommended to supply a pond with water from another pond, since this water may carry diseases and the level of dissolved oxygen may be lower. It is therefore wiser not to design ponds in series.
Fish must not be stressed. If you handle the fish, except when you are taking them to the market, 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, or rubbing off the scales and the protective slime layer, means disease causing animals (pathogens) can enter the fish more easily.
So, fish must be kept in good condition at all times by using water with plenty of oxygen, with the correct pH and with a low ammonia content.

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

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, ragged fins and sores on the body. Something is wrong when the fish stop eating suddenly. You must check the fish often, especially in very hot weather when dissolved oxygen shortages occur more often as in warmer water less oxygen can be dissolved than in warmer water.

Do not get discouraged if occasionally you 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 what the cause is.

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 while nutritional diseases are caused by dietary shortages.
There are also diseases caused by pollutants and bad water quality and there is evidence that most fish deaths probably result from these types of problems.

The fish farmer should focus on the prevention of diseases as the treatment of fish diseases is often difficult, time consuming and expensive.

4.5 Reproduction

The selection of fish species for culture depends, amongst other factors, on whether it is easy to breed the fish yourself or whether it is easier to obtain young fish from the wild.
Even when culture can be started using young fish caught from the wild, it is important to achieve controlled reproduction. Controlled reproduction provides a supply of eggs and young fish in adequate numbers for the fish farming and avoids problems of either collecting brood stock or harvesting young fish from the wild. Controlled reproduction will provide you with seed at the moments you require it and not just during the few months of the year when natural spawning occurs in the wild.

The reproductive cycle of nearly all fish is regulated by environmental stimuli (day length, water temperature, water level, etc.) which trigger the release of hormones by the fish brain that 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 reproduction cycle functions, you can use this knowledge by providing the appropriate environmental stimuli to the fish (e.g. higher the water level) which cause the fish to spawn.

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 involved in the regulation of the reproduction cycles.

The chapters on carp, tilapia, and catfish provide more specific information on reproduction in these species.

4.6 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 harvest can start (usually after 5 to 6 months) but harvest only what can be eaten or sold within one day. At harvest, 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 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 grow on. 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 one time.

There are different kinds of nets with which you can harvest the fish from the pond as shown in figure 13.

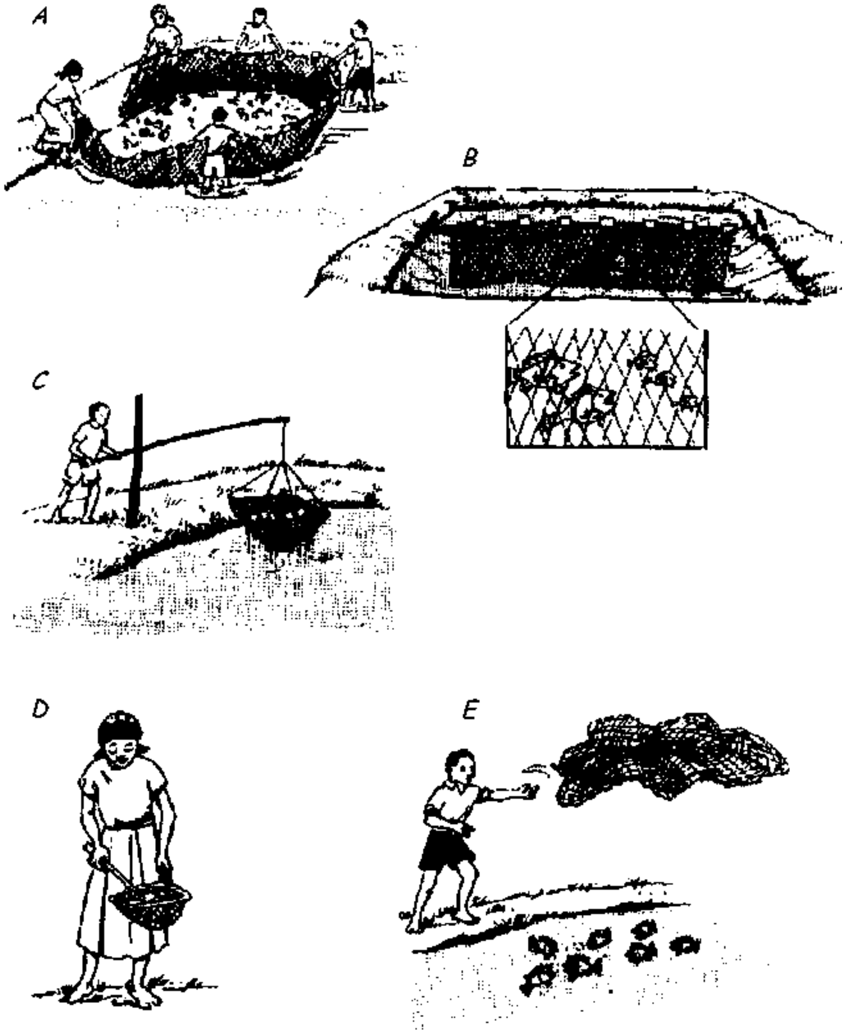

Figure 13: Different nets for fish harvesting (Murnyak and Murnyak, 1990). A. seine net; B: gill net; C: lift net; D: scoop net; E: cast net.

The method used for continuous selective culling is to hang a net in a pond whereby the fish will attempt to swim through the meshes of the net. By selecting the proper size of net mesh you can make sure that any fish smaller than the size you wish to harvest will swim through the net whilst the larger fish will get stuck (except in gill nets). A gill net is often used with this method of harvesting (figure 13B) which causes the fish to get stuck behind their gills. The size of fish caught in this way can be estimated by trying to measure the size of fish which gets just stuck into this net. All fish smaller and larger will not be caught. In this way it is possible to harvest fish throughout the year without having to drain water from the pond or disturb the remaining fish in a serious way.

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

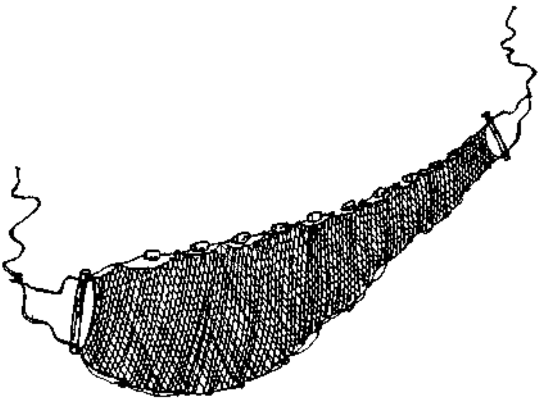

Figure 14: Seine net (FAO, 1995).

At first, most of the fish can be caught in a seine net (figure 13A, figure 14 and the text box: How to make a seine net) with a mesh size of 1 cm when the water level still rather high. 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 15). As the water flows out of the pond, large quantities of fish can be caught. Place slatted boxes or (scoop) nets (figure 13D) under the drainpipe to prevent fish from escaping as the pond is drained.

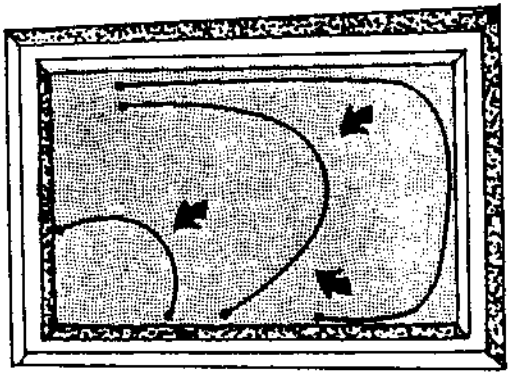

Figure 15: Harvesting technique with a seine net (FAO, 1995).

When the pond is completely drained, the remaining fish can be gathered by hand from the pond bottom. Try to catch as many of the fish as possible before the pond is completely empty as stranded fish can be missed or damaged.

After harvesting, the pond is dried until the pond bottom cracks and limed (reducing pond bottom acidity) thereby killing unwanted animals and plants on the pond bottom.
Some more simple, and therefore cheaper, nets are:

- A lift net (figure 13C) 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.
- A scoop net (figure 13D) is a small net with a handle that is held in one hand. It is often used when counting and weighing fish and fingerlings.
- A cast net (figure 13E) is a round net that is thrown into the pond from the shore and pulled back to capture the fish.

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:

- Tie two ropes, forming the top and bottom lines, between two trees.
- Mark each rope at 15 cm intervals. Make sure these two ropes are a few meters longer than the final net is to be.
- 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.
- 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.
- Repeat the process until the last marking on the top rope is reached.
- Attach the sinkers onto the bottom rope at 15 cm intervals. Tie the cork floaters onto the top rope also at 15 cm intervals.
- 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 which is taken care of in this way will last much longer.

4.7 Maintenance and monitoring

In order to achieve a high fish production in the pond, regular maintenance and monitoring is necessary. Daily management includes making sure that one should:

- Check the water quality (temperature, pH, early morning dissolved oxygen levels)
- Check the pond for possible water leaks
- Clean the screen of the water in- and outlet
- Watch the fish while feeding: Do they eat normally? Are they active? If not, check dissolved oxygen level (if near zero stop feeding and fertilizing and flow water through the pond until fish behave normal again) or look for symptoms which could indicate a disease
- Watch out for predators and take precautions if necessary
- Remove aquatic weeds growing in the pond

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 radiation into the water and thus oxygen production by the water plants, clog filters and injure fish gills. A method for measuring turbidity is shown in figure 11. A suitable method for reducing turbidity is a siltation tank. This is a small reservoir at the inlet to 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 to clear muddy water is to put hay and/or manure into the pond and leave it there to decompose (lime, gypsum or alum can also be used). In the case of water turbidity caused mainly by other factors than algae abundance (water colour is not greenish), some much used practices to decrease this turbidity are the following. Bring animal manure in the pond before stocking of the fish at a rate of 240 g/m^2 three times with a time interval between the applications of three to four days. Another method to decrease turbidity is applying lime, gypsum but preferably alum at a rate of 1 gram per 100 litre of water. This method should not be used during very hot weather because the hay will begin to rot very quickly. However, the only real long-term solution to turbidity is to divert muddy water away from the pond and ultimately protect roads and dikes from erosion causing the high water turbidity.

Water acidity, alkalinity and hardness

Other important water quality characteristics are water acidity, alkalinity and hardness.

Water suitable for aquaculture should have a certain degree of acidity indicated by the water pH-value which should preferably be in between 6.7 and 8.6 (figure 16). Values above or below this range inhibit good fish growth and reproduction. Algae require a pH of about 7 and a slightly lower (alkaline) pH of 6.5 favours good zooplankton (tiny animals in the pond water on which the fish feed) and fish growth.

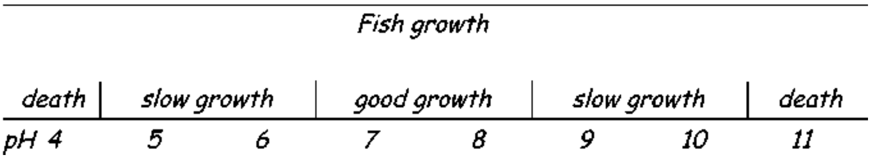

Figure 16: The effect of pH on fish growth (Viveen et al., 1985).

Sometimes the pH of the pond water can change quickly. For example, a heavy rain may carry acid substances coming from the soil dissolved in the 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.

Water alkalinity is a measure of the acid-binding capacity of the water (buffering ability) and the opposite of the 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" water. One method of measuring hardness is to look closely at the pond dikes where the water line is. If there is a white line on the dike of the pond where the water was, there are salts present in the water which have dried on the pond dikes. Water hardness 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 and thus increase water fertility so natural fish food production and ultimately fish production in the pond will 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 liming is to increase either the pH of the pond water to 7, the water alkalinity and the water hardness. Ponds that have just been built need a different treatment than ponds which have already been limed before.

- Newly built ponds
  These should be treated with 20 to 150 kg agricultural lime per 100 m^2 (Appendix 3). This is mixed with the upper (5 cm) layer of the pond bottom. The pond is subsequently filled with water till 30 cm. Within one week the pH of the pond water should have reached 7 and you can start fertilizing.
- 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 disease bearing animals, 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 3).

Oxygen supply
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 in the water. Do not feed and fertilize the pond at this moment because this is often one of the reasons for the oxygen shortage. Another possible cause of oxygen shortage problems can be an over-stocking of fish in the pond. This can causes oxygen stress for the fish which can result in disease outbreaks and mortality.

Toxic substances
Finally, 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 so chemicals should never be used in the area around the pond especially when sprayed on windy days.

5 Carp culture

Carp belong to the freshwater family **Cyprinidae**. This is a widespread and abundant fish family absent only from South America, Madagascar and Australia in their natural distribution. 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, which is farmed in Europe, Asia and the Far East, Indian carps and Chinese carps as shown in table 4.

Table 4: Different carp species and their food preferences.

Common name	Scientific name	Food preference
Common carp		
carp	*Cyprinus carpio*	small plants and tiny animals
Indian carps		
catla	*Catla catla*	algae and dead plants
rohu	*Labeo rohita*	dead plant material
calbasu	*Labeo calbasu*	dead plant material
mrigal	*Cirrhina mrigala*	dead material on pond bottom
Chinese carps		
grass carp	*Ctenopharyngodon idella*	water plants
silver carp	*Hypophtalmichthys molitrix*	algae
bighead carp	*Aristichthys noblis*	tiny animals
black carp	*Mylopharyngodon piceus*	molluscs
mud carp	*Cirrhina molitorella*	dead material on pond bottom

These different carp species have different food preferences as shown in table 4. You can take advantage of this by keeping the different species together in one pond: building a polyculture system. In this way the different species, which feed on different food items in the pond, utilize the naturally occurring food in the pond much better. These different carp species do, in this way, not compete for the food sources and therefore fish production is much higher than would be possible with the culture of a single carp species or even of the different carp species alone.

5.1 Common carp

The common carp is a widely cultured strictly freshwater fish (figure 17) which can reach a length of about 80 cm and weight of about 10 to 15 kg. The temperature range is from 1 to 40°C while the fish starts growing at water temperatures above 13°C and reproduces at temperatures above 18°C when the water flow is increased suddenly. Carp are usually mature after about 2 years and a weight of 2 to 3 kg. In temperate zones, carp spawns 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. The common carp is a hardy fish species and thus resistant to most diseases when environmental conditions are maintained properly.

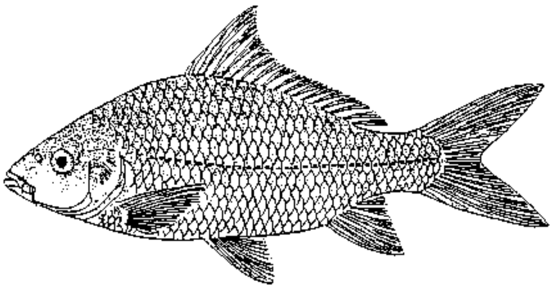

Figure 17: Common carp (Cyprinus carpio) (Hanks, 1985).

Egg production

Carp spawning can be carried out in outdoor ponds naturally or in a fish hatchery artificially using induced spawning methods. Induced spawning is a technique which uses substances (called hormones), which are produced by the fish itself, to trigger spawning. These hormones are being fed to the fish via the feed or injected into the fish's 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 common carp breeding are obtained when brood-fish are carefully chosen. The following points for recognizing ready-to-spawn fish should be taken into account (see also figure 18):

1 a fully mature female has an almost rounded, soft, bulging belly with obscured ridge on it and vent projecting into a small papilla like outgrowth;
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 belly.

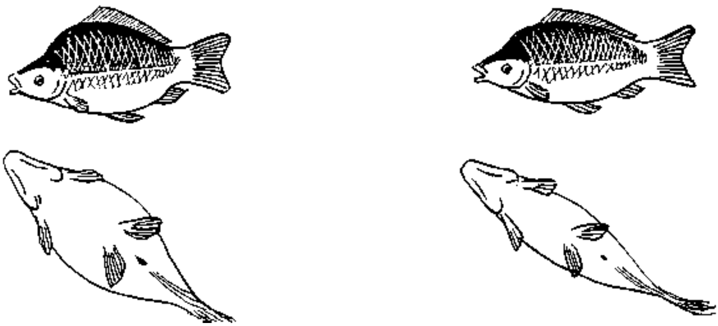

Figure 18: Ripe female (left) and male (right) common carp (Costa-Pierce et al., 1989b).

Brood-fish are fed with rice bran, kitchen refuse, corn, etc. In the natural system of fish reproduction in outdoor ponds, fish are allowed to spawn in special spawning ponds and the parent fish are removed after spawning. Spawning ponds are usually 20-25 m^2 in area and the pond is dried for a few days before filling with clean freshwater up to a depth of 50 cm. Water is released into the spawning pond on the morning of the breeding date and brood-fish as well as egg collectors are put 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 in the pond 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. An 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*). For making *kakabans,* the *Indjuk* fibres are washed clean then layers thereof arranged in 1.2 to 1.5 m 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.

For spawning, *kakabans* are kept in a floating position a little under the water surface, propped up on bamboo poles. Five to eight *kakabans* are required per kilogram weight of female carp stocked. A gentle flow of water is supplied in the spawning pond when the brood-fish are released and the *kakabans* are placed. By habit, the fish first attaches its eggs on 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 19), they are transferred to the nursery ponds 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 that the eggs are always fully submerged in a layer of 8 cm water. The eggs hatch in 2 to 8 days depending on water tem-

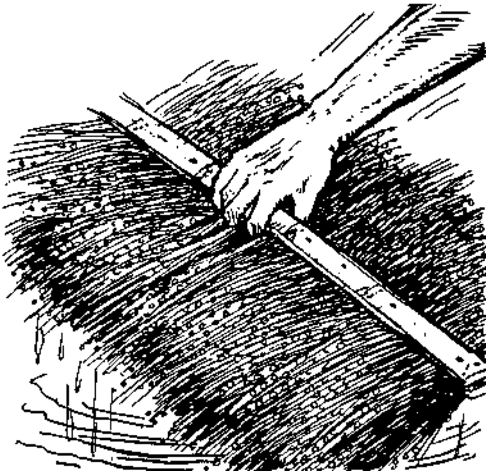

Figure 19: Taking out a carp egg collector after spawning (Costa-Pierce et al, 1989b).

perature. At the most suitable water temperature for hatching (20 to 22°C) hatching will take place within 4 days.

Nursery ponds

Nursery ponds are 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 which is determined by the water flow into the pond. In stagnant water (no water flow-through) ponds, 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 or fry 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 to grow to market size. Regular application of worm castings and rice bran/coconut oil cake increase food availability 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 is completely mixed dry at a 1:1 ratio and then wetted until small 1 to 2 mm 'balls' could 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. Natural fish food production can be increased by using fertilizer. The best growth of common carp occurs with stocking densities of 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 fertilization and water temperature. In the tropics, daily fish production rates vary from 30 g/m² in unfed and unfertilized ponds up to 800 g/m² in supplementary fertilized and fed fish culture ponds with regular water exchange.

5.2 Indian and Chinese carps

These strictly freshwater carp species cannot withstand low water temperatures and have an optimum growth rate at about 25°C. They are sexually mature at 2 to 3 years of age in the case of Indian carps (figure 20) or 4 to 9 years of age in the case of Chinese carps (figure 21) and will spawn only at water temperatures above 25°C. But the age of sexual maturation also depends on sex and growth rate. As males grow faster and thus mature earlier, they can spawn one year earlier than the females.

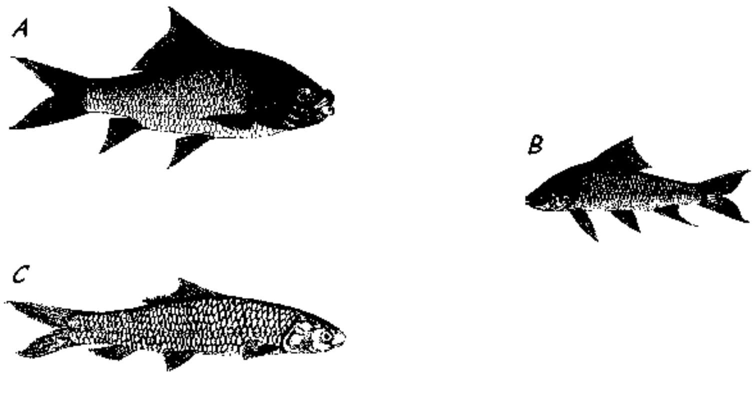

Figure 20: Indian carps (Mohammed Mohsin et al., 1983). A: catla; B: rohu; C: mrigal.

Mature fish weigh at least 5 kg in the case of Chinese carps or 2 to 4 kg in the case of Indian carps. The use of even larger fish is always better because of the larger quantity of eggs or sperm (and thus ultimately young fish) the female and male will produce at spawning. These fish species, unlike the majority of carp species, spawn eggs which float on the water before hatching occurs.

Egg production

Until recently, the supply of young fish for the culture of Indian and Chinese carps depended completely on the collection of fish eggs, fry and fingerlings from the rivers in which the adult fish spawned. Currently, these carp species are injected with hormones to induce spawning artificially. However, this method of fish reproduction requires a high level of knowledge and inputs so the small-scale fish farmer should buy the young Indian and Chinese carps from the local commercial fish dealer and preferably from the local extension service.

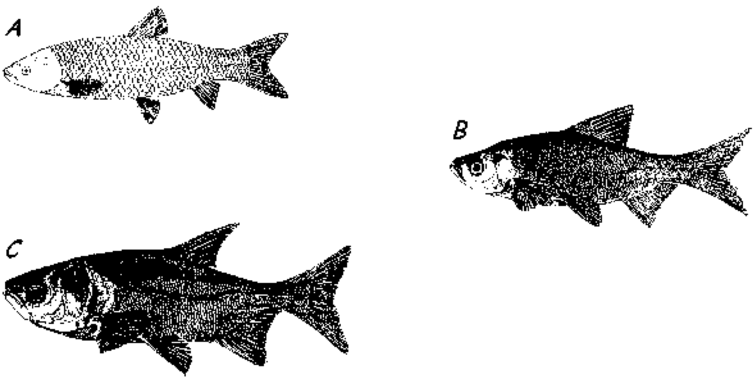

Figure 21: Chinese carps (Mohammed Mohsin et al., 1983). A: grass carp; B: silver carp; C: bighead carp.

Nursery ponds

The area of nursery ponds varies considerably from country to country. In India, for example, small ponds of 10 m² are used, whereas in China pond size varies up to 20,000 m². The ponds are varying from

0.5 to 1.0 meter in depth. In these nursery ponds the fry can be kept in floating cages before being released into the pond. The ponds are stocked at 20 fish/m².

Before stocking, prepare the ponds by applying animal manure on the pond bottom at a rate of 200 g/m² to increase pond fertility and thus fish growth. Supplementary feed is sometimes used but algae and tiny animals living in the pond are still the main feed needed by the fish fry. Any supplementary feed given acts mainly as additional fertilizer as it will not yet be eaten by the small sized fish fry because this food is still too large sized to be eaten.

Grow-out ponds

In China, grow-out ponds are often 2 to 3 meters deep. These ponds are stocked at densities of about 60-100 fingerlings/100 m² depending on local conditions of the farmer. The fish may be cultured for three years before being harvested.

The average yield is about 400 g/m² for Chinese carps. Higher yields can be obtained in polyculture of different carp species. In polyculture of Chinese carps the total stocking density may be 2 per m² of which 25% is grass carp, 25% bighead carp and 50% silver carp.

Indian carps are raised in smaller and shallower ponds of about 0.5 m deep. Stocking density of Indian carp is about 90 g/m². The fish are harvested after eight months when they have reached a weight of 300 g.

The growth rate of both Indian and Chinese carp species can be increased when additional feed, in the form of plant material, is given. Snails can be given to mollusc-eating black carp. Grass carp is an excellent species for reducing weed growth in ponds or irrigation canals as naturally growing aquatic plants can form a significant part of their diet.

When grass carp are stocked in polyculture with other fish and fed grass only, then for every 10 grass carp, 2 algae (phytoplankton) or tiny animals (zooplankton) eating fish of the same size can be stocked per 15 m^2. Every kilogram of grass carp stocked can support 190 gram of (phytoplankton)/tiny animals (zooplankton) eating fish and 150 gram of fish species which eat almost anything (omnivores).

When ponds are stocked with common carp, bighead carp and tilapia at a stocking density of 18,000 fish/ha, for every 2 bighead carps (or other zooplankton eating fish), 3 common carps (or other bottom feeding fish) and 4 tilapias (or other algae eating fish) can be stocked. The ponds should in this case preferably be fertilized with duck manure at a rate of 1,000 kg/ha twice a week.

6 Tilapia culture

Tilapia is a fish which is ideally suited for polyculture under poor environmental conditions and/or when pond management is of low priority.

Tilapias are a group of tropical freshwater fish species native to Africa and the Middle-East. 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 and 30°C. Water temperatures as low as 12°C are tolerated but water temperatures below 10°C are survived 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 rural fish farming. However, one advantage which could be a constraint to profitable fish farming, is the continuous reproduction of tilapia. Tilapia become sexually mature already 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 a strong food competition between the stocked tilapia and the newly born recruits. This will in turn decrease the growth rate of the originally stocked tilapia resulting in high numbers of small sized tilapia at harvest.

There are at least 77 known species of tilapia. The different tilapia sub-species are classified according to their breeding behaviour and food preferences. The substrate spawners, which make nests at the bottom of the pond and spawn in them, have the name Tilapia. They guard their young in the nests, have coarse teeth and feed mainly on water plants. The mouth-brooders, which hatch the fertilized eggs in the mouth of the female or male parent (parental mouth-brooders), belong to the tilapia sub-species *Sarotherodon*. They have fine teeth and mainly feed on algae. The tilapia species belonging to the genus *Oreochromis* spawn in nests on the bottom of the pond and brood the eggs in the mother's mouth (maternal mouth-brooders). They have fine teeth and feed mainly on algae. Of all tilapia species, Nile tilapia is the fastest growing species (figure 22).

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, by using different control methods.
The simplest method is continuous harvesting. By using a selective net made from natural material or nylon the largest fish are removed. By removing the market sized fish the remaining fry and young fish are allowed to continue their growth. This method is labour intensive and enlarges the period before maturity is reached, and is therefore of only limited value. There is also the risk of genetic deterioration of the stock when the large, fast-growing fish are sold and the remaining slow-growing individuals are used as 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. Again the fish tend to breed before they have reached market size and overpopulation can still be a problem.
However, overpopulation can be controlled most economically for the small-scale subsistence farmer by stocking predatory fish (e.g. catfish or snake-head) together with the tilapia in the pond. These fish species will eat the majority of the tilapia fry when the adults start to breed and will therefore prevent overpopulation of the fish 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 the tilapia stocked, a number of factors should be considered such as the time, size and density of stocking of both tilapia and predator. 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 length per 100 m^2 or 7 snake-heads of at least 25 cm length per 100 m^2. When other predatory fish species are stocked one must 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. So, when 10 cm tilapia are stocked a predator of at least 25 cm (10/0.40) length must be stocked otherwise the predator will eat the stocked tilapia! The predator stocking density depends on its voracity so an estimation can be made by comparing the voraciousness of the predator to be stocked with those of the moderate voracious catfish and the highly voracious snake-head. The outcome of this can then be used to determine the number of predator to be stocked: in proportion between that of catfish and snake-head.

As tilapia males grow faster than females they are mostly bigger at the same age. So, when buying tilapia fingerlings for grow-out purpose, one should pick out the larger fingerlings despite the higher costs because these costs will be more than compensated by a higher fish growth rates and thus higher fish yields. Male tilapia can be distinguished from female tilapia by the absence of a vertical opening on genital papillae (figure 22).

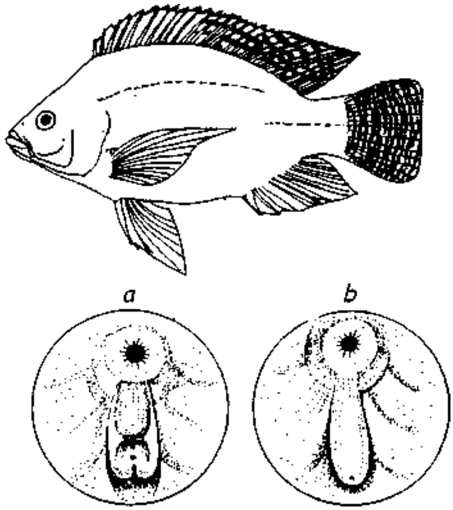

Figure 22: Genital papillae in female (a) and male (b) tilapia (FAO, 1995).

6.1 Egg production

Egg production presents no problem as the fish readily spawn in the ponds. The preferred water temperature during spawning is 20 to 30 °C. 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 stocking rate for males is generally 10-25 per 1,000 m^2. The fry are collected at intervals of one month and grown to fingerlings in nursery ponds. The average monthly production is about 1,500 fry/m^2.
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 the sex ratio of one male to four or five females. Tilapia males (of the substrate spawners) will begin digging holes in the pond bottom immediately, and the female will be attracted to the hole and 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.
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. Supplementary feeding is provided at a rate of about 6 to 8% of body weight, depending on food type, once they are transferred to the nursery ponds. When wheat bran is used, feeding levels can vary from 4% up to 11% of the fish's body weight per day.

6.2 Grow-out ponds

Tilapia culture is generally oriented to producing fish of marketable size of at least 200-300 g. Ponds which are used for extensive or semi-intensive culture can vary in size from a few square meters to several thousands of square meters. Typical intensive cultivation units are about 800-1,000 m^2. These ponds are a practical size for the farmer to manage.
A stocking density of 2 fingerlings/m^2 is recommended together with the application of fertilizers and/or additional feeding as a higher food availability delays tilapia female spawning frequency and size at ma-

turity. So, 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 fertilized with chicken manure and ammonium phosphate. Supplementary feed often used are rice bran, wheat bran and dried chicken manure.

6.3 Feed and fertilizer

Although tilapia can be divided into tilapia species which eat mainly water plants and species which eat mainly smaller plants (algae) under pond culture conditions they have highly flexible feeding habits so nearly any kind of food supplied will be eaten. Dead material found on the pond bottom also forms a large part of their food. Fertilizing tilapia ponds with manure and/or artificial fertilizers increases overall fish food production in the ponds.
A variety of feeds can be used when culturing tilapia in ponds. Tilapia young rely mostly on the natural production of food in the pond. Adult tilapia can be raised solely on the natural food production in the pond resulting from manure and/or artificial fertilizer application. This natural feed production can be supplemented, to a bigger or lesser extent, by the addition of other food.
Tilapia can be fed plant materials like leaves, cassava, sweet potato, cane, maize and papaya and various waste products like rice bran, fruit, brewery wastes, cotton seed cake, peanut cake and coffee pulp.

The type of food used depends on the 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 food formulations are presented in table 5. The amount of food to be fed to the fish depends on fish size and food type. Careful observation of the fish in the pond while feeding is the best way to determine the amount to be fed. Do not give the fish more than they will eat at one moment.

Table 5: 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 polishings 12% wheat 18% peanut oil cake 4-8% fish meal 1% oyster shell

6.4 Stocking density and production levels

In general, a stocking density of 2 tilapia fingerlings/m^2 is recommended.

Polyculture systems of tilapia together with common carp, mullet or silver carp can contribute to maximum utilization of natural occurring food in ponds. The annual fish yield in polyculture can reach 750-1,070 g/m^2/year.

Examples of typical production levels obtained in different culture systems are listed below:

Unfertilized ponds without predator stocked	30-60 g/m^2/year
Unfertilized,fed ponds with predator stocked	250 g/m^2/year
Ponds fertilized with pig manure	500 g/m^2/year
Ponds fertilized with poultry manure	300 g/m^2/year
Ponds fertilized plus supplementary feed	800 g/m^2/year

7 Catfish culture

Catfish belong to the fish order called *Siluriformes* subdivided into the families **Ictaluridae**, **Pangasidae** and **Clariidae** and consist 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 23).

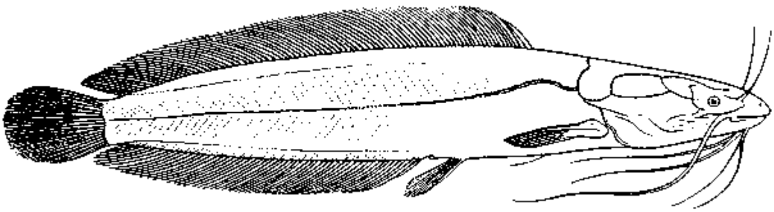

Figure 23: African catfish (Clarias gariepinus)..

All farmed catfish are freshwater species. Catfish have either a naked skin or their skin is 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 water for long periods of time is of special value in tropical countries where higher water temperatures cause practical problems during transportation.
Channel catfish spawn easily in shallow ponds in which the eggs are spawned in a nest and guarded by the male fish. The Asian catfish

spawns easily in captivity while the African catfish needs more care but can also be spawned naturally in ponds.
Catfish have, just like tilapia, a broad food preference and will eat almost anything which is present but show slight preference for small fish (measuring up to 30% of their own body length) and pond bottom material like vegetable matter. They are warm-water fish with a temperature range of 16-30°C.

Many catfish species have, besides their gills which take up oxygen from the water, a pair of extra air-breathing organs which enable them to also take up oxygen from the air. So they are able to spend considerable time out of water and thus they sometimes crawl out of ponds to look for food (this is the reason why channel catfish is sometimes called 'walking' catfish). Because they can live under poor environmental conditions (like 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.

7.1 Egg production

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 both sexes of catfish the urogenital opening is situated just behind the anus. The adult male can be distinguished from the female by the elongated backwards projecting form of thus papilla. In the female the papilla has the form of an oval eminence. In figure 24, mature female (A) and male (B) catfish are shown lying on their backside. Catfish fingerlings have not yet developed a papilla.

In natural spawning a pair of catfish are left in the pond which contains a suitable nest area for spawning. 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 which increases with increasing body weight.

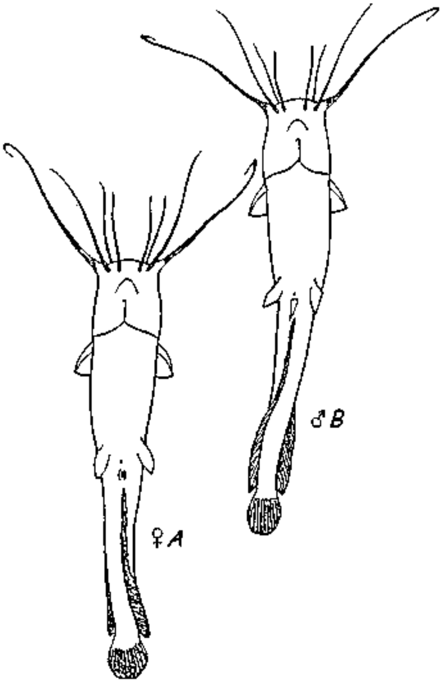

Figure 24: Genital papillae in female (A) and male (B) African catfish (Viveen et al., 1985).

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 we are not able to let the fish spawn naturally and the same holds for some **Clariidae**. The Asian catfish can be spawned in ponds naturally when feeding is stopped and the water level in the ponds is raised and kept high. The African catfish will also spawn naturally on a number of substrates (e.g. sisal fibres, palm leaves and stones) in this way.

7.2 Hatcheries

When the eggs of the channel catfish hatch in the spawning ponds, the fish fry are collected and transferred to nursing ponds for rearing. In fish hatcheries, the eggs are hatched in simple aluminum troughs placed in running freshwater as the eggs are kept in motion artificially (as is otherwise done naturally by the males while guarding the eggs) in this way. The eggs of the **Ictaluridae** catfish family hatch usually in 5 to 10 days at a water temperature of 21 to 24°C while the eggs of the **Pangasiidae** catfish family hatch in 1 to 3 days at 25 to 28 °C water temperature. 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 to 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 again depending on 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. So, small sized catfish for use in fish culture are mostly caught in the wild or bought at the market, from fish dealers or from the local extension service.

7.3 Fry production

Catfish eggs are small and hatch into very small fish larvae. Channel catfish larvae hatch with a very small yolk gland. In this so-called yolk gland, there is some extra food for the fish after hatching and before they will have to search their own food when the yolk in this gland is completely eaten. The fry are reared in nursery troughs until this moment of total yolk absence and the fry have started to feed on natural food sources in the pond. This moment is at about 4 days after hatching and the fish are then transferred to fry ponds. Fry ponds vary in size and are stocked at a density of 50 fish fry per m^2 pond surface and start fertilizing when the Secchi depth is between 25 and 50 cm. Fertilizing might be done by adding animal manure (5 kg cow manure or 3 kg chicken/pig manure per 100 m^2) and/or artificial fertilizers (50 g superphosphate and 100 g urea per 100 m^2). About two weeks after stocking, the algae 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 which is naturally occurring in the pond. Supplementary feeding is recommended since natural food production is not always sufficient.

7.4 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 for 2 years until they have reached market size.
The fingerlings stocked should be of the same size as otherwise cannibalism will occur again as the largest ones will start eating the smallest ones when there is not enough food 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 have usually a depth of 1 to 3 meters. Fingerling 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 in surface.

7.5 Feed requirements

African catfish feed on the natural food sources present in the pond. The addition of fertilizer to catfish ponds is aimed at increasing overall food production in the ponds. Experiences in the past has learned that pond fertilization using animal manure yields a higher fish production than using artificial fertilizers (which are often also expensive).

Appendix 1: 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 m^2 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. With 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 meter at the deep end (figure 25). 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.

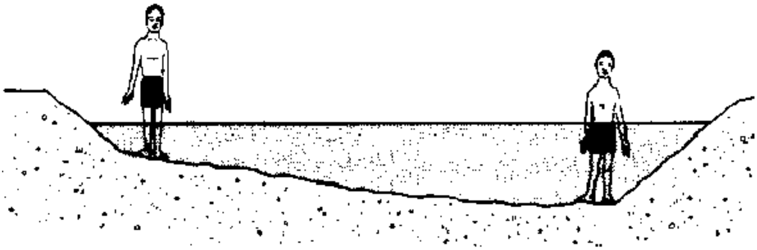

Figure 25: Cross-section of a pond (Murnyak and Murnyak, 1990).

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.

Dugout 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 26).

Figure 26: Dugout 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 27).

Figure 27: 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 (only necessary for contour ponds)
3 Dig the pond and build the dikes
4 Build the inlet and outlet
5 Protect the pond dikes
6 Fertilizing the pond
7 Fence the pond
8 Fill the pond with water
9 Check for problems before stocking fish

1 Prepare the site

First remove trees, bush and rocks and cut the grass in the area planned to build the pond. Then measure and stake out the length and width of the pond (figure 28). The pond dikes will extend several meters above the ground level. In hilly areas, try to measure the slope of the land with a level or stick to find the best suitable site and orientation for the pond.

Figure 28: Staking out the pond (Murnyak and Murnyak, 1990).

Remove the top layer of soil containing roots, leaves, etc. and deposit this outside the pond area (figure 29). But save the topsoil for later use when grass is to be planted on the pond dikes.

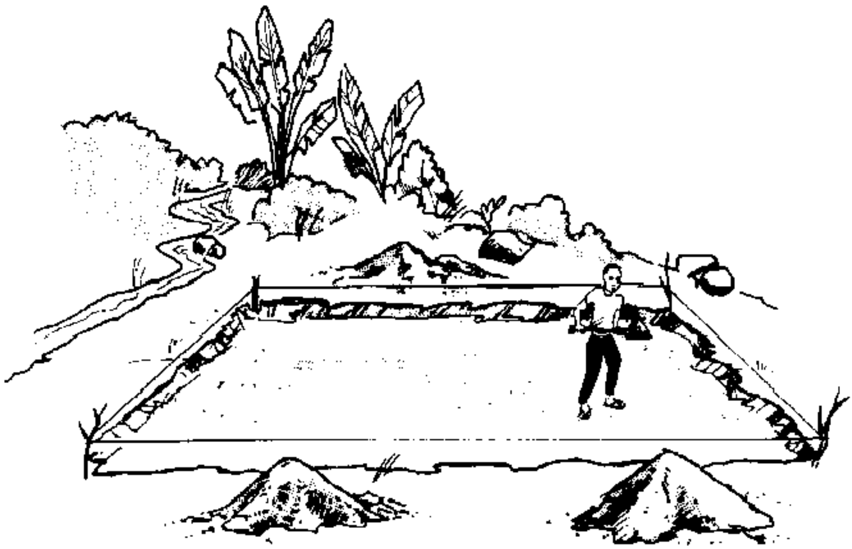

Figure 29: Remove the top soil (Murnyak and Murnyak, 1990).

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 dugout 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 30). Fill the trench with good clay soil. Add several inches of clay at a time and then compact it well. This will provide a strong foundation upon which the pond dikes can be built.

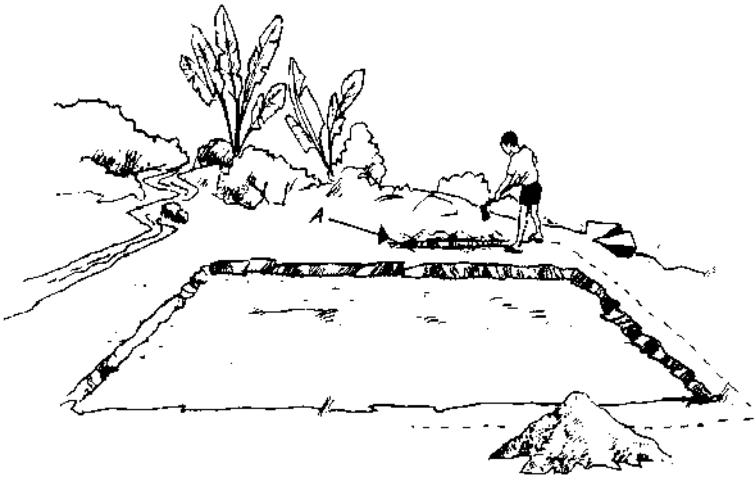

Figure 30: Digging a 'core trench' (A) (Murnyak and Murnyak, 1990).

The drawing in (figure 31A+B) 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 upper drawing (figure 31A) 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 lower drawing (figure 31B) the clay core stops the water from seeping under the newly built dike.

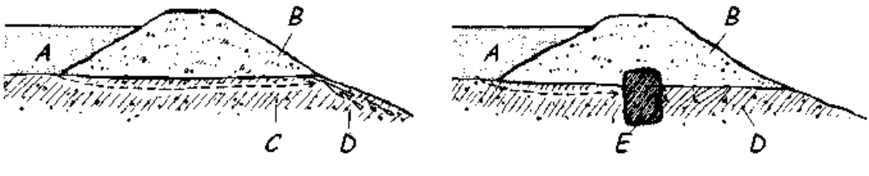

Figure 31: The function of the core (Murnyak and Murnyak, 1990). A: water; B: pond bank; C: ground; D: seepage; E: clay core.

3 Dig the pond and build the dikes

Use the soil which 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.

Compact the soil often while you are building the dike. After adding each 30 cm of loose soil trample it down by foot 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 32). This will make the dam strong.

Figure 32: Compacting the dike (Viveen et al., 1985).

The pond dikes should be about 30 cm above the water level in the pond. If catfish will 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. Then do not add any more soil on top of the dikes.

If you have not yet made the pond deep enough, continue digging but bring the soil outside of the pond area. If you put it on top of the pond dikes they will become too high and unstable, and it will be hard to work around the pond.

The pond dikes should have a gentle slope. This makes them strong and prevents them from undercutting and collapsing into the pond. The most easy 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 meter in height for every 2 meters in length. It is easy to make a triangle as shown in figure 33 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 still too steep!

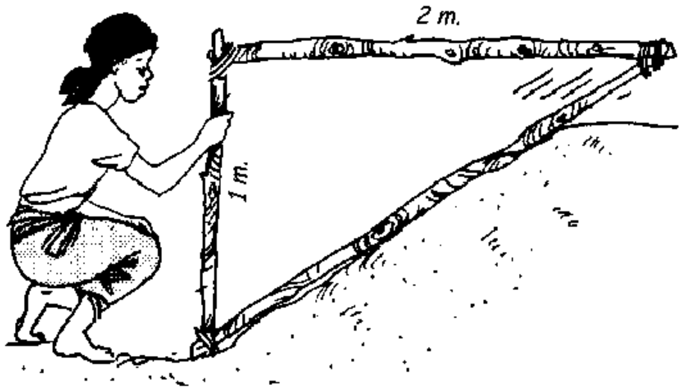

Figure 33: Measuring the slope of the dike (Murnyak and Murnyak, 1990).

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. This makes it easy to use nets when harvesting the fish and they will slide easily over the pond bottom.

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 34 and figure 35).

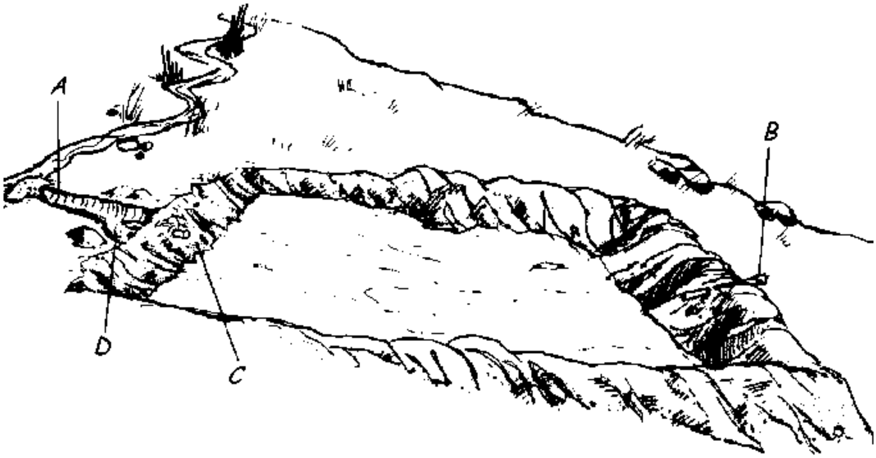

Figure 34: The water inlet and outlet of a pond (Murnyak and Murnyak, 1990). A: inlet canal; B: overflow pipe; C: inlet pipe; D: silt catchment basin.

Figure 35: Cross-section of the water inlet and outlet of a pond (Murnyak and Murnyak, 1990). A: silt catchment basin; B: overflow pipe; C: inlet pipe; D: screen.

The water coming into the pond often contains a lot of soil and silt. This will make the pond very muddy. A silt catchment basin will stop this soil from entering the pond. Widen and deepen 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 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 **outlet** is an overflow pipe which 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 35. If you install it with the intake underwater as shown, this will prevent the screen from clogging with debris that may be floating on the pond surface.
The inlet and outlet 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 things like branches and leaves from entering. The OUTLET 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 36):

- piece of metal with holes punched in it (figure 36A);
- screen or wire mesh (figure 36B);
- a clay pot with holes punched in it (figure 36C);
- a loosely woven grass mat (figure 36D).

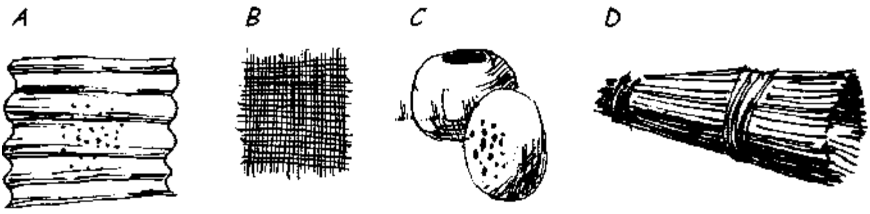

Figure 36: Materials for screens (Murnyak and Murnyak, 1990).

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. Plant grass such as Rhodes grass (*Chloris gavana*) or star grass (*Cynodon dactylon*) on the dikes. 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.

In heavy rains the pond dikes can be destroyed by flooding if too much rainwater and run-off water flow directly into the pond. This problem is most common in contour ponds built on hillsides.

To prevent this, divert 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. Using the dirt from this ditch, build a small ridge below it. The ditch will carry run-off water away from the pond. This will prevent flooding and protect the pond dikes (figure 37).

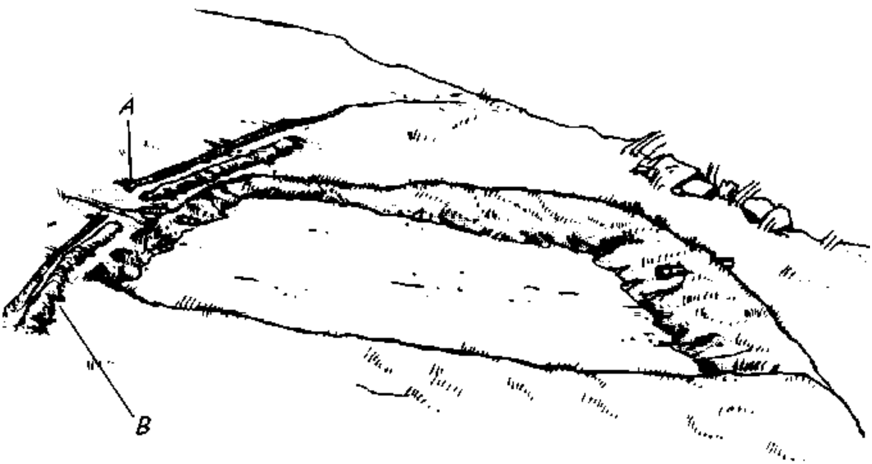

Figure 37: Dike protection by diverting run-off water (Murnyak and Murnyak, 1990). A: ditch; B: dyke.

6 Fertilizing the pond
The natural fish food production in the pond can be increased by applying fertilizer to the pond. Fertilizers which can be used include animal manures, compost or chemical fertilizers. Before filling the pond with water, spread fertilizer on the dry pond bottom. When the pond is filled with water, adding fertilizer to the pond water should take place at regular time intervals (e.g. each day) and preferably in the late morning or early afternoon. This continuous adding of fertilizer will ensure a continuous production of natural fish food. For detailed information on the application rates of different fertilizers see Agrodok no. 21 on 'Integrated fish farming'.

If the soil is acidic, add lime or wood ashes to the pond bottom in addition to fertilizer before filling the pond. Use 10-20 kg of lime or 20-40 kg of wood ashes for each 100 m² of pond bottom (see also the section on water acidity, alkalinity and hardness, Chapter 4).

7 Fence the pond
Putting a fence around the pond will protect children from falling into the pond and it can help keeping 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 where the water will splash on when coming from the inlet pipe. This will keep the 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.

Do not fill the pond too full so it overflows. The overflow pipe is used to get rid of too much rain and run-off water. Water in the pond should not flow through (and thus be stagnant) as water flowing through the pond slows down fish growth by flushing away the naturally produced fish food. The only water added to the pond should be for the water losses due to 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 slowly the pond should start to hold water.

9 Check for problems before stocking the fish

Wait 4-7 days before stocking the pond with fish so the natural food production has enough time to reach a sufficient level for the fish. From this point onwards it is important to maintain the pond in a good state and monitor water quality.

Appendix 2: Overview of widely cultured fish species and their food preferences

Algae-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)
Snake-head species (*Channa* spp. = *Ophiocephalus* spp.)

Omnivores
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 3: Characteristics of liming materials

The most important liming materials to 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 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 that for example 550 g quicklime has the same liming effect as 1000 g agricultural lime.

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

Application of liming materials

Ponds with acidic soils or acidic water and/or ponds with soft water of low alkalinity require an application of lime.
table 6 should serve as a guideline for estimating the required amount of lime, expressed as kg/ha of agricultural lime.

Table 6: The required amount of agricultural lime (kg/ha).

pH pond bottom	Heavy loams or clays	Sandy loam	Sand
5 - 5.5	5400	3600	1800
5.5 – 6	3600	1800	900
6 - 6.5	1800	1800	0

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

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