Chapter 4
Types of fish farms: ponds, cages and tank systems

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

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

A number of factors need to be considered when designing a successful pond –
- The type of soil;
- A reliable source of good-quality water (ideally gravity-fed and gravity drained);
- The size, type, number and shape of ponds;
- The species to be cultured and the stages of its lifecycle.

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

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

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

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

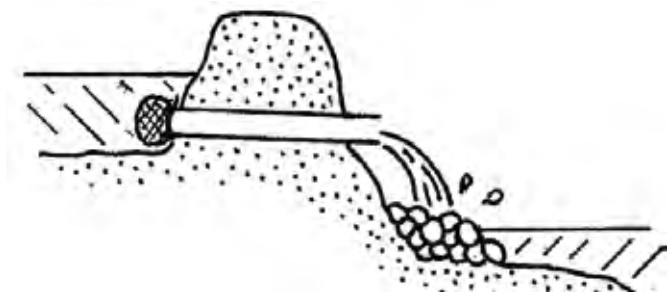
A good way to tell if the soil is right for a fish pond is to wet a handful of soil with just enough water to make a ball in your hand. Then squeeze the soil and if it holds its shape when you open your hand, it will be good for constructing a pond. The more clay in the soil, the better it is for building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

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

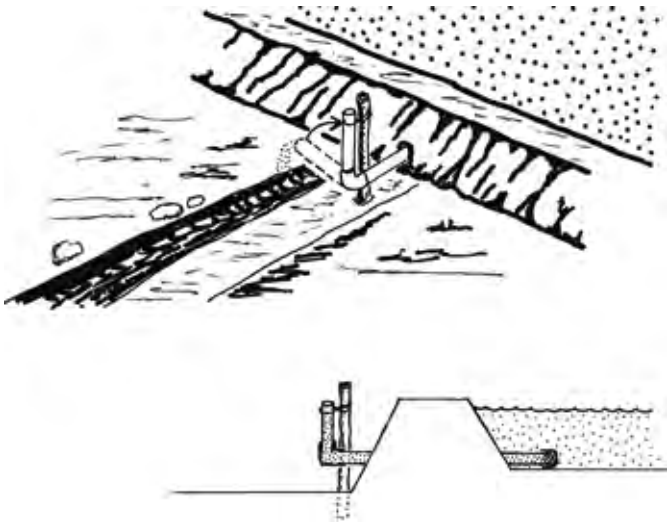
A good indicator of the quality of the soil is whether it can or has been used for growing crops. If crops grow well in that location, the soil will probably be good for the fish pond. If crops were grown before the nutrients were used up, then it will probably still be free of harmful substances.

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

Water availability and quality
There must be sufficient water available to



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



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

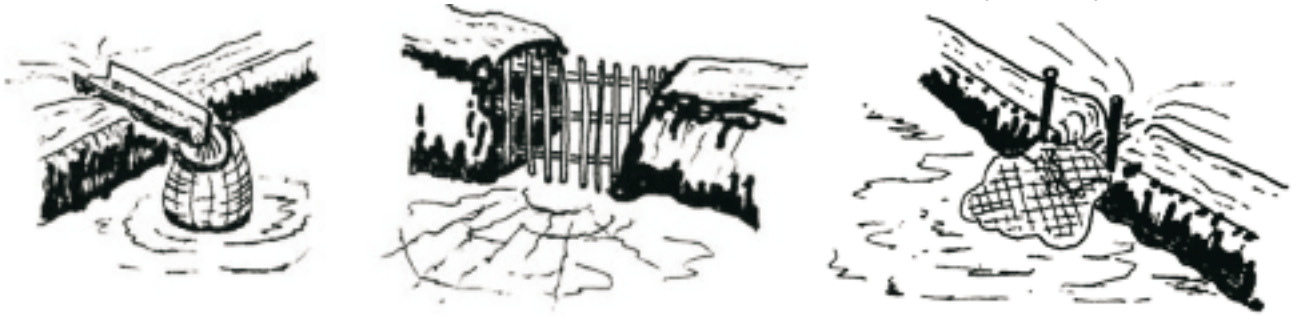
ensure the ponds are always full when holding fish. If water is only available for part of the year, production should be restricted to fall within the same period. As the fish grow they will require more food and in turn will produce more waste. This will change the biological load on the pond and more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

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

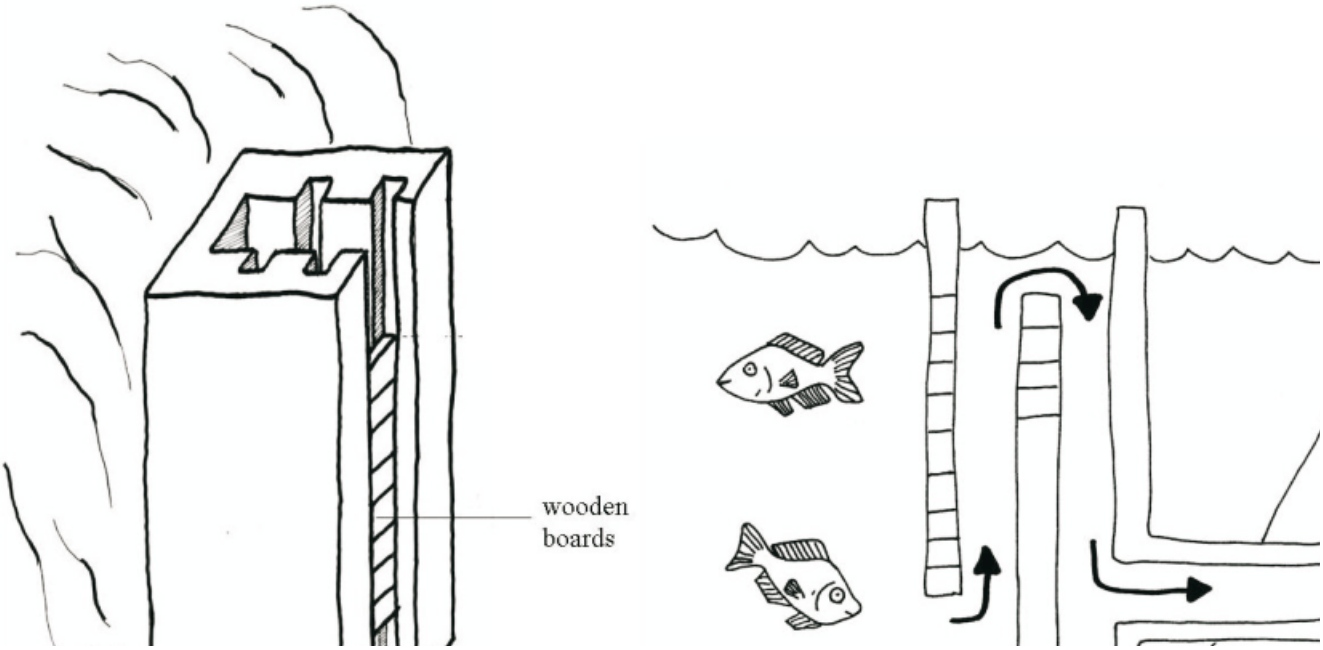
Supplying the water to the ponds is best performed using gravity, meaning the natural movement of water from a high point to a lower point without the need for pumping. The ponds should therefore be designed to have the water supplied from the higher ground and allow for drainage to the lower ground.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

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

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



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



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

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

Pond designs

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

Fish grow bigger in larger ponds even when the stocking densities are the same as in small ponds and the management of the ponds is identical. This means that the weight of fish produced per hectare in a 0.5-ha pond may be almost double than that produced in a 0.1-ha pond. The reason for this is that large ponds have a larger surface area and are more often subjected to wind action, which results in more oxygen entering the water and the water being mixed better.

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

INFO BOX: HOW TO CALCULATE POND AREA IN HECTARES

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

Example: 50 x 40 paces = 2 000 m^2.
2 000 divided by 10 000 = 0.2 hectare

Advantages of small and large ponds:

Small ponds	Easier to net and harvest fish; Easier to manage, maintain and treat for disease; Not eroded by the wind easily.
Large ponds	Cost less to build per hectare of water; Better production possible per hectare; More stable – less prone to temperature fluctuations; Have more oxygen available for fish.

INFO BOX: EXAMPLE OF HIGHER GROWTH RATES USING LARGER PONDS

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

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

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

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

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

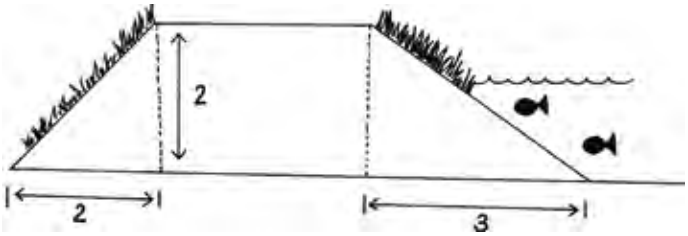
- allows for light to penetrate the water thereby allowing the growth of plants and algae;
- reduces temperature fluctuations; and
- reduces the chances of thermal and oxygen layering of the water.

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

Stratification (layering) occurs when the water is too deep and mixing cannot occur properly. This results in warm water on the top (heated by the sun) and cold water near the bottom. The levels of oxygen may also be high near the top and low (or even zero) near the bottom. It is obvious that low or zero oxygen levels are not good for the fish in the pond as many species prefer to live near the bottom and so this may result in large fish kills. Another problem that may occur when the oxygen level drops too low is that the bottom of the pond may start to rot. As it rots, it will release hydrogen sulfide (H_2S) (which smells like rotten eggs), poisoning the water above it, thereby killing all the fish. Therefore, it is not a good idea to build ponds deeper than 1.8 m unless sufficient mixing of the water through aerators or uplift pipes is used.

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

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



Suggested ratios of pond walls.

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

The pond should be built to suit the requirements of the species to be cultured. For example, shallow ponds are better for grass carp as the growth of plants on the bottom will only occur if the light can reach the bottom of the pond. If ponds are used for holding cages of tilapia broodstock, they should also be shallow enough to allow the breeding cages to be easily staked into the soil. Ponds used for the later stages of carp or tilapia grow-out can be deeper (max 1.8 m) as this increases the amount of water available to grow fish, thereby increasing production.

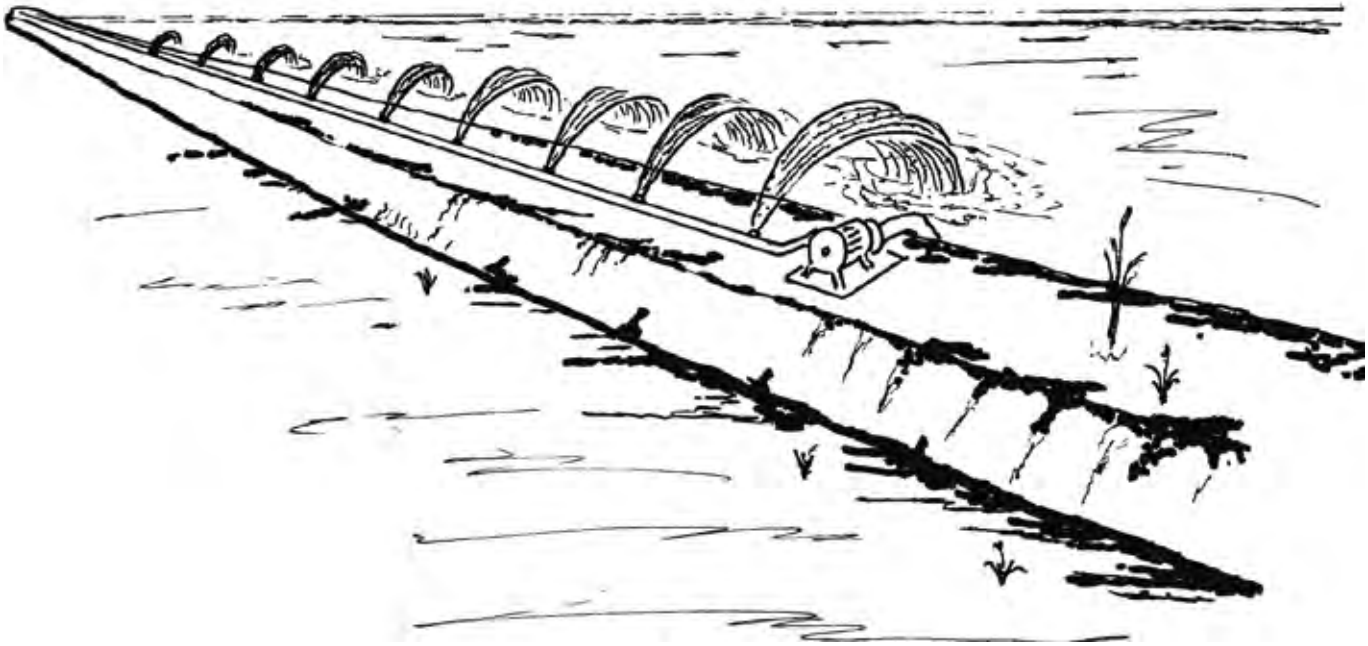
A channel through the middle of the pond can help with draining the pond and harvesting fish.

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

Predator control

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

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



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

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

Pond construction by cooperatives

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

Tanks and raceways

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

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

Tanks and raceways are typically constructed from either brick or concrete and are long-lasting and durable. More recently, circular tanks are made of various types of plastic, often supported by a steel-mesh galvanized frame. Some of these tanks are made for domestic water storage and are black in colour. This makes the fish impossible to see and thus is not desirable, and these tanks are often too deep. Many of the pale blue-coloured tanks contain a fungicide in the vinyl to prevent algae and mould, and this is toxic to the fish. Plastic tanks should ideally be a pale colour, and not deeper than 1.2 m.

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

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

Cages

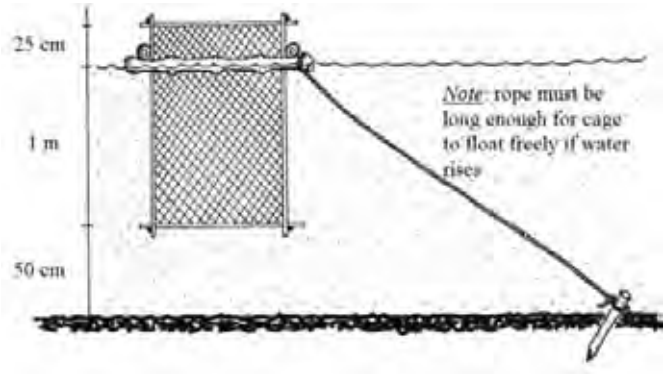
Cages can either float in the water or be staked into the ground of the pond (in shallow areas of water). They are usually used between tank and pond culture as they make use of the pond water while still maintaining the control of a small area. There is therefore no control of the water quality when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

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

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

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

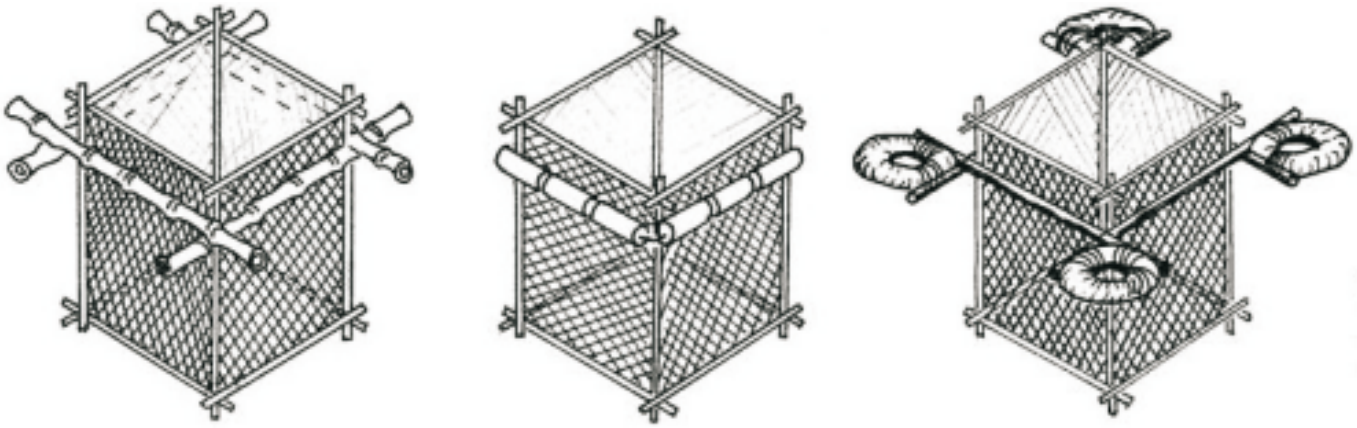
Cages used in large open waters such as in dams, lakes or the sea must be strong enough to handle rough weather and be easy to access, clean and harvest from. Floating cages should be secured to the bottom or side of the pond to prevent them from drifting away in rough weather. Predators (e.g. otters,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



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

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

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



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