Agrodok 21

On-farm fish culture

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Foreword

This Agrodok is about integrating fish culture on the farm, an important form of small-scale sustainable agriculture in tropical areas. The system can be built up in stages until an optimally integrated production system is achieved, based on the inputs available on the farm. The information in this book is designed to help with the first steps, and has been made as practical as possible. Please bear in mind, however, that production figures given are dependent on local conditions, and therefore can only give an indication of the possibilities.

The illustrations of water plants in this Agrodok were made available by the Information Office of the University of Florida, IFAS, Center for Aquatic Plants, Gainesville, USA. The other illustrations were adapted by the Agromisa Illustration Group. We would like to thank Dr A.A. van Dam and Dr M.C.J. Verdegem from the Department of Fish Culture and Fisheries at the Wageningen Agricultural University for their guidance.

We welcome additional information concerning the contents of this book.

Wageningen, January 1997

W.G. van de Poll
Co-ordinating editor

Contents

1 Introduction

Advantages of integrating fish farming

This Agrodok describes how you can integrate fish culture with crop and animal production on a farm. This book follows on from Agrodok No.15 'Small-scale freshwater fish farming', which describes in detail the basic principles of raising fish and building a fish pond.

Once agricultural activities on a farm have been diversified integration can be the next step. A farmer can diversify by raising different kinds of crops or animals. The different activities become integrated when the waste products from one activity are used for the production of another crop or animal. For example, animal dung can be used to improve the fertility of the soil, which will increase plant growth. Animal dung can also be used as a fertilizer in a fish pond to increase fish production. By using these methods production on an integrated farm will be higher than on a farm where activities are carried out separately. Production costs can be kept low by using the by- products (e.g. stalks and leaves) from the different activities on the farm for fish culture. These by-products form an inexpensive way of making fish feed, which is cheaper than having to buy feed.

The advantages of integrated farming include:

- Minimizing of waste products, which improves the local environment.
- Decreased need for artificial fertilizers, which can increase profits by decreased production costs.
- Increased fish and vegetable production, which can increase household consumption or income.
- Decreased dependence on production inputs from outside the farm, which increases the stability of the farm.
- Increased productivity and efficiency on the farm.

The most important of the above advantages is the decrease in waste products. Improved soil structure, through the use of pond bottom silt in agriculture as fertilizer, means that water is better retained and less erosion takes place. These long-term advantages outweigh any others which lead only to an increase in fish production.

The advantages of integrated fish culture mentioned here give a general indication of what can be achieved. Production methods and yields depend on local conditions. For example, farmers in Malawi, Africa adjust their integrated plant-fish culture system each year according to the amount of rainfall. In dry years the farmers grow vegetables on the pond bottom as there is not enough water to raise fish. The vegetables grow well on the fertile soil at the bottom of the pond, and suffer less from the drought.

Both plant and animal by-products can be used as fertilizer for a pond on an integrated fish farm. Applying natural fertilizer increases the amount of food available in the pond, so that the fish need less direct feeding. The basic principles of integrated fish culture are outlined in Chapter 2.

Some fish can be fed directly with plant waste. For other sorts the waste must first be made into compost. The compost is then used as a fertilizer in the pond, which increases the amount of natural food available, in turn resulting in an increase in fish production. Chapter 3 describes how plant waste can be used in a fish pond.

Chapter 4 describes a special system of integrated plant-fish production: integrated rice-fish production. This production system is used commonly in Asia and can be practiced both extensively and intensively according to the local situation.

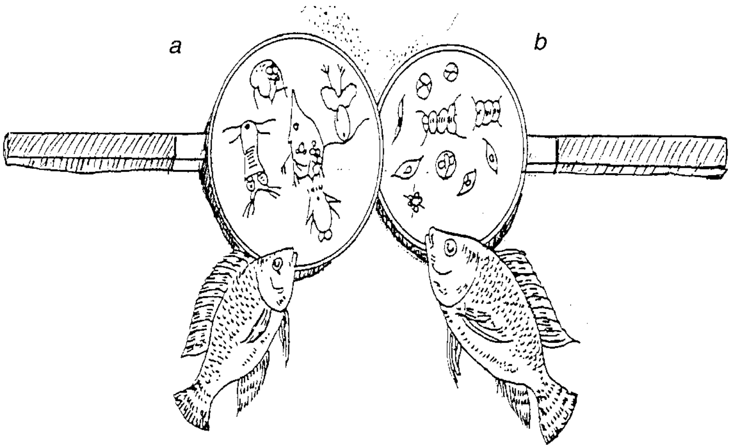
Animal dung can be used as fish food for some fish species, or alternatively as fertilizer for the fish pond. There are various systems in which fish production can be integrated with other forms of animal production e.g. ducks or pigs. Whether fish production can be integrated with other forms of production depends on the local production and marketing conditions. The soil must be suitable for making a fish pond, and suitable fish species must be available. Chapter 5 describes the use of animal dung in fish production.

In this book the common names are used of fish and plant species. In Appendix 6 is a list given of the Latin names.

2 Principles of integrated fish culture

2.1 The biology of a fish pond

Fish are not the only organisms living in the water of a pond. Food for the fish also grows naturally in a pond. The naturally occurring food sources include very small plants (algae or phytoplankton) and very small animals (zooplankton) (figure 1). Both these sorts are too small to see with the naked eye. If a large amount of algae is present, the water will have a green colour.



a: Zoo plancton; b: Algae

Figure 1: Naturally occurring fish food seen through a magnifying glass (Edwards & Kaewpaitoon, 1984).

Water plants are larger plants, which can be seen with the naked eye, and grow in the fish pond all the year round. Some grow on the bottom of the pond, some in the water and others float on the surface of the pond. Some fish species eat water plants.

The water in a pond must be of good quality so that the fish will be healthy and grow well. In order to grow, fish need oxygen. This is produced mainly by the algae floating in the water, which makes the water green in colour. Climate is important as it determines the temperature of the water in the pond. The higher the water temperature the faster the algae and zooplankton grow. However, most tropical algae, zooplankton and fish species grow fastest at a water temperature between 25 and 30°C.

2.2 Water quality

The two most important factors which determine the quality of the water are the temperature of the water and the amount of oxygen dissolved in the water. The plants in the pond (especially algae) produce oxygen with the help of sunlight, some of this oxygen they use themselves. The more sunlight the pond receives the higher the oxygen production.

When it is dark no oxygen is produced by plants as there is no sunlight. As oxygen continues to be used by all living organisms in the pond water, however, the amount of oxygen in the water decreases during the night. In the early morning the amount of oxygen in the water is at its lowest level, as fish, algae and zooplankton have been using oxygen all night, and no oxygen production has taken place.

The oxygen content of the water is usually highest at the end of the afternoon, as oxygen is produced throughout daylight hours.

Climate also influences the oxygen content of the water. The amount of oxygen in the water depends on the temperature of the water. Less oxygen can dissolve in warm water than in cold water. However, fish need more oxygen in warm water as they are more active. The optimal temperature varies depending on the fish species but the average is between 25 and 30°C.

Algae produce less oxygen in cloudy weather, as less sunlight falls on the water. Windy conditions lead to a rise in oxygen content as more air mixes with the water.

Fertilizer application has a large influence on the oxygen content and the living conditions of the fish in a pond. Too much fertilizer can lead to an oxygen shortage which will result in fish dying.
Good fertilizer practice is very important. See the following paragraph.

2.3 Management of fertilizer application

Good fertilizer practice is important to maintain water quality and to maintain a good amount of naturally occurring fish food available in the water. The amount of fertilizer added to the water depends on the number of fish in the pond. If too little fertilizer is put in less natural food will grow and less fish will be produced. Putting in too much fertilizer or fertilizing irregularly can lead to oxygen shortage and fish will die.
If a pond is fertilized regularly, the amount of fertilizer it can absorb will increase over time. More fish will be produced without a decrease in oxygen content occurring. Fertilizer should be applied at least once a week, and it is best to do this every day. A well managed and fertilized pond can sustain 3 kg fish per 100 m² per day. In practice this amount is usually lower because there is not enough water or there are too few fish. Sometimes the weather conditions are not favourable, and time is also needed to harvest the fish and to drain the pond.
Good fertilizer is animal dung or composted plant material. It is important to spread the fertilizer evenly over the pond. If too much is put in one place it will decompose without bacteria. If this happens, then little natural food will be produced in the pond. One way of ensuring that the fertilizer is evenly spread is house the animals directly above or in the pond. For example, ducks can swim in the pond. It is easier to spread fertilizer from animals on the banks of the pond by mixing it with water first. Chapter 5 gives information on how many animals can be kept per pond.
We mentioned above that spreading fertilizer influences the oxygen content of the pond water. As the amount of oxygen in the water goes up and down over a day the time at which fertilizer is spread is also important. It is best to spread fertilizer over a pond when oxygen pro-

duction is at its highest. The end of the morning is therefore the best time to add fertilizer to the pond.

The organisms in the pond water which break down plant and animal waste need oxygen. The process of breaking down the waste products releases many nutrients, which are used by the algae to grow. The algae in their turn produce oxygen.
However, if there are too many algae in a pond (water colour is dark green) the algae use too much oxygen during the night so the fish and zooplankton will die due to a lack of oxygen in the early morning. If too much fertilizer is spread, too much oxygen may be used by the waste processors to break down the fertilizer. This will also lead to an oxygen shortage for the fish, and they may die.
To sum up, there is an optimum amount of fertilizer which a pond requires whereby the algae produce enough oxygen and whereby there are no fish gasping at the surface for oxygen at sunrise (figure 2). Other signs of too little oxygen in the water include many air bubbles rising to the surface, brown or grey water colour and a strong unpleasant smell to the water.
When the correct amount of fertilizer is added the water turns green (mid green, between light and dark green) as a result of the algae. It is easy to check whether the pond is receiving the right amount of fertilizer by putting your arm in the water up to the elbow (figure 3).

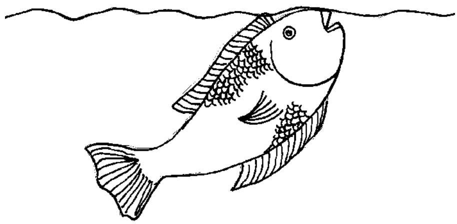
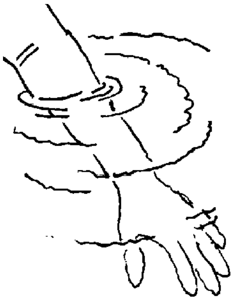


Figure 2: When a pond receives too much fertilizer you will often see fish gasping for oxygen at the surface in the early morning.

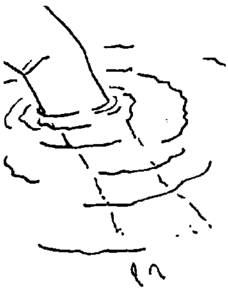
2.4 Fertilizing the bottom of the pond

Fertilizer can be applied to the bottom of the pond before filling the pond with water. Tiny plant and animal organisms in the soil break down the fertilizer. When the pond is filled, the nutrients available from the fertilizer are taken up by the water. These nutrients form food for the algae and zooplankton, which in turn are eaten by the fish.



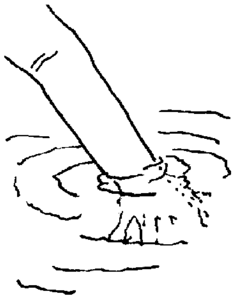
A: Insufficient fertilizer

If you can still see your arm and even your hand then there is not enough algae present in the pond, so it needs more fertilizer.



B: Correct amount of fertilizer

If you can see about half of your arm below the elbow then there is enough natural fish food available and the pond is receiving the right amount of fertilizer.



C: Too much fertilizer

If you can hardly see your arm at all in the water then there are too many algae in the water. If this is the case then you should immediately stop fertilizing the pond until the water turns a lighter colour (as in B).
It is also a good idea to add fresh clean water to the pond, if possible, and to aerate the water. You can do this by stirring the water with a branch or by using a paddle-wheel.

Figure 3: Checking the amount of fertilizer using the lower arm.

Plant material can also be used as fertilizer in or on the pond bottom when preparing a pond for fish. Barnyard grass is a good example. Sow between 7.5 and 10 kg of seed per 100 m^2 on the pond bottom. After 45-60 days growth fill the pond with water and let the grass rot for 7-10 days. Nutrients are then released upon which the algae and zooplankton can feed. This method is used a lot in nursery ponds for small fish whose main source of food is zooplankton. After the fish have been harvested, and before the pond is refilled, the bottom will not need fertilizing if the sludge layer is not removed. This sludge is made up of organic material from fish manure and uneaten fish food which has sunk to the bottom of the pond.

2.5 Plant by-products and animal manure

Plant material (by-products and waste) can be used directly as fish food. If you are not raising plant eating fish it is better to compost plant material first and then use it as fertilizer. Another alternative is to feed the plant material to animals and then use the animal manure as fertilizer for the fish pond. It is often difficult to determine where the border lies between feed and fertilizer as many agricultural by-products can be used for both.

Animal manure can be used as fertilizer and also directly as fish food for some fish species such as the silver striped Catfish and Nile Tilapia. Poultry manure makes better fish food than other species of animal manure because it contains a large amount of bacteria. Most animal manure is used indirectly by fish, as algae first break down the manure for their own growth. Zooplankton feeds on algae, and fish eat both zooplankton and algae. However, not all fish species eat algae and/or zooplankton (Appendix 1).

2.6 Choice of fish species

Because different species of fish eat different types of food it is possible to raise a number of different fish species in one pond. This makes better use of the different food sources in the pond. The most common fish species used and their food preferences are listed in Appendix 1. It is recommended that omnivorous fish species (fish which eat both animal and plant material) are raised as they can live on a variety of food sources. It is not a good idea to raise large numbers of meat eating fish (predators) as these are likely to eat the other fish.

The way in which the pond is fertilized also determines the fish species that can be raised. Alternatively, the fish species present will determine how the pond is fertilized. Snakehead and catfish can obtain oxygen from the air as well as from the water and are therefore less sensitive to changes in the oxygen content of the water. Tilapia cannot obtain oxygen from the air, but they are less sensitive to oxygen shortages in the water than other fish species (Appendix 1). The amount of fertilizer that can be used will depend on how sensitive the fish are to oxygen shortages.

2.7 Food supplements for fish

Yields can be increased by giving the fish extra food. In ponds which are well fertilized the fish will usually receive more than enough protein. However, they may not obtain sufficient energy, which can limit production. By feeding the fish grain which is rich in energy you can supplement this deficiency. The by-products from grain production, such as wheat and rice bran, or broken rice, make excellent food supplements for fish ponds which are fertilized using animal dung. In Cambodia the leaves from the ipil-ipil tree, Sesbania tree and kapok tree, together with tender leaves from water hyacinth and morning glory plants are cooked with rice husks and used as fish food. Termites are also a good source of protein-rich food. The termites are extracted from their mounds by sieving the earth. The soil left over is good for producing earthworms (Chapter 4, section: "Other integrated fish-rice culture systems").

3 Plant material for fish food and fertilizer

3.1 Introduction

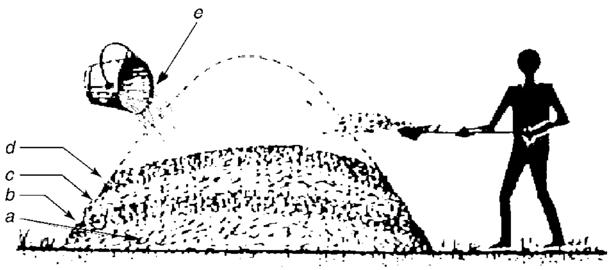
Plant material can be used directly as food for plant eating fish. Plant waste material can be used as well as crops that cannot be sold. Sometimes it is worthwhile growing certain crops specially for the fish. Generally speaking the type of plant material available will determine how it can best be used for the fish: as direct food or as fertilizer through converting it into compost or animal manure. If (water)plants or plant by-products are only available in small quantities or irregularly then it is best to use them directly as fish food in the pond. If you have a large amount of plant material available and the whole fish raising period is long it is better to compost the plant material or feed it to farmyard animals and use their manure for the pond.

3.2 Composting

Composting plant material has a number of advantages. Where there is a large amount of fresh material available transport costs are considerably reduced by making compost first. Composted fish food is also more stable, more concentrated, of better quality and contains less disease organisms.
Not all plant material is suitable for use as direct fish food. It is better to make compost from the less suitable types. Generally speaking it is better to compost plant material and use it as fertilizer than as direct fish food. Compost used as fertilizer will have most effect if it is evenly spread over the pond.
Detailed information on how to make and use compost can be found in Agrodok No. 8: 'The preparation and use of compost'.

Composting is done in the corner of a pond in some places in Africa. This method is less effective than making compost on land and after that spreading it over the whole pond. Fish production is higher using

the latter method. This is probably because the nutrients from a compost heap in the corner of a pond are not spread well throughout the pond.
Carry out composting of plant and animal waste on land as follows:
Start the heap by making a foundation of coarse plant material such as twigs or sugar cane stalks (figure 4). The outside air can easily flow in under the heap and any excess water flows away more quickly. Decomposition is easier if the material is put on in layers; layers of easily decomposable material alternated with material more difficult to decompose.
Alternate layers of plant material, of manure and of mud or pond sludge. Add water to the compost heap to speed up the rotting. Driving a number of bamboo sticks into the compost heap will improve the aeration, thus raising the temperature at which decomposition takes place. The compost is usually ready for use after 6 to 8 weeks, although it very much depends on the material that is being composted. The compost is ready to used when it has become crumbly and looks like good dark soil.



a: coarse plant material
b: fine plant material
c: pond sludge or mud
d: animal manure
Layers of plant material etc. are heaped on top of these layers.
e: adding water

Figure 4: Example of how to make a compost heap.

Fish food made from composted water hyacinth (figure 5), dung and rice straw fed to Nile tilapia can give a production level of 360 kg per 100 m². The following recipe is used for the compost:

Dry 1,000 kg of water hyacinth in the sun until the weight is reduced to approximately 400 kg. Then mix the dried water hyacinth well and spread it over a layer of (rice) straw measuring 3 x 3 m. Make the compost heap about one metre high and drive bamboo sticks through it so that air can reach the inside.

Mix the compost heap every two weeks by bringing the material at the bottom up to the top and the material at the top down to the bottom. After two months the compost will be ready to spread over the pond.

To harvest 25 kg Nile tilapia from a pond of about 100 m² after six months, you need to feed them 2 kg of compost every day. For these quantities you will need four compost heaps of the size described above.

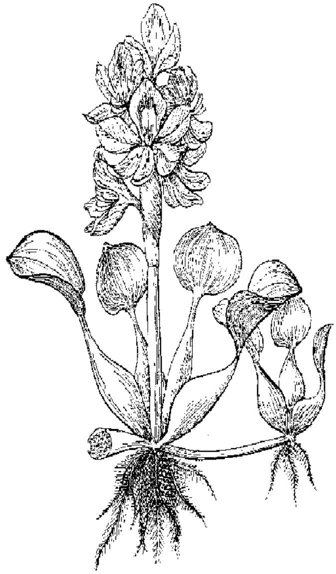


Figure 5: Water hyacinth.

3.3 Land plants

Waste or by-products from land plant cultivation can be used as fish food for plant-eating (herbivorous) fish species such as grass carp and omnivorous fish species including most tilapia, catfish and common carp species (Appendix 1). If the fish cannot eat the plant waste directly it can be used as fertilizer by composting it first (Chapter 3, section: "Composting"). Generally speaking only the young, fresh and soft parts of the plant (such as leaves and stems) are suitable for feeding the fish directly. It is also a good idea to make these parts of the plant as small as possible so that the fish can eat the material more easily. Crop by-products are often more nutritious than the harvested products. By-products such as leaves, stems and shoots often contain more minerals and proteins. Crops which can be used as fish food are often grown close to fish ponds or on the dykes in order to keep the transport distance short. A fish pond can also have advantages for crop production. The land around the pond is often more fertile because it is wetter and can be easily irrigated. After the fish harvest the sludge can be used as fertilizer on the crops. If you want to raise fish all year round it is important to grow some perennial crops. These can then be used for fish food in the dry season.

In China, land plants used as fish food are often grown on the dykes and the slopes between the fish ponds. These plants not only provide food for the fish but they also help to strengthen the dykes. Appendix 3 provides a list of grasses which are often used for this purpose. Fish species which eat grass include grass carp (20 fish weighing 7 g each), catla, rohu, mrigal, silver and common carp (4 fish of each weighing 7 g each). These figures are based on ponds which are 100 m^2 in area and 2 m deep. The fish can be fed with napier grass for example. When grass can be seen floating on the surface after feeding, the fish have eaten enough. Catla, silver and common carp grow quickest and will reach a weight of 1 kg after about six months. They are then ready to harvest. After harvesting these fast growers, young fish can be put out in the pond as there is a continuous supply of napier grass. Fish harvests of 40 to 60 kg can be obtained without any extra feeding or fertilizing. An area twice the size of the fish pond is needed to grow enough napier grass to feed the fish.

Appendix 4 provides a list of vegetable crops which are often grown for fish food on fish pond dykes.

Another successful Chinese fish production system integrates fish, mulberry and silk cultivation. Mulberry trees are grown on the dykes between the fish ponds, and produce about 370 kg of leaves per 100 m^2 of dyke. The leaves are used as feed for the silkworms. 370 kg of leaves produce 27 kg of silkworm cocoons. These cocoons in turn produce 185 kg of silkworm manure and skins (after the silkworms have shed their skins). The silkworm manure can be used directly as fish food and fertilizer for the fish pond. The cocoons contain the (butterfly) pupa which have a food conversion of 2 (Chapter 3, section:

"Nutritional value of plants", for a description of the term food conversion) when this is used directly as fish food. Good yields can be obtained by using fish food and fertilizer from silkworm production. figure 6 gives the food conversions for the different products from the integrated fish-mulberry-silk system. Polyculture is often practised, where different fish species are raised together. Fish species used include grass carp (195 fish weighing 50 g per 1,000 m²), bighead carp (45 fish weighing 50 g per 1,000 m²), common carp (75 fish weighing 25 g per 1,000 m²) and crucian carp, 195 fish weighing 10 g per 1,000 m²). The fish ponds used vary in area from 5,000 to 10,000 m² and are usually between 2 and 2.5 metres deep. Fish yields of 270 kg per 1,000 m² are obtained without using extra feed or fertilizer.

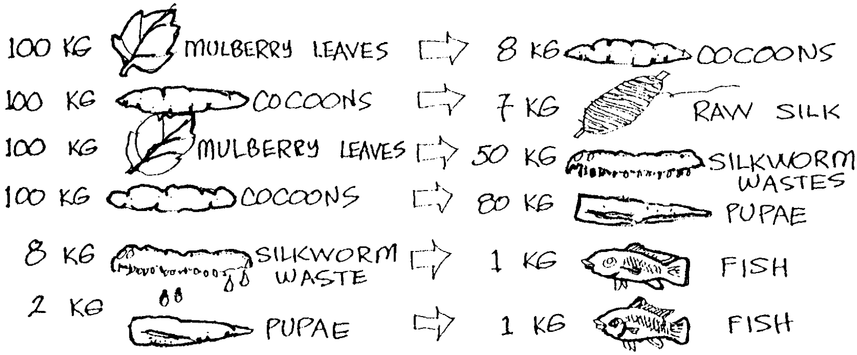


Figure 6: Food conversions for products in an integrated fish-mulberry-silk system.

3.4 Water plants

Water plants can be used directly as fish food for plant eating fish such as grass carp. Plant eaters prefer soft water plants. Water plants are also a good source of food for some omnivorous fish species. For example, silver barb grows quickest when fed on duckweed. Cassava leaves and morning glory leaves (figure 7) also produce good growth in silver barb. Bigger fish are better able to consume water plants as they have larger mouths. For this reason it is worthwhile chopping the plants up before feeding them to the fish. Water plants can also be composted and used to fertilize the pond.

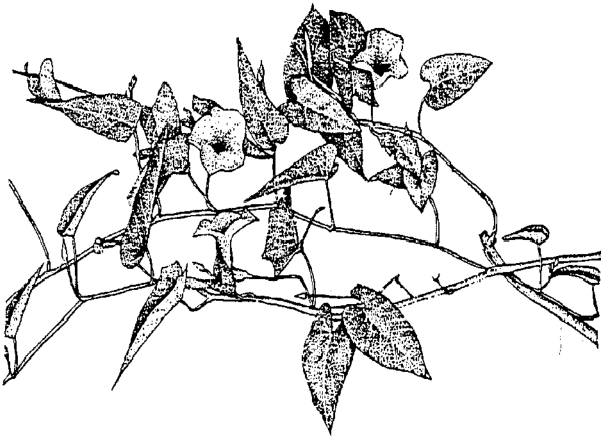


Figure 7: Morning glory in bloom (Halwart, 1995).

Most water plants are less suitable than land plants as fish feed as they contain a large amount of water. This means that a far larger amount of water plant material than land plant material is needed to enable the fish to grow to the same weight. However, water plants contain good nutrients and the quality of water plants is less dependent on the season. Water plants grown in water which contains a lot of nutrients produce better quality fish food than plants from water which has not been treated with fertilizer. In China many water plants are grown in the irrigation and drainage ditches around the fish ponds.

Appendix 2 provides a list of commonly grown water plants which can be used for fish food. We strongly advise against growing alligator weed (figure 8) and water hyacinth as these plants can create serious problems. They grow very fast and they can cover the whole water surface within a very short time. This destroys the conditions which other plants and animals need in order to survive. In addition, these plants make it very difficult to carry out activities in or on the water. It is also much cheaper to harvest these plants where they grow naturally.

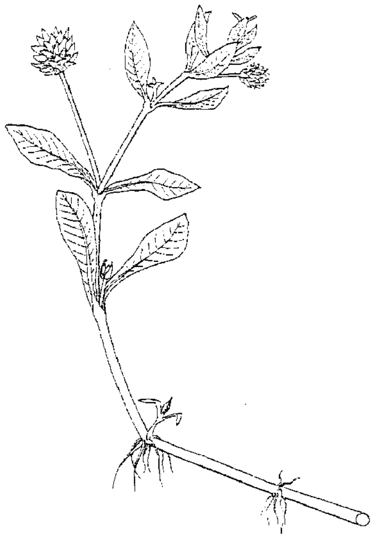


Figure 8: Alligator weed.

Duckweed

There are different types of duckweed: *Lemna* species, *Wolffia* species and *Spirodela* species (figure 9). Duckweed is valuable fish food and floats on the surface of the water. It grows fast: the number of plants can double within two days. Float bamboo poles on the surface of the water in order to prevent the weed from being blown by the wind into a corner of the pond. These divide the pond into sections about 3 x 3 metres. Fruit trees and vegetables are often planted on the dykes of the pond in order to protect the duckweed from strong sunlight. These trees also form an extra source of income. The duckweed in the pond must be harvested every week so that the faster growing algae does not take over. It should be harvested in such a way that a small amount is left in the pond for the next growing period. Duckweed production decreases considerably when the temperature falls to below 15 to 20°C. At these lower temperatures water fern often takes over.

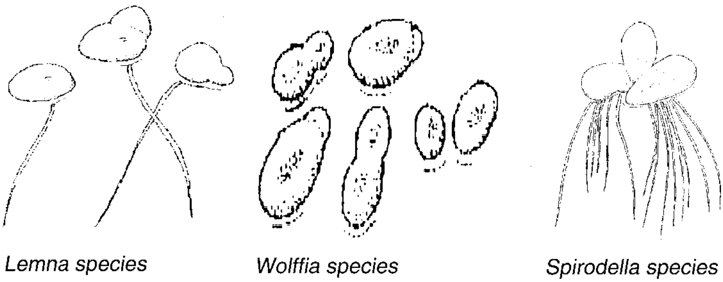


Figure 9: Different types of duckweed.

Duckweed is suitable food for various fish species. A pond one metre deep used to raise tilapia fed on duckweed will usually contain 2 to 3 fish per square metre. Duckweed can also be used where several fish are raised together. In carp polyculture three species of young fish with different eating habits are placed in a pond 1.50 to 2.50 m deep. Grass carp (50 fish per 100 m²) or common carp (25 fish per 100 m²) eat duckweed from the surface. Silver carp (50 per 100 m²) or rohu carp (37 per 100 m²) eat algae in the pond. Catla carp (37 per 100 m²) filter zooplankton from the water. The fourth searches for food mainly at the bottom of the pond: mrigal carp (50 per 100 m²) and common carp (25 per 100 m²). In a pond that is set up in this way nearly all available food sources are used by the different carp species. In a period of 18 months it is possible to obtain 150 kg fish per square metre.

Water chestnut

The water chestnut is a common 'cash crop' in India (figure 10). It is also possible to integrate production of this water plant with raising common carp. The leaves and dead material at the bottom of the pond form food for the carp. The young water chestnut plants are planted out in May or June on the bottom of the pond.

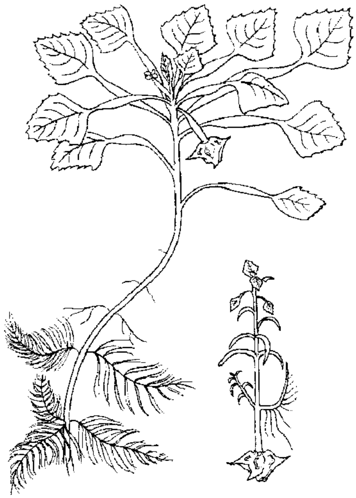


Figure 10: Water chestnut.

They grow in the mud at the bottom of the pond. The pond is stocked at a rate of twenty common carp weighing 50 g per 100 m² in September or October. The water chestnut fruits ripen during the winter and are harvested in the period from November to January. A yield of 75 to 100 kg of fruit per 100 m² can be obtained. In April and May the fish weighing 0.75 to 1 kg can be harvested, which should yield a total production of 10 to 12.5 kg per 100 m² of pond.

Water hyacinth

Water hyacinth (figure 5) can also be used as fish food. In order to harvest 25 kg of tilapia each year from a fish pond of 100 m^2, the fish need to be fed 10 kg of fresh water hyacinth daily. The best way of using fresh water hyacinth as food is to chop it up into pieces of approximately 5 cm. Better still is to make compost from water hyacinth (see Chapter 3, section "Composting"). Then only 2 kg per day is needed.

Water hyacinth is a weed which grows rampantly in the wild, therefore it is not recommended that you cultivate it. A water surface area approximately half the size of the fish pond will yield enough fish food for Chinese carp polyculture. This polyculture system consists of grass carp (220 fish of 500 g per 1,000 m^2), silver carp (320 fish of 50 g per 1,000 m^2), 'bighead' carp (80 fish of 50 g per 1,000 m^2) and common carp (240 fish of 50 g per 1,000 m^2). The ponds where these carps are raised vary in surface area from 5,000 to 10,000 m^2 and in depth from 2 to 2.5 m. Yields of 600 kg per 1,000 m^2 can be obtained without using extra feed or fertilizer.

Water fern

The water fern lives together with a blue green algae. It is not used often as fish food as it has a low nutritional value and contains less protein than duckweed. Azolla dies and turns red when the water temperature rises above 20°C. Where rice and fish are raised together Azolla can be used as 'green manure' by mixing it with the soil before the young rice plants are transplanted. The water fern breaks down in the soil, releasing nutrients which can be taken up by the young rice plants.

3.5 Nutritional value of plants

Most plants used as fish food have a food conversion of 30 to 40. This means that a fish must eat 30 to 40 kg of the food in order to increase its weight by 1 kg. If you know the food conversion value and how much plant material you need then you can work out how much land you need to grow enough food to obtain the desired amount of fish.

Example: To provide enough protein for a family of five you need to produce 200 kg of fish per year. This figure assumes that one third of the family's protein requirements are obtained from animal sources. If the fish are fed with napier grass (food conversion 30) then you need 200 x 30 = 6,000 kg of grass. Appendix 3 gives the production figures for grasses: for napier grass this is 300,000 kg per hectare per year (1 hectare = 10,000 m^2). In order to harvest 200 kg of fish you will need 6,00/300,000 = 0.02 hectares which is 200 m^2 of land devoted to napier grass. We must add, however, that we do not advise the cultivation of crops especially for fish food. It is better to use the by-products from crops already grown on the farm for fish production, or to grow crops which provide food for people or other animals and by-products for fish food.

4 Integrated rice and fish culture

4.1 Introduction

Raising fish in a rice field (integrated rice-fish culture) usually results in a lower fish yield than in a fish pond, but rice is also produced. There are a number of ways to integrate rice and fish production. If wild fish are present they can be caught from the rice fields. If there is few wild fish present young fish can be placed in the rice fields and raised in them. A combination of both can also be used by placing large enough fish (longer than 5 cm) in the rice field, and feeding the fish regularly. By feeding the fish you can ensure that the small fish grow quickly and therefore will not be eaten by the wild fish.

There are a number of advantages to integrated rice-fish cultivation. The presence of fish in a rice field generally increases the rice yield by 10 to 15%. By cultivating two products you decrease the risk of loss if one crop fails. Fish is a source of protein, and by integrating production with rice you can improve your own food security. Fish also sometimes eat the animals which transfer diseases to people, so raising them can improve public health. Some fish species, such as the common carp eat mosquito larvae and snails which spread disease.
Raising fish in a rice field is also a biological way of reducing weeds, insects, snails and some rice diseases. This is a safe and cheap alternative to using chemical pesticides to control insects and algae. The water in the rice field must be at least 20 cm deep in order for the fish to be able to survive and move freely.

It is not always possible to integrate rice and fish production. The use of pesticides for rice production can be harmful to the fish. Short-grain rice varieties have a short growing period, which may not be long enough for the fish to be able to mature. Short-grain rice also needs only shallow water in which to grow. The water may then be too warm to raise fish.

Rice and fish production do not need to be integrated by always producing the two crops simultaneously, but may be done by alternating production: rice can be grown in the rainy season and fish in the dry season, or the other way round. By not raising the two together, any pesticides used for the rice will be less dangerous to the fish, and it is easier to control the water level so that it is right for both rice and fish. In areas where rice production is not profitable in all seasons, fish production forms an alternative source of income from the field.

4.2 The biology of a rice field

Integrating rice and fish production makes better use of the nutrients available in the rice field. The fish also increase the fertility of the rice field, partly through the manure they produce and partly because they stir up the bottom which increases the amount of oxygen and nutrients which the rice plants can use for growth.

Rice fields are shallow temporary swamps. The water is warm and sunlight can penetrate as far as the bottom, especially when the rice plants are still young. In these conditions algae grow fast. Algae use nutrients which the rice plants need. By releasing fish which eat algae, the rice will be able to use more nutrients for their growth. Tilapia are algae eating fish.

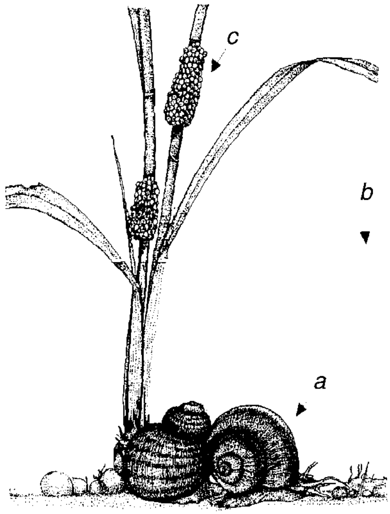
One of the biggest problems in rice cultivation is the fast growth of weeds. Up to half of the rice yield can be lost through competition from weeds. Raising plant-eating fish can help to solve this problem. Release young fish 2 to 3 weeks after transplanting the rice. This is the time when competition between the rice plants and weeds for nutrients is greatest. Grass carp at a density of 2 fish (longer than 15 cm) per square metre can keep a rice field completely free of weeds. The fish do not eat the rice plants. However, for grass carp to survive the water must be at least 50 cm deep. Javanese barb, silver barb, as well as some tilapia species (*Tilapia rendalli*, Zill's tilapia, *Tilapia zillii* and Nile tilapia, all in a density of 3 fish of 50 g or more per 100 m^2) are also good to use against weed. Using larger fish is better as they have a wider mouth and can therefore eat more weed than smaller fish. Fish species which search for food at the bottom of a pond are also good for keeping a rice field free of weeds. These fish stir up the bottom, so the water becomes cloudy, and less sunlight can penetrate, which reduces the growth of weeds. The common carp is a very good weed eater. Fish which feed from the bottom of the pond should only be released once the rice plants have 5 to 7 shoots, otherwise the plants will be uprooted by the fish. Releasing a combination of fish species leads to better results than using just one fish species. A good polyculture is the combination of common carp with Nile tilapia. Weed growth can also be reduced by making the water deeper, as well as by using fish.

Before the rice plants are planted out, pigs can also be put in the rice fields to eat the weeds. Local pig breeds fed on market waste can be used. 25-30 pigs per 100 m^2 can rid a rice field of weeds in one day.

Fish can also reduce the number of insect pests in a rice field. Insects which damage rice include plant hoppers, stem borers, leafhoppers and leaf folders. Fish only eat insects which live entirely in the water or on the root of the plant or which fall into the water. Common carp, and to a lesser extent grass carp, longer than 7 cm with a density of 2 fish per square metre, will keep a rice field insect free.

Snails can reduce a rice yield by half. Fish are a good way of reducing the number of snails in a rice field. Not only do fish eat snails, but they also eat the algae upon which snails feed. Black carp and to a less extent cichlid species can decrease the amount of snails in a field. The fish should weigh more than 50 g and be stocked at a density of 2 fish per 100 m^2. In the first weeks after transplanting the rice farmers remove snails by hand as this is when the plants are most vulnerable. Snails eggs can be caught easily in this period by laying sticks in the drainage canals (figure 11).

Ducks are put out in rice fields to eat snails in China, Indonesia and Vietnam. It is important to keep an eye on the ducks so that they do not start to eat the young rice plants once they have eaten all the snails. Ducks can be put in the fields from the time of the first flooding until the field is prepared for transplanting, then again 35 days after the rice plants have been transplanted and after the rice has been harvested. Two to four ducks per 100 m² can get rid of the snails in a rice field within two days. Two weeks after transplanting the rice you can release common carp and Nile tilapia into the rice field, and these will eat the remaining smaller snails.



a: snail
b: water level
c: egg packets

Figure 11: The golden apple snail and two egg packets on rice stems (Halwart, 1995).

Another way of dealing with snails is to drain the rice field completely so that the snails move to the deep parts where water is left. You can then easily remove the snails by hand from these deeper pools. By then making the rice field as flat as possible you will reduce the number of active snails in future. Rice plants which are raised from seed in the field are most likely to be eaten by snails in the first four weeks after sowing, and transplanted rice in the first two weeks after transplanting. If there are a lot of snails in the field you can reduce the amount of damage to the rice by sowing or transplanting more. It is also a good idea to transplant older, and therefore stronger, rice plants. Other ways of reducing the amount of snails include changing the crop in the field, burning the rice stalks and leaving the field fallow for a while. These methods work best when all rice growers in the area do the same with their fields.

4.3 Suitability of a field for fish culture

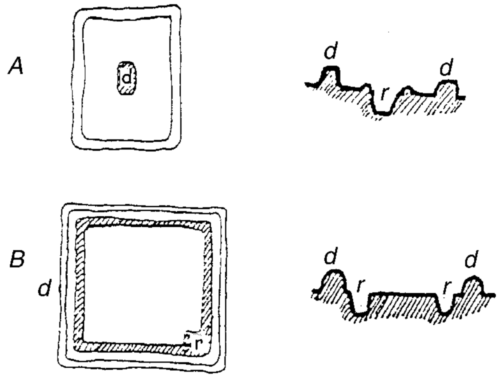
Site selection

The rice field must be able to hold water at a constant level for the whole period during which rice is grown. The longer it is capable of doing this the better it will be for fish culture. The best fields for this are those lying just above the high water line, or ones with high dykes so that they will not flooded. The highest level of fish production will be achieved where the water is at least 30 cm deep. If some parts of the field are a little shallower it will not matter. How watertight a field is depends mainly on the type of soil: clay soil lets less water through than sandy soil. A simple way of testing the soil is to make a ball from the soil. If you can throw the ball of soil a distance of 50 cm to your other hand without it falling apart then the soil will hold water well.

You can improve the water holding capacity of sandy soil by applying fertilizer often during the rice growing period. It is possible to raise fish successfully on sandy soil, but it requires more work to keep the water level constant. If the rice field is close to the house it will be less effort to check the water level, feed fish and keep thieves away.

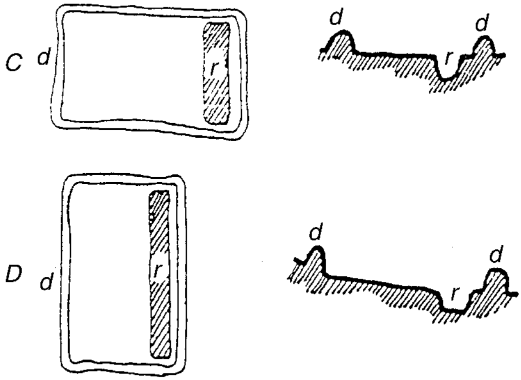
Fish refuges

Fish in rice fields need one or more refuges, which are deeper parts in the rice field. These places can be a deeper channel or a small pond area in the rice field or adjoining it. These are used for the fish to rest or hide, for feeding them, checking growth and harvesting the fish. The shape, size and number of the refuges depends on the number of fish and how important fish culture is in relation to the rice cultivation. This means that a number of combinations of shape, size and number of refuges is possible, depending on the siting of the rice field. figure 12 (A-F) shows topviews and cross-sections of various fish refuges (with d = dyke and r = refuge).



A: *Easy access for the fish. Transferring the dug out soil to the dykes can take a lot of time.*

B: *Easy access for the fish. Most suitable for large flat rice fields. Digging out can be expensive. Difficult access to field for water buffaloes.*

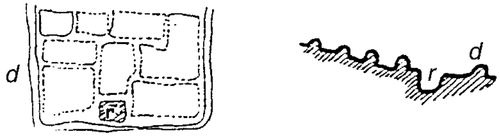


C: *Good for flat or gently sloping land, especially for fields smaller than 5,000 m?.*

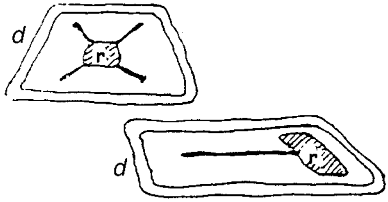
D: *A channel in the lowest part of a field on sandy soil will lead to high water loss. Regular application of fertilizer to the channel can help.*

Figure 12: Topviews and cross-sections of fish refuges.

E



F



E: Typical general layout of rainfed rice fields in northeast Thailand. A small pond in the lowest part of a system of many small rice fields. The dykes are higher in the lower areas so that water stays within the fields.

F: Shallow, narrow channels make it easier for the fish to reach the refuge. Do not plant rice where the channels run.

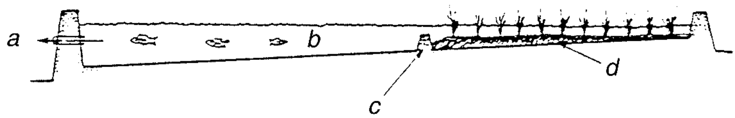
Figure 13: Topviews and cross-sections of fish refuges.

The deepest part of the field or an existing fish pond in the rice field is usually used as a fish refuge. The depth of the refuge must be between 0.5 and 1 metre. In northeast Thailand experience has shown that a channel on one side of a rice field is enough, and the dug out soil can be used to raise the dyke level. Whether or not a refuge is made, and how big it is, will depend on how important the fish culture is in comparison to the rice cultivation, as well as on the amount of labour available, the siting and size of the rice field and the soil type. A narrow channel will collapse quickly in sandy soil, but not in clay soil. In sandy soil, the width of a channel should be three times its depth. A fish refuge is not needed in a field that is well irrigated and where the water is at least 30 cm deep.

Water intake and outlet

A rice field usually needs a water outlet to prevent flooding and damage to the dyke. In order to prevent fish from escaping through the outlet it is a good idea to place a fine screen over the outer end of the inlet (supply) pipe and the inner end of the outlet (discharge) pipe. These screens also make it easier to clear the snails which collect on the sides of the irrigation canals. The screens can be made from a piece of metal with holes in it or a fine nylon mesh (figure 15A). The inlet and outlet pipes can be made of bamboo or wood. In most fields the water in- and outlet are made by protecting a hole in the dyke with a bamboo screen or some other kind of net or mesh (figure 15B). Farmers in the wetter areas of northeast Thailand use a 'li'. This is a bamboo hoop net which is used to catch wild fish entering the field (figure 15C). The small fish caught can be released into the field, but not the big fish. figure 15D shows a simple water outlet. The depth of the water outlet is determined by the depth of water which gives the highest rice production. The size of the outlet depends on experience, but too small is better than too big.

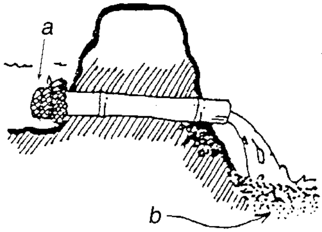
An integrated rice-fish culture system works best if it is possible to separate the fish pond from the rice field when circumstances require this. For example, when the rice is to be harvested, the water level can be lowered through the outlet ([a] in figure 14). The fish will be drawn to the pond and can survive, to be harvested later.



a: water outlet
b: deeper part of field: fish pond
c: small ridge to seperate rice field and fish pond
d: shallow part of field

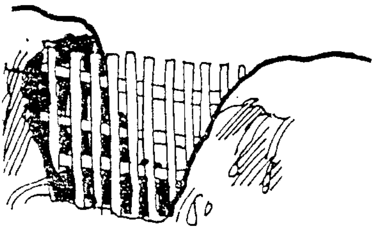
Figure 14: Cross-section of a rice-fish culture system in which the components can be separated (Noble & Rashidi, 1990).

Also if there is a very dry period, you can carry out only one of the two cultures for that season. By doing that you increase the chance to get at least one harvest instead of loosing all because of shortage of water.

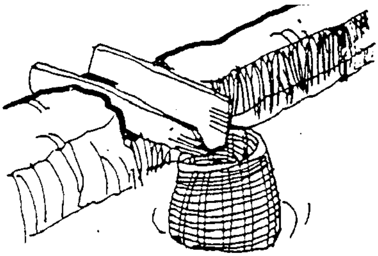


A: Bamboo water inlet pipe with net screen.

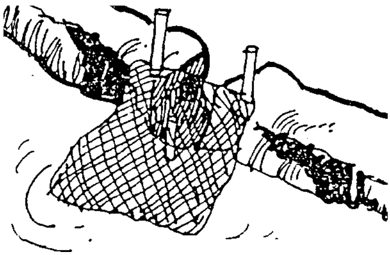
a: net screen
b: pebbles/small stones to prevent soil being washed away



B: Bamboo 'screen'.



C: Water inlet pipe made from a hollow piece of wood with a basket or fishnet as a screen.



D: Hole in dyke for water outlet with net for protection.

Figure 15: Examples of water inlet pipes, outlet pipes and 'screens'.

Field preparation

A number of basic preparations for making a rice field more suited to fish culture are explained here and illustrated in figure 16-figure 22 (Fermin, 1992).

- figure 16: Dig out a fish refuge, a channel or deeper area in the rice field, before the rainy season begins. Dig a channel 1 m wide and 0.5 m deep, depending on the number of fish to be released. A guideline is that the channel should take up a tenth of the area of the rice field, but experience will show exactly how big it needs to be. The refuge should be separated from the rest of the field by a small dyke.

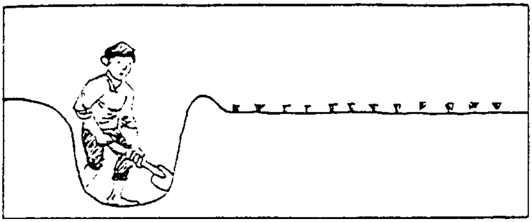


Figure 16: Digging out a fish refuge.

- figure 17: When there is sufficient water in the refuge, either from rainfall or from the irrigation canal, the refuge can be fertilized using chicken, pig or cow manure. Half a kilogram per square metre is usually enough to provide natural food for the fish (Chapter 5).

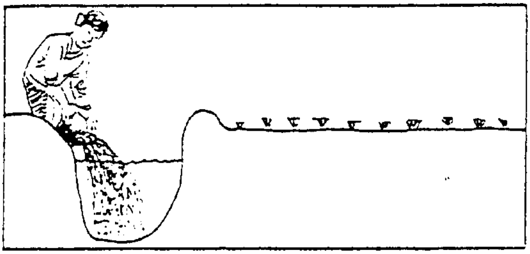


Figure 17: Fertilizing the refuge.

- figure 18: Release the fish (at least 7 cm in length) two weeks after applying fertilizer. A mix of Nile tilapia, silver barb and common carp at a density of 25 fish per 100 m² is usually a successful combination.

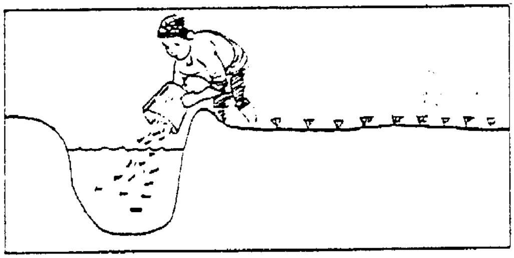


Figure 18: Releasing the fish.

- figure 19: When the rains begin you can start to plough and harrow the rice field. The field can also be fertilized using animal or green manure such as water fern (Chapter 3, section: "Water plants"). Snails can be removed by hand, or ducks can be put in the field to eat them. Pigs can be used to eat the aquatic weeds (Chapter 4, section: "The biology of a rice field").

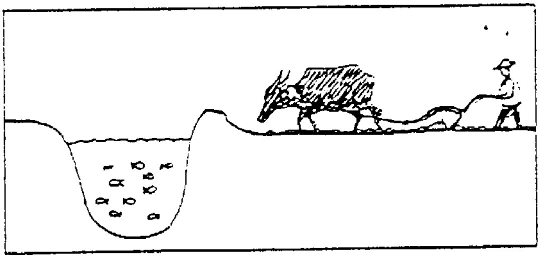


Figure 19: Ploughing the rice field.

- figure 20: After levelling the ground, the young rice plants can be transplanted from the seedbed to the rice field. Make sure that there is at least 3 cm of water in the rice field while transplanting.

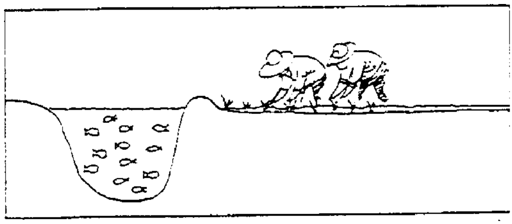


Figure 20: Transplanting young rice plants.

- figure 21: Two to three weeks after transplanting the rice plants break open the dyke between the rice field and the fish refuge so that the fish can swim into the rice field. Make sure that the water in the rice field is 20 cm deep and that this slowly increases to 30 cm as the rice starts to put out runners.

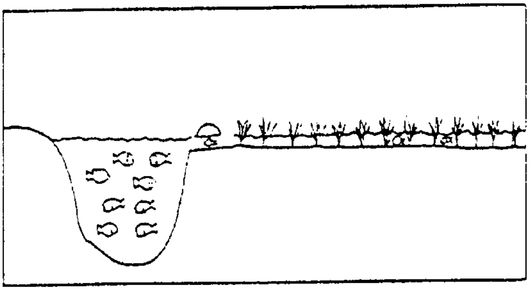


Figure 21: Fish swimming into the rice field.

- figure 22: After the rice has been harvested the larger fish can be caught from the refuge. If most of the fish are still too small to be sold they can be fed regularly until they are a better size.

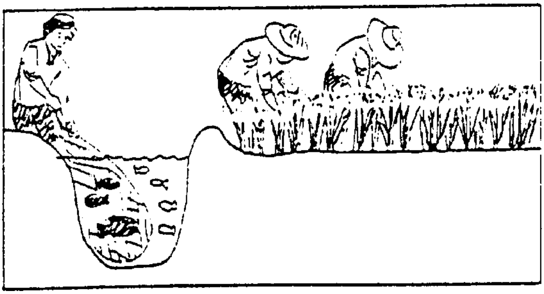


Figure 22: Harvesting rice and catching the larger fish.

4.4 Choice of fish species

The types of fish which occur naturally in rice fields are often predators, such as snakehead, catfish species and climbing perch. Sometimes catching wild fish is preferred to raising fish as the wild fish taste better and can be sold for a higher price. In areas where traditional rice varieties are cultivated wild fish caught in the fields form an important source of protein. When fish larger than 7 cm are released into the rice field and are fed, they will be too large for the wild fish to eat. Then it is possible to harvest both wild and cultured fish. Small fish can be released where there are almost no wild fish present which might eat them.

Rice fields are temporary shallow swamps where the water can be muddy and lacking in oxygen. The temperature of the water can vary a lot and reach temperatures as high as 30 to 35°C. Fish which are to be raised in rice fields must be resistant to these kinds of conditions. Fish which grow quickly are desirable as the growing period for rice is often short.
A rice field contains many different food sources and is therefore ideally suited for raising several fish species together (polyculture). The most commonly used fish species for rice fields are the common carp, silver barb and Nile tilapia. The silver barb is becoming increasingly popular in southeast Asia as it is omnivorous (eats both plants and animals) and it is easy to sell. However, the silver barb is very sensitive to oxygen shortages. Its growth rate is also less sensitive to increased fertilizer application than that of other fish species such as Nile tilapia.

There is no single combination of fish species which works best everywhere, as all places have their own particular conditions. Big fish are more expensive than small ones, but are less likely to be eaten by predators. For farmers who are raising fish for the first time, or who are not going to feed the fish, we recommend beginning with not more than 30 fish of 7 cm in length per 100 m².
A combination often used in Thailand consists of 120 common carp, 120 silver barb and 60 Nile tilapia per 100 m². In China, grass carp, common carp and crucian carp are often combined. With a combination of 50 grass carp, 30 common carp and 20 crucian carp it is possible to harvest 90 kg of rice per 100 m² of rice field. A combination of 50 grass carp, 30 common carp and 20 crucian carp yields the highest fish harvest (20 kg per 100 m² rice field. The prices of rice and fish will determine the best combination of the two products. Appendix 5 gives an overview of different combinations of fish, stocking densities

and harvest yields for several rice-fish culture systems. Note that fish should be at least 7 cm long when released (0).

It is always better to raise a combination of fish species instead of just one species. Different fish species eat different types of food, resulting in higher yields.

There are a number of factors which will determine what fish species are most suitable:

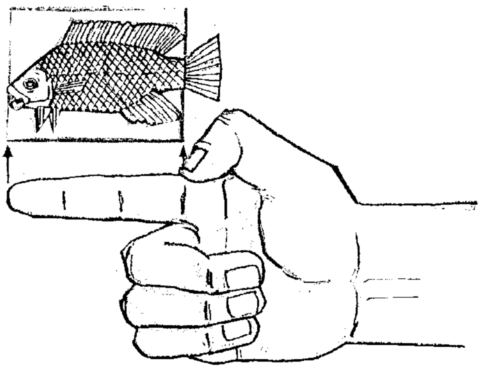


Figure 23: The minimum length for young fish to be raised in rice fields.

- Availability.
  A farmer is always dependent on the fish which are available locally.
- Preference.
  A family usually prefers a certain fish species. Many farmers choose to stock a rice field with large fish which are more likely to survive. Other farmers will choose smaller fish because they are cheaper. A family with limited financial resources must often choose between a few large fish or many small fish.
- Food preferences of fish species.
  <u>Tilapia</u>: a strong fish which does well in water of low quality, and reproduces easily. The high rate of reproduction means that farmers can keep a few large fish the whole year round, which will provide them with young fish, so they do not have to buy any. A disadvantage is that a rice field can quickly become too full of young tilapia as they breed so fast. If this happens the fish cannot grow well. If there are predator fish in the field they will eat the small tilapia and keep numbers down. Some farmers do not like the taste of tilapia, and they say it does not ferment well. Another complaint is that ti-

lapia competes with other fish species for food and can chase other fish away.

Common carp: does well in low quality water and grows well in most rice fields. Survival rates are often low as they are easily caught by predators.

Chinese and Indian carp: grow badly in rainfed rice fields as the water level varies too much. These species grow better where the water is at least 50 cm deep (Indian deepwater rice cultivation).

Silver barb: survives well in rice fields. This species is more sensitive to water quality and grows less well in shallow water (less than 10 cm deep), in rainfed rice fields where depth varies than common carp and tilapia.

Snakeskin gourami: grows well in rainfed rice fields. The field must be stocked with breeders, not young fish, from which the young fish can be harvested and sold.

Rice fields which have silted up too much to be used for rice cultivation can still be used to produce fish. Snakeskin gourami, tilapia species such as Mozambique or Javanese tilapia and Zill's tilapia are examples of fish which can be raised in brackish water.

4.5 Releasing the fish

When you buy fish you must release them into the rice field as soon as possible. The container the fish are in must be handled very carefully and kept out of direct sunlight. When releasing the fish a large difference in temperature between the water in the container and in the rice field can kill the fish. The best way to avoid this is by mixing small amounts of water from the rice field gradually into the water in the container so that the fish can get used to the new temperature. When the temperature in the container feels the same as in the rice field the fish can be transferred to the rice field. The best time to do this is early in the morning or late in the afternoon when the water temperature is lower.

Fish, which are smaller than 5 cm, are usually released one week after transplanting the rice. Fish longer than 5 cm are usually released two weeks after transplanting the rice. If rice is sown directly into the field from seed it will take longer before fish can be released as the rice plants are weaker.
The earlier fish can be released the longer the amount of time available for raising fish and the higher the fish production will be. There are also less predators around earlier in the season, and the larger the fish the less vulnerable they are to predators. However, there must be enough water in the rice field to be able to release the fish safely. When large fish are released you must make sure that the rice plants already have 2 or 3 shoots so they will not be damaged.
In a rainfed rice field small fish can be released before the rice is planted. They can grow in the fish refuge until the rice field has been planted. The rice variety will also affect the time at which fish can be released. Traditional long grain varieties are often stronger than modern short grain varieties, and are better able to stand up to fish activity. Fish can be released earlier into fields where the traditional long grain varieties are cultivated.

4.6 Fertilizing and feeding

Fertilizing the rice field can increase both fish and rice production. Spread 2 to 5 kg of fresh water fern Azolla per 100 m² over the soil one week before planting the rice. Azolla can either be cultivated or harvested from the wild. Fresh manure or compost can also be used, depending on what is available. The addition of 3 kg of manure per 100 m² per week substantially increases the amount of natural food in the water.

We recommend feeding the fish from halfway through the rice cultivation period, as by this stage the rice plants will have grown so much that no sunlight will penetrate the water. Feeding is usually only done where a large number of fish have been released (more than 50 fish per 100 m²) and it will increase the yield. Fish can be fed rice chaff or rapeseed. Earthworms are another food source for fish which can be collected from the rice field during the rainy season. Earthworms can be raised in animal manure or compost to be used as fish food. Fish can be caught one week before the rice is harvested by letting the water level in the rice field go down slowly so that the fish will swim into the refuge. If the fish are not big enough to eat or sell they can be left in the field after the rice is harvested. Depending on how many fish are present they can either be kept in the refuge or a part of the rice field can be flooded again.

The water plant elephant ear or taro can be used as fish food. This plant can be grown on the dykes surrounding the rice field. All parts of the plant can be used as food for people, fish and pigs. Use shoots from the wild to start cultivating this crop. Cut the old leaves off, leaving just the young leaves and the shoot. Cut away half of the root or tuber (figure 24), and plant it 5 to 10 cm below the water level of the rice field (figure 25). There should be 60 cm between the plants on the dyke. The first plants can be harvested after 4 to 5 months. Various water plants can be used for fish food (Chapter 3), and silver barb eat nearly all types of plant material.

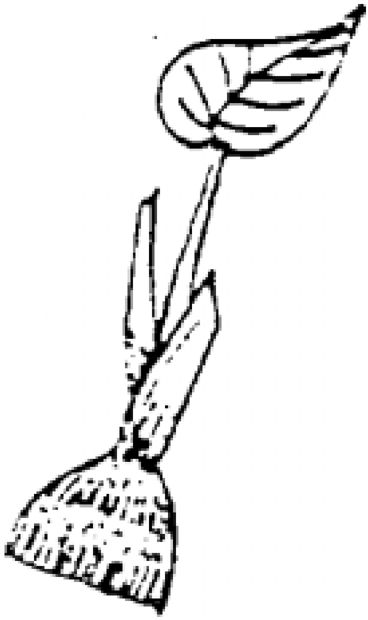


Figure 24: A trimmed elephant ear/taro ready for planting.

4.7 Fish yields

Wild fish grow more slowly than cultured fish, and the number of wild fish in a pond will depend on the natural environment. This means that fish production based on wild fish will have lower yields than for cultured fish. A maximum yield of 2 kg per 100 m² per year can be expected for wild fish, whereas raising fish can produce a yield as high as 5 kg per 100 m² per year (Appendix 5). Production levels can be further increased by feeding the fish, using fertilizer on the rice field soil and using several fish species together.

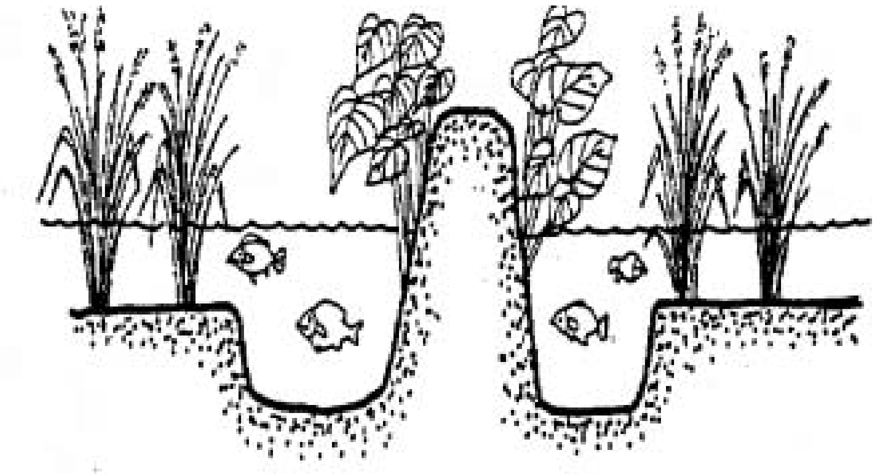


Figure 25: Elephant ear//taro planted on the dyke of a fish pond.

Traditional rice varieties are taller than modern ones, which means they grow better in deeper water. Deeper water will also give a higher fish production. Traditional rice varieties also have a longer ripening period, which gives the fish a longer amount of time in which to grow. In some areas of India yields of up to 15 kg of fish per 100 m² are obtained annually, where the fish are fed (Appendix 5).

4.8 Other integrated fish-rice culture systems

There are various ways in which rice and fish cultivation can be combined with keeping other animals (Chapter 5).
In Thailand, an integrated system of pig, rice and fish culture is practised. The fish pond is linked to the rice field. During the rainy season the rice field is fertilized using water containing pig manure from the fish pond. The water in the fish pond is used during the dry season to water vegetables or rice seedlings in the rice field.

In China and Indonesia, rice, ducks and fish are raised together. The ducks are fed with rice in the evenings. The ducks also eat insects and snails from the rice fields, which means it is not necessary to purchase expensive chemical pesticides. The water in the rice field is 10-15 cm deep and the rice plants are planted 25cm apart so that ducks can swim around freely. A rice field of 100 m^2 can sustain 30 ducks, which can be introduced when they are between 7 and 10 days old. Manure from the ducks and the fish fertilizes the rice field, so that artificial fertilizer does not have to be bought. Ducks raised in rice fields grow more quickly than ducks which kept on land. They reach a weight of about 1kg after about six weeks. At this point they should be removed from the rice field as they no longer eat insects and will start to eat the rice plants.

In Indonesia, the dykes around rice fields and fish ponds are used to grow trees. Sesbania trees are planted at intervals of 40 cm on the dykes. Over a period of three years the following products can be harvested: leaves and flowers for human consumption and animal feed, large branches for firewood and shade for people and animals. In Bangladesh trees are planted on the dykes of rice fields for firewood. Species used include *Eucalyotus camldulensis, Swietenia macrophylly* and rosewood, ladyfinger, ridge gourd, ash guard and papaya.

5 Integrating animal production with fish culture

5.1 Animal manure

Animal manure can be added fresh to a fish pond or after a period of storage. Manure should not be kept for too long before use, as its quality decreases when it is stored. There are some risks involved in using animal manure. The manure can contain bacteria or worms which are harmful to humans, and which can also infect fish. People who eat the sick fish may then also become ill. This problem is overcome by cleaning the fish well and frying or cooking it thoroughly. We strongly advise against the use of human faeces as fertilizer for a fish pond as disease can be passed on to fish and then to humans. If fish has a strong taste it is a good idea to stop fertilizing the fish pond two days before harvesting, or to transfer the fish to containers with fresh water a few days before harvesting.

The choice of animals to keep for manure for a fish pond will depend on a number of aspects: local customs, the local economy (market preferences) and other production factors.

The quantity and quality of the manure produced depends on the animal's age and the quality of food it receives. Low quality food produces low quality manure, high quality food produces high quality manure. Average annual production of an adult animal (kgs fresh manure per year) varies: a cow produces the most (6,000 kg to 9,000 kg), followed by pigs (3,000 kg to 4,000 kg) with chickens and ducks producing the least (50 kg). However, the dry material content of the manure (manure without water) is much higher in chicken and duck manure (30-50%) than for pigs (20-30%) and cows (15-20%). The nutrient composition (nitrogen, phosphorus and potassium) of chicken manure is best, followed by duck, pig and cow manure respectively.

Generally speaking, the best (optimum) amount of manure (Chapter 2) is 1 kg of dried manure per 100 m^2 per day, for a fish pond containing the optimum number of fish (200 fish heavier than 50 g each per 100 m^2). When this amount of manure is used, the amount of fish harvested increases in proportion to the fish density. Where there are more than 200 fish per 100 m^2 then the amount harvested does not increase so much. There is also no point applying less manure than the amount indicated, as it will not be sufficient to produce extra natural food. If you add more it will only make the water quality worse, and then the fish will not grow enough. If the pond receives other types of fertilizer as well as animal manure then the total amount applied should be reduced accordingly. The optimum application of 1 kg of dried fertilizer per 100 m^2 per day is equivalent to 2.5 kg of fresh chicken or duck manure, 4 kg of fresh pig manure or 6 kg of fresh cow manure.

A small-scale integrated fish cultivation system using animal manure as fertilizer will often produce yields which are sufficient to feed the family. An example from Thailand shows that a farm with 30 ducks per 200 m^2 yielded 110 to 290 kg of fish per year. An average of 180 kg of manure for a pond of 200 m^2 is enough to feed 5 people for a year. These figures are based on the assumption that a third of the total protein requirements are obtained from animal products.

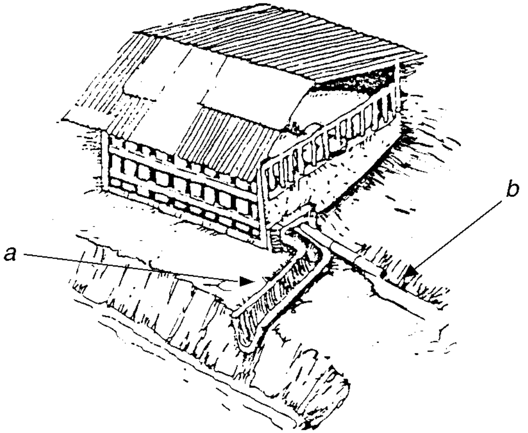
5.2 Integrating fish culture with pig raising

The stocking densities given below are for a standard pond size of 100 m^2 (e.g. 10 x 10 m), for fish released when they are 10 cm in length.

Pig housing

In general, pigs need a minimum floor area of 1 to 1.5 m^2 per pig. There are two ways of housing pigs combined with fish.
The most common is to build the sties on the banks of the pond (figure 26). Dig the drainage channels so that the pig manure can be rinsed with water into the pond. It is a good idea to make a sty with a hard floor, so that less manure is lost. Lay the floor so that it slopes down

towards the pond, as that makes it easier to wash the manure into the pond. Surplus manure can always be carried to another pond if necessary.



a: outlet (drainage) canal for manure into the pond
b: second outlet canal for overflow or when a is closed

Figure 26: Pig sty construction for integration with fish raising.

In some cases pig sties are built above the pond. These are made of wood, built on stilts with a slatted floor so the manure falls into the pond. Where the sty is above a small pond it must be built on the windward side, so that the wind spreads the manure over the pond. If the pond is large it is worth building the sties in different places above the pond.

There are a number of disadvantages to building sties above a pond. It is often damp and draughty above a pond which can cause respiratory problems in pigs. You cannot use any cleaning materials to clean the sty as they will pollute the pond. For further information on pig keeping, see Agrodok No.1 'Pig production in the tropics'.

Production cycles

The period required for pigs to grow from 20 kg to 100 kg is approximately 6 months, during which time they will provide manure. This amount of time is sufficient for raising most kinds of fish. Tilapia takes about 3 months to grow to market size (150 g), which means that for one pig cycle two lots of tilapia can be raised. As the pigs grow, the amount of manure they produce also increases. In the first 60 days they produce about 1.5 kg manure per day. A pig between 60 and 220 days old produces approximately 3 kg manure per day.

The average food conversion of pig manure is 25. This means that 25 kg of pig manure is needed to produce 1 kg of fish. As the fish grows, the amount of food needed also increases. If the fish production cycle is the same length as that of the pigs then the food requirements of the fish rise at approximately the same rate as the increase in pig manure.

If two lots of fish can be produced within one pig cycle then it is necessary to ensure that there is not too much manure in the pond water. At the beginning of the second fish cycle the pigs will already be 3 months old, and producing too much manure for small fish. The surplus manure which is not put in the pond can be used on crops or for making compost.

Choice of fish species and fish densities

Between 1 and 4 pigs can be kept per 100 m². In Asia the most common fish species kept with pigs is Nile tilapia. Between 250 and 300 fish are released per 100 m². Polyculture of different Indian carp species is done using the following proportions: 32 catla carp, 24 rohu carp and 24 mrigal carp per 100 m² of pond. An alternative polyculture system uses Indian and Chinese carp species together: 16 catla carp, 16 rohu carp, 12 mrigal carp, 16 silver carp, 9 grass carp and 12 common carp per 100 m².

By raising fish species which are less sensitive to oxygen shortages such as catfish, densities of up to 300 fish per 100 m² can be achieved. Catfish can be stocked at higher densities because they obtain oxygen from the air as well as from the water. If other by-products are available for feeding the fish then less pigs are required.

Yields

In a combined production system of pigs (1 to 2 pigs per 100 m² pond) with fish (100 to 200 fish per 100 m²) a fish yield of 20 to 50 kg per 100 m² can be obtained in a period of six months. A combination of Nile tilapia (200 fish per 100 m²) with common carp (50 per 100 m²) will yield between 40 to 50 kg per 100 m² of pond in a six month period. Raising a combination of Indian and Chinese carp, as described above, can yield 30 to 40 kg in a six month period and up to 60 kg per 100 m² in 10 to 12 months. Silver striped catfish (at a density of 400 fish per m²) can yield as much as 150 kg per 100 m².

5.3 Integrating fish culture with chickens

Many small-scale farmers in the tropics keep chickens. Chicks are not expensive to buy or to feed, and they produce eggs and feathers as well as meat. Chickens can be kept for eggs (layers) or for meat (spring chickens). Chicken manure contains a lot of nutrients and makes very good fish food. Not only chickens but also turkeys and other sorts of fowl can be kept with fish. Chickens are more susceptible to disease than ducks or geese, so it is a good idea to vaccinate chickens.

Chicken housing

Generally speaking, one chicken requires one square metre of floor space. Most chicken coops (henhouses) are built of wood or bamboo on land. The manure is collected regularly and spread fresh or dried over the pond. In southeast Asia chicken coops are often built above the fish pond. The holes in the floor must be big enough to allow the chicken manure to fall through into the pond. The best construction for a coop is open, and well ventilated, but watertight (figure 27).

Production cycles

Laying hens start to lay eggs when they are 22 weeks old. They can produce eggs for up to one year, during which time they will lay between 250 and 280 eggs. After the laying period the hens lay fewer eggs and are then usually slaughtered for meat. Spring chickens kept for meat grow quickly. The speed at which they grow depends on the feed they receive, but generally speaking these chickens reach an end weight of 1 to 1.5 kg within a period of two months.

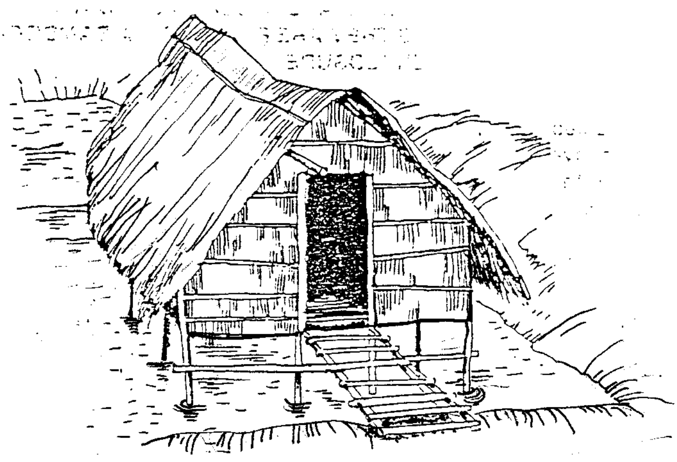


Figure 27: Example of a chicken coop above a fish pond.

For a fish cycle of six months three lots of spring chickens can be reared. In order to ensure that the amount of manure supplied to the pond does not vary too much it is best to keep a combination of spring chickens of different ages together. If you keep laying hens then you can raise two lots of fish during the laying period of one lot of hens. You can find more information on poultry keeping in Agrodok No.4: 'Small-scale poultry production in the tropics'.

Choice of fish species and stocking densities
A combination of carp species in a pond of 100 m² is often raised in the following proportions: 40 fish which feed from the surface (e.g. catla and silver carp), 20 rohu carp, 30 bottom feeders (mrigal and common carp) and 10 grass carp. The maximum number of chickens that can be kept is 10 per 100 m² of pond when carp are raised, which are sensitive to oxygen content. If tilapia are raised (less sensitive to oxygen content) at a density of 200 fish per 100 m² then up to 50 chickens per 100 m² can be kept. Where catfish are kept (at a density

of 400 fish per 100 m²) up to 120 chickens per 100 m² of pond can be kept. Catfish can be kept in water with very low oxygen content.

Yields

The combination of carp species described above will yield the first fish for the market after 6 to 7 months, with a total production of up to 60 kg per 100 m² of fish pond. Four to five spring chickens per 100 m² of pond is sufficient to obtain 25 kg of Nile tilapia and carp after six months, with no extra feeding. A combination of tilapia and catfish (200 fish per 100 m²) with 60 chickens per 100 m² can yield up to 75 kg of fish.

5.4 Integrating fish culture with ducks and geese

Like chickens, ducks and geese are attractive poultry for small-scale farmers. Duck and goose manure also contains a lot of nutrients and is suitable for feeding fish. Ducks and geese swim in the fish pond, thus spreading their own manure. The amount of manure produced over a two month period is approximately 6 to 9 kg per bird.

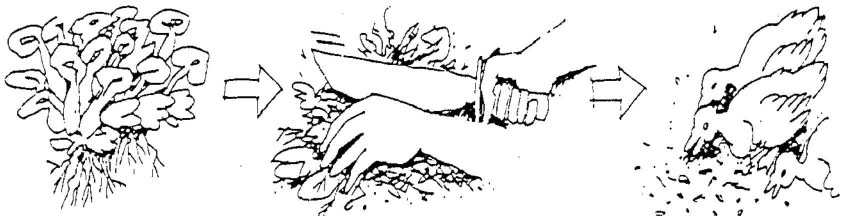


Figure 28: Chopped water hyacinth makes good food for ducks.

Ducks and geese grow quickly, are strong and easy to keep. They eat waste products as well as weeds, frogs, insect larvae and snails from the pond. It is especially good to keep ducks and geese if you have a large amount of tender green grass or water weeds available. Chopped up water hyacinth makes good feed for ducks (figure 28). These food sources can form a large proportion of the feed for ducks and geese, supplemented with less bulky feed such as grain.

Ducks stir up the bottom of the food when looking for food. This reduces algae growth as sunlight cannot penetrate so deep into the water. By keeping the ducks in one half of the pond only, algae can grow in the other half, which also provides food for the fish. Geese spend less time in the water than ducks, and more time on the banks resting and looking for food. The banks of the pond have to be fenced off so that they are not destroyed by the geese. Ducks raised in water grow more quickly than those raised on land, and are cleaner and more healthy. One advantage of geese is that they are good guard animals.

Housing for ducks and geese

Generally speaking a minimum area of 0.5 m² per duck or goose is required. Ducks and geese can be housed in a variety of ways. A pen can be built which floats on the water, or resting on stilts above the water or on the bank of the pond. Ducks and geese only need shelter for resting (figure 29).

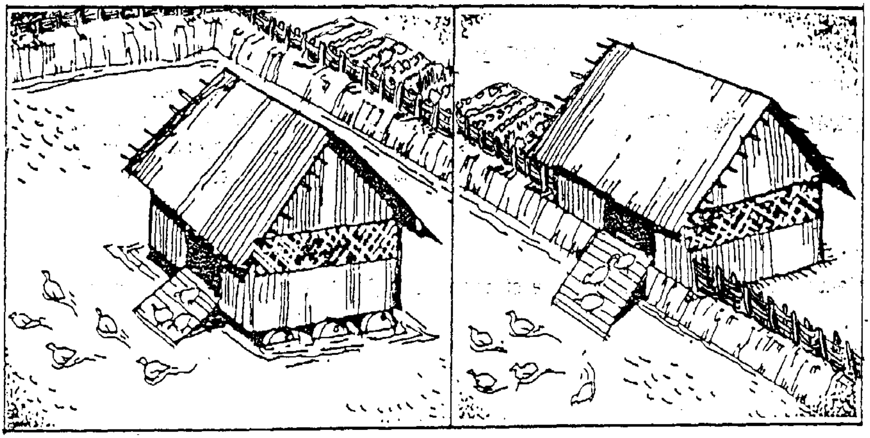


Figure 29: Duck shelter construction for above the pond or on the dyke.

A shelter built above the water must have a floor of slats or mesh which will let the manure through. Ideally all the manure should fall into the water. By fencing off the banks with wire or netting, and not building a shelter on the banks you can ensure that all manure is deposited in the water, and that the dykes remain undamaged.

Production cycles

Duck chicks take approximately 2 months to reach a market weight of 2 to 3 kg. Geese take the same amount of time to reach their market weight of 4 to 4.5 kg. As most fish species take about 6 months to reach market weight, 3 lots of duck or geese can be raised during each fish cycle. In order to ensure that the manure supply remains constant it is best to keep ducks or geese of different ages together. The fish cycle needs to end at the same time as that of the ducks or geese. Once the fish has been harvested the pond will be empty of fish or even dry, and it is not good to add manure to it. During this period the manure can be used for crops or added to compost.

Ducks can also be kept for their eggs. A duck starts to lay eggs at 24 weeks, and will continue to do so for a period of approximately 2 years. After that age egg production declines and the ducks are slaughtered. For each cycle of egg-laying ducks a number of lots of fish can be raised. Hybrid ducks such as Peking and Khaki Campbell can lay between 150 and 200 eggs per year if they are well fed and not disturbed during the laying period. Geese are not as productive as ducks: they only lay 30 to 60 eggs per year.
More information about keeping ducks and geese you can find in the Agrodok 'Duck keeping in the tropics'.

Choice of fish species and stocking densities

The fish for stocking the pond must be at least 10 cm in length otherwise they will be eaten by the ducks or geese. Different sorts of carp are usually kept in combination with ducks and geese, with a stocking density of 45 to 60 fish per 100 m². One possible combination is 24 catla carp, 18 rohu carp and 18 mrigal carp per 100 m². When common carp are added the proportions are 18 catla, 18 rohu, 12 mrigal

and 12 common carp per 100 m². If silver and grass carp are added as well, then the densities become 9 catla, 12 rohu, 9 mrigal, 12 common, 9 silver and 9 grass carp per 100 m². Other fish species can also be raised together with ducks and geese. These include grey mullet and various tilapia species. When tilapia are combined with ducks and geese an average of 100 or 200 fish per 100 m² can be raised. About 3 ducks or geese per 100 m² will provide sufficient manure.
When common carp are raised on their own (at a density of 200 fish per 100 m²) then a maximum of 7 ducks or geese can be kept per 100 m². Where tilapia are raised (200 fish per 100 m²) a maximum of 35 ducks or geese per 100 m² can be kept. When fish which are not sensitive to oxygen content are kept, such as catfish, at a density of 400 fish per 100 m², then a maximum of 70 ducks or geese per 100 m² can be reared.

Yields

Where fish production is integrated with ducks you can obtain yields of 30 to 55 kg per 100 m² per year. The yield will depend on the number of ducks per square metre and the fish species raised. A combination of Mozambique tilapia and African catfish will yield 35 to 40 kg of fish per 100 m² per year. When a high density of Nile tilapia (400 fish per 100 m²) is used up to 70 kg per 100 m² can be harvested. However, the fish harvested will be small in size. The maximum number of ducks or geese reared for meat is 70 per 100 m². The maximum number of laying ducks or geese is 75 per 100 m² when carp species are raised (200 fish per 100 m²). Where tilapia are raised, which are less sensitive to oxygen content, at a density of 200 fish per 100 m², then 350 ducks or geese for meat, or 400 laying ducks or geese can be kept per 100 m². Where catfish are reared (400 fish per 100 m²) the number of ducks or geese for meat rises to 700 per 100 m², or 800 egg laying ducks or geese per 100 m². Catfish can breathe in oxygen from the air as well as from the water. This means that more animals can be kept per square metre, and production levels of 150 kg per 100 m² can be obtained.

5.5 Integrating fish culture with other farm animals

Cattle

Fish rearing is not often integrated with ruminants as these often graze in pastures, which makes collecting manure difficult and time consuming. Cattle produce large amounts of manure each day, but it is of poor nutritional quality. However, large numbers of cattle are raised in the tropics, and during the time that they are kept tied up it is easier to collect the dung. Cows can be fed napier grass for example. Cow dung is commonly used to fertilize fish ponds in India, but fish yields are rarely higher than 20 kg per 100 m².

On a farm with a biogas converter the fish harvest can be doubled by first processing the cow dung in the biogas converter before using it to fertilize the fish pond (figure 30).
A fish pond of 100 m² area can be stocked with 10 catla, 12 rohu, 10 mrigal, 10 silver, 3 grass and 5 common carp, all weighing 7 g. The pond requires 0.75 litres of manure from the biogas converter daily. Any surplus processed manure from the biogas converter can be used on crops, and the gas produced can be used for cooking or light in the house. Manure from the biogas converter must not be added to the fish pond on days when it is cold or cloudy as the manure is not completely decomposed by the converter. Manuring must also be stopped when fish are seen at the water surface gasping for oxygen. After 6 months, the first fish will have reached a weight of about 1 kg. Harvest every two months, replacing the fish removed with young fish each time. A pond of 100 m² will yield up to 50 kg of fish.
If you consider starting a biogas activity, you can find information for orientation in Agrodok No.23 on 'Biogas'.

Sheep and goats

Sheep and goats are important animals for many small-scale farmers in Africa, Asia and Latin America. Sheep and goat manure can be used as fertilizer in a fish pond. It is possible to house the animals in a pen above the pond.

There are a number of combinations of fish and sheep rearing systems used in Indonesia. Large gourami is raised at a density of 30 fish per square metre. The sheep are kept in a pen above the pond, with about 5 sheep per 100 m². The sheep are fed grass (10 kg per sheep per day) and waste from soyabean cake production (4 kg per sheep per day). Goat manure can also be used for fish ponds. There are no figures available, but 4 to 5 goats will be sufficient for a pond of 100 m².

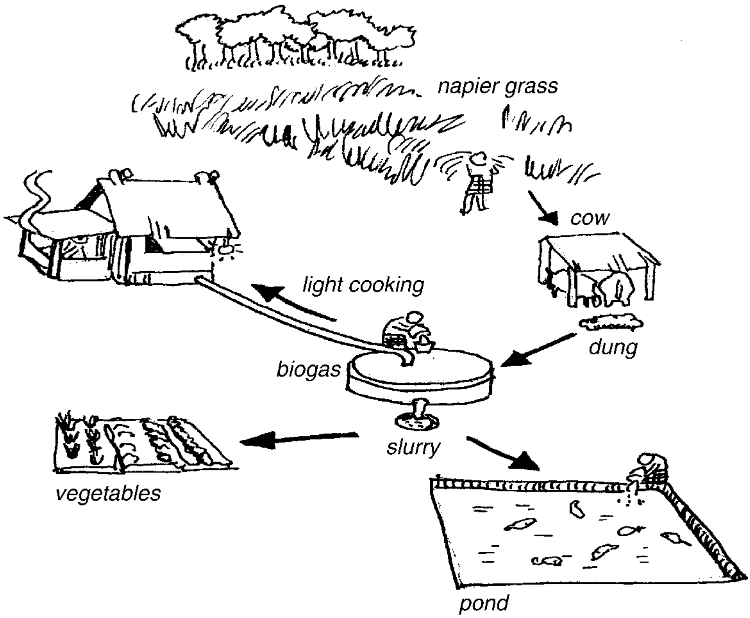


Figure 30: Diagram of an integrated cow-biogas-fish-vegetable cultivation system.

Rabbits

Rabbits make a good combination with fish production. The animals can be housed in a hutch of bamboo or wood placed above the pond. Rabbit dung can be used directly as fish food. Rabbit dung contains more protein and energy than dung from other animals.

Appendix 1: Fish species

Algae-eaters	
Chinese silver carp	Hypophtalmichthys molitrix
Indian catla carp	Catla catla
Indian rohu carp	Labeo rohita
Milkfish	Chanos chanos
Mullet	Mugil cephalus
Plant-eaters (herbivores)	
Chinese grass carp	Ctenopharyngodon idella
Chinese 'Wuchang' bream	Megalobrama amblycephala
Large gourami	Osphronemus goramy
Snakeskin gourami	Trichigaster pectoralis
Tilapia	Tilapia rendalli
Zill's tilapia	Tilapia zillii
Zooplankton-eaters	
Chinese 'bighead' carp	Aristichthys nobilis
Snail-eaters	
Chinese black carp	Mylopharyngodon piceus
Cichlid species	Haplochromus spp.
Predator fish (fish-eaters)	
Catfish species	Clarias spp., Pangasius spp.
Snakehead species	Channa spp.
Omnivores (eat small plants and animals)	
Barb species	Puntius spp.
Catfish species	Clarias spp., Pangasius spp.
Chinese mud carp	Cirrhinus molitorella
Climbing perch	Anabas testudineus
Common carp	Cyprinus carpio
Crucian carp	Carassius carassius
Indian mrigal carp	Cirrhinus mrigala
Tilapia species	Oreochromis spp., Sarotherodon spp., Tilapia spp.)

Appendix 2: Water plants as fish food

Table 1: Common water plants suitable for use as fish food

Common name	Scientific name	Characteristics
Alligator weed	Alternanthera philoxeroides	Troublesome waterweed: chokes water ways, free floating.
Duckweed family	Lemna spp., Wolffia spp., Spirodela spp.	High yielding, high in protein, sugars, fat and sufficient crude fibre; production in the tropics averages 25/tons/ha/yr.
Water hyacinth	Eichhornia crassipes	Troublesome waterweed: chokes water ways, free floating production 150,000 to 300,000 kg per hectare per year; leaves and stem can be used; food conversion 45 to 50.
Water lettuce	Pistia stratiotes	Vegetable.
Water spinach	Ipomoea aquatica	Variable water and marsh plant, very palatable as vegetable for humans, high yielding, can also cover dykes.
Water fern family	Azolla spp.	Capable of doubling weight in 3 to 10 days; high protein and crude fibre content, but low in sugar, production 150 tons/ha/yr.

Appendix 3: Grasses as fish food

Table 2: Common grasses suitable for use as fish food

Common name	Scientific name	Characteristics
Barnyard grass/millet (million dollar grass)	Echinochloa crusgalli	Tall, robust annual, grows vigorously, 60 to 120 cm tall.
Cassava (manioc/tapioca)	Manihot spp.	First cutting at 40 cm from the ground 8 weeks after planting, then every 4 weeks; chopped leaves and tubers used.
Guinea grass (colonial/tanganyika/land grass)	Panicum maximum	Tall, vigorous tufted perennial, stems up to 3.5 m; cut at 60 to 90 cm; needs moist soils.
Hybrid napier grass (elephant/uganda grass)	Pennisetum americanum	Tall, erect perennial with thick stems up to 4.5 m; drought resistant; first cutting at 7 cm from the ground at 7 weeks after planting; then cut every 4 weeks at 10 to 15 cm; chopped leaves and stems used; production 225,000 to 300,000 kg per hectare; food conversion 25 to 30; can be cropped for 5 years.
Lalang grass	Imperata rundinacea	Highland grass, up to 40 cm; extremely drought resistant; palatable if cut frequently.
Napier grass (elephant/uganda grass)	Pennisetum pupureum	Tall, erect perennial with thick stems up to 4.5 m; needs moist soils; first cutting at 7 cm from the ground 7 weeks after planting; then cut every 4 weeks at 10-15 cm; chopped leaves and stems used; production 225,000 to 450,000 kg per hectare; food conversion 30 to 40.
Para grass (california/water/mauritius grass, giant couch)	Brachiaria mutica	Very long trailing stems up to 2.5 m; broad hairy leaves; needs wet soils, protein rich.
Rye grass	Lolium spp.	Adapted to low temperatures; cut frequently; leaves and stems used; production 75,000 to 150,000 kg per hectare; food conversion 17 to 23.
Star grass	Cynodon plectostachyus	Also stabilizes pond dykes.
Sudan grass	Sorghum sudanense	Slender annual; leafy stems up to 3 m; drought resistant; cut frequently; leaves and stems used; production 150,000 to 225,000 kg per hectare; food conversion 19 to 28.

Appendix 4: Plant crops as fish food

Table 3: Common plant crops suitable for use as fish food

Common name	Scientific name	Characteristics
Bean family	Mucana spp., Phaseolus vulgaris, Vigna spp.	Edible beans and/or pods.
Cabbage family (includes mustard)	Brassica spp.	Mustard meal contains toxic substances.
Centro	Centrosema pubescens	Creeping, perennial herb, very leafy, fairly drought. Resistant, vigorous and fast growth.
Ipil-ipil (lead tree)	Leucaena leucocephala	Legumes: first cutting at 50 cm from the ground 8 weeks after planting, then every 10 weeks at 30 cm from the ground; chopped leaves also used.
Maize, corn	Zea mays	Very palatable and highly nutritious, grown in dry season.
Puero (kudzu)	Pueraria phaseoloides	Vigorous, dense growing vine; needs moist clay soils; palatable and high yielding.
Pumpkin family	Cucurbita spp.	Vegetable.
Romanian lettuce	Comfrey symphytum	Vegetable.
Sorghum family	Sorghum spp.	Vegetable.
Stylo	Stylosanthes humilis	Erect annual herb up to 1 m, narrow leaves.
Sugar cane	Saccharum officinarum	Vegetable, leaves can be used.
Sweet potato	Ipomoea batatas	Creeping plant with perennial vines; needs moist soils and more than 4 months of warm weather; leaves and stem are good fish feed.
Tomato	Solanum lycopersicum	Vegetable.

Appendix 5: Production figures

Table 4: Production figures for different integrated rice-fish culture systems

Country	System (refuge type)	Fish species	Fish size	Fish density (100 m²)	Fish yield (kg/100 m²)	Rice variety	Rice yield (kg/100 m²)	Net income (US$/ 100 m²)
Philippines	irrigated (trench)	CC/ON	5/1 g	33/17	ng	IR66 (modern)	60	ng
Philippines	irrigated (pond)	ON	3 g	50	ng	IR64 (modern)	60	ng
Indonesia	rice-fish-duck	CC	5 g	50	19	IR64 (modern)	117	21
Indonesia (East Java)	rainfed sawah-tambak (trench)	MF/PG	5-7 cm	55/55	28	ng	ng	ng
India	deepwater	IMC	275 g	100	11	NC-492 (trad.)	23	ng
India	deepwater (rice-Azola-fish (trench)	ON	19 g	60	ng	CR1009 (trad.)	ng	2.6
Thailand	rainfed (pond)	CC/ON/PG/AN	fingerlings	32	3	glutinous (trad.)	23	1.2
Thailand	irrigated (pond)	CC/ON/PG	2-3 cm	90	2	RD-6 (glutinous)	35	4.2
Zambia	irrigated (pond)	TR/OM	fingerlings	50	2	Supa (trad.)	15	K100,000

Legend:
ng = not given
trad. = traditional rice variety
AN = Aristhichthys nobilis (grass carp)
CC = Cyprinus carpio (common carp)
IMC = Indian major carps
MF = Chanos chanos (milkfish)
OM = Oreochromis macrochir (tilapia)
ON = Oreochromis niloticus (Nile tilapia)
PG = Puntius goniotus (silver barb)
TR = Tilapia rendalli (tilapia)

Appendix 6: Latin names

Fish species

Black carp	= Mylopharyngodon piceus
Catfish	= Clarias spp. and Pangasius spp.
Catla carp	= Catla catla
Cichlid species	= Haplochromus spp., Haplochromus mellandi
Common carp	= Cyprinus carpio
Crucian carp	= Carassius carassius
Gourami	= Osphronemus goramy
Grass carp	= Ctenopharyngodon idella
Grey mullet	= Mugil cephalus
Javanese barb	= Puntius javanicus
Leafhoppers	= Nephotettrix spp., Nilaparvata spp., Recilia spp.
Mrigal carp	= Cyrrhina mrigala
Nile tilapia	= Oreochromis niloticus
Rohu carp	= Labeo rohita
Silver barb	= Puntius gonionotus
Silver carp	= Hypothalmichthys molitrix
Silver striped catfish	= Pangasius sutchi
Snakehead	= Channa spp.
Snakeskin gourami	= Trichogaster pectoralis
Stem borers	= Scirpophaga spp.
Tilapia	= Sarotherodon spp., Tilapia spp. and Oreochromis spp.

Plant species

Alligator weed	= Alternantha philoxeroides
Ash guard	= Benincasa cerifera
Barnyard grass	= Echinochloa spp.
Blue green algae	= Anabaena azolla
Cassava	= Manihot esculenta

Climbing perch	= Anabas testudineus
Elephant ear or taro	= Colocasia spp.
Fresh water fern Azolla	= Azolla pinnata
Ipil-ipil tree	= Leucaena spp.
Ladyfinger	= Hibiscus esculentus
Morning glory	= Ipomoea aquatica
Napier grass	= Pennisetum purpureum
Papaya	= Carica papaya
Ridge gourd	= Luffa acutangula
Rosewood	= Dalbergia lablab
Sesbania	= Sesbania grandiflora
Sesbania tree	= Sesbania spp.
Water chestnut	= Trapa bispinosa
Water fern	= Azolla pinnata
Water hyacinth	= Eichornia crassipes

Others

Golden apple snail	= Pomacea canaliculata

Further reading

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