INTRODUCTION

Tilapia are a group of cichlid species that originate in Africa. There are many species of fish in the group, but only two of them have so far been introduced into Thailand. The Mozambique tilapia (*Oreochromis mossambicus*) was the first to be introduced, but for various reasons it didn’t develop any popularity as an aquaculture species. In 1965 the Emperor of Japan gave a few Nile tilapia (*Oreochromis niloticus*) to H.M. King of Thailand which he spawned and distributed. Such was their popularity that within 25 years Nile tilapia became the most widely cultured fish in Thailand. The descendants of these fish, now known as the Chitralada strain, are recognized as a superior tilapia strain and are now grown worldwide.

Red tilapia, commonly known in Thailand as “pla taptim”, have actually been around a long time, but only became a consumer species around the year 2000 due to extensive market promotion. Most red tilapia strains are a hybrid of Nile and Mozambique tilapia and are not a unique species in themselves. They grow at a similar rate to Nile tilapia, but are not as strong and survival is poor during early rearing. They do, however, have a greater tolerance of high salinity.

Both Mozambique and Nile tilapia are maternal mouthbrooders. The male fish digs a hollow or “lec” on the pond bottom and it is here that spawning takes place. Typically the female lays 200–800 eggs in the lec and they are immediately fertilized by the male. The female then picks up the eggs in her mouth and leaves the male to protect his lec. The female incubates the eggs in her mouth right through hatching and until the young fry are about 2 weeks old. During this period the female does not eat, hence one of the reasons that female fish grow slower than males.

Tilapia are a very adaptable species and can be reared in tanks, cages or earth ponds both in fresh and brackish water (ideally not more than 20 ppt salinity). Some species, such as *O. mossambicus* and *O. spilurus*, can be reared in full strength seawater, although they grow much slower than Nile tilapia. Unlike most other fish species, tilapia are able to consume minute phytoplankton that they filter out of the water. For this reason, expensive, commercial feeds are not necessary to achieve growth and nutrient-enriched water (“green water”), produced by the addition of animal manure or fertilizer, is sufficient to achieve a marketable fish. Besides phytoplankton, Nile tilapia will also eat zooplankton,
detritus, aquatic plants, insects and even small fish fry. Commercial pellet, waste food and almost any other type of feed given, with perhaps the exception of meat, is also eagerly devoured. Very little investment is, therefore, required in their nutrition and they are an excellent species for utilizing canteen, factory and agricultural waste products.

The biggest drawback to the culture of Nile tilapia is that they mature very early (within 6 months from hatching) and readily breed in grow-out ponds. This causes overcrowding and typically results in long grow-out periods of up to a year and a harvest of small, mixed-sized fish with very little market value. To overcome this problem, Nam Sai Farms produces all male fish by feeding male hormone-impregnated fish meal for 21 days to hatchlings. Not only does this solve the problem of overcrowding, but male fish grow significantly faster and achieve a larger size than females. The benefit to the farmer is huge, as the culture period is reduced to as little as 6 months, and the harvest consists of even sized, large, fat fish with high market value. The fish at Nam Sai are tested on a monthly basis by gonad squash method and are very close to 100% male. **Furthermore, they are male for life, despite what some people would have you believe.**

**SITE SELECTION**

Success or failure of a fish farm will be determined to some extent by site selection. The following factors should be considered:

1) **Soil**

The best way to find out if soil is suitable is to look for other ponds, canals or rice paddies nearby. Note the water clarity and ask local farmers how well the soil holds water. Ideally you want a soil that holds water and doesn’t make the water turbid.

As a general rule, clay soils or loams with a high clay content are best, as they hold water well and resist erosion, but beware of acid sulphate soil. If the pH of a soil (only take samples 20cm or more below the surface) is well below 4, then huge amounts of lime will be necessary to neutralize the acidity. A pH of 4 and above is fine.

Silty soils hold water well, but they can cause very turbid water and pond erosion can be severe during heavy rain. Suspended solids shade sunlight and make cultivating phytoplankton difficult. Such ponds are typified by very low dissolved oxygen in the early morning.

Very sandy and rocky soils are not generally good for aquaculture, as they don’t hold water well. They are also prone to erosion and bank collapse.

Laterite soils, despite being sandy, generally do hold water sufficiently and can be used for aquaculture.

2) **Elevation, slope and land shape**

Most plots of land are not an ideal square shape, but aim for areas as close to this ideal as possible. Access road and water supply costs will be cheaper if the land is wide enough to accommodate paired ponds. Fish transfer, staff monitoring and theft prevention will also be easier. Avoid long, narrow
strips of land that can only accommodate a long single line of ponds.

Flat land – this is ideal and makes farm design and excavation very simple. Water recirculation is possible without the need for high-head pumps. The only disadvantage is that gravity feed and drainage of water from ponds will not be possible.

Sloping land – a gentle slope can be of advantage, as it may be possible to design a farm so that water supply and drainage can be carried out by gravity. Farm design and excavation will be trickier, however, and a high-head pump will be necessary if one wants to recirculate water back through the farm.

Steep sloping land – this is not recommended for tilapia farms, as excavation will be difficult and expensive. There will also be a risk of land subsidence and the water may be cold if the area is located at high elevation.

1) Water

A typical tilapia grow-out farm, that discharges all effluent, will require approximately 3,250 to 3,750 m³ of water per hectare per month. Recirculating pond systems (zero discharge) may use as little as 300 m³ of water per hectare per month and a water supply will only be needed during the dry season.

Ideally, a site should have year-round water supply from a river, canal, lake or spring. Most often this water will have to be pumped into the farm, but any site that has sufficient elevation to allow water to feed the farm by gravity will save much on energy costs. Ground water can be used, but it requires more expensive capital investment and pumping costs. On the plus side, it is free of predators, aquatic life and most important, disease organisms.

Whatever the source of water, pay attention to water quality in terms of:

- **Turbidity** – highly turbid water will require more reservoir space to allow suspended solids to settle. Ponds won’t go green if water is very turbid.
- **Salinity** – very saline water (over 25 ppt) for short periods of the year is acceptable and can be an advantage for killing external parasites. If only sea water is available for a large part of the year, then a recirculating pond system will have to used.
- **pH** – acidic water (below pH 5) will require the use of a reservoir where water acidity is neutralizing using lime before use. Ideally the pH of supply water should be between 6 and 9. It can be measured with a pH test kit or pH meter.
- **Pesticides** – be careful of any sites that have vegetable, flower or fruit farms adjoining, as they often use lots of pesticides. They will be blown onto your land during spaying and may get into irrigation systems.
- **Heavy metals** – not a common problem, but possible in mining areas, near landfills or close to industrial areas.

If pesticide or heavy metal contamination is suspected, then water and soil samples should be sent to a lab for analysis.

Most sites that have good water supply are often flood-prone. Ask local people and look for floodwater lines on power poles. Even sites that flood regularly to 2 m depth can be used for fish farms, but a
large flood barrier should be incorporated into the design. Of course excavation costs will be higher and flood barriers take up land area that could be otherwise used for farming fish.

2) Access and location

Land rental and purchase prices will generally decrease with increasing distance from major roads. Many farmers will be attracted by this, but should be careful to consider the following points, as they will all affect a farm’s running costs:

- Does flooding make access difficult during the rainy season?
- Is there an electricity supply and how common are power cuts?
- Proximity to materials (fry, feed, fertilizer, ice) and markets.
- Availability of labour.
- Is there access by public road or is it necessary to cross private land?
- Is the location risky in terms of theft, drugs and violent crime?

3) Prior use of land

Prior use of a site will have a large effect on its suitability for a fish farm:

- Rice paddy and agricultural – ideal for excavating fish ponds, but aim to dig during the early dry season.
- Wooded – land clearance will be time consuming and costly.
- Old fish/shrimp ponds – if the design is good, only minor excavation work will be required, but excavation will be expensive if major changes in farm design are necessary.
- Marsh – often flood prone and tricky to excavate. Water drainage will be required. Excavators may get stuck at times.

FARM DESIGN

The following points should be taken into consideration when designing a farm.

- Is an outer flood barrier required?
- What size and depth of ponds are ideal?
- Could an outer canal can be used to recirculate water and provide protection against theft or sabotage?
- Consider how the design will affect length of access roads and electricity supply.
- Locate accommodation and bathrooms next to reservoirs to reduce water piping costs.
- Measure land elevation and be aware of water flow direction.
- Newly filled soil will contract by 10-20% in the future as it compacts down. Build bunds higher to allow for this.
- Try and maintain pond widths as standard so that a single seine net can be used for any pond.
- Keep bund widths over 4 m to avoid pond leakage and allow easy access.
1) Flow-through or recirculating system

Flow-through farms are those in which water is utilized only once and then discharged into the environment. They often have a reservoir for storing supply water, but not for treating effluent. If the water is fresh, then the effluent may be useful to irrigate crops, as it will be high in nutrients. The following are diagrams of flow-through farms:

Recirculating water systems utilize more land for reservoirs and canals, leaving less rearing pond area. They are environmentally friendly, as they don’t discharge effluent and utilize 10 times less water than flow-through farms. They are useful where water supply is poor in quality and quantity.
2) Pond size

There is no ideal pond size for growing tilapia. Big ponds require less time in labour (fertilising, feeding, etc), but are more difficult to harvest, take longer to prepare and fill with water and provide less control over wild fish species invasion. Small ponds are more costly to excavate (per unit area), but control of predators is easier and they are of advantage if selling fish regularly in small amounts (selling directly to the public and retailers).

The total number of ponds on a farm should take into account the method of sale. Some farms may consist of a single pond, but will generally be restricted to selling wholesale as they will not have a regular supply of fish available to be able to build up a retail market.

For those farmers planning to sell retail, it will be important to have a continual supply of tilapia all year round. If the grow-out period is 4 months, then it will be necessary to have a total of 8 ponds in order to have a pond available to sell every 2 weeks, or twice this if a pond per week is required. An extra couple of ponds should be added to allow for draining and pond preparation time.
As a guideline the following table can be used to determine ideal pond size:

<table>
<thead>
<tr>
<th>Main market</th>
<th>Fish sold per day (tonnes)</th>
<th>Pond size (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail</td>
<td>0.2 - 1.0</td>
<td>0.2-0.8</td>
</tr>
<tr>
<td>Retail &amp; wholesale</td>
<td>0.6 - 2.0</td>
<td>0.5-2.0</td>
</tr>
<tr>
<td>Wholesale</td>
<td>2.0 or more</td>
<td>&gt;2.0</td>
</tr>
</tbody>
</table>

Note: 1 ha = 10,000 m² and ponds sizes relate to the area of water and not the total area of land.

3) Pond depth

An ideal water depth is between 1.2 to 2.0 metres and newly excavated ponds should be 2 - 3 m deep to accommodate the water and to allow for some soil compaction. Ponds deeper than this are expensive to excavate, often provide little if any increase in fish production and require more fertilizer to stay green. This is because the phytoplankton that produce oxygen and provide food for the fish, are inhibited at depth due to the low light conditions. Water circulating machines such as paddle wheels or pumps will be necessary to achieve good production in deep ponds.

There is one exception to this rule and that concerns rain-fed ponds where a large volume of water is needed to prevent the pond quickly drying out in the dry season. In this case it may be necessary to increase water depth during the rainy season to 3 metres or more.

Ponds shallower than 1 m are not recommended, because temperature fluctuation will be very high and production per area will be lower due to the reduced volume of water and lower overall biomass of phytoplankton.

These recommendations are for rearing ponds. For reservoir ponds, the deeper the better, as water clarity improves with increasing depth. In this case it will be more of an issue of excavation cost and the ability of an excavator to dig very deep.
POND PREPARATION

There are four important steps in pond preparation:

1) **Eradicate wild fish from the pond.**

This is particularly important when stocking monosex tilapia, as any female tilapia (either wild fish or those left from the last culture cycle) will breed with the male tilapia you intend to stock. The result is overpopulation of the pond, leading to slow growth and a harvest mixed with small fish.

Drying the pond for 1-2 weeks is the best way to kill any unwanted remaining fish. This will also be beneficial to the pond bottom. If the pond cannot be dried, then apply a piscicide (such as rotenone, tea seed cake or cyanide) to any puddles of water remaining on the pond bottom.

2) **Lime the pond bottom.**

After draining the pond, it is advisable to treat the pond bottom with hydrated lime (CaOH). This is recommended practice in aquaculture, as it will kill some disease organisms and will buffer fluctuations in pond water pH. 600 kg per hectare is sufficient for old ponds and new ponds with a neutral pH. Extra lime will be needed for new ponds in acid soil areas. If soil pH is around 4, then 3,000 to 3,500 kg of lime per hectare will be required to neutralize soil acidity. If insufficient lime is applied, then water pH will drop later causing reduced growth and stress to the fish.

pH is measured on a scale of 1-14 and pH 7 is neutral. Acidic water will have a low pH and alkaline water a high pH. It can be measured very simply and cheaply using a pH test kit. For measuring soil pH, mix 1 part soil to 3 parts water, mix thoroughly and measure the water pH.

3) **Filter incoming water**

Once the pond has been limed and all wild fish eliminated, the pond can be filled with water. It is important that water is screened through fine netting to ensure that no wild fish fry or eggs can get into the pond. This can be done by attaching a filter bag to the water intake pipe or by pumping the water into a fine-meshed hapa.
4) **Add fertilizer to create green water.**

Once the pond has been filled with water, Nam Sai Farm recommends the addition of 30 kg of inorganic fertilizer (16-20-0 or 15-15-15) per rai to make “green water”. This is done by dissolving the fertilizer in water and broadcasting the solution around the pond. Alternatively, the fertilizer can be hung in a sack at the water intake where it will gradually dissolve.

Organic fertilizers, such as compost and animal manure can be used, but chemical fertiliser will create better water quality, thus ensuring higher survival of the newly stocked fish. A week is normally sufficient for the water to turn green, after which time fish can be stocked.

**FRY TRANSPORT**

The sex reversed tilapia fry you have purchased from Nam Sai Farm have been starved prior to packing. This will ensure that the water in the bags stays relatively clean and the fish should survive for 18 hours without any significant mortality.

Occasionally, however, significant mortalities do occur for a number of reasons. Nam Sai Farm asks all customers to follow the following set of guidelines with respect to fry transport:

- Please order and confirm in advance, as this will enable our staff to starve the fish for the optimum period prior to packing.
- Arrange a time to pick up the fish and arrive on time. Our staff will attempt to finish packing the fish at the time arranged. Not only will this minimize your wait, but it will also reduce transport time.
- Try and avoid travelling long distances during the day in April and May due to the extreme heat.
- If travelling during the day, then cover the bags with wet sacking to keep the temperature down.
- Alternatively, transport the fish in insulated tanks with aeration. This allows better control of temperature and carbon dioxide toxicity cannot occur as in sealed plastic bags.
PHOTO OF FRY IN TRUCK WITH SACKING

If a significant number of fish die in the bags during transport, then please inform Nam Sai Farm sales manager as soon as possible. The dead fish can be preserved in formalin solution (1 part formalin to 9 parts water). New fish will be given to customers to replace those lost during transport if Nam Sai Farm is at fault.

FRY RELEASE

Care should be taken when stocking your fish that the water temperature in the bags is not very different to that in the pond. If it is, then the fish will suffer shock on contact with water in which they are stocked. The recommended way to stock fish is to first unload the bags from the truck and to then float them in the pond for a period of 15 minutes. After this time the water temperature in the bags should have equilibrated with that in the pond and the fish can be released. To do this, first pull the neck of the bag to snap off the elastic band, then hold the bag upside down and discharge the whole of the contents into the pond.

NURSERY

Small, one-inch fry are very susceptible to predation by fish, snakes and birds. They are also less tolerant to poor water quality than older, larger fish. Farmers that stock small fry directly into large, manured grow-out ponds find the results are a bit “hit and miss”. If survival is high, then the fish may be too dense and not grow very well. If survival is low, then the fish grow fast, but the total harvest will be small.

The solution is to nurse small fry to a large size and then stock graded fingerlings (2-4”, 2-50g) in the grow-out pond. Not only will this ensure better control over fish density, but culture period and individual size variation of the harvest is reduced. The result is a much higher profit margin.
1) Nursing tilapia fry in hapas

Hapas are very useful for nursing tilapia fry, as predation can be eliminated, they reduce the need for special nursery ponds (can be fitted in grow-out ponds and supply channels to save on space) and allow fish to be harvested quickly and simply using a bamboo pole to confine the fish in the corner of the hapa.

Fish grow slower in hapas, however, due a combination of high stocking density and poor water exchange. It is important that the fry do not become too dense or mortality will be high.

The following table provides a guideline:

<table>
<thead>
<tr>
<th>Size of tilapia</th>
<th>Recommended stocking density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td>Grams</td>
</tr>
<tr>
<td>1.0</td>
<td>0.2</td>
</tr>
<tr>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>3.5</td>
<td>10.0</td>
</tr>
<tr>
<td>4.0</td>
<td>20.0</td>
</tr>
<tr>
<td>4.5</td>
<td>50.0</td>
</tr>
</tbody>
</table>
The following guidelines should be followed when nursing fry in hapas:

- Only install hapas in water of good quality, avoid using grow-out ponds with high organic matter input.
- Cover hapas with bird netting.
- Make sure all holes have been repaired in hapas before using them.
- Ideally hapas should be about 1 m deep and fixed 60-70 cm underwater.
- Don’t use recycled plastic rope for hapas, as it will deteriorate and snap in high wind.
- Use bamboo (“mai roowak”) for attaching hapas, as it is cheap, strong and flexible.
- Feed 20-25g of good quality powdered or pelleted feed (depending on size of fish) per m2 of hapa per day divided into 3 feeds.
- Growth is much faster and FCR lower in ponds that are green and have aeration.
- Change hapas once per month, grade the fish and thin them out.

For optimum survival, it is recommended that fry nursed in hapas are size graded and thinned out once per month. Grading fry by size is achieved by sieving fish through netting, plastic mesh or parallel bars. Several sizes of grader will be necessary depending on the size of fish that will be graded.

Counting fry can be done by volume or weight. Small plastic cups can be used for measuring fry by volume:

\[
\text{Total fry} = \text{no. fry in 1 cup} \times \text{total no. cups}
\]

The weight method is similar, but the number of fish are counted in a weighed sample:

\[
\text{Total fry} = \frac{\text{total weight of fry}}{\text{no. fry in sample} \times \text{weight of fry in sample}}
\]
Please note:

- It is better to count the fish in more than 1 cup or sample to get a more accurate estimate of total fry numbers.
- If the number of fish in sample 1 and 2 is very different, then this will indicate that there has been error in counting.
- Be careful that the sample is representative of fish from the whole batch by confining and mixing the fish before taking samples. Large and small fry will tend to separate out.
- The more even size the fish are the more accurate will be the estimate of fry numbers.

2) Nursing fry in earthen ponds

The main advantage of nursing fry in earth ponds is that growth is fast. Small ponds of 0.1 – 0.4 hectares are recommended, as they allow better protection against predatory birds and fish.

The following guidelines should be followed:

- Erect bird netting over the pond
- Ensure all predatory fish are eradicated from the pond
- Screen water when filling the pond.
- Use 30 kg of 16-20-0 or 15-15-15 fertilizer per rai to get the pond green before stocking fish.
- Stock fry within a week of filling the pond.
- Stocking slightly larger fry will improve survival.
- Use a good quality powdered feed (30% crude protein or higher) and small size commercial pellets as the fish get bigger.
- Change water in the pond if it gets too green and/or fish begin to die.
- Installation of a paddle wheel or some other aeration device is not essential, but recommended for improving growth and survival. Aerate at night and longer on cloudy days.
GROW-OUT

Tilapia can be stocked alone or in combination with other fish species and/or crustaceans. The advantage of stocking many species is diversified risk and a larger total harvest per pond without significant increase in costs.

Fingerling, size graded tilapia (3-4 inch) should ideally be stocked in grow-out, as the fish will attain market size very quickly (grow-out ponds can produce multiple crops per year this way) and harvested fish will be very even in size. 1 inch fry can be stocked, but stock twice as many fish per rai to allow for high mortality. Results will be unpredictable, as survival of 1” fry is unreliable. If survival is high, then the fish will be too dense and will stop growing before achieving market size. If survival is low, then the fish will grow very fast to a large size, but the total biomass of fish harvested will be low.

Typically 3.5–7.5 tonnes of tilapia can be produced per hectare. With aeration and the use of good quality feed, this yield can be increased to 12-18 tonnes per hectare. However, frequent water exchange will be necessary to maintain water quality and running costs will increase significantly. There is also greater risk and disease problems are more common.

1) Stocking density

Stocking density is one of the most important factors that will determine the yield and profit of a tilapia pond. Stock too many and they won’t grow to market size, stock too few and the overall harvest will be small. There is no set number of fish that should be stocked in every case, as it depends on the size of fish stocked, the size of fish desired at harvest and the method used for culture (feed, water exchange and aeration). The following points can be used as a guide:

- Most farms in Thailand stock 1 inch tilapia at 1-3 fish per m² (10,000-30,000 fish per hectare) and raise fish to 300-600g. Nam Sai generally recommends farmers stock 20,000 1 inch fish per hectare. This should be reduced to 10,000 fish per hectare if 3-4 inch fingerlings are stocked.
- Stocking graded fingerlings (10-50g)) is recommended, as grow-out period is shorter and the harvested fish will be more even in size.
- Stock at low density if a large market size fish is required.
- It is possible to stock at high density and harvest half of the fish once growth slows down. The rest of the fish will then carry on growing. This strategy is good if there is no water supply in the dry season.
- A higher stocking density can be used if fish are fed and aeration and/or water exchange is provided.
- As stocking density increases, feed and production costs per kg increase, but more fish can be produced.
- As a general rule stock at higher density if market price is high, as the extra investment in feed, aeration, etc will be cost-effective.
2) Pond fertilization and “green water”

Tilapia have the ability to filter microscopic plants (phytoplankton) and animals (zooplankton) from water. Farmers can use this ability to eliminate the need for expensive commercial feeds. It is similar to rearing sheep on grassland, but there are other added advantages besides providing food for the fish:

- Phytoplankton produced oxygen that is essential to fish.
- Phytoplankton absorb nitrogenous waste produced by fish.

Phytoplankton are no different than any other plant species in that they harness energy from sunlight in a process called photosynthesis. In the process they produce sugars from carbon dioxide and water, whilst oxygen is produced as a byproduct. During darkness, photosynthesis is not possible and plants respire just like animals, a process that utilizes oxygen and produces carbon dioxide. It is for this reason that dissolved oxygen is lowest at dawn and highest in the afternoon. This is also the reason that pH is lower in the morning, as some of the carbon dioxide produced from respiration will combine with water to produce carbonic acid. Large daily pH fluctuations can be reduced somewhat by occasional addition of crushed limestone to increase alkalinity (ideally maintain at 100 mg/l or more) and so buffer pH changes.

Apart from carbon dioxide and sunlight, plants also require certain minerals and trace elements for growth. Nitrogen (N) and phosphorous (P) are the most important of these, although, potassium (P), magnesium (Mg) and other elements can also be limiting in water. By adding large amounts of these nutrients in the form of inorganic N-P-K fertilizer, manures or other organic fertilizers a dense phytoplankton bloom can be created. This is visible to the farmer as green water and it is the aim of the farmer to maintain a correct level of phytoplankton by monitoring the color and clarity of the water. Too green and oxygen may become too low at dawn (resulting in fish mortality), not green and the fish don’t grow well, as they don’t get much to eat.

Approximately 4 kg of N and 1-2 kg of P per hectare per day is required to maintain a green pond. These figures are for weights of N and P only so be careful when calculating amounts of fertilizer to add. For example, urea (46-0-0) is actually 46% N, whilst triple super phosphate (0-46-0) is 46% P₂O₅ and only 20% P. The following table can be used as a guideline:

<table>
<thead>
<tr>
<th>Type of fertilizer</th>
<th>Amount/hectare/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-20-0 (N-P-K)</td>
<td>175 kg</td>
</tr>
<tr>
<td>46-0-0 (urea) + 0-46-0 (phosphate)</td>
<td>61 kg + 40-70 kg</td>
</tr>
<tr>
<td>15-15-15</td>
<td>187 kg</td>
</tr>
<tr>
<td>Fresh chicken manure</td>
<td>1,875 kg</td>
</tr>
<tr>
<td>Chicken manure + 46-0-0 (urea)</td>
<td>1,100 kg + 26 kg</td>
</tr>
<tr>
<td>Fresh pig manure</td>
<td>5,000 kg</td>
</tr>
<tr>
<td>Cow/buffalo manure</td>
<td>6,000 + kg</td>
</tr>
<tr>
<td>Ami (MSG waste)</td>
<td>1,250 liters</td>
</tr>
</tbody>
</table>
The following points should be noted with regards to fertilization:

- Fertilize ponds on a weekly basis.
- Fertilizer requirements will increase as the fish grow.
- The use of feed will reduce or even eliminate the need for fertilizer, as it also contains N and P.
- Inorganic fertilizer can be either be dissolved in water and broadcast or suspended in a bag near the water intake or a paddle wheel.
- Organic fertilizers, such as manures, are best applied regularly in small amounts at a number of locations spread out around the pond.
- Inorganic fertilizer provides for better water quality, but has less food value. Manures are generally cheaper, keep the water much greener for longer, but low dissolved oxygen in the morning is not uncommon. Only use inorganic fertilizer if sensitive species such as prawns, shrimp and sea bass are to be stocked.
- Fertilize according to the needs of the pond. Increase fertilization if a pond is not green and decrease or stop altogether if the pond gets very green and fish start to die. Exchange some water if the problem becomes acute.
- Chicken manure is high in P and it is cheaper when used in combination with urea. Avoid chicken manure mixed with rice husk, as it will float around for months.
- Don’t exchange water unless there is a problem with water quality, otherwise fertilizer will be lost from the pond.
- Don’t use organic fertilizers in nursery ponds with hapas, as mortality will be high and the water will cause skin irritation to staff when working in the pond.
- If a pond won’t go green in the rainy season, then be careful of not adding to much fertilizer, as the pond may be short of sunlight and not nutrients. When the sun does come out, the pond may become too green and fish death may result.
- If a pond won’t go green when using inorganic fertilizer, it could be due to another nutrient being limiting. Dolomite can be added to provide Mg and 15-15-15 instead of 16-20-0 if K is limiting.
- Composted agricultural waste can be used for fertilizing ponds. Compost heaps are usually located half submerged in the corners of ponds. Nutrients will gradually leak out into the water.

3) Supplemental feeding

Although not essential, most farmers in Thailand do use some feed for rearing tilapia. Fish grow slower and yield is lower when only fertilization is used (“green water”). Supplemental feeding means providing an edible food source, usually on a daily basis, which will add to the natural food the tilapia are already eating. This food is only a partial fulfillment of the total fish’s diet, as the idea is to keep costs low. Most low cost feedstuffs are low in protein. They will provide energy to the fish so that protein they consume from natural food is conserved for growth and not burned as energy. Fortunately, tilapia are fairly omnivorous and can utilize a wide variety of feedstuffs including canteen waste, cereal grain residues, brewery yeast, bread, wafer, spoiled animal feeds, crop wastes, duck weed, mill sweepings, fruit waste and more.

PHOTO OF SUPPLEMENTAL FEEDS

These feeds are used in combination with “green water” techniques and fertilization will still be carried out, albeit at a reduced rate, as the supplemental feed will supply nutrients to the pond. The following
considerations should be made when evaluating a potential feedstuff:

- Will the fish eat it?
- Are the increased returns (faster growth and increased size of the harvest) cost effective in terms of added costs and labour?
- Is it safe from micro-organism infection?

For example, a farmer can find a supply of oil palm meal for 7 baht per kg. He finds it is safe for the fish and they like to eat it. He compares the investment and income of a fed and non-fed (fertilized only) pond and gets the following results:

<table>
<thead>
<tr>
<th>Details</th>
<th>Fertilized only</th>
<th>Fed with oil palm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of culture period (months)</td>
<td>7.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Pond preparation time (months)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Fish harvest and draining (months)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total culture period (months)</strong></td>
<td><strong>7.7</strong></td>
<td><strong>6.7</strong></td>
</tr>
<tr>
<td>Total investment in fertilizer ($/ha)</td>
<td>1,700</td>
<td>1,450</td>
</tr>
<tr>
<td>Total investment in oil palm meal ($/ha)</td>
<td>0</td>
<td>1,040</td>
</tr>
<tr>
<td>Cost of fry stocked ($/ha)</td>
<td>161</td>
<td>242</td>
</tr>
<tr>
<td>Pond rental, labour &amp; other costs ($/ha)</td>
<td>400</td>
<td>600</td>
</tr>
<tr>
<td><strong>Total costs ($/ha)</strong></td>
<td><strong>2,261</strong></td>
<td><strong>3,332</strong></td>
</tr>
<tr>
<td>Total fish harvested (kg/ha)</td>
<td>3.875</td>
<td>5.560</td>
</tr>
<tr>
<td>Mean price of fish per kg ($)</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Total income ($/ha)</strong></td>
<td><strong>3,487</strong></td>
<td><strong>5,004</strong></td>
</tr>
<tr>
<td><strong>Total profit ($/ha)</strong></td>
<td><strong>1,226</strong></td>
<td><strong>1,672</strong></td>
</tr>
<tr>
<td><strong>Profit per month ($/ha)</strong></td>
<td><strong>159.22</strong></td>
<td><strong>249.55</strong></td>
</tr>
</tbody>
</table>

It is clear that the farmer makes more profit by feeding oil palm meal as a supplemental feed, but that may not necessarily be the case if he had fed at a much higher rate.

Although this is a hypothetical example, most farmers in Thailand do find that supplemental feeding with, rice bran, canteen waste, and many other feedstuffs is more profitable than using a fertilized system only. What feedstuff they use, however, depends on what is available at what price within a reasonable distance from the farm. For this reason, farmers vary in the types and amounts of inputs they use and they chop and change depending on what is available at what price. Interestingly, it is very common practice to use commercial pig pellets. Like other supplemental feeds, they are cheap and contain low levels of protein, but they are freely available and safe from micro-organism infection.

4) **Complete feed diets**

Complete feed diets are those in which most food eaten by the fish is provided by the farmer and very
little comes from natural sources. They are used to increase production per area of pond, speed up growth and provide a clean and consistent product. When used in combination with aeration and/or water exchange, they allow the farmer to stock at high density and still maintain good growth. Of course the investment costs are higher and a good quality diet, containing all the necessary nutrients in the right amounts for the fish, is essential. As a general rule, the price of tilapia should be at least 2.5 times higher than the price of feed for them to be cost effective. Floating extruded pellets are best, as they make it easy to monitor feeding response and so give better food conversion to meat. Sinking pellets entail feeding tray monitoring to reduce wastage. Diets ranging from 15-35% crude protein can be used. High protein feed is more expensive, but growth and food conversion is better.

One can expect a food conversion of between 1.1 and 1.7 for a decent floating pellet with 30% crude protein. That means you get an increase in weight of fish by 1 kg for just over 1 kg of feed:

$$\text{F.C.R.} = \frac{\text{Amount of feed eaten (kg)}}{\text{Gain in weight (kg)}}$$

For example, a farmer stocks 10,000 30g tilapia in a 1 hectare pond. He harvests 5,800 kg of tilapia at harvest and uses 7,790 kg of feed in total:

$$\text{F.C.R.} = \frac{7,900}{5,800} - (10,000 \times 30 / 1,000)$$

$$= \frac{7,900}{5,500}$$

$$= 1.44$$

F.C.R. is much lower for poor quality feeds such as rice bran, corn, etc. That means you need to use more of it and it may not necessarily be cheaper. For example, if rice bran is 5 baht per kg and gives an F.C.R. of 4 and a commercial pellet diet is 17 baht per kg and gives an F.C.R. of 1.3, then which would be the most cost-effective feed to use:

Rice bran 4 kg x 6 baht = 24 baht per kg of fish produced.

Pellet 1.3 kg x 17 baht = 22.1 baht per kg of fish produced.

For a given feed, the results can be very variable, and it is important that when feeding the following points are covered:

- Don’t over-feed fish – observe their behavior and stop feeding once the fish slow down and begin to eat very slowly. Appetite will vary depending on time of day, temperature, cloud cover, water quality, size of fish, etc. One way is to give them enough feed that they can consume in 10-15 minutes time.
- Feed at least 2 times per day, preferably 3.
- Use a floating feeding ring to stop feed being washed onto the bank.
- Feed a pellet that is smaller than the fish’s mouth.
- Spread the feed out to prevent dominant fish getting all the feed.
- Keep records of food fed to different ponds so that FCR can be calculated. This way feeding technique and performance of different feeds can be assessed.
- Protect stored feed from rodents, as not only do they eat the feed, but will urinate on it and can spread Leptospirosis disease.
- Keep feed dry and airy to maintain freshness. Buy regularly in small amounts.
- Don’t use any feed with obvious fungal contamination, as it will be toxic to fish.

5) **Polyculture in “green-water” systems**

Nile tilapia can be raised in conjunction with other species of fish and also crustaceans. Although more complicated, better use is made of natural food and yield is higher. The reason is that Nile tilapia will tend to concentrate their feeding activity on the one or two sources of food that they prefer. In a fertilized-only system, this will be primarily phytoplankton plus some periphyton, zooplankton and detritus. Aquatic plants, surface insects and animal material are eaten to a much lesser extent. By stocking a variety of different fish, any food not eaten by the tilapia will be eaten by another species and will not be wasted.

The following table can be used as a guide for stocking 3 inch per-nursed fish in fertilized ponds:

<table>
<thead>
<tr>
<th>Type of feeder</th>
<th>Species available</th>
<th>Number per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytoplankton</td>
<td>Nile tilapia, silver carp</td>
<td>10,000 - 20,000</td>
</tr>
<tr>
<td>Macrophyte</td>
<td>Grass carp, silver barb</td>
<td>200 – 250</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>Rohu, bighead carp, catla, striped catfish</td>
<td>500 – 800</td>
</tr>
<tr>
<td>Bottom/detritus</td>
<td>Common carp, <em>Clarias</em> catfish, mrigal, snakeskin gourami, giant gourami, shrimp, prawns</td>
<td>500 – 800</td>
</tr>
<tr>
<td>Carnivorous</td>
<td>Snakehead, sea bass, climbing perch</td>
<td>70 – 140</td>
</tr>
</tbody>
</table>

6) **Polyculture using cheap supplemental feeds**

As already mentioned, cheap supplemental feeds are used to increase fish growth and yield. Different species of fish will prefer different types of food and this will affect optimal stocking rates for each species. For example, catfish make good use of canteen waste, grass carp and silver barb enjoy eating vegetable matter (duck weed, morning glory, etc), giant freshwater prawns prefer animal wastes, etc. There are no set rules concerning ideal species and numbers to stock. Each farmer should find his own preference based on trial and error. The following points should be considered:

- More fish can be stocked with increasing levels of feed inputs.
- Air-breathing species, such as *Clarias* catfish, can be stocked at very high density.
- Aeration will be necessary to increase pond yield above 1 tonne per rai for non-air breathing species.
- Stock more fish per rai if the market size of a fish is small and vice versa.
- Aim to have all species stocked achieve market size at the same time.
- Beware of predation between species and stock suitably sized fingerlings to avoid this.
- Utilize species with high market demand and price if possible.
- Optimize yield by suiting species to feed availability.
7) Polyculture using commercial pellet

Most commercial pellets available for tilapia are floating. Bottom-living crustaceans, such as giant freshwater prawns, tiger shrimp or white shrimp can be stocked in polyculture with tilapia without the prawns eating any much of the feed. They will happily survive on natural food, faecal material from the tilapia and any dead fish. At the same time they will release nutrients from the pond bottom for recycling back into the food chain. The relationship between crustaceans and tilapia in earthen ponds is known to be symbiotic in that they provide food for each other rather than competing.

Although tilapia do like to consume small shrimp and prawns up to 0.2g in size, farmers do successfully stock small post larvae without any problem probably because they are difficult to catch. Pre-nursing of shrimp or prawns, just like tilapia, would be recommended to get better consistency of results. Nam Sai has done trials stocking 2-5 0.3g freshwater prawns with 1 30g tilapia per m2 successfully. Rearing will be more problematic if the fish are stocked denser than this and regular water exchange will be necessary to maintain growth and reduce mortality. Aeration is not essential, but best used as a precautionary measure for the prawns. Growth and food conversion ratio (F.C.R.) of the tilapia will improve as an added advantage. Feeding should be carried out three times per day, but don’t overfeed the fish. By slightly underfeeding them, they will be forced to eat some natural food and this will improve F.C.R. Using this method, up to 100 kg of prawns and 1,000 kg of 700g size tilapia per rai can be produced in 4 months.

The system could be further improved by introducing other species that won’t eat the tilapia pellets, but can grow on natural food only. For example snakeskin gourami are smaller and less aggressive than tilapia. As such, they can’t compete with the tilapia for food and will resort to eating detritus and periphyton, their preferred natural food.

The important thing to remember when looking at a polyculture system incorporating commercial feeds is that it is only possible if there is a good market price for produce. In the red tilapia/prawns example, both red tilapia and prawns fetch a high market price. If market prices are low, then rearing methods should be limited to “green water” with or without supplemental feeding with cheap feedstuffs.

FISH HARVESTING

1) Seine netting

The most common method of harvesting fish in ponds is to use a seine net. This can be made out of a variety of meshes and materials. Knotted polyethylene is the cheapest and most durable material, but it has an abrasive effect on the fish. Knotless nylon, although more expensive, is much softer and more suitable for fry and fingerlings.

The net itself should be about 8 m deep and at least 40% longer than the width of pond to harvest. The bottom of the net has lead weights sewn in to stop fish swimming under. The net is pulled from one end of the pond to the other by workers spaced out at intervals (the more people the easier it is). Each worker pulls the bottom of the net whilst keeping it tight to the bottom. The process is made easier by reducing the water level to about 80 cm deep. All workers should attempt to reach the far bank at the same time to give the fish less chance of escaping. Many sweeps of the net will be necessary and the water level should be dropped as the number of fish reduces. Finally the pond is pumped dry and any remaining fish caught in the mud on the bottom.
2) Harvest basin

Another method of harvesting fish requires that the pond is designed with one deep corner, approximately 50cm deeper than the rest of the pond. A bamboo and net barrier is put across the corner prior to harvest. The pump is set up so that water is pulled through the barrier, whilst the fish congregate against the net and can be easily scooped up. This method is more stressful to fish and is not recommended if the fish are to be kept alive after harvest.

Once caught, fish can be transported in a variety of ways. For short distances they can be scooped up in plastic baskets or nets and carried to the truck or waiting hapa. For longer distances they can be transported in bins or tanks of water on a truck. Plastic bins are particularly useful, as two people can lift them on and off a pick-up truck fairly easily.

MARKETING

Tilapia are marketed both live and dead in Thailand. In North and North-East Thailand, the public prefers to buy live fish and so farms generally sell directly to market traders, often through a middle man who takes care of transport. In Central Thailand, the public mostly prefers to buy dead fish on ice and wholesalers take care of supplying tilapia to retailers. There are some live fish sales in Central Thailand, however, and this trend seems to be increasing.

Fish harvesting and marketing in Thailand usually falls into one of the following categories:

1) Employment of a pond harvester or cooperative

In this case the farmer negotiates a price before harvesting the fish. The price is typically 25% cheaper than that given by wholesale markets, as the fish harvester takes responsibility for pumping the pond, employing staff, harvesting and selling all the fish. The farmer need only watch as the fish are weighed.

This method is frequently employed by small farms, especially those involving animal integration, as it is not cost-effective for them to buy harvesting equipment and they don’t have large numbers of experienced staff to do the job.

It is also used in areas where the demand is for live fish and there are no wholesale markets. In Chiang Rai, for example, there are a number of cooperatives. Besides harvesting the fish and providing a market, they make it possible for a farmer to sell large volumes of live fish in a single day. His time can then be spent on rearing fish rather than marketing them.

2) Sell to the wholesale fish market

In this case the farmer harvests his own fish and delivers them to the wholesale fish market. This enables the farmer to get a better price, but necessitates investment in a net, labour, transport, ice, etc. Often the fish must be sent to the market at night or in the very early morning and this also has its costs.
Many farmers find that wholesale fish markets will only quote a price once they see the fish. This leaves the farmer in a poor position, because he has to harvest his fish first and is then at the mercy of the fish wholesaler who will often give a very poor price.

3) Sell the fish retail

This method enables a farmer to cut out the middle man and gain a control over the price of his fish by selling to shops, market stalls and the public. The disadvantage is that the fish must be sold in small volumes and it takes time to sell a whole pond. It also takes time in building up a market and it is essential that the farm always has a supply of fish to maintain his regular customers.

FISH FLAVOUR

Most fish species reared in freshwater are notorious for picking up muddy or earthy off-flavours. This is caused by two chemicals, geosmin and MIB (2-methyl-iso-borneol), which can be produced by certain species of freshwater blue-green algae and actinomycetes bacteria. The reasons as to when and why these chemicals are produced is not fully understood, as if you have these species of blue-green algal species in your pond, you don’t necessarily get off-flavour. They are certainly more prevalent in the dry season than the wet season and the following factors are known to improve flavour:

- Reduce use of manures and other organic fertilizers, particularly towards harvest time
- Provide aeration
- Drain and dry ponds after every harvest
- Don’t over-fertilize ponds
- Don’t overfeed fish

Off-flavour of fish can be tested by smelling and tasting samples of fish cooked (without seasoning) by microwave or steaming. Only one or two fish will be sufficient, as all the fish in the pond will have the same flavour. Meat nearest the head will have more off-flavour than that nearer the tail.

If fish are found to have off-flavour, then reduce fertilization and exchange water. An alternative is to harvest the fish live and keep them in water free of geosmin and MIB for 3 days. There will be some weight loss, but meat quality will improve due to fat depletion.

HEALTH CONSIDERATIONS

Some people worry that the use of male hormone for 21 days in sex reversal could be a health risk to the consumer. This was disproved many years ago, as it was found that the levels of male sex hormone in market-sized monosex fish was actually lower that in males in mixed sex populations.

In reality tilapia are a very healthy food to eat. Like most fish, they are relatively low in total fat and relatively high in polyunsaturated fatty acids. Polyunsaturated fatty acids, such as omega-3 fatty acids in fish oil, have been found to decrease blood triglyceride and cholesterol in animals and humans. Thus, adequate consumption of fish helps maintain a healthy heart and lowers the risk of stroke and heart attack.