Chapter 7
Feeds and feeding

Why feed the cultured fish?
A fish farmer may wonder why he needs to add extra feed to his pond when he already adds fertilizer to provide food for the fish. Since food is expensive, the farmer may not be willing to provide the fish with extra food and must therefore be taught why additional feeding is necessary. By correctly feeding the fish the farmer will be able to improve production and increase his profit.

This section, together with Appendix 1, gives information on energy, nutritional requirements and the feeding habits of fish. First, the types of food available to them and the ways one can provide the fish with these nutrients are described. Finally, some notes on the economic effects of feeding are included.

Energy requirements
Fish (and other animals) require food to supply energy for movement and other activities as well as for growth. As fish are 'cold-blooded', their body temperature is the same as the water in which they are living. They therefore do not have to use energy to maintain a stabile body temperature and therefore tend to be more efficient users of food than other animals. The optimum temperature for growth is different for each species. Within a species' preferred range of temperatures, the metabolic rate, and the need for food, increases as the optimum temperature is reached. This explains why in areas where there is a wide temperature range during the year, the fish eat much more food during the summer than in winter.

Energy can be defined as the capacity to do work. Free energy is that which is left for biological activity and growth after the energy requirements for maintaining body temperature are satisfied. Excess energy is dissipated as heat. This is important to fish farmers as the most economically important outcome is the quantity and cost of the energy available for the growth of the animal being cultured. This energy is supplied by food. The food requirements of fish vary in quantity and quality according to the species, its size, its feeding habits, its environment, etc.

The gross energy (GE), also known as gross calorific value of a food, is the total energy contained in it. Not all of the energy is available to the fish. Different parts of the diet have different amounts of energy available. The digestible energy (DE) of a food is the GE of the food less the energy of the feces. The energy available for the 'building blocks' of growth is what remains after the energy for metabolism, reproduction, etc., has been supplied.

Metabolism is the sum of all chemical and energy processes of the body. Metabolism includes the storage of food energy as fat, protein and carbohydrate, and its conversion into free energy for work and growth. The metabolic rate of small fish is greater than that of large fish. Small fish grow faster than large ones in terms of percentage increase in weight per day. Therefore, the feed requirements of small fish are different to those of larger fish, with smaller fish requiring a higher feeding

Nutritional requirements of the juvenile stages of local aquaculture species:

Nutrient	**Species**			
	Tilapia	Common carp	Trout	Catfish
Protein	35%	25–38%	40%	40–42%
Lipid (fat)	8%	Up to 18%	12%	10–12%
Energy (Kcal/kg)	2500–4300	2700–3100	2800–3000	2800–3100

Fish feed is about 50% of the cost to produce the fish. Therefore, the farmer needs to ensure that the feed is not wasted and that the correct feed is being given to the fish. There are many different types of feeds, so speak to your local feed supplier for the appropriate ones for your fish.

ration. At a certain body size, growth rate starts to decline rapidly. The optimum marketable size normally occurs around this point. A summary of the essential components of feeds is given in Appendix A.

Nutrional requirements of particular fish
As each species eats a different diet, each species of fish has its own nutritional requirements. Carnivorous fish (such as catfish and trout) require a high protein diet (around 40%) which has a high proportion of fishmeal. Herbivorous species require a lower protein content (around 30%) and can be fed a higher proportion of plant meal (such as soybean or maize) as part of their diet. An example of the nutritional requirements of a few species is shown in the table on page 40.

Feeding habits
It is important to know the feeding preferences of the species being cultured so the correct food can be provided at all times in order to maximize growth. The feeding preferences are determined by observing the fish as well as by examining the gut of naturally occurring fish.

Fish (and other animals) can be divided into different feeding classes:

Herbivores – feed only on plants (e.g. *Tilapia rendalli*, grass carp)
Carnivores – feed only on other animals or meat (e.g. trout, bass)
Omnivores – feed on both animals and plants (e.g. common carp)
Planktivores – feed on the very small plants and animals in water (e.g. mullet, silver carp)
Detritivores – feed dead plant or animal material on the bottom (e.g. *Oreochromis mossambicus*).

Natural foods are the best foods for fish and include algae (phytoplankton), zooplankton, detritus, snails, worms, insects and insect larvae, small plants like duckweeds and various other weeds and grasses that are found in a fish pond. If the fish is carnivorous, smaller fish can be a food source. Some fish prefer only one kind of food while others will eat a few kinds of food.

The farmer should encourage the growth of these natural foods by maintaining the quality of the water, proper fertilization of the pond bottom and the water, etc. Sometimes, however, the farmer must add food to the pond because the pond is not producing enough food for good fish growth. The best supplementary foods a farmer can put into the pond are extra natural foods. But there are a great number of other foods that fish will eat.

Depending on the type of fish in the pond, almost anything can be used as a supplementary food. Common supplementary foods are: bread crumbs, rice bran, fish meal, ground-up maize, oats, barley, rye, potatoes, broken rice, soy bean cakes, peanut cakes, corn meal, cottonseed oil cakes, coconut cakes, sweet potatoes, guinea grass, napier grass, water hyacinth, wheat, and leftover animal feeds and some animal manures.

Raw materials containing high amounts of animal protein, such as fishmeal and blood meal, are scarce and expensive. It is therefore easier to obtain the relatively high protein requirements for catfish by using feedstuffs that contain higher quantities of vegetable protein such as plant oilseed cakes and meals. These by-products from the agriculture industry are more common, cheaper and generally available in large quantities.

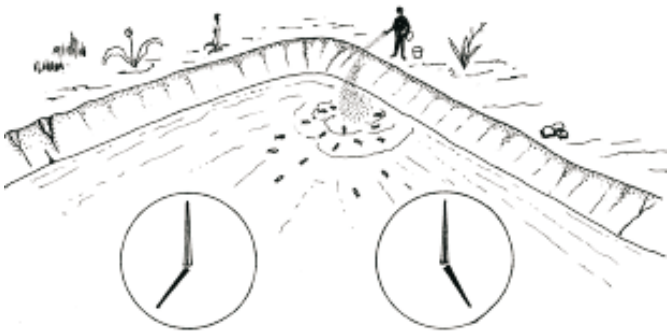
INFO BOX: STORAGE OF DRY FEED

- Feed deteriorates rapidly unless stored in cool, dry conditions.
- Feed bags should be stored in rat-proof indoor conditions, and raised above the ground to prevent moisture contamination.
- Feed should never be stored in humid places such as net equipment stores or tunnels.
- Feed should not be stored for more than 6 months.

As there is little large-scale intensive aquaculture in most African countries, the present demand for raw materials comes mainly from domestic poultry and livestock industries. Consequently, there are generally no specific vitamin and mineral supplements available for aquaculture species.

The type of extra food supplied depends on the kind of fish. For example, tilapia will eat many vegetable or grain-sourced waste products, including the supplementary foods listed above, which is why they are such good pond fish. The silver carp, on the other hand, will eat only phytoplankton, even when it is a fish of marketable size. It is therefore important that the farmer knows what the fish will accept before putting extra food into the pond.

When the stocking density of fish is increased to levels beyond those capable of surviving on the natural food in the pond, the growth of the fish can only be maintained by supplementing the natural food with some artificial feed. This is the single most important management element to increase the pond's fish production. The type and quantity of food fed must be carefully considered as it may negatively affect the health



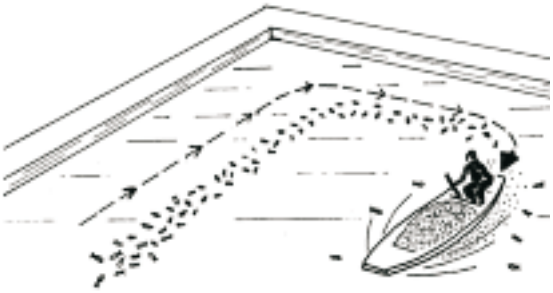
Fish should be fed in the same place and at the same times every day, preferably in the early morning (7am) and late afternoon (5pm).

INFO BOX: FLOATING AND SINKING FEEDS

- Floating pellets have an advantage in that you can observe the fish feeding, which provides information both on the condition and size of the fish as well as the amount of feed that they will eat at one feeding. Once they stop taking the feed no more pellets should be given.
- Sinking pellets are better designed for fish that prefer to feed off the bottom of the pond and that do not rise to the surface for floating pellets. The disadvantage is that it is difficult to know when the fish have eaten their fill, with the subsequent risk of over-feeding the pond, thus polluting it.

Various types of artificial feeds and their uses:

FEED TYPE	SIZE	ATTRIBUTES
Artemia or brine shrimp	Microscopic	Artificially newly-hatched livefood for fish fry. Contains all the feed requirements for swum-up fry. Dried eggs are available in cans that are easily stored until used.
Specialised dry micro-sized fry and larval feeds	Several microns only	In powder form for swim-up fry and very small juveniles. Can be laced with hormones or other treatments, such as to produce mono-sex tilapia.
Flakes	Thin, easily crumbled	Ideal high-protein feed for small fish and ornamental species.
Spirulina flakes or pellets	1–5 mm	Spirulina-based dry foods for vegetarian fish, like some tilapia and ornamental species.
Crumbles	0.1–1 mm	Residue of pellets, ideal for juvenile fish.
Pellets	0.5–1 mm	Fishmeal-based balanced diet for juveniles and fingerlings.
	1–3 mm	Used to stimulate growth of juveniles and sub-adult fish, with high protein content.
	3–5 mm	Reduced protein content for adult fish.
Floating	1–5 mm	For surface-feeding fish like trout.
Sinking	1–5 mm	For bottom-feeding fish like tilapia, carp and catfish.
Chicken or rabbit pellets	3–5 mm	Not designed for fish, but acceptable to most tilapia, carp or catfish species. May be more readily available then actual fish pellets.



Methods of adding supplemental feeds to a pond. Adding food at wooden stakes (far left) and from an open-bottomed boat (left).

Recommended feeding levels (% of body weight/day) for catfish at different temperatures (Hogendoorn *et al.*, 1983).

Temperature (˚C)	Fish body weight (g)					
	1	5	25	50	100	200
21	3.6	2.5	1.7	1.4	1.2	1
23	5.1	3.7	2.6	2.3	2.0	1.7
25	6.5	4.7	3.4	3.0	2.6	2.3
27	7.4	5.4	3.9	3.4	3.0	2.6
29	7.9	5.6	4.0	3.5	3.0	2.6
31	8.0	5.5	3.8	3.2	2.7	2.3
33	7.8	5.1	3.4	2.8		

of the fish in the pond (i.e. by causing a drop in oxygen levels, possible pollution, etc.). Feeding should be performed at the same times (early morning and late afternoon) to improve food consumption and to teach the fish to come to the same area of the pond.

Food should be fed in the shallow end of the pond or around wooden stakes, which encourages the fish to come to the same place in the pond to feed. This allows the fish farmer to check the health of his fish at each feeding. If ponds are too big to feed by hand, an open-bottomed boat can be used to supply a stream of feed around the pond. The build-up of waste on the bottom of the pond depends to a large degree on the amount of artificial food fed. It is therefore important that any excess or uneaten food is removed if the fish are not feeding. If the waste builds up, it will lead to high levels of ammonia and nitrate, which will cause a drop in dissolved oxygen levels, all of which are dangerous to the fish.

The amount of feed used per day is generally calculated for a two-week period and adjusted every four to six weeks after catching a few fish with a cast net and recording their average body weight. The biomass of the fish and the daily quantity of feed are then calculated according to the recorded average body weight (see example for catfish, in table above) and estimated survival rate. It may be difficult to predict growth and survival rates as they depend on many factors (such as fish density, feed quality, temperature, predation, etc.).
If the temperature changes by 4˚C (up or down)

INFO BOX: HOW TO CALCULATE THE AMOUNT TO FEED THE FISH

- Juvenile fish should be fed 6-8% of their body mass per day, distributed over 3-4 times per day.
- Medium-sized fish should be fed at about 4-5% of their body mass per day.
- Adults of near harvest-sized fish should be fed at about 1-2% of their body mass per day.

To calculate how much feed would be required for a two-week period:

Food for 2 weeks = Average fish weight (g) x number of fish in pond x % fish bodyweight x 14 days. Example: 4000 x 100 g (medium-sized) tilapia with a total mass of 400 kg will need 5% body mass feed/day
= 20 kg/day, over 14 days
= 280 kg fee

INFO BOX: WHEN AND HOW TO FEED FISH IN PONDS

- Fish should be fed at the same place and same time each day. This makes monitoring of fish stocks much easier as the fish get used to these routines.
- Watch the fish: when they stop eating, stop feeding.

from the preferred range of the species, the feeding rate should be reduced by 25%. If the temperature changes by 8˚C, the rate should be half (50%) of normal. It is very important that the fish are not fed more food than they can eat. Not only is this a waste of money but it also leads to poor water quality and possible death of all of the pond's fish.

If the level of dissolved oxygen drops between 3-5 mg/ℓ, the amount of food added to the pond should be halved. No feed should be given if the dissolved oxygen falls below levels of 2 mg/ℓ. Every effort should be made to bring the oxygen level up to an acceptable level before feeding resumes.

If the fish should stop feeding, the cause of this should be determined immediately. The illustration below depicts various reasons why fish may stop feeding. All of these possibilities should be considered and investigated, otherwise the fish in the pond may die.

As in any business, it is important to reduce costs while trying to increase production. In aquaculture, fish farmers try to feed just the right amount and type of food to allow the fish to grow but not waste food as it is expensive. Some foods, such as those with a higher protein level (e.g. fishmeal) may produce better growth than plant-protein diets. However, the high protein content may be more expensive and therefore the cost of the diet must be carefully considered in relation to its contribution to improving fish growth. The concept of food conversion ratio (FCR) is important to understand as it helps describe how well a diet is used by the fish to grow. FCR is defined as the mass of food consumed divided by the mass of fish produced (see examples in the boxes, above).

If the cost of the feeds were the same per kg, the diet with the lower FCR (of 1) would be

EXAMPLE 1

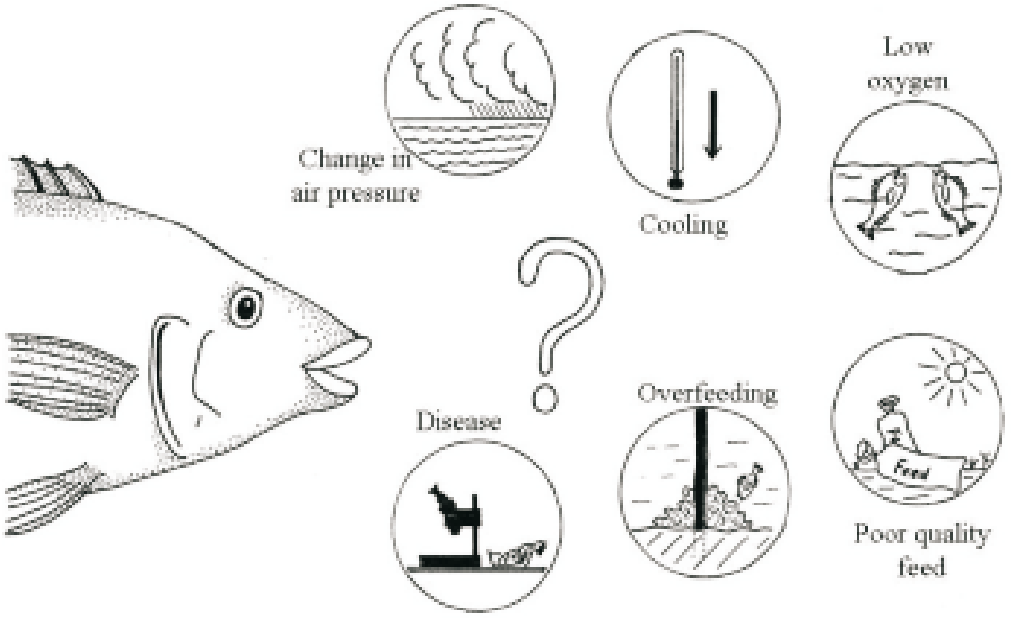
A 20 kg bag (costing R8/kg) of a diet containing mostly plant proteins was fed to fish newly stocked into a pond. When they were stocked, all the fish weighed about 5 kg. After the food was finished, the fish were caught and weighed again (none had died), weighing in at about 15 kg each.

Feed conversation ratio (FCR) =
Feed fed to pond / Increase in fish mass
20 kg / (15 kg – 5 kg = 10 kg)
= 20/10
= 2

EXAMPLE 2

Another pond was fed 10 kg (costing R20/kg) of a higher protein diet, containing more fishmeal, and the fish also grew from 5 to 15 kg.

The feed conversation ratio for this pond is:
FCR = 10 kg / 10 kg
= 1



A few reasons why fish may stop feeding. The exact reasons should be determined immediately and the appropriate steps taken to correct them.

cheaper to use as you only use 1 kg feed instead of 2 kg of feed to produce 1 kg of fish. However, the cost of the plant-based diet in this example is R8/kg, and therefore:

The cost of producing 1 kg of fish = R8/kg x 2 (FCR) = R16/kg produced.

Similarly, the cost of the fishmeal diet = R20/kg x 1 (FCR) = R20/kg fish produced.

Therefore, although the fishmeal diet has a better FCR than the plant-based diet, the cost of the plant-based diet is cheaper per kg of fish produced and is therefore the more cost-effective diet to use.