CHAPTER 35
AQUACULTURE: FARmed FISH

Words to know

angling quality  the ease or difficulty of catching a fish
aquaculture  the commercial farming of fish, molluscs (e.g. oysters), crustaceans (e.g. prawns) and aquatic plants (seaweeds) in natural or controlled marine or freshwater environments
carnivorous  meat-eating
carrying capacity  the maximum weight of fish a dam can support
cold-blooded  animals, such as fish, whose bodies do not stay at a constant temperature; instead, their body temperature matches that of the environment
extensive farming  aquaculture systems with low stocking rates where fish feed on organisms that naturally live in their environment and there are low levels of environmental control
fingerling  a fish older than ‘fry’ stage but not yet an adult
fry  a young fish just after hatching
hatchery  a place that produces fingerlings for sale to the public and for stocking public waters
intensive farming  aquaculture systems with high stocking rates, where farmers provide the feed for the fish and there are a number of artificial controls on the environment for the fish
omnivorous  eating both meat and plants
spawning  the process of egg-laying by a fish
zooplankton  microscopic animals living in the surface waters of dams, rivers and other water habitats
Introduction

Aquaculture is the farming of fish or other aquatic organisms – what is generally called ‘seafood’ – usually in farm dams, ponds or especially constructed tanks or floating cages. Aquaculture farming can be dated to around 500 BCE with the raising of carp in China. Fish farming can occur in freshwater, brackish (slightly salty) water or sea water. Like any other type of farming, there are standard management activities such as feeding, restocking and protecting stock from predators. These activities distinguish aquaculture from hunting and gathering methods of harvesting seafood, such as recreational fishing, shellfish collection on a beach or net casting by hand.

Aquaculture is a developing industry and, during the last 10 years, there has been a growing demand for freshwater fish to stock farm dams. In addition, farms have diversified to include the farming of molluscs (mussels, oysters), crustaceans (crayfish, crabs and lobsters) and aquatic plants (mainly seaweeds) for human consumption. Oyster production is the main aquaculture system in New South Wales with the Sydney rock oyster the main species grown in the state. The most economically significant fish in aquaculture today include Australian bass, barramundi, catfish, golden perch, Murray cod, salmon, silver perch, trout and tuna. Other farmed aquatic animals include edible and pearl oysters, mud crabs, mussels, prawns and yabbies.

Commercial aquaculture is a highly specialised field. It requires a lot of capital to set up and much technical knowledge to operate. There are several types of aquaculture enterprises:

- hatcheries that produce fertilised eggs, larvae or fingerlings
- nurseries that look after the fingerlings
- fish farms that grow the juvenile fish to a marketable size.

Farms may specialise in one of these production areas or feature aspects of all three elements of aquaculture, from spawning to marketing adult fish. The systems may range from extensive farming through to intensive farming, depending on stocking rates and the level of environmental control. In extensive systems, the water provides the medium in which organisms reproduce to become a source of food for the fish. In intensive systems, high-protein food is fed to the fish and many environmental variables are controlled allowing for high stocking numbers.

Land-based farms are divided into pond- or dam-based, or recirculating aquaculture systems. The distribution of aquaculture farms depends on the temperature requirements of fish species; for example, in New South Wales farms with silver perch are widely distributed, while trout farms are located on the cooler southern and western slopes of the Great Dividing Range.

A number of federal, state and local government regulations must be complied with, and a clear code of practice must be followed by aquaculture managers. State and federal departments of agriculture and fisheries conduct aquaculture research.

In New South Wales, this department is trying to find out more information on stocking farm dams and is looking at nutrition, dam sizes, stocking rates, suitable species, growth rates and cultural practices.

By studying these factors, research scientists hope to improve the carrying capacity of a dam, thus leading to increased fish production. Aquaculture researchers are also trying to make sure that the industry develops in a sustainable way.
Species of fish

Fish can be divided into two groups – native species and introduced species – depending on whether or not they naturally occur in Australia. Native species grow well in warm waters and can be found on the coast, lower slopes and inland plains. Trout require cold waters and should be stocked only in dams on the upper slopes and highlands of the Great Dividing Range.

The group of animals known as fish includes many different species, as different from each other as goats, pigs and alpacas. With farmed animals, we think of only one species (e.g. cattle), which is divided into different breeds. With fish, different fish farms specialise in one species and it is helpful to know the scientific name of the fish. Common names can sometimes be confusing, because one species may have more than one common name, and sometimes common names may sound as though unrelated species are related (e.g. golden perch and silver perch). However, when different species are closely related, the first part of the scientific name will be the same (e.g. *Macquaria*, for Australian bass and golden perch).

Native fish species

Among native fish species, the following seven are suitable for farming (Fig. 35.1).

**Australian bass (Macquaria novemaculeata)**

The Australian bass is carnivorous and eats a variety of foods including insects, shrimps, yabbies and small fish. It has excellent angling quality, is a popular fish for eating and adapts well to farm dams.

**Barramundi (Lates calcarifer)**

The word ‘Barramundi’ probably comes from the Queensland Dharumbal language, meaning ‘eating fish with large scales’. The name has been used in Australia for this carnivorous freshwater fish species only from the 1980s; until then it was – and still is – known as Asian bass (the fish is also found in Asian countries). Barramundi is perhaps the best native fish for eating. For this reason, it fetches high prices. It also has excellent angling quality: these characteristics make it popular for recreational fishing. Barramundi is found in tropical and semi-tropical waters.

**Catfish (Tandanus tandanus)**

The catfish is carnivorous and feeds mainly on shrimp, yabbies, worms and insects. It is a very good angling and eating fish, although many recreational fishers reject it because of its repulsive appearance. Great care must be taken when landing and handling this fish because of the spines on its pelvic fins, which can pierce the skin and cause considerable pain.

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5. On what basis are fish divided into their two groups?

6. List the native species suitable for farming in dams.

7. Which native species is omnivorous?

8. Which fish species were introduced into Australia?
Golden perch (Macquaria ambigua)
Golden perch is carnivorous and feeds mainly on yabbies, shrimps and small fish. It has excellent angling and eating qualities and can reach an acceptable size in 2 years. It is also commonly known as the ‘yellowbelly’.

Silver perch (Bidyanus bidyanus)
Silver perch is probably the best warm-water species for stocking in farm dams. It is omnivorous and feeds mainly on insects, shrimp, zooplankton, algae and aquatic plants. It does well in dams where weeds are growing. It has good angling and eating qualities, and can reach an acceptable eating size in 2 years. Because of the noise it makes when lifted from the water it is commonly known in many areas as the ‘grunter’.

Murray cod (Maccullochella peelii peelii)
Murray cod is the largest Australian freshwater fish and it generally only lives inland of the Great Dividing Range. It requires more space than other species, because it is aggressive, carnivorous and territorial.

Southern bluefin tuna (Thunnus maccoyii)
The southern bluefin tuna is a massive carnivorous fish that lives in the oceans of the southern hemisphere. The fish can reach weights of more than 200 kg, although under 100 kg is more common for tuna found near Australia. Southern bluefin tuna is very popular for eating, particularly in Japan. It is regarded as an endangered species, because of overfishing. It is the most important aquaculture species in South Australia.

Introduced fish species
Introduced fish species include the Atlantic salmon, rainbow trout, brown trout and brook trout.

Atlantic salmon (Salmo salar)
Salmon is regarded as freshwater fish, even though it will naturally spend part of its life in the oceans. Wild salmon generally grows to be 2–10 kg. Salmon has arguably the best angling quality and is a favourite for recreational fishing.
Trout (Fig. 35.3) are cold-water fish and show good survival in dams on the highlands. The rainbow trout is probably the best for stocking in farm dams because it has the fastest growth rate. Its angling and eating qualities are excellent. It is carnivorous and its prey includes worms, grasshoppers, yabbies and frogs.

**Sustainable aquaculture**

Marine-based aquaculture systems are the most vulnerable to climate change effects. Changes in ocean currents, winds, nutrient availability, temperature ranges and natural events will affect the stability of fish populations.

Poor site selection and poor management of fish farms and other aquaculture ventures can have negative consequences for the environment. Concerns arise where natural habitats such as mangroves are cleared for intensive aquaculture systems. Discharge of untreated waste into surrounding water and overfeeding in fish farms can cause changes in the structure of surrounding natural communities. This can lead to algal blooms or excessive microbial activity, both of which result in lower oxygen levels, which can kill other fish and animals living in the water. These are examples of poor management outcomes.

Fish caught in the wild are often used as food sources for commercial aquaculture operations which in turn places pressure on the numbers of wild species as well as the diversity of life in natural situations. Similarly farmed fish that escape into the natural environment also place pressure on the natural population.

Where fish are farmed in sea cages, such as southern bluefin tuna, the cages are treated or painted with an antifouling agent to stop other marine life growing on or attaching to the cages (Fig. 35.4). Environmentalists are concerned about the use of these substances. Some people are also worried about the long-term environmental effects of the antibiotics used in salmon farming.

Producers and others who work in the aquaculture industry are of course interested in keeping it viable and are working with researchers and others to find ways to deal with these issues.

**Production cycle**

Introduced species are usually stocked as fingerlings (i.e. 75–100mm long) while native fish are stocked at the advanced fry stage. Trout are usually reared in a hatchery on artificial food and are much easier to rear to the fingerling stage than the native warm-water fish such as perch, catfish, cod and bass. Stocking warm-water fry early in the summer allows them to take full advantage of the summer and autumn growing season.

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**Figure 35.3** a Brook trout (*Salvelinus fontinalis*) b brown trout (*Salmo trutta*) c rainbow trout (*Oncorynchus mykiss*)

**Figure 35.4** A southern bluefin tuna sea cage in Port Lincoln, South Australia
Tuna are farmed differently; they are caught at sea when they are approximately 2 years old (or around 15 kg in weight) and are then grown out in sea cages until ready to harvest.

Survival after stocking will be reduced if predators are present. Predators can include larger fish. For this reason dams should not be restocked with fingerlings until most of the larger fish have been removed.

Growth rates depend on the conditions under which the fish are grown. Rates are usually greater at lower stocking rates.

Managing the farm

Animal welfare

Welfare concerns arise from issues due to stocking densities. Overcrowding can increase aggressive behaviours, competition for available food and increase levels of nitrogenous compounds and waste in the water, lowering oxygen levels and increasing water toxicity levels due to ammonia production.

These types of interaction cause stress and physical damage due to fighting, and increase the risk of disease. Management techniques that maintain stocking densities, keep as close as possible to the normal conditions for each fish species and that separate sizes according to the stage of growth have a positive effect on welfare.

While some people do not think cold-blooded animals such as fish deserve the same level of care in handling as warm-blooded land animals, fish still have a nervous system and are able to feel pain. An ethical approach to farming tries always to minimise pain in the lifecycle of animals. In some Australian states, fish are protected by laws prohibiting cruelty to animals.

Managing dams

Fish will survive and grow in very small dams provided adequate food is available. Dams of 0.1 hectares (100 m²) or larger will yield the best results. In general, the larger the surface area of a dam or pond, the greater the amount of fish that can be produced. Most of the food for fish in a dam is produced on the dam walls. Dams with gently sloping sides get more sunlight and will produce more food than deep dams with steep, shaded sides. Figure 35.5 shows dams suitable for fish.

Care must be taken to prevent excessive bank erosion by other livestock, such as sheep and cattle. This can also turn the water muddy, which will reduce the light penetration: food production will then be reduced. Other animals can be limited to a part of the dam by fencing it off or by putting in a water trough. This is an example of an extensive production system. Intensive systems use tanks, troughs or cages, where the farmer regularly changes the water, provides concentrated feed and constantly monitors the environment, especially temperatures, which more than anything else affect how quickly fish grow. The fish stocking density is higher in intensive systems.
The site for an aquaculture activity must have a regular supply of clean water. Trout and salmon also require high oxygen levels in the water. Native fish need water temperatures below 30°C. The water quality determines the stocking levels and, as a result, the productivity of the enterprise.

When managing fish in farm dams, consider the following factors:

- water quality
- excessive plant growth
- amount of oxygen in the water
- stocking rates.

**Water quality**

There are many environmental factors that determine acceptable levels for water quality. Major factors include:

- water acidity or alkalinity levels (pH)
- salinity levels
- amount of dissolved nutrients in the water
- presence of toxic nitrogenous waste materials
- turbidity (how muddy or clear the water is)
- contaminant concentrations, such as the presence of heavy metals or chemical contamination from crop spraying.

**Excessive plant growth**

While some plant growth is necessary in a dam to provide food and shelter for the insects and shrimp that the fish eat and to provide shelter for the fish, too much plant growth makes harvesting difficult.

**Lack of oxygen**

Low levels of oxygen are not usually a problem but can occur during summer, and also quite often after heavy rain (when dead grass and animal faeces may be washed into a dam).

The first sign of oxygen deficiency in water is the presence of dead fish or fish coming to the surface gasping for air. To replace the oxygen, the water must be circulated. This can be done by pumping water from the bottom and spraying it back onto the surface of the dam.

**Stocking rates**

The maximum weight of fish a dam can support is called its carrying capacity. This depends on factors such as the species of fish, the water quality, the amount of food provided and the size of the dam.

**Feeding**

The naturally occurring foods for fish in farm dams are insects, yabbies and zooplankton.

Fertiliser, provided it is not used in excess, will increase food production in a dam. It should be added in spring and autumn. The fertilisers used are superphosphate, sulfate of ammonia, potash and ground limestone.
Controlling pests and diseases

Farmed fish may be eaten by predators, such as other fish or birds. If other species of fish are present in the environment, they will also compete for feed with the stock fish. Preventing disease is as important for fish as for other farm animals.

Undesirable fish

Some of the undesirable fish that can be found in farm dams include the mosquito fish (Gambusia holbrooki), the redfin (Perca fluviatilis) and the European carp (Cyprinus carpio, a relative of goldfish; Fig. 35.7). These fish should be removed from a dam before starting to stock it with fingerlings.

Birds

The main predatory bird is the cormorant, which greatly affects the survival of fish. Once cormorants have found a dam containing fish, the birds will continue to work it until most of the fish have been taken.

Disease

Parasite infestation is a common problem often related to overcrowding. Sea lice are the main parasites of fish. They cause skin damage, gill congestion and lowered growth rates. Bacteria are a major cause of disease in salmon and trout farms while barramundi suffer problems associated with a number of viruses.

Marketing

Any species of fish commercially farmed must have market acceptance; that is, people wish to consume the product. Many producers cater for specialised or niche markets to gain an economic advantage. Australia has developed a reputation as a producer of quality seafood and aquaculture produce. Salmon and trout, tuna, silver perch and barramundi are currently the fish producing the most value in the farmed fish industry.

Demand is increasing for Australian native fish species and, coupled with the closeness to Asian markets, Australian aquaculture has become competitively positioned. Southern bluefin tuna is Australia’s leading exported fish and the top four export markets for tuna are Hong Kong, Japan, the United States and China.

In time aquaculture will supply more than half of the fish consumed in the world. Australia exports approximately 75 per cent of its fish products and aquaculture production accounts for 40 per cent of Australian fisheries’ gross value.
Chapter review

Things to do

1. If you have a swimming pool, grow some trout during the winter or spring; they can be obtained from a hatchery. The trout will survive if the water temperature is kept below 20°C. Feed them twice a day and clean the pool every 3 days to remove uneaten food and faeces. Do not use chlorine, because this will kill the fish. Measure the length of the fish and work out their growth rate.

2. Silver perch and golden perch are active predators, ambushing or seeking out food items. When anglers fish for these species, worms, yabbies and shrimp are the most common baits. Go to a dam containing perch and find out for yourself which bait is the best.

Things to find out

1. Look up books or the internet to find out how Sydney rock oysters or yabbies are farmed. Make a list of the similarities and differences between how they are produced and how fish are farmed.

2. Some environmentalists claim that farmed salmon are the ‘battery hens’ of the sea. Discuss what they mean by this and whether you believe their concerns are valid.

3. When releasing fingerlings into a dam, why is it necessary to add small amounts of dam water into the bag for about 20 minutes before releasing the fish from it?

4. Why is it illegal to use English perch (redfin) or European carp for stocking dams in New South Wales?

Extension activities

1. Describe the freshwater farming techniques needed for barramundi or rainbow trout farming.

2. Compare and contrast extensive and intensive aquaculture systems. Indicate the advantages and disadvantages of each system.

3. Discuss the differences between aquaculture and fishery management.

4. Describe the farming techniques required for prawn farming.

5. Aquaponics is a food production system that combines aquaculture with hydroponic practices. Research how aquaponic systems are built and list the advantages of combining these two systems of food production.

Test yourself

1. Why is aquaculture an important industry?

2. What are the two forms of aquaculture farming?

3. Describe the common species of farmed fish.

4. What factors limit the level of productivity in an aquaculture enterprise?

5. Discuss the impact of climate change on aquaculture.

6. What welfare considerations must be taken into account when farming fish?