Specified Skills
Educational Textbook for the Fishing Industry Skills Proficiency Test (Aquaculture)
(Feed-Supplied Aquaculture)

Japan Fisheries Association
(First Edition: February 2020)

Table of Contents

1. Sea Aquaculture for Fish in Japan

Within the sea aquaculture for fish conducted in Japan, yellowtail species (yellowtail, greater amberjack, and yellowtail amberjack) are produced in the largest quantities, followed by red sea bream, coho salmon, bluefin tuna, striped horse mackerel, blowfish species, and jack mackerel (Fig. 1). Although all of these fish can be found throughout Japan's territorial waters, with the exception of flounder and coho salmon, aquaculture production is concentrated in Western Japan and the sea to the west of it.

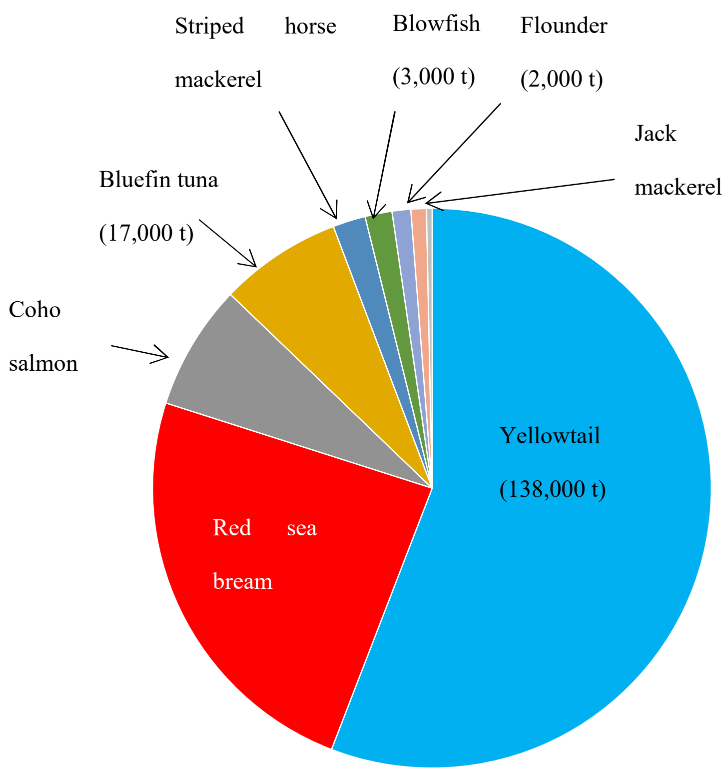


Figure 1: Japan's Sea Aquaculture Yield for Fish (2017)

Source: "Production Statistics for Fishing and Aquaculture in 2018," Ministry of Agriculture, Forestry and Fisheries

2. Natural and Artificial Seeds

Fish aquaculture begins with securing fry called "seeds." There are two methods of securing these seeds. The first is catching fry in their natural habitat and using them as seeds for aquaculture (Fig. 2). Seeds for yellowtail and greater amberjack aquaculture are secured by this method, which is called "natural seed collection."

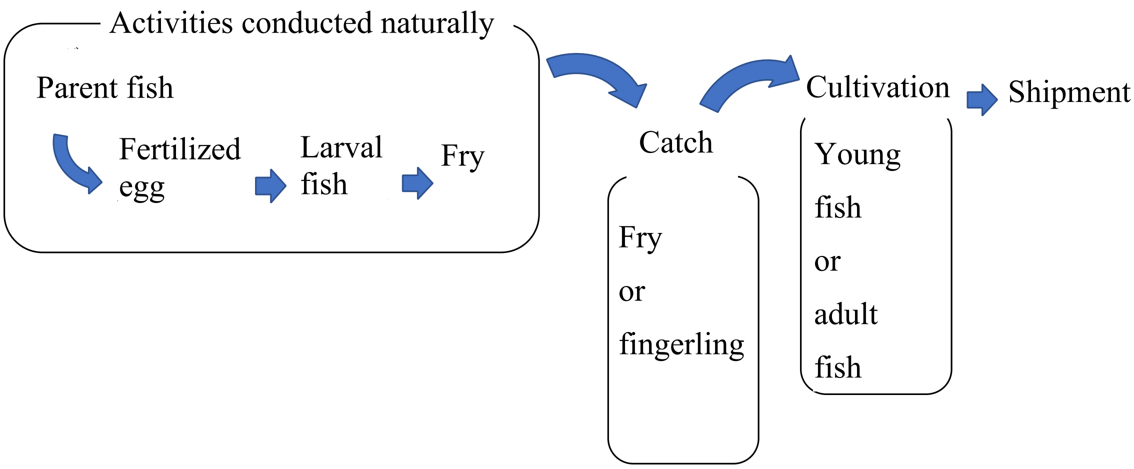


Figure 2: Natural seed collection aquaculture method

The second method involves artificially producing seed. First, fry that have first been taken from natural environments are grown to larger sizes. After the fry are grown, the environment is adjusted such that the fry can become parent fish, and their maturation is promoted by administering hormones related to sexual maturity. Eggs are collected from these mature parent fish, fertilized with discharged semen, and hatched. Spawning is divided into cases in which mature parent fish are put into aquariums and naturally spawn and cases in which hormones are administered to induce spawning, after which spawning occurs. Furthermore, when spawning does not naturally occur in an aquarium, pressure may be applied to the stomach region to eject the eggs and sperm so that fertilization can be carried out artificially in some cases.

A fish that has hatched from a fertilized egg is called a larval fish, and these larval fish are grown into a fry and used as seeds for aquaculture. Moreover, fry produced in this way are also grown into parent fish. A method of creating a production cycle with artificially produced fish, without catching fry from their natural environment, is referred to as "complete aquaculture." Red sea bream, flounder, and tiger puffer are produced using this method.

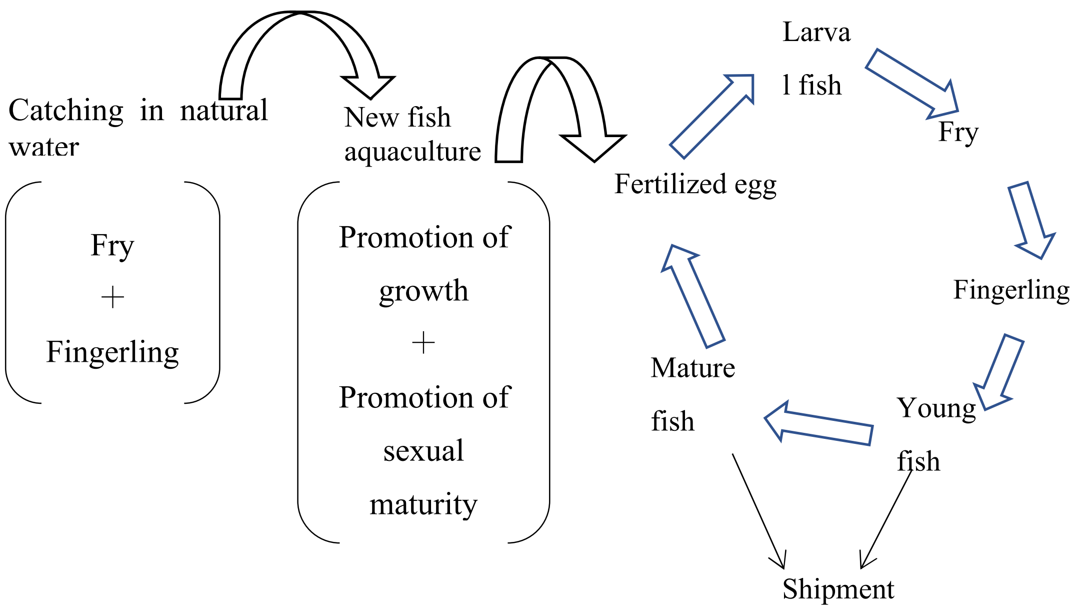


Figure 3: Complete aquaculture method

In aquaculture using subdivided fish tanks, fry are contained in a separate fish tank on the sea surface. A square fish tank with a height and width of about 10 m, called a "subdivided fish tank," is used for this purpose (Fig. 4). Compared to a land fish tank, a subdivided fish tank has the merits of enable large capacity production with lower facility costs, and eliminated the electricity fees required for water replacement, since this occurs naturally through the flow of the ocean. However, it has also the demerit of being easily affected by typhoons and red tides. A net hangs down below the sea surface of the fish tank. The mesh of the net is replaced with larger mesh as the fish grow. Fish aquaculture in Japan is often conducted in shallow waters on coasts (waters), so the nets are not very deep (4 to 8 m). Compared to red sea bream and striped horse mackerel, which have comparatively small bodies, yellowtail and tuna are larger and swim more actively, so larger fish tanks are used.

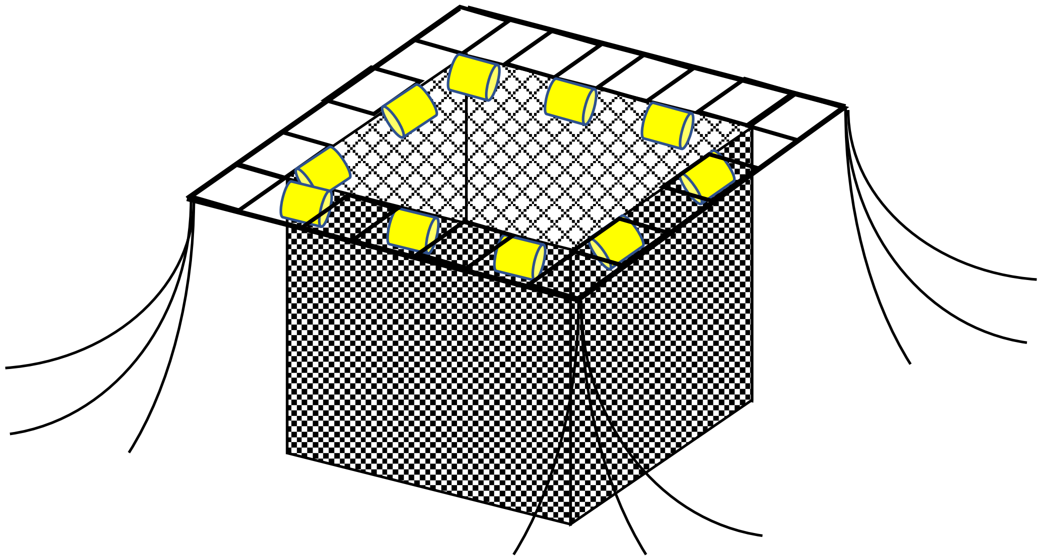


Figure 4: Subdivided fish tank

3. Feed

Regardless of the type of fish, live feed is no longer used by itself. Instead, modern aquaculture always uses mixed feed, e.g., moist pellets, dry pellets, or extruder pellets (Fig. 5). Generally, feed is either given twice per day in the morning and at night or once per day at one of these times (feed may be given every other day when the fish grow larger), but the smaller the fish, the more times per day they are fed. The amount of feed given also increases as the fish grow. The ingredients for mixed feed include fish meat or fish powder, and there are also additives such as oils, vitamins, minerals, and binders, which are mixed in.

Moist Pellets

Made from ingredients such as raw feed, fish powder, and fish oil. The mixture can also be adjusted by changing the proportions, and additives such as nutrients and vitamins can be included as well. This type of mixed feed is often formulated at the aquaculture site.

Dry Pellets

Made from ingredients such as fish powder, flour, and soybean oil residue. The nutrient content is balanced in accordance with the type of fish and to avoid crumbling in water. Generally, dry pellets are produced at a feed plant then purchased and provided at the aquaculture site.

Extruder Pellets

Mad from ingredients such as fish powder, flour, and soybean oil residue. Processing at high temperatures and pressures improves the digestion and absorption of the ingredients. Generally, feed produced at a feed plant then purchased and provided at the aquaculture site.

Figure 5: Various mixed feeds

4. Breeding Environments

The quantity of fish to be put into one fish tank should not be thought of in terms of the number of fish, but in terms of the weight per m^3. Generally speaking, this weight should be 4 to 8 kg/m^3. Thus, when the fish are small, many can be put into one fish tank, but as they grow, the number must be reduced. When the number of fish for one fish tank is too high, it may diseases to spread or worsen the water quality.

In fish aquaculture, when fish die in the period from the start of cultivation to the time of shipment, the main factor is disease. The causes of diseases are bacteria, parasites, and viruses. In some cases, treatments and prevention methods are available, but there are also diseases for which there are still no countermeasures. When fish become ill, medicine may be administered for treatment. In this case, it is important to follow the dosage and regimen specified by fisheries medicine, which is determined for each type of fish and each disease. If there are no countermeasures available, the fish that have fallen ill or died must be quickly removed from the fish tank, and measures must be taken to prevent other fish from becoming infected.

In addition, waters where aquaculture fish tanks are installed are generally waters with calm sea surfaces. In such waters, red tides may occur during hot periods in the summer. If red tide occurs, in many cases this causes the deaths of numerous fish in tanks. Red tide occurs due to a certain type of phytoplankton occurring in large quantities. This occurs due to an excess of substances that provide nutrients to phytoplankton being present in the water. When red tide occurs, large-scale dying off of the fish be prevented by relocating the fish tank or increasing the depth of the net.

After fish have been kept in a fish tank for 1 to 2 years, they grow to a size suitable for shipment. Currently, in Japan, fish that are not very big such as red sea bream and flounders are often transported to the sites of consumption while still alive, but large fish such as yellowtail, greater amberjack, and bluefin tuna, are killed at the production area, processed, vacuum packed before being transported to the sites of consumption.

The production method differs for each type of fish. Methods for each type of fish are described below.

5. Yellowtail Aquaculture

Yellowtail are distributed along the northwest Pacific Ocean and mainly inhabit the area around the Japanese archipelago. On the other hand, greater amberjack are distributed in waters the world over, including the Pacific Ocean, the Atlantic Ocean, the Mediterranean Sea, and the Indian Ocean, and they mainly inhabit warm areas and the tropics.

As shown in the photographs, yellowtail and greater amberjack have a similar appearance and are extremely difficult to tell apart. The greatest differentiating characteristic of the greater amberjack is that it has a pattern on its head resembling the Chinese character "八." In fact, *kanpachi*, the Japanese name for this fish, is said to be derived from this pattern.

Figure 5: Yellowtail (left) and greater amberjack (right)

(1) Yellowtail and Greater Amberjack Spawning Seasons and Locations

Yellowtail begin spawning around December to January around the midpoint between the Okinawa Islands and China in the East China Sea and in the waters contiguous with the Kuroshio Current. Around March to April, the spawning location moves to the western seas of Kyushu, and after that, it moves northward along the coast of the Japanese archipelago.

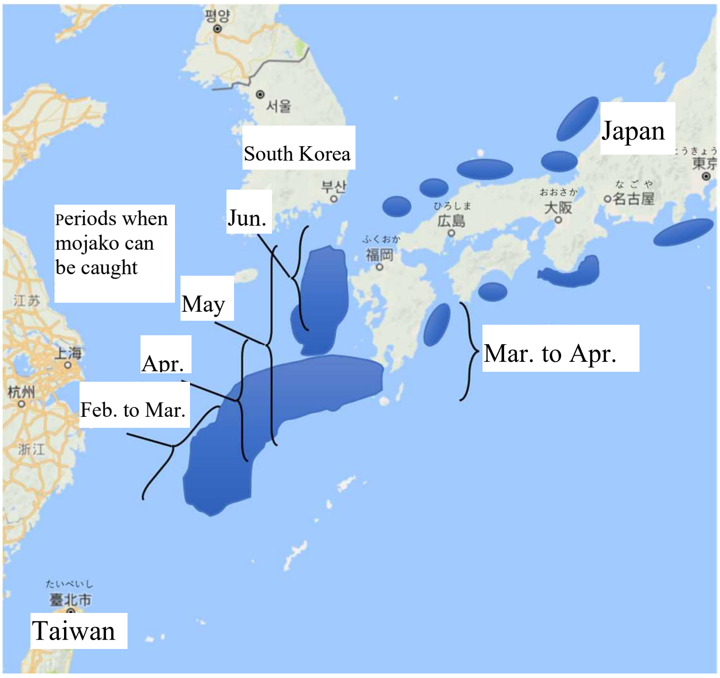


Figure 6: Spawning locations of yellowtail and periods when mojako (yellowtail fry) can be procured

* Yellowtail larvae procurement must be carried out within the period determined by each region.

The specific spawning locations of greater amberjack are not clear, but it is thought that areas with high water temperature such as the southern seas of China, the area around Taiwan, and the waters of the Ogasawara Islands in the Pacific Ocean are spawning locations (Fig. 7). When the seawater temperature reaches 20°C or higher, spawning begins.

Figure 7: Greater amberjack spawning locations (presumed)

(2) Yellowtail and Greater Amberjack Names

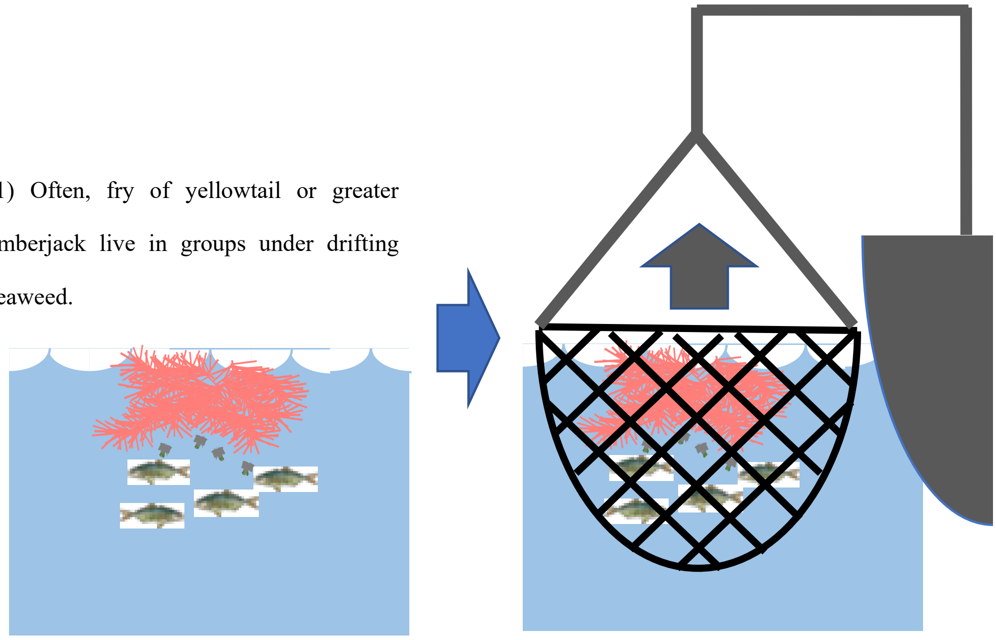
Yellowtail are known as *shusseuo*, meaning the fish are called by different names as they grow. In Kanto (Eastern Japan), they are called *wakashi*, *inada*, *warasa*, and *buri* in the stages of their life cycle. in Kansai (Western Japan), the names used *mojako*, *shibasu*, *hamachi*, *mejiro*, and then *buri*. In Kyushu, they are called *mojako*, *wakanago*, *yazu*, *hamachi*, and *buri*. In aquaculture, they are sometimes referred to as *hamachi*. Similar to yellowtail, greater amberjack are also called by different names as they grow, and their names are *mojako*, *neigo*, *kampachi*, and *akabara*.

The fry of yellowtail and greater amberjack are called *mojako*. This name is a combination of *jako*, which means "fry," and *mo*, which is used because they form groups next to drifting seaweed (*nagaremo* in Japanese) which flows from the coast and gathers above the surface of the sea.

(3) Securing Seeds for Aquaculture

For greater amberjack and yellowtail, fry (*mojako*) gather near drifting seaweed which floats on the surface of the sea. When beginning aquaculture for greater amberjack or yellowtail, fry are first collected together with the drifting seaweed (Fig. 7). This is then brought onto a fishing vessel to a location near the aquaculture site and put into the fish tank, and then aquaculture commences.

(1) Often, fry of yellowtail or greater amberjack live in groups under drifting seaweed.



(2) When drifting seaweed is found, a ship approaches and the drifting seaweed is scooped up whole in a net.

Figure 7: Collecting yellowtail and greater amberjack fry

(4) Feeding Methods

Immediately after they are put into the fish tank, the yellowtail and greater amberjack fry are provided with feed frequently throughout the day. The feed used is a mince of seafood species such as jack mackerel, mackerel, and seahorse (recently, mixed feed is also increasingly used), but as the fry grow larger, the mince is reduced and increasing amounts of mixed feed (artificial feed) are introduced as the fish grow accustomed to it.

After the fish have grown accustomed to artificial feed, moist pellets, which are mixed and formed from minced fish meat, powdered feed, and nutrients, as well as dry pellets and extruded pellets for grown fish, are used.

Feed is supplied 4 to 8 times per day until the fry reach 100 g in weight, and it is supplied more often the smaller the fish are. After they exceed 100 g in weight, they are fed twice per day, in the morning and the evening.

The food supply ratio for yellowtail each day with respect to the weight of the fish when using dry pellets is as shown in Table 1. For example, a fish weighing 100g would receive 4.0 gram (or 4.0%) at 22°C. This indicates the total feed per day. This proportion changes based on various conditions, such as the water temperature and the health condition of the fish. For greater amberjack, feed required is about 20% less than for yellowtail. If too much feed is given, feeding efficiency will suffer and the remaining feed will also worsen the water quality and the substratum around the aquaculture fish tank.

Fish weight (g)	18°C	19°C	20°C	21°C	22°C	23°C	24°C	25°C	26°C	27°C	28°C
10	4.5	5.0	5.5	5.9	6.3	6.7	7.2	7.8	8.5	8.7	9.0
30	3.7	4.2	4.8	5.3	5.8	5.9	6.4	6.9	7.5	7.7	8.0
50	3.0	3.6	4.2	4.8	5.4	5.9	6.4	6.9	7.5	7.7	8.0
100	2.3	2.8	3.2	3.6	4.0	4.5	5.0	5.7	6.4	6.5	6.7
200	2.1	2.4	2.8	3.2	3.5	3.9	4.2	4.7	5.3	5.4	5.6
300	1.9	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.2	4.3	4.5
400	1.8	1.9	2.1	2.4	2.6	2.8	3.1	3.3	3.6	3.8	4.0
500	1.7	1.8	1.9	2.1	2.4	2.3	2.6	2.8	2.9	3.0	3.2
600	1.6	1.7	1.8	2.0	2.1	2.3	2.6	2.7	2.8	3.0	3.2
800	1.4	1.6	1.7	1.8	1.9	2.1	2.3	2.4	2.5	2.6	2.8
1,000	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.4	2.5
1,200	1.2	1.3	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2
1,500	1.1	1.2	1.3	1.4	1.6	1.5	1.6	1.7	1.8	1.8	1.8
2,000	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7
2,500	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.6
3,000	0.8	0.8	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3

Table 1: Examples of dry pellet feed ratios for yellowtail

(Examples published by Marubeni Nisshin Feed Co., Ltd.)

(5) Aquaculture Environments

The appropriate water temperature for yellowtail is 18 to 27°C. If the temperature exceeds 28°C, feed intake drops, and at 32°C and above, fish may die. The appropriate water temperature for greater amberjack is 20 to 31°C. At temperatures of 15°C or below or 32°C or above, the fish cease to grow.

The salinity of seawater is about 30 to 33 psu, but the fish stop eating feed if it drops to about 20 psu. (*psu is a unit indicating about how much salt is contained in seawater. For example, 10 psu means that about 10 g of salt is contained in 1kg of seawater.)

Normal seawater contains 6 to 8 mg/L of oxygen. Yellowtail and greater amberjack move actively when the dissolved oxygen in the water ranges from 6 to 7 mg/L, and their food intake and growth suffer if it falls to 4mg/L or below.

(6) Aquaculture Facilities and Density

Aquaculture for both yellowtail and amberjack generally takes place in subdivided fish tanks. When viewed from above, the fish tanks used are square, and each side ranges from 10 to 30 m. The depth of the fish tanks is generally 4 to 10 m.

As for the volume of the fish tank nets, generally density is 7 kg per m^3. However, the water temperature, dissolved oxygen content, tide speed, size of mesh and thickness of mesh threads, and density are all adjusted with the growth of the fish.

(7) Fish Diseases and Countermeasures

Diseases known to be contracted by yellowtail and greater amberjack include bacterial diseases (such as vibriosis, piscicida, nocardiosis, streptococcosis, mycobacteriosis, and gliding bacterial disease), parasitic diseases (such as Benedenia seriolae, white spot disease, and heteraciniosis), and viral diseases (such as iridovirus).

Countermeasures for bacteria include the oral administration of antibacterial agents and antibiotics (for vibriosis, piscicida, and streptococcosis), but the usage of pharmaceuticals is determined by law for each type of fish and disease, and these usage regulations must be followed. There are also cases in which the infected fish must be culled (such as infection with nocardiosis or mycobacteriosis).

As countermeasures for parasitic diseases, medicated baths (Benedenia seriolae) and freshwater baths (Benedenia seriolae) are used, but if the dosage is wrong these treatments can actually end up killing the fish, so caution must be taken.

Vaccination is the only countermeasure for viral diseases. Commercial vaccines are administered to the stomach of the fish when the fish weighs between 10 and 300 g. Alternatively, commercial vaccines can also be orally administered when the fish weighs between 50 to 500 g.

(8) Shipping

There are three methods used for shipping yellowtail and greater amberjack.

i. A method in which the fish are killed at the production site and shipped without removing their organs (Fig. 8).

With this method, the fish are processed at the site of consumption.

ii. A method in which filleting takes place at the production site prior to shipping. The fish are killed using *ikejime*, then the organs are removed, and the head is cut off (Fig. 9). Afterward, the fish is filleted into three pieces (Fig. 10). These fillets are then vacuum-packed and sent to the sites of consumption.

iii. A method in which the fish is shipped alive from the site of production. In this method, a live fish truck or live fish vessel carries the fish from the site of production to the site of consumption or a processing site near the site of consumption.

Fig. 9: Round

Fig. 9: Dress

Fig. 10: Fillet

6. Red Sea Bream Aquaculture

Red sea bream (Fig. 11) are distributed throughout Japan with the exception of Okinawa, and inhabit not only Japan but also the East China Sea. They live at a depth of about 30 to 200 m along coasts. Their appetite begins to increase at 18°C or higher, they are most active between 26 to 28°C, and they feed mainly on small crustaceans. The spawning temperature is 18 to 20°C, and the Sea of Japan, the Pacific Ocean, the Seto Inland Sea, and the western waters of Kyushu are known spawning grounds.

Fig. 11: Red sea bream

(1) Securing Seeds for Aquaculture

Currently, only artificial seeds are used for red sea bream aquaculture. Maturation can be promoted by controlling the water temperature, and the lengths of days can both induce maturation and enable adjustment of spawning periods. To obtain fertilized red sea bream eggs, mature female and male red sea breams are kept in an aquarium, and natural fertilization takes place. Generally, an aquarium for adult fish is installed on land, and within that aquarium, sexual maturation is induced and spawning takes place. In one spawning period for one fish, about 2 to 10 million eggs are produced. A fertilized egg is about 1 mm in size, and the eggs are separated pelagic eggs which are circular in shape (Fig. 11). Hatching takes about 40 hours at around 19°C. A hatched larval fish (Fig. 12) is around 2.5 mm in total length and exceeds 3 mm in total length 3 days after hatching, at which time it opens its mouth and begins eating feed.

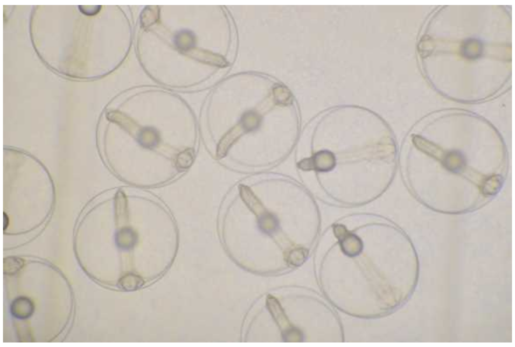
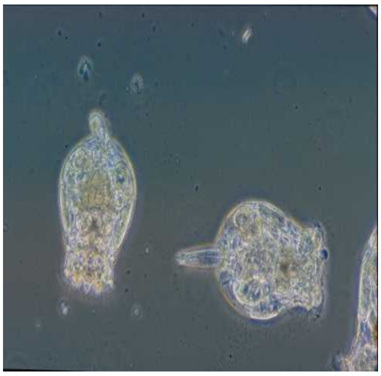


Figure 11: Red sea bream egg

Figure 12: Laval red sea bream

As the larval fish grow, the feed used progresses from marine Brachionus (such as Brachionus plicatilis) (Fig. 13) to brine shrimp nauplii (Fig. 14), and then to mixed feed.



© Japan Fisheries Research and Education

Figure 13: Brachionus plicatilis

© Japan Fisheries Research and Education Agency

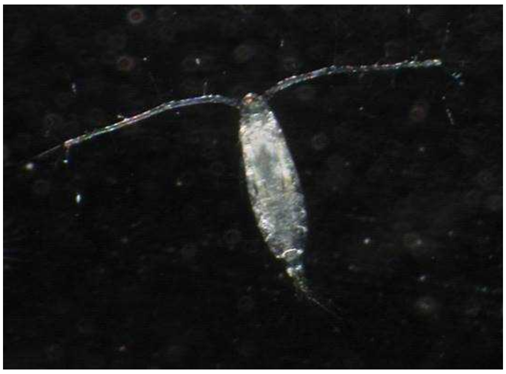
Figure 14: Brine shrimp nauplii

Marine Brachionus are cultivated at seed production sites. Freshwater chlorella is used as feed for this cultivation, but since nutrition would be insufficient with only this feed source, the marine Brachionus are fed to the larval fish after nutritional fortification.

For brine shrimp nauplii, commercially available dried eggs are rehydrated in seawater and then hatch after about 24 hours. Brine shrimp nauplii also provide insufficient nutrition, so they also undergo nutritional fortification before being fed to the larval fish.

The red sea bream are cultivated in a land aquarium until they are about 10 to 30 mm in total length. When they reach or exceed this size, they are moved to subdivided fish tanks on the sea, where cultivation continues. Moving the fish to fish tanks on the sea is called *okidashi* (moving offshore). The fish grow to a total length of about 50 mm about 90 days after hatching. During the period when their total length is between 10 and 50 mm, the fish are given mixed feed in accordance with their size. Generally, when the fish exceed a total length of 50 mm, they are transferred from a seed producer to an aquaculturist, where cultivation is continued.

In addition, the main feed used for small freshwater fish and fry is shown in Figs. 15 and 16.



© Tomo Kotani

Figure 15: Copepoda

© Tomo Kotani

Figure 16: Water flea

(2) Aquaculture Methods after Starting Cultivation

Currently, live feed is almost never used alone, and dry pellets are mainly used.

Red sea bream feed more slowly than types of yellowtail, and it takes time for the feed to be eaten. For this reason, the number of feedings must be increased, and sufficient time must be provided for feeding. In addition, caution must be taken to provide only the amount of food that will be eaten to prevent feed from being left over in the tank.

(3) Aquaculture Environments

When the water temperature reaches 29°C or higher, the daily feed intake of red sea bream changes significantly. Furthermore, red sea bream cease to eat much feed when the temperature drops to 17°C or below, and at 10°C or below, they eat almost none.

Red sea bream cease to eat feed when the dissolved oxygen content falls below 4 mg/L, abnormal behaviors appear when the amount drops to 3 mg/L or below, and they begin to die off when the amount falls to 2 mg/L or below.

(4) Aquaculture Facilities and Density

Currently, aquaculture facilities often use subdivided fish tanks, and the shape and sizes of these tanks differ depending on the region. In waters with shallow depth, even when using large square tanks with sides of 8 to 12 meters, the net depth is just 3.5 to 4.5 m. Offshore aquaculture is conducted with square tanks with 12 m sides and a depth of 12 m, or with circular tanks 20 m in diameter and 8 to 10 m deep.

Generally, the total weight of fish under 1 year old (fish born that year) should be 4 to 5 kg per m^3 of fish tank volume, and when they have reached sufficient size for harvesting (approximately 1,000 g), a maximum density of 8 kg/m^3 is considered appropriate.

However, while almost no disease is seen at densities of 3 kg/m^3 or below, diseases start to occur when density exceeds this level.

(5) Adjusting the Body Color of Red Sea Bream

There is a high likelihood of sunburn when cultivating red sea bream in shallow waters; thus, a shading net is attached to the aquaculture fish tank to provide shade and prevent this. Furthermore, in order to make the red color of the red seam bream more vibrant, frozen krill, which is abundant in carotenoids (the main component of red pigmentation), or a powdered extract is mixed into the feed.

Figure 15: Sea surface subdivided fish tank with a shading net attached

(6) Fish Diseases and Countermeasures

Diseases known to be contracted by red sea bream include bacterial diseases (such as vibriosis, gliding bacterial disease, Edwardsiella, and Epitheliocystis), parasitic diseases (such as white spot disease, bivagina tai, and skin fluke infection), and viral diseases (such as iridovirus and lymphocystis) are known.

As countermeasures for bacterial diseases, cultivating the fish in low-density conditions (for vibriosis and gliding bacterial disease), administering antimicrobials (for vibriosis and Edwardsiella), and chemical (hydrogen peroxide agents) baths (for bivagina tai) are effective.

As countermeasures for parasites, oral administration of pharmaceuticals (lysozyme chloride powders for white spot disease), moving fish tanks (for white spot disease), freshwater baths (for skin fluke infection), and chemical (hydrogen peroxide agents) baths (for skin fluke infection) are effective.

Examples of countermeasures for viral diseases include the administration of vitamins to enhance strength as a preventative measure, activation of immune system function through the administration of immunostimulators, stress reduction, and cultivation in low density environments. Recently, vaccination (for iridovirus) has also been conducted. However, when a disease has appeared, prompt removal of the diseased or dead fish is the best countermeasure. Furthermore, with regard to fisheries medicine, dosages and directions to be followed are decided differently for each type of fish and type illness, so such medicines must be handled carefully.

(7) Shipping

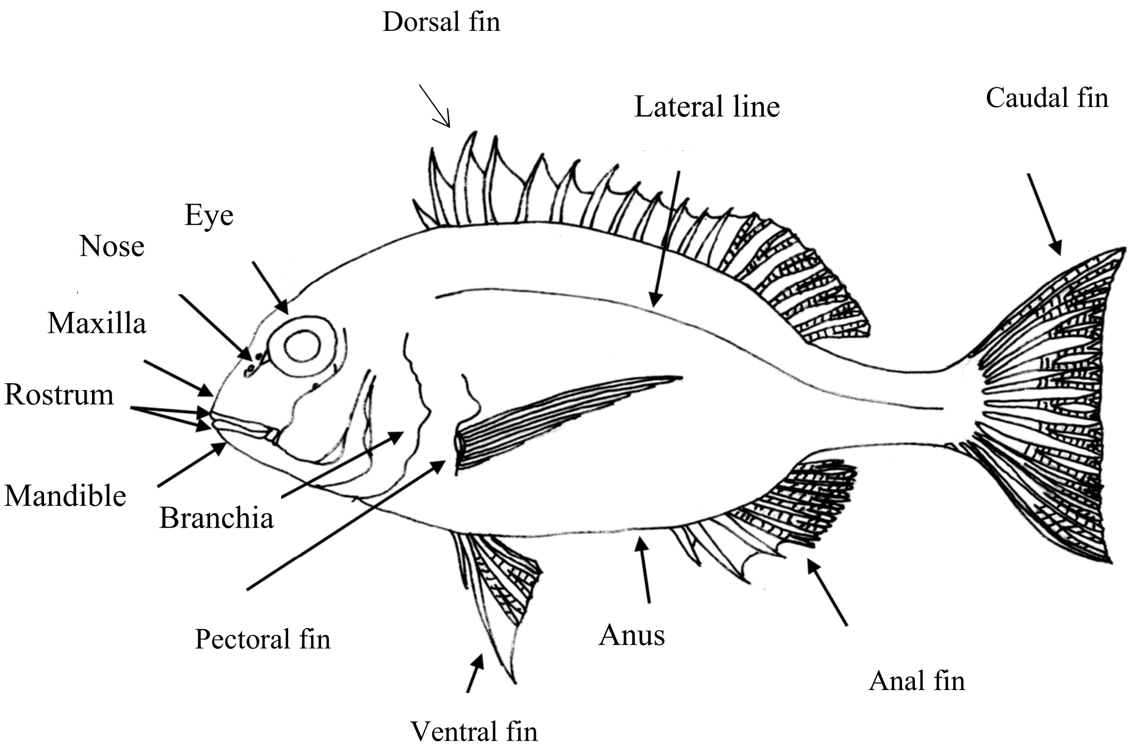
Before shipping live red sea bream, feeding must be stopped a few days prior, allowing the fish to eliminate all waste and completely empty their stomachs. This is done in order to prevent worsening of the water quality during transportation. Furthermore, in order to avoid damage to the mucosa and scales, it is also important to prevent fish from rubbing against netting fabric or coming into contact with other fish during shipping. The fish are placed in confined spaces when being transported, so sometimes they are allowed to become more accustomed to these spaces prior to shipping. Ships, trucks, and airplanes are used for the transportation of fish. For each of these, oxygen is supplied when the water cannot be changed. Moreover, low-temperature and freezing processing are conducted to lower the activity levels of the red sea bream.

7. Fish Parts and Measurement

In order to learn about the state of the fish being cultivated, it is necessary to learn about the size of fish. However, in order to learn about size, it is also necessary to learn about the names for fish parts.

(1) Names of Fish Parts

At aquaculture sites, instructions for job activities may be given by the names of fish parts, so it is important to memorize these names.



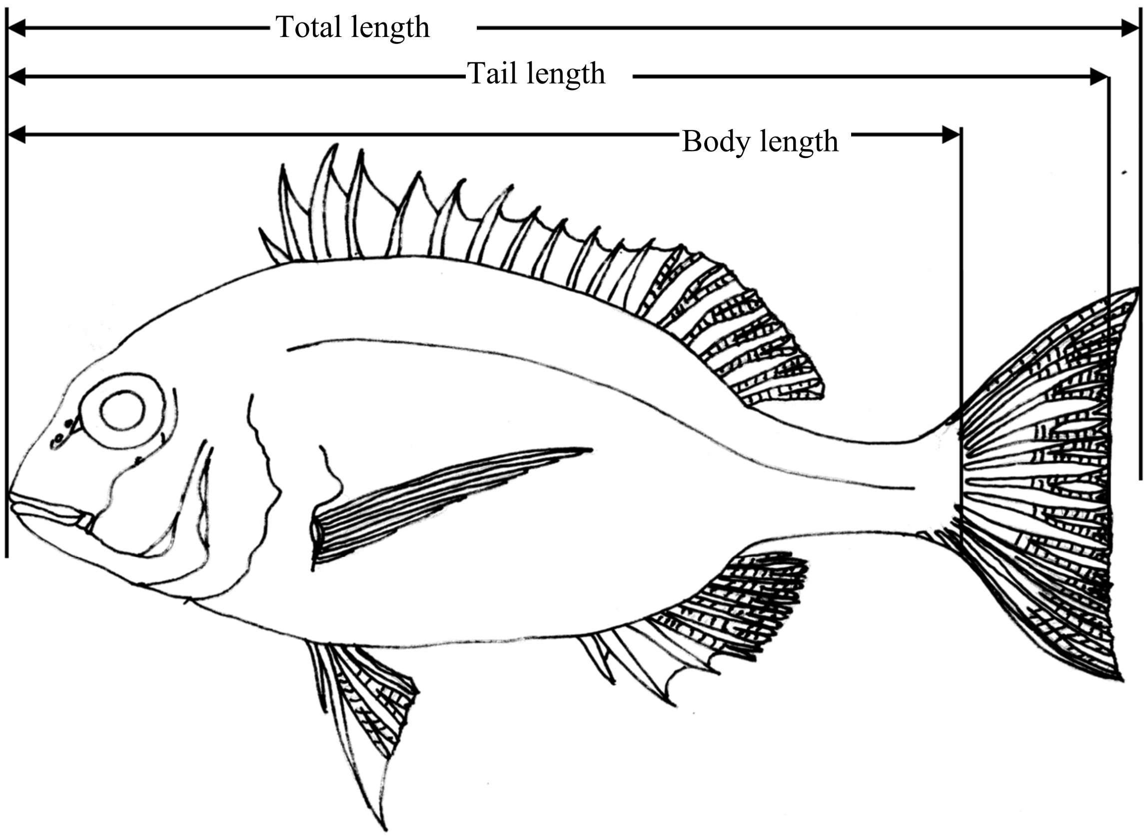
(2) Fish Measurement

When measuring fish size, one of the following is measured.

Total length: the length from the frontmost tip of the body to the rearmost tip of the caudal fin

Tail length: the length from the frontmost tip of the rostrum of the maxilla to the most depressed part of the caudal fin

Body length (standard body length): The length from the frontmost tip of the rostrum of the upper jaw to the rearmost tip of the vertebrae, or to the base of the caudal fin



8. *Ikejime* Killing Method

This is a method in which a living fish is quickly killed and the freshness of the fish is maintained by delaying rigor mortis. *Ikejime* may be conducted when shipping the cultivated fish. Furthermore, there are also various other killing methods which are used, such as *nojime* (immediate killing) and *shinkeijime* (destroying the spinal cord to preserve freshness). In the following photographs, incisions have been made at the head and tail to drain the blood from the fish. In this way, it is also easy tell by looking at the fish that *ikejime* has been performed.

Ikejime performed on a red sea bream

Ikejime performed on a greater amberjack

Ikejime performed on a flounder