Specified Skills

Educational Textbook for the Fishing Industry Skills Proficiency Test (Aquaculture)

(Feedless Aquaculture)

Japan Fisheries Association

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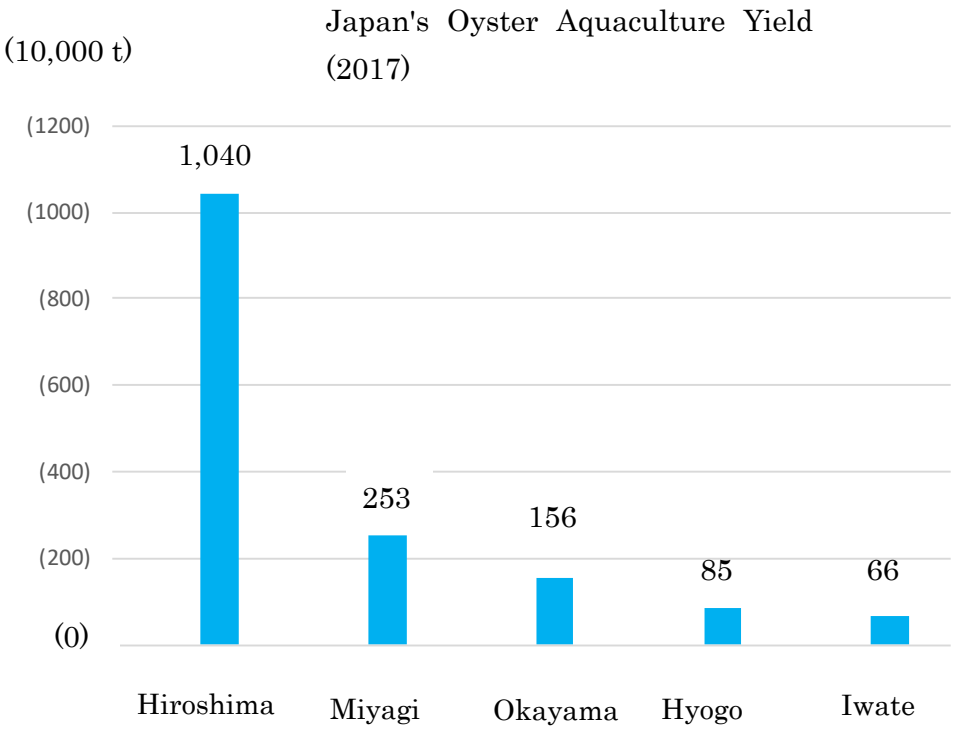
1. About Oysters

Oysters are shellfish that are eaten all over the world. About half of the shellfish aquaculture in Japan is oyster aquaculture. In Japan, approximately 176,000 tons of oysters are cultivated (as of 2017). The prefectures with the highest yields are Hiroshima, Miyagi, Okayama, Hyogo, and Iwate, in that order (Fig. 1).

Most of the oysters cultivated in Japan are Pacific oysters. In addition to the Pacific oyster, famous types of oysters cultivated around the world include the European flat oyster (in France and Spain), the Eastern oyster (in the Atlantic seaboard of America), the Portuguese oyster (in Portugal, Spain, and France), and the Sydney rock oyster (in Australia). The Japanese Pacific oyster is also grown and cultivated in various countries.



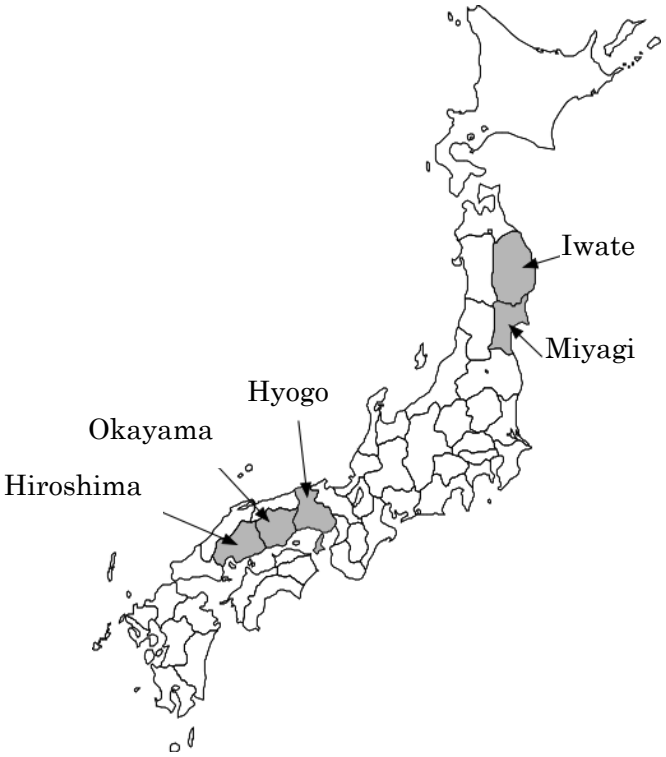


Figure 1: Japan's main oyster production sites and their yields

2. Life Cycle of Oysters

Oysters can be seen on the coasts of Japan (Fig. 3).

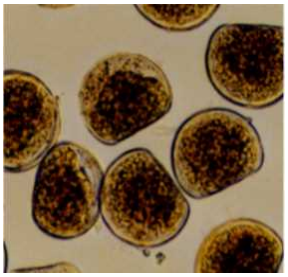
It is difficult to distinguish between male and female oysters in winter, but in summer, the differences become apparent. In summer, female oysters gather their eggs, male oysters gather their sperm, and they both release them into the seawater at the same time. The sperm fertilizes the eggs that have been released, and these eggs become floating larvae 0.1 mm in size that swim around in the seawater. During this stage in the life cycle, it is impossible for the larvae to escape from predators, so they may be eaten by fish or other animals, decreasing in number.

After 2 to 3 weeks, the floating larvae have grown to 0.3 mm and become adhesion-period larvae (Fig. 4). Adhesion-period larvae firmly adhere to the surface of a rock or a shell and then become spat.

Oysters cause a flow of water with their gills, sucking seawater into their shells then using their gills to filter out food floating in the seawater, carry it to their mouths, and eat it (Fig. 5).

Farmed oysters normally grow to a size of about 10 cm in 2 to 3 years.

Figure 3: Oysters inhabiting the coast



D-type larvae

Adhesion-period larva

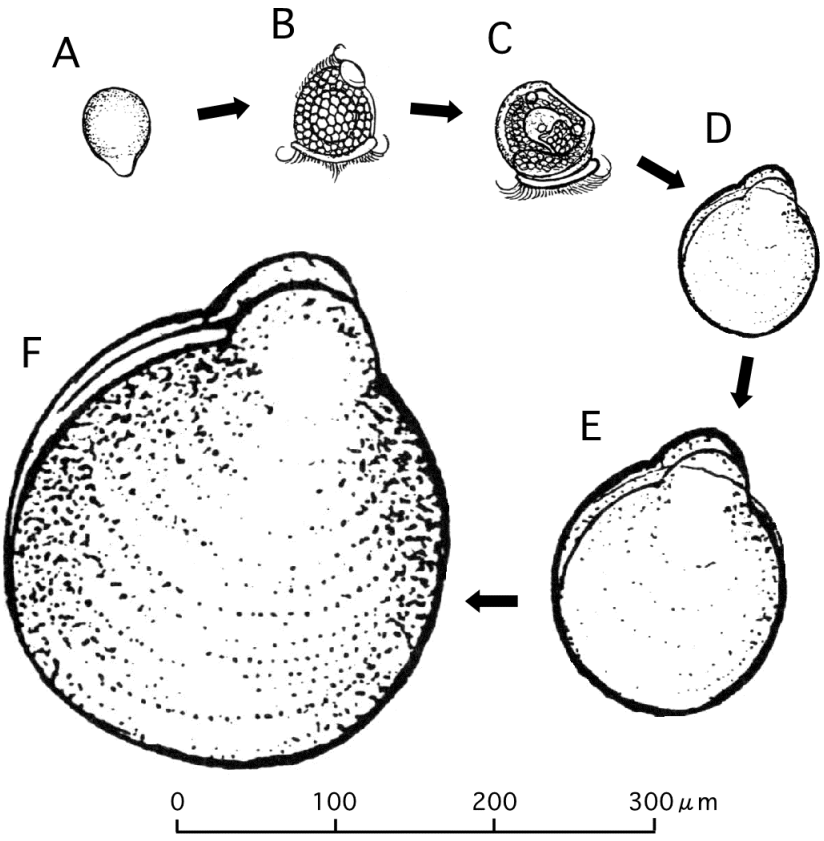
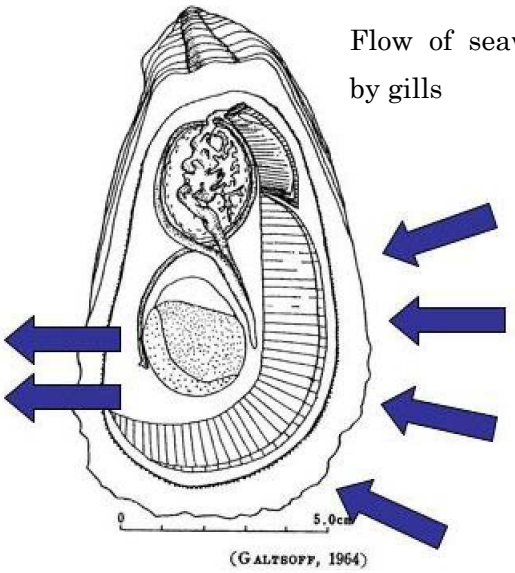


Figure 4: Growth of oyster larvae

A: fertilized egg, C: D-type larva, D/E: umbo-period larva, F: adhesion-period larva



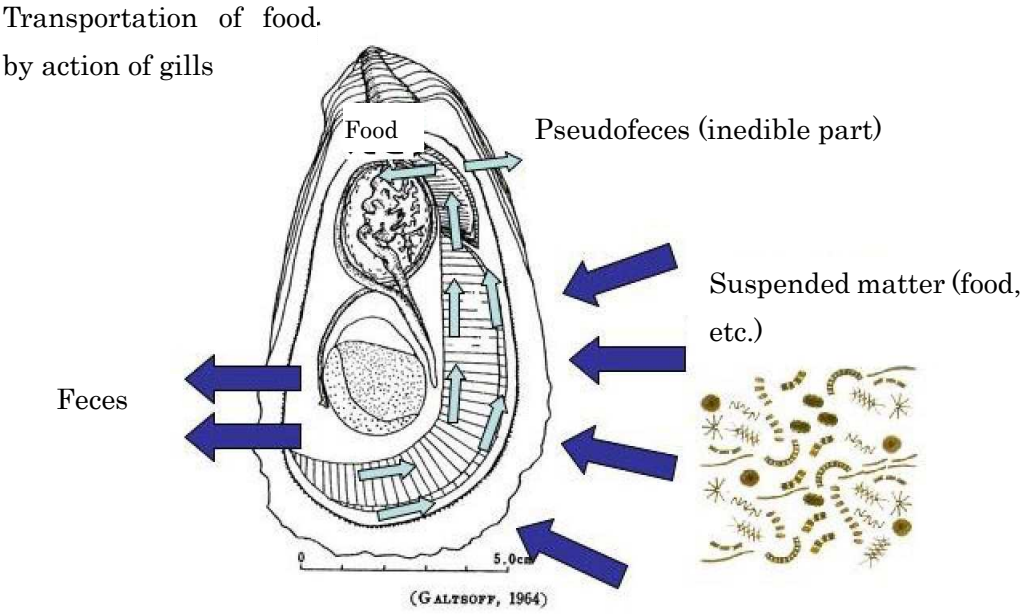


Figure 5: Action of oyster gills

3. Oyster Exterior (Fig. 6)

Oysters have two valves. The shapes of oyster valves are not predetermined. They grow in accordance with the shape of the location to which they are adhered. The sunken valve that adheres to a rock or shell is called the left valve, and the flat valve is called the right valve. The two valves are connected by a hinge and an adductor muscle. When the adductor muscle contracts, the hinge closes, and when the adductor muscle relaxes, the hinge opens. When oysters die, the hinge opens. When healthy oysters are taken out of the water, they firmly close this hinge and are able to stay alive for some time.

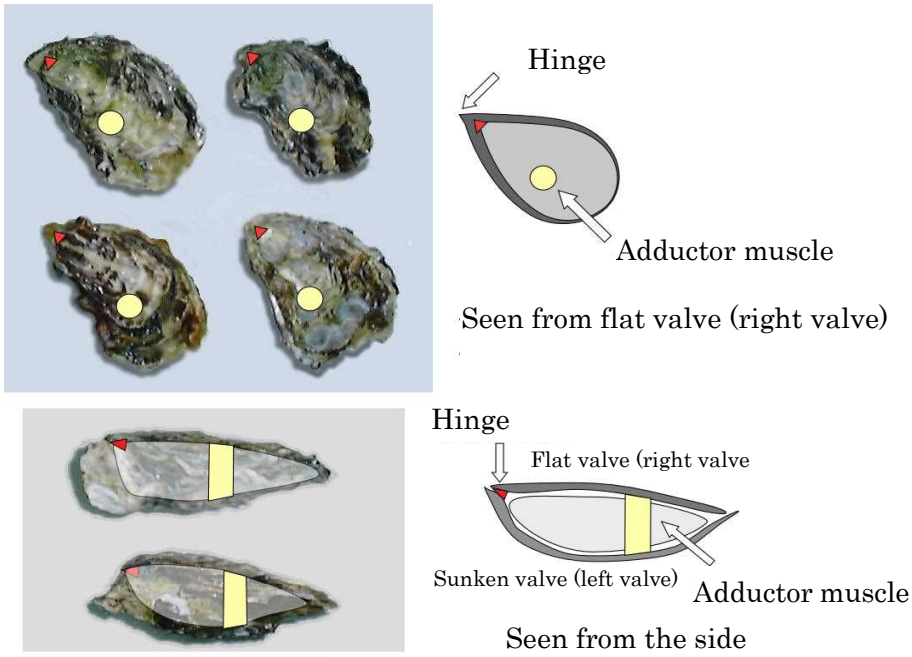


Figure 6: Oyster exterior

4. Oyster Interior (Figs. 7, 8)

Adductor muscle: A muscle for closing the two valves. When the shells are opened and oysters are shucked, this muscle is cut.

Gills: Organs used for breathing and eating feed. A flow of water is caused by fine cilia invisible to the eye on the surface of the gills, and seawater is sucked into the valves.

Mantle: A layer covering the soft tissue of the valve. From fall to winter, it stores nutrients and has a white appearance. In summer, when the nutrients become depleted, it turns transparent.

Digestive diverticulum: This is an organ that digests and absorbs food that has been eaten. It has a brown appearance.

Gonads: Parts that develop around the digestive diverticulum from spring to summer and store the eggs and sperm.

Heart: Located next to the adductor muscle. The beating of the heart can be seen in a shucked oyster that is still alive.

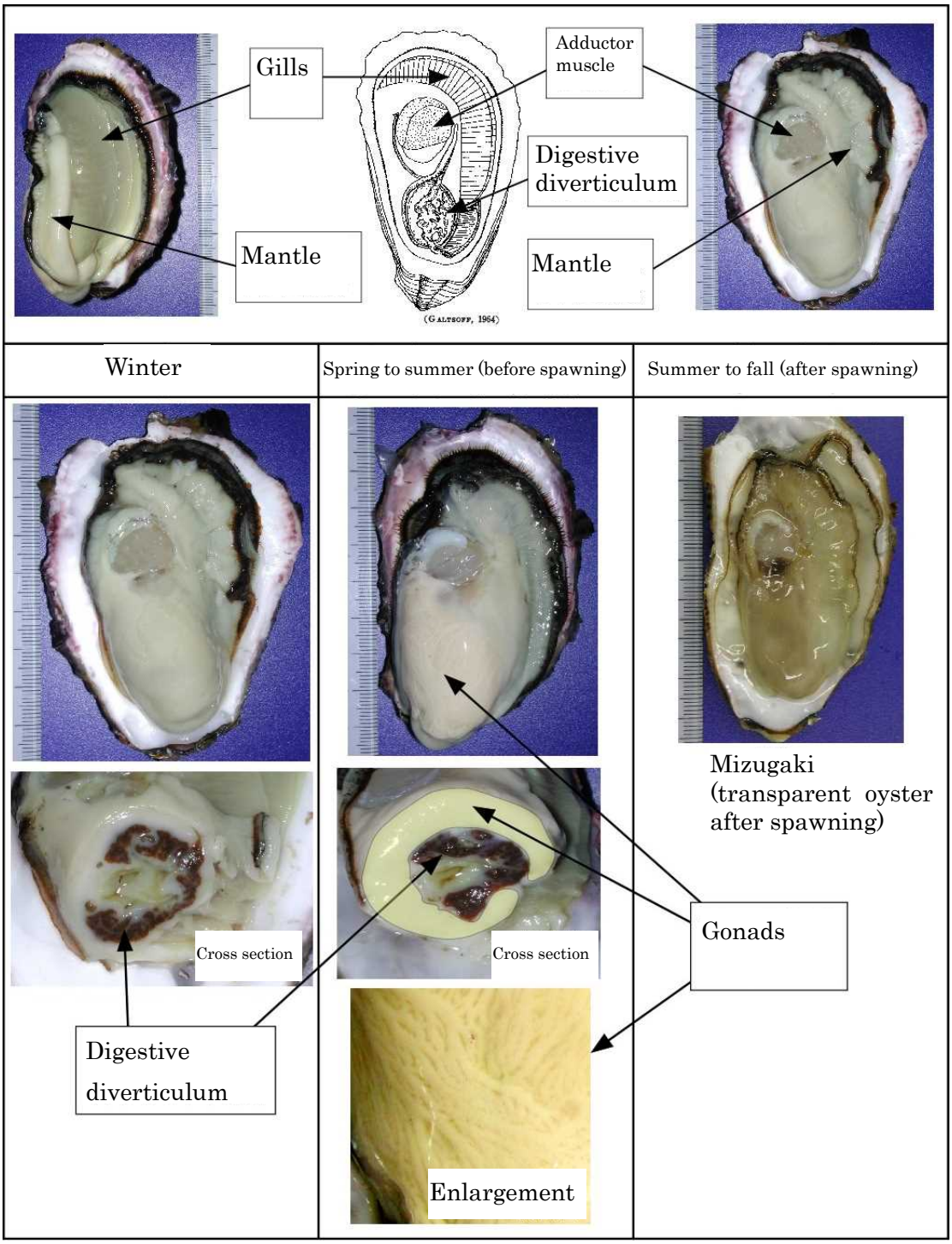


Figure 7: Oyster interior

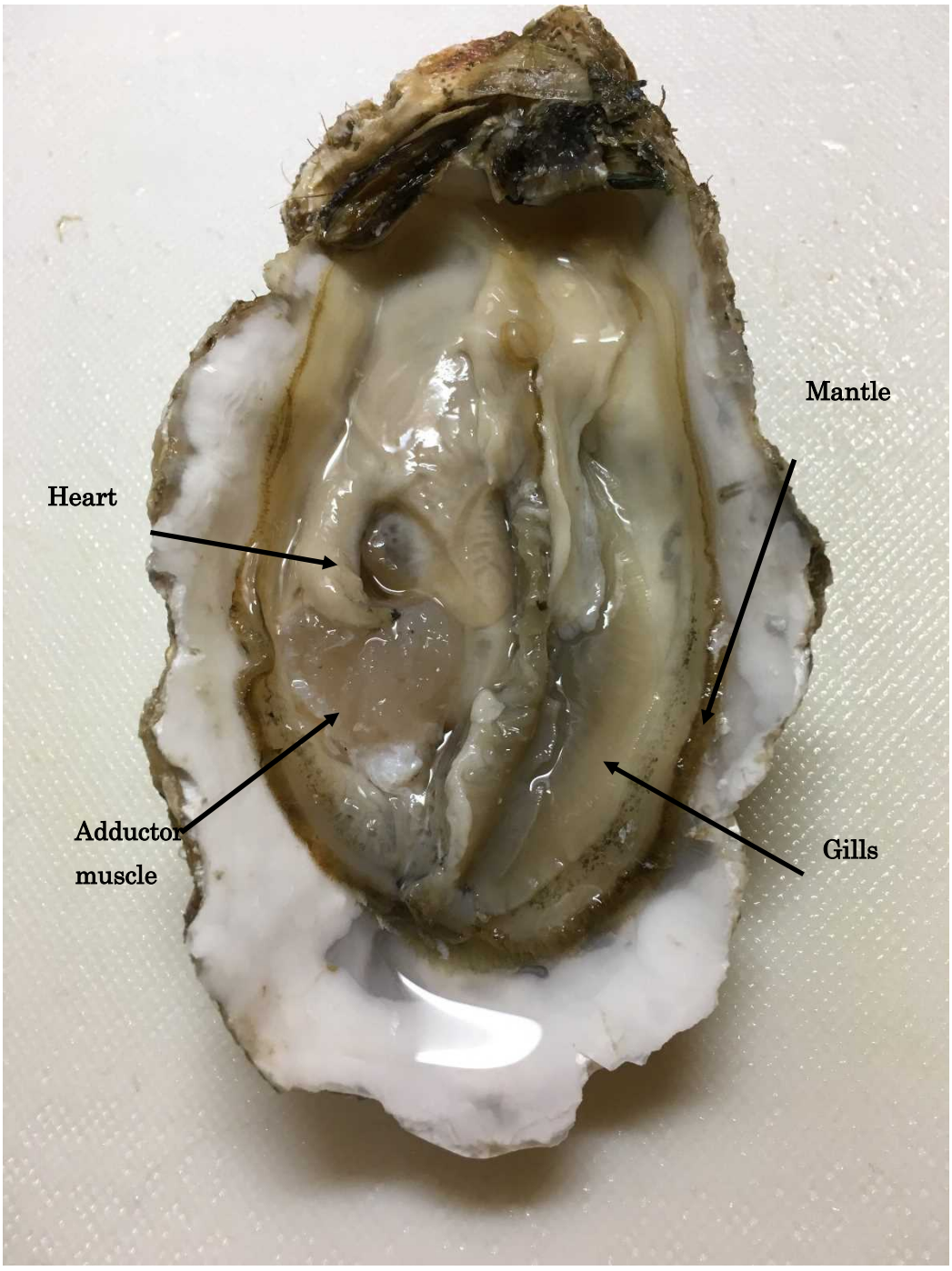


Figure 8: Half of an oyster

5. Oyster Aquaculture Methods

For oyster aquaculture, oyster spats born in the sea are manually gathered, cultivated, and shipped. Feed is not used in oyster aquaculture. Oysters grow by eating phytoplankton naturally occurring in the sea.

Main aquaculture methods include the bottom culture method, the stake-suspended culture method (simple suspended culture method), the raft-suspended culture method, and the longline culture method (Fig. 9).

The locations and cultivation methods for oyster aquaculture are set by regulations determined by fishery cooperatives, and these regulations must be followed.

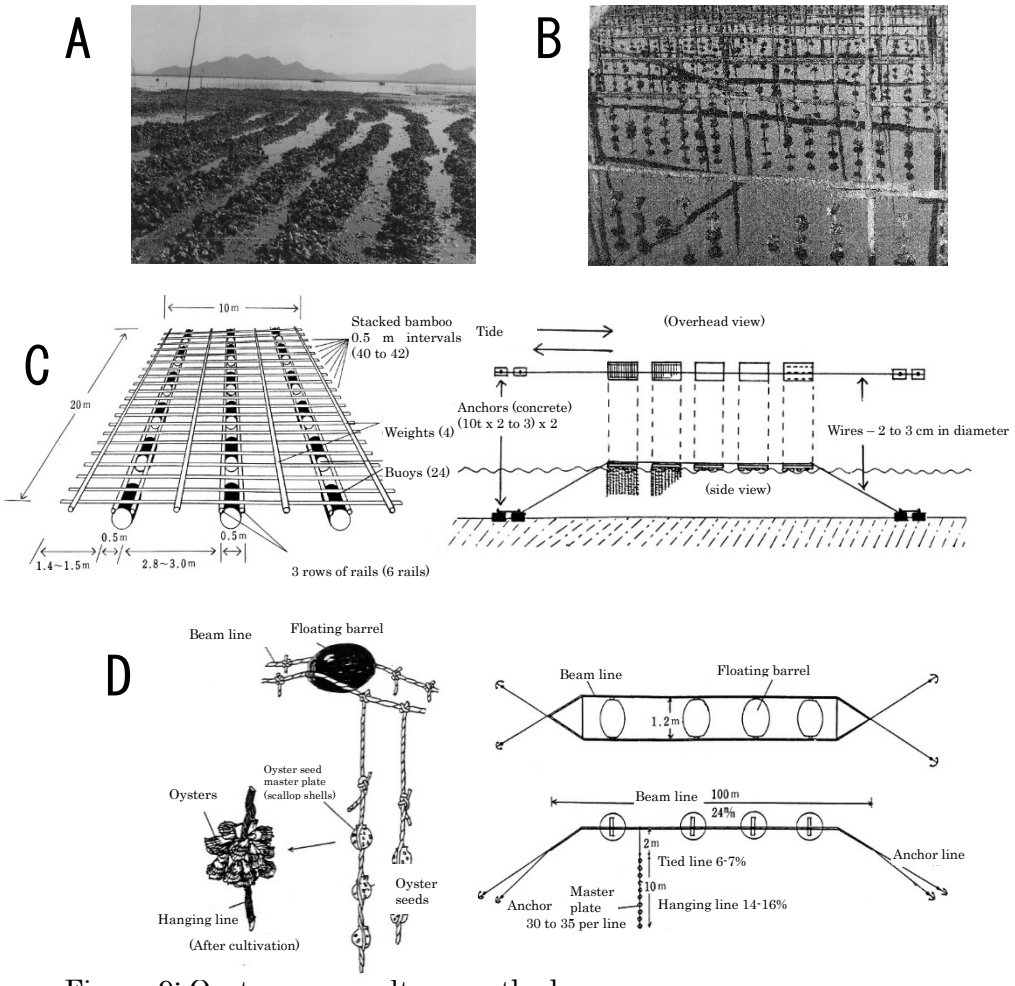


Figure 9: Oyster acquaculture methods

A: bottom culture method, B: stake-suspended culture method (simple suspended culture method), C: raft-suspended culture method, D: longline culture method

6. Natural Seed Collection

Securing seeds for cultivation is the most important task in oyster aquaculture. In Japan, production by natural seed collection is most common. Floating larvae, which appear in the sea in the summer, are made to adhere to an adhesion tool. In Japan, scallop shells are used as adhesion tools (Fig. 10).

To collect natural seeds, a seed collection stack, which consists of scallop shells with holes in the middle and wires are passed through them, is hung in the sea (Fig. 11). The period for hanging it in the sea is determined by using a plankton net to investigate larvae and conducting a test to observe the number adhered to a test stack.

Artificial seed production, which consists of manual cultivation of larvae in a tank by fertilizing eggs with sperm, is also used.

Figure 10: Seed collection stacks

Figure 11: Conducting seed collection

7. Raising from the Ground (Suppressing)

The oyster seeds that have been collected are first transferred to suppression racks in mudflats, where their growth is suppressed (Fig. 12). The oyster seeds on these racks are exposed to the air at times due to the ebb and flow of the tide. This slows their growth, but these environmental changes also make them more resilient. Most seeds used in oyster farming in Japan are created in the Hiroshima Bay and Sendai Bay areas.

Figure 12: Suppression racks (left) and seed boards (right)

8. Restringing (Main Hanging)

The scallop shells to which the oyster spats have adhered are called seed boards or master plates.

To give the oysters space to grow large, the seed collection stack is separated, intervals are created between the seed boards, and they are then restrung on wires or ropes (Fig. 13).

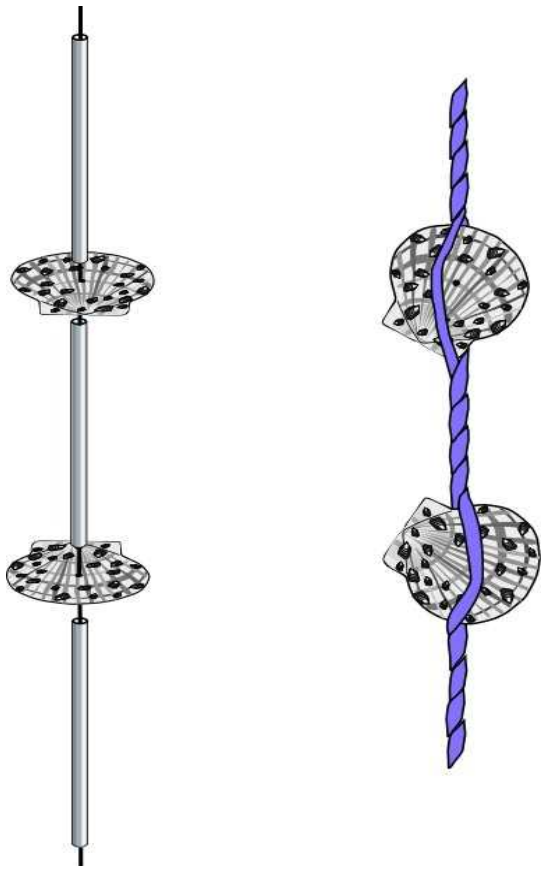


Figure 13: Methods of hanging seed boards
Wire method (left)
Rope method (right)

The wires or ropes connecting the seed boards are hung from rafts or longlines (Fig. 14).

Figure 14: Oyster aquaculture raft assembled from bamboo (Hiroshima Bay)

9. Aquaculture Management

The growth of oysters differs depending on the season, location, and density of the aquaculture facility, so various modifications must be made to account for these differences. The time of restringing may be changed to suit the harvesting period, and the depth of hanging at the aquaculture facility may be changed depending on the season. From summer to fall, typhoons that threaten Japan can destroy farming facilities, so attention must be paid to weather forecasts.

To avoid the influence of waves and wind, aquaculture facilities may be moved to the lees of an island. If oyster excrement and shells gather at the seabed of farming locations and contamination becomes severe, fish and shellfish will be unable to live there. In order to cultivate oysters in a healthy fashion, the number of aquaculture facilities must be adjusted, and the seabed must be cleaned to prevent contamination from aquaculture from becoming too severe.

10. Harvesting

Harvesting begins around October or November when the seawater temperature drops and the oysters begin to gain weight. Machines such as cranes, shucking machines, and washing machines are used for harvesting the oysters.

When the oysters are landed, a washing machine is used to completely remove mud and deposits that are stuck to the valves. These landed oysters are stored in a pool filled with seawater, and the insides of the valves are also cleaned (Fig. 15). There is also a method of landing the oysters, separating them, and transferring them into a cage which is used to ship the oysters with the valves still attached.

Figure 15: Oyster harvesting using a crane (left) and an on-land pool (right)

11. Shucked Oysters

In Japan, oysters are usually shipped shucked with their shells removed.

A tool such as a knife or an oyster opener is used to open the shell and remove the oyster.

The blade of the knife or oyster opener is inserted between the valves, the adductor muscle is cut, the valves are opened, and the oyster is removed (Fig. 16).

Figure 16: Method for using an oyster opener to remove the shell and the location to insert the knife

12. Shipment

After oysters have been shucked and removed from the shells, they are thoroughly cleaned with cool, clean seawater.

After washing, the shucked oysters are packed into various containers and shipped (Fig. 17).

There is also another method of shipping in which the oysters are not shucked and shipped with their shells still attached.

Figure 17: Oyster shucking (left) and cleaning (right)

13. Periphyton and Harmful Creatures

There are harmful creatures who obstruct the growth of farmed oysters and even kill them in some cases.

Various creatures adhere to aquaculture facilities (such as raft buoys (floats), ropes, glass floats, and cages) as well as to the surfaces of oysters. These creatures are called periphyton.

Some examples of periphyton are blue mussels, Hydroides elegans, sea squirts, and barnacles, which surround oysters and adhere in large numbers, depriving them of oxygen (causing oxygen deficiency) and killing them. In addition, blue mussels, barnacles, and sea squirts also steal the oysters' food, obstructing their growth (Fig. 18).

There are also cases of fish such as blowfish or bluefin tuna eating oyster spats in the early stages of the aquaculture process.

Certain types of harmful plankton are known for killing shellfish such as oysters. In addition, oysters have been known to die in large numbers from unknown causes in the time period from summer to fall.

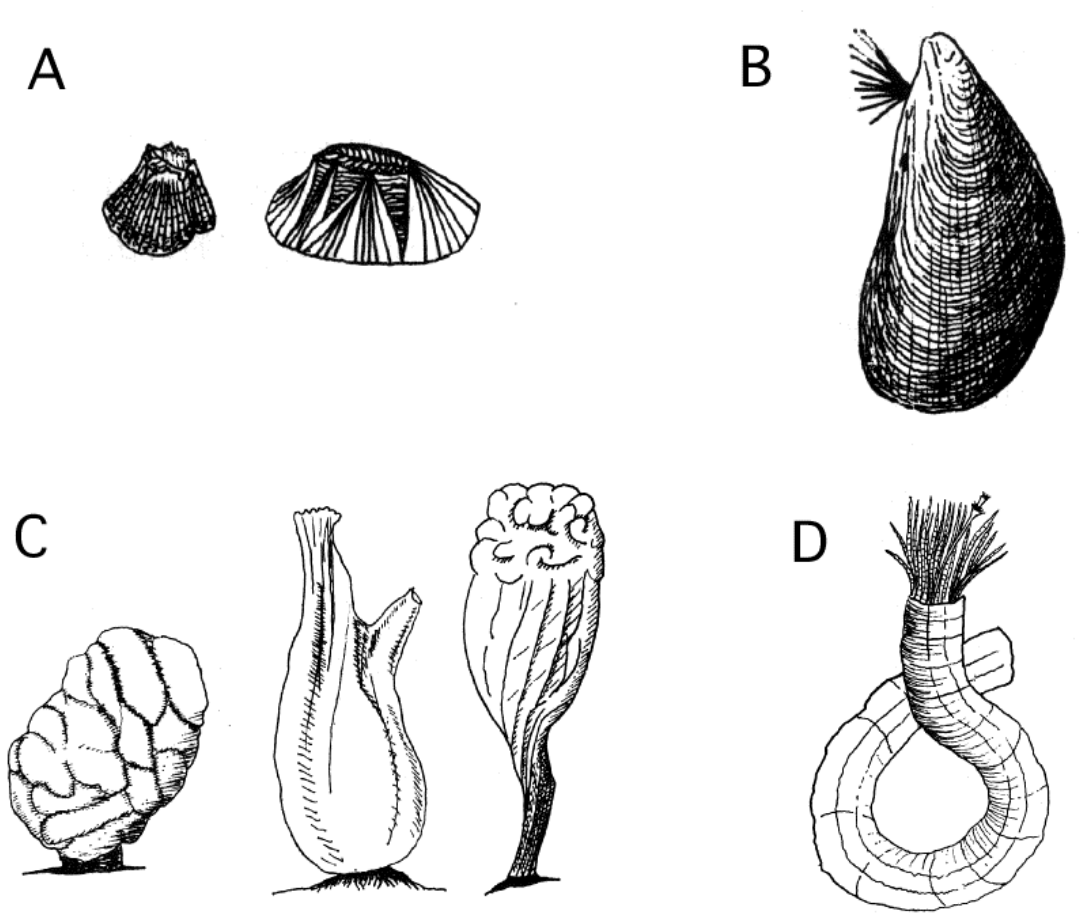


Figure 18: The main periphyton and harmful creatures in oyster farming
A: barnacle, B: blue mussel, C: sea squirt, D: Hydroides elegans (related to lugworms)

14. Hygiene Management

Oysters are food. Accordingly, there are rules for hygienic handling that must be properly observed.

- Aquaculture must not be conducted in contaminated waters with abundant bacteria.
- When landing oysters, wash them sufficiently with clean seawater to remove the mud and deposits.
- Immediately wash shucked oysters that have been removed from their shells with clean seawater.
- Washed oysters must be stored at temperatures of 5°C or below.
- The temperature must be maintained at 5°C or during transport as well.
- At the time of shipment, the following information must be clearly recorded: whether the oysters are for raw consumption or for cooking (heating), the expiration date, the name of the producer, the storage method, and the aquaculture region.
- Cultivating oysters in their shells in clean seawater to reduce bacteria within the oysters and enable them to be consumed raw is called "purification treatment."

15. Shellfish Toxins and Shipping Regulations

When oysters eat plankton carrying toxins which live in the sea (shellfish toxin plankton), these toxins are stored in the oysters. When shellfish such as oysters contain toxins like this, it is referred to as "shellfish toxicity."

Shellfish toxicity does not kill the oysters, but if a person eats them, it may induce poisoning resulting in paralysis or diarrhea, and in particularly severe cases, it can be fatal.

If the shellfish toxicity of oysters exceeds the standards, shipment is cancelled.

"Paralytic shellfish toxins" and "diarrheal shellfish toxins" are common types of shellfish toxins. The toxin volume is expressed as "mouse units," and safe toxin amounts are determined for each type.

Harmful plankton surveys and shellfish toxin tests are conducted regularly to ensure that consumers can safely eat the oysters. When testing detects shellfish toxicity in oysters exceeding safe levels, shipment restrictions are imposed.

Scallops

1. Japanese Scallops

The relatives of the scallops that are eaten in Japan are the following four types: Japanese scallops, Japanese bay scallops, Farrer's scallops, and Noble scallops. However, the types other than Japanese scallops are only obtained in small numbers. Scallops are bivalve mollusks that live in cold waters, and they are the type of shellfish that grows both the fastest and the largest. They inhabit most of the waters around Hokkaido, and there are both farmed and natural Japanese scallops. In the Sea of Okhotsk (Fig. 1), the seabeds are cultivated and scallop seeds are spread in large amounts.

This is called "bottom-culture spreading (propagation)," and 3 years after spreading the seeds (for four-year shellfish), the grown scallops are pulled up with dredge nets (*hasshaku*) and landed (Fig. 2).

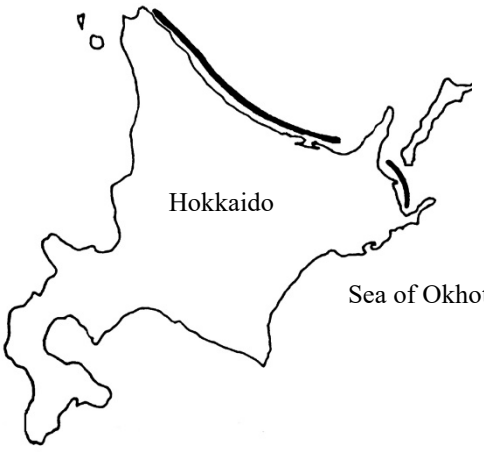


Figure 1: Production area for bottom-culture scallops

Scallop aquaculture is commonly conducted in the northern Sea of Japan, Uchiura Bay, and Lake Saroma in Hokkaido, as well as Mutsu Bay in Aomori Prefecture and along the Sanriku Coast extending from Iwate Prefecture to Miyagi Prefecture (Fig. 3).

About half of the shellfish aquaculture yield in Japan in 2017 was from scallop aquaculture.

Figure 2: A dredge net (*hasshaku*)

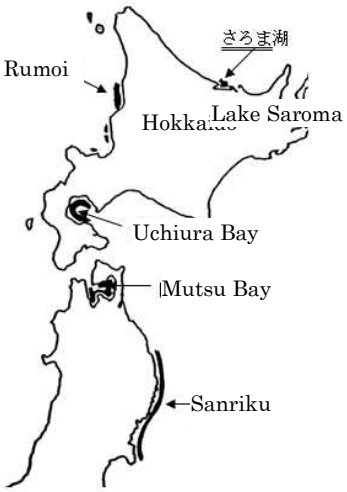


Figure 3: Production areas for farmed scallops

2. Scallop Yield

In 2017, Japan's nationwide yield for scallops was 174,000 t, and the prefectures with the highest yields were Hokkaido with 84,900 t and Aomori Prefecture with 84,300 t, followed by Miyagi Prefecture (Fig. 4).

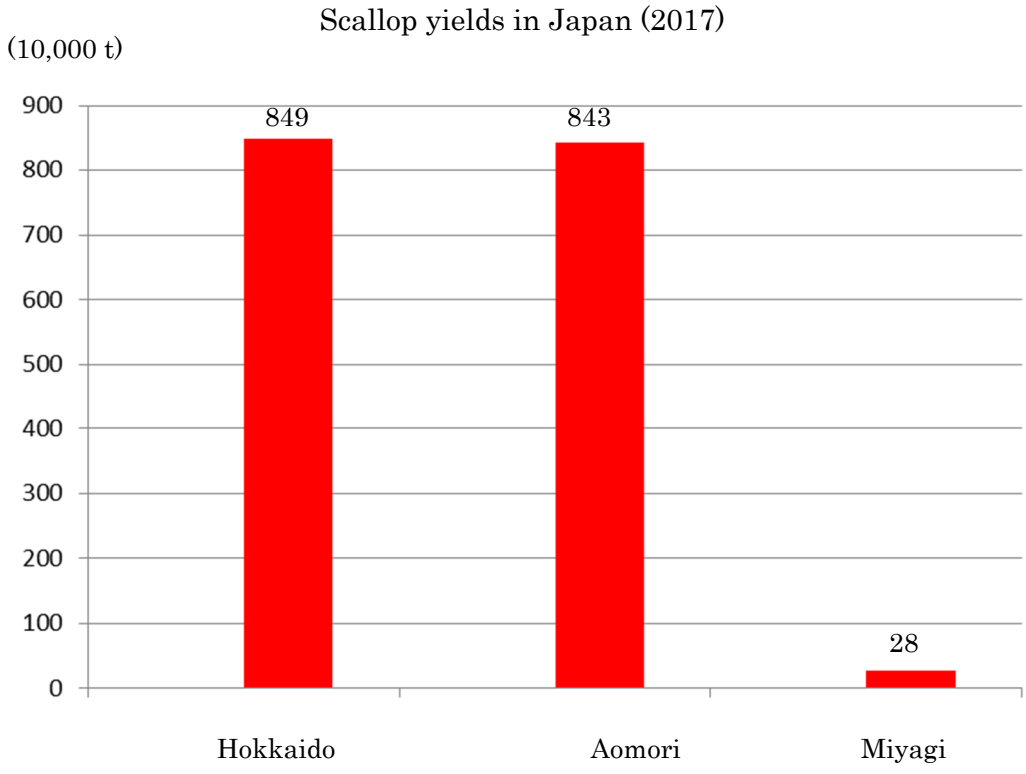


Figure 4: Japan's main scallop production areas and their yields

3. Life Cycles of Scallops

For scallops, males and females are separate, and when the temperature falls starting in December, gonads develop and they reach sexual maturity.

When spawning season nears, the gonads swell to a large size. For males, they turn a cream color (Fig. 5) and produce sperm, and for females, they turn a reddish-pink color (Fig. 6) and produce eggs.

Figure 5: Male scallop (♂)

Figure 6: Female scallop (♀)

A rise in water temperature provides stimulation, and when the temperature of the water reaches 4 to 8°C, the sperm and eggs are released into the sea. Spawning season starts around February in earlier regions, and after fertilization in the seawater, the eggs develop into larvae that float in the water after about one week.

After about 40 days, the larvae have grown to about 0.3 mm in size, and they begin to adhere to seed collection tools, ropes, and seaweed using their byssi at this stage (Fig. 8). During the larva stage, it is impossible for the scallops to escape predators, so they may be eaten by fish or other animals, decreasing in number.

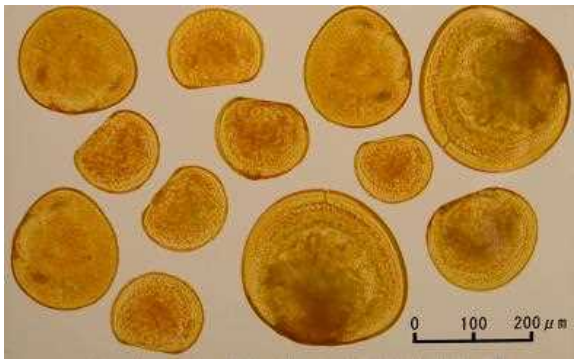


Figure 7: Floating scallop larvae

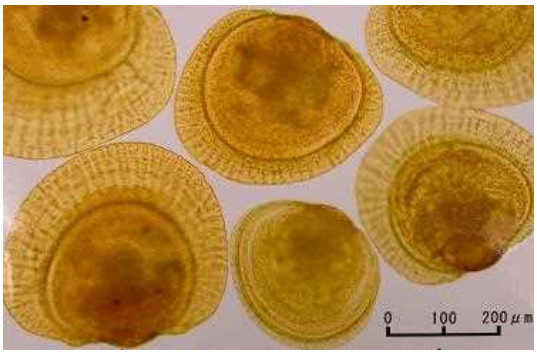


Figure 8: Scallops just after adhesion

Next the larvae become spats, and after between 40 to 60 days, when they have grown to around 8 to 10 mm, their adhesion strength weakens and they naturally fall off and transition to life on the seabed. Scallops take in phytoplankton and detritus, filtering these materials out of seawater through their gills and consuming as food in order to grow.

Aquaculture scallops grow to a size of 10 cm within 2 years, and bottom-culture scallops grow to a size of 10 cm in 3 to 4 years, at which time they can be harvested.

4. Scallop Exterior

Scallops have two shells. The white one is called the right shell, and the brown one is called the left shell (Fig. 9). The right valve is rounder and larger than the left valve, and when scallops are on the seabed, the right shell is on the bottom.

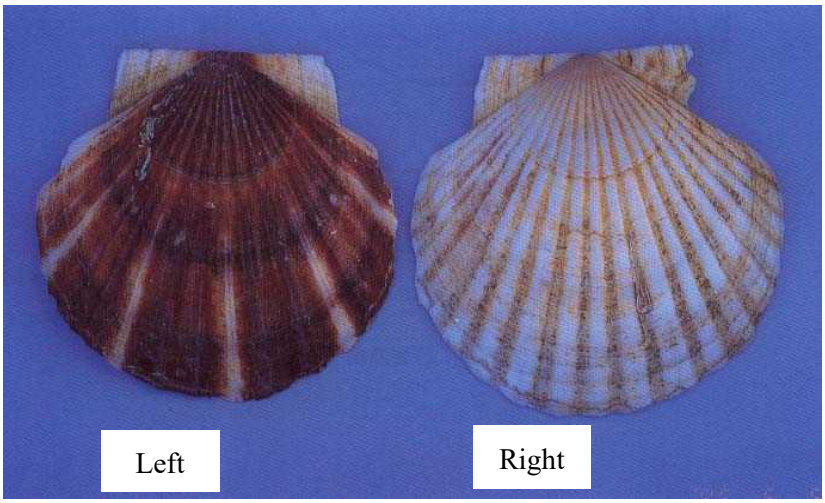


Fig. 9: Shape of scallop

The size of the shell is measured by the "shell height" or the "shell length." In addition, growth stops due to cold water temperatures in winter, spawning in spring, and high temperatures in summer. These stops are visible in the ring formations, and the age of a scallop can be determined by counting these rings (Fig. 10).

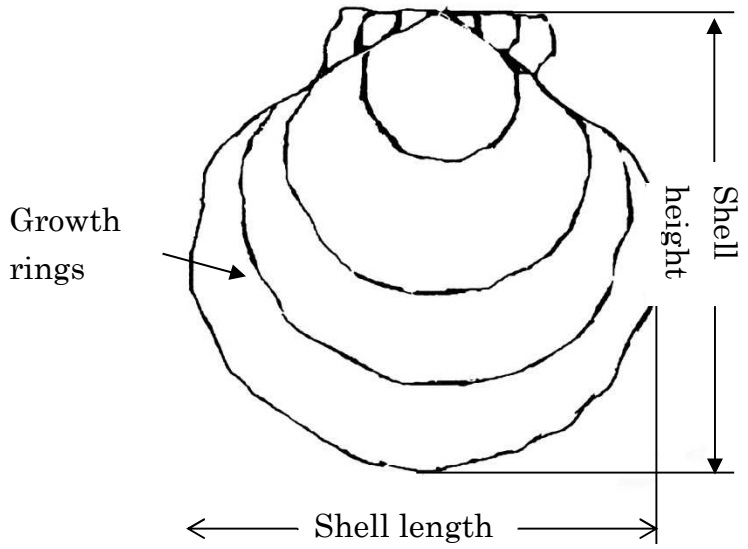


Figure 10: Scallop exterior

5. Scallop interior (Fig. 11)

Adductor muscles: Scallops have two types of adductor muscles. The large adductor muscle is used for closing the shell instantaneously when swimming. The other adductor muscle is small and located to the side of the large adductor muscle, and it is used to keep the shell tightly closed. The adductor muscles contain glycogen, which is the basis for the umami of the meat.

Mid-gut gland: Called *uro* in Japanese, this gland is responsible for actions of the kidneys, pancreas, and stomach. Food taken in through the mouth (such phytoplankton) is digested here, and a portion is absorbed.

Gonads: Located to the side of the adductor muscles, these grow from winter to spring. They turn white in male scallops and reddish pink in females.

Mantle: Called *himo* in Japanese, this is a thin layer covering the internal organs, and there are many eyes all around it. The mantle also creates the shell and determines the direction of swimming.

Gills: These are soft, brown organs to the side of the adductor muscles that are responsible for breathing, and they also filter and collect food from seawater (such as phytoplankton).

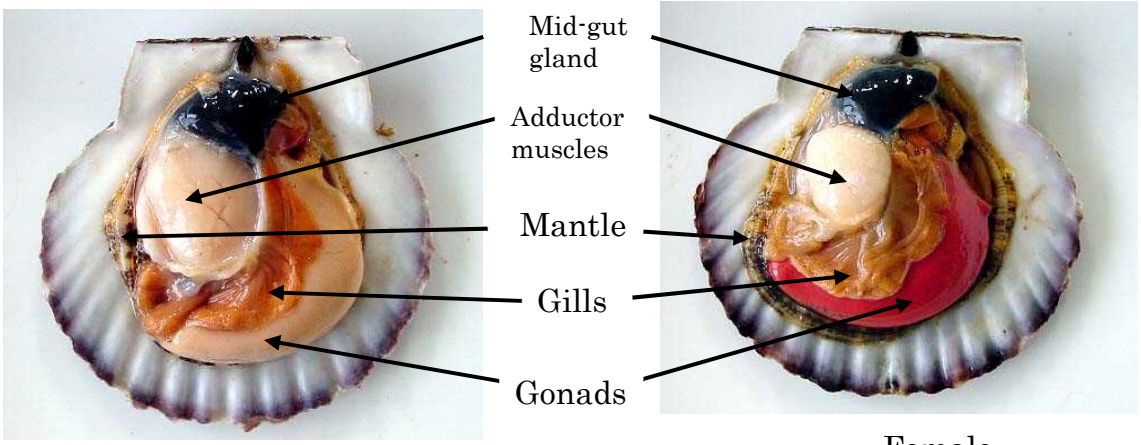


Figure 11: Scallop interior

6. Scallop Aquaculture

For scallop aquaculture, scallop spats born in the sea are usually gathered, cultivated, and shipped. Cultivated scallops grow by eating food sources such as phytoplankton in the sea.

In most areas, the aquaculture methods used is the longline hanging method (Fig. 12).

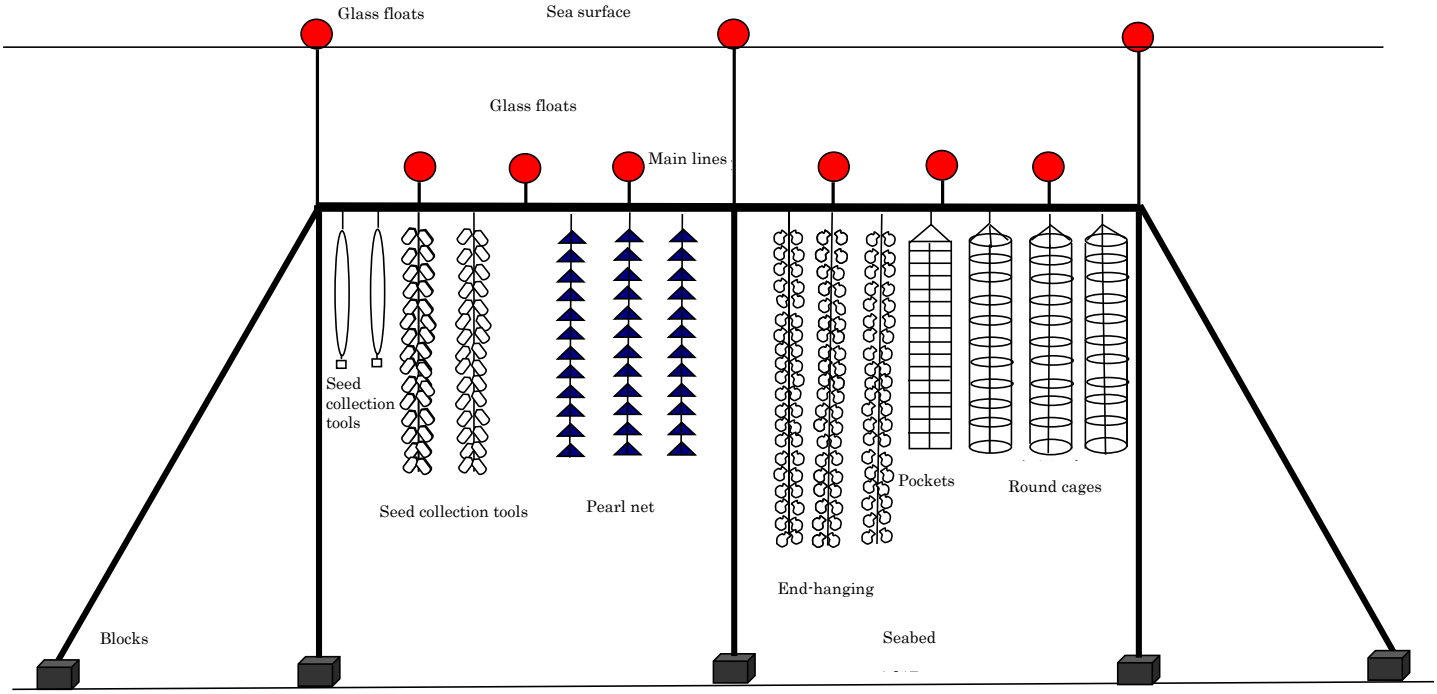


Figure 12: Scallop aquaculture facility diagram

However, depending on the waters and the sizes of the scallops to be shipped, the shipping period and the aquaculture methods differ. The locations and aquaculture methods for scallop cultivation are set by regulations determined by fishery cooperatives, and these regulations must be followed.

7. Natural Seed Collection

Scallop larvae floating in the sea have a characteristic which causes them to adhere to objects once they reach a size of about 0.3 mm. Seed collection tools make use of this characteristics, and they are lowered into the sea so the floating larvae will adhere to them. The process of collecting spats which have adhered to these tools and grown is called "natural seed collection."

There are two types of these seed collection tools: onion bag, which have Netlon nets or old nets inside of them, and stick nets, which are old net rolled into stick shapes.

When casting the seed collection tool, floating larvae are collected by using plankton beforehand, the number and size of the larvae are confirmed using tools such as microscopes to determine the casting period. Seed collection tool are always cast multiple times (Fig. 13).

Uchiura Bay
(stick net)

Mutsu Bay, Sea of Japan
(onion bag)

Figure 13: Seed collection tools

If sufficient spats cannot be gathered using natural seed collection, this has a major impact on scallop aquaculture and bottom-culture (propagation) yields, so seed collection is the most important task. Note that in Japan, there is no use of artificial seed production whatsoever for scallops.

8. Seed Collection and Dispersal

Seed collection for scallops starts from around March. The spats that have adhered to seed collection tools grow quickly, so the seed collection tools are hauled out of the water and the spats are collected.

The spats taken from the seed collection tools are transferred into cages with large meshes, in accordance with the growth stage.

(1) Provisional Dispersal

In the Uchiura Bay area, where stick net seed collection tools are used, as well as areas where many starfish, crabs, and other sea life enter the onion bags, these creatures are removed in order to prevent pest damage to the spats.

In addition, after the sizes of the spats are organized using a sieve, the following main dispersal task can be conducted efficiently. This process is called "provisional dispersal," and it is conducted from around July. The spats that have been provisionally dispersed are stored in pearl nets (cushion cages) and hung in the aquaculture facilities (Fig. 14).

Figure 14: A pearl net (cushion cage)

(2) Main Dispersal

The spats that were provisionally dispersed and hung are landed. Seeds for bottom-culture use and half-developed scallops are sorted according to spat size using sieves so that mature scallops can be shipped. A number of scallops determined according to the purpose is put into pearl nets, and the scallops are once again hung in the aquaculture facilities. This process is called "main dispersal," and it is conducted from around August. In addition, depending on the periods for shipping the scallops as partially or fully mature scallops, second and third dispersals may also be carried out in some cases.

In areas where provisional dispersal tasks are not conducted, seed collection tools are hauled up from late July to August, and starfish and crabs are removed. Furthermore, the sizes of the spats are organized by using a sieve, a number of scallops determined by shipping size is inserted into a pearl net, and the scallops are once again hung from the farming facilities.

In addition, at the time of each dispersal, the sizes of the meshes and the pearl nets themselves are changed to match the growth of the scallops. It is important to appropriately adjust the number of spats to added to each net in order to avoid impeding growth.

9. Spat Cultivation (Medium-Term Cultivation)

The spats for main dispersal are hung for a certain time period and cultivated in containers such as pearl nets until they reach a certain size suitable for aquaculture or bottom-culture spreading.

10. Adult Shellfish Cultivation (Main Cultivation)

Spats used for medium-term cultivation are transferred into round cages (andon cages) (Fig. 15) or pocket cages (Fig. 16) until they develop into partially and fully-mature scallops. Alternatively, they may be hung in aquaculture facilities by forming a hole in the end of the shell, directly attaching a rope using a pin with a hook attached or similar method, and hanging the shell with this rope (this is referred to as "end-hanging farming") (Fig. 17).

Afterward, the aquaculture process carried out until shipping is referred to as "main cultivation."

During this period as well, it is important to appropriately adjust the number of scallops in each cage to avoid impeding growth.

Figure 15: A round cage

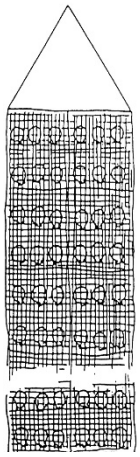


Figure 16: A pocket cage

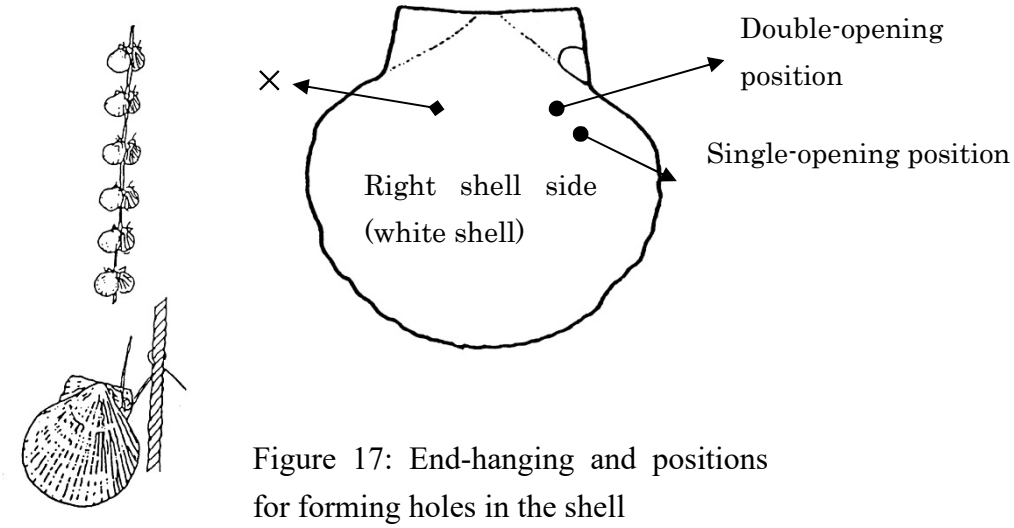


Figure 17: End-hanging and positions for forming holes in the shell

11. Aquaculture Management

When handling scallops, aquaculture workers must keep in mind that they are living creatures. Classification when sorting the spats by size and hole-forming work for end-hanging should be conducted early in the morning when possible, before the water and air temperatures rise. When these operations must be performed during the day, it is important to carry them out in a cool work shed and avoid direct sunlight.

Spats are particularly vulnerable to direct sunlight, high temperatures (approx. 22°C and above), drying (wind), rainwater, and oxygen deficiency, so ample caution must be taken. Furthermore, shells with a cracked valve (referred to as chipping), shells for which the interior has become yellowish-brown (referred to as internal coloring), and shells for which growth has stopped are referred to as "abnormal shells" (Fig. 18).

When abnormal shells are cultivated at high densities or cages or scallops crash into each other due to the aquaculture facilities swaying due to factors such as rough seas, the shells of the scallops may become damaged.

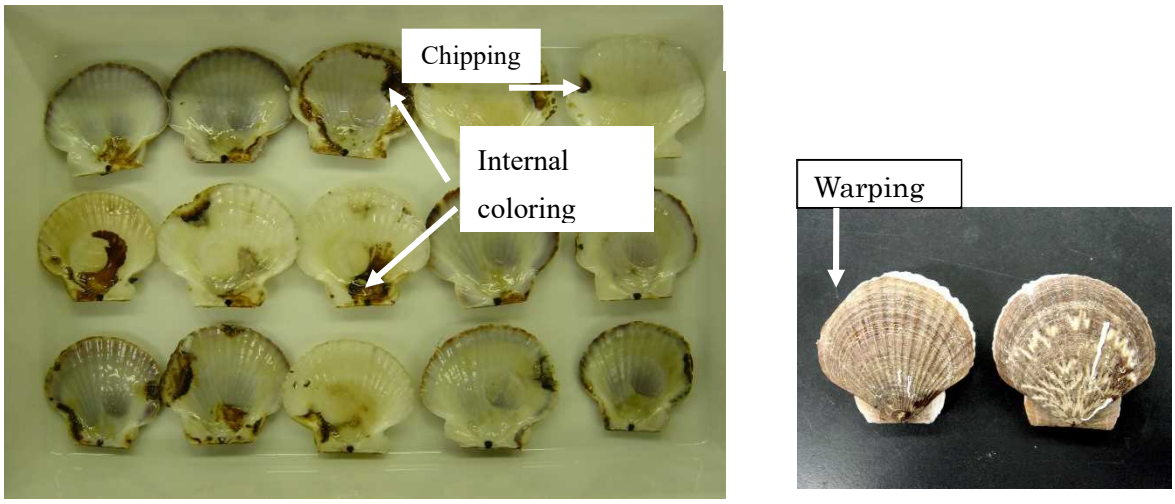


Figure 18: Abnormal shells

12. Periphyton and Harmful Creatures

In certain years, various creatures adhere to aquaculture facilities (including ropes such as the main lines and hanging lines, pearl nets, round cages, and glass floats) or to the surfaces of scallop shells. Furthermore, starfish and crabs also feed on scallops directly (Fig. 19).

Starfish that have entered seed collection tools

Pugettia quadridens (crab) that has entered a seed collection tool

Glebocarcinus amphioetus (crab) that has entered a pearl net

Figure 19: Harmful creatures

In addition, other examples of periphyton that adhere to farming facilities and shells include blue mussels, barnacles, sea squirts, sea anemone, and polychaetes (Figs. 20 and 21).

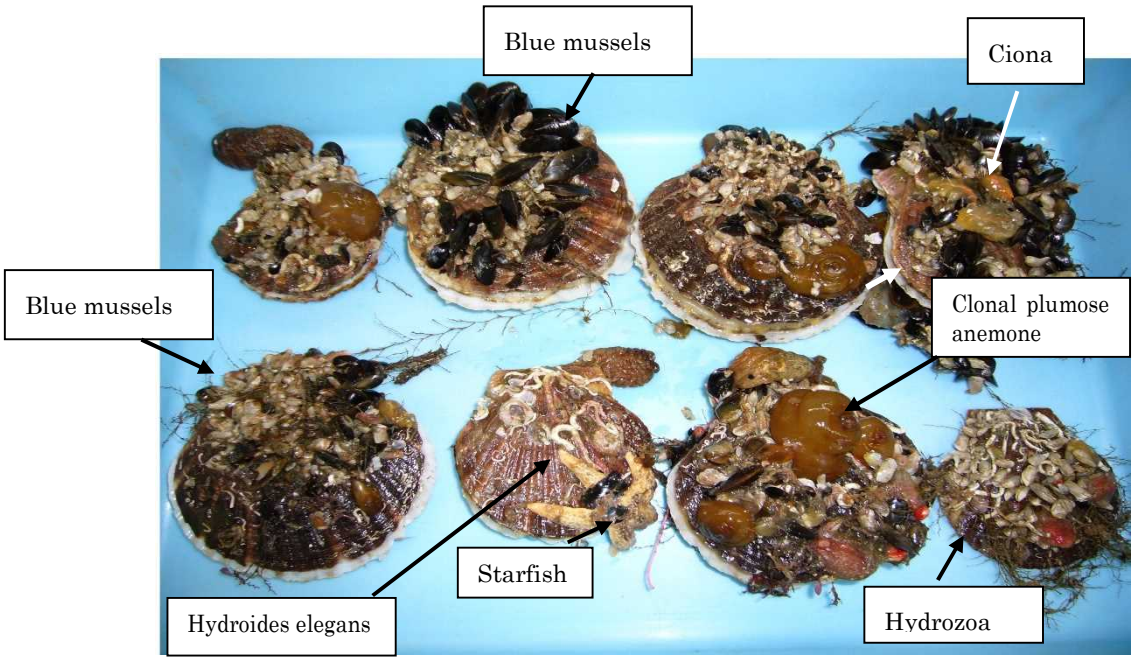


Figure 20: Periphyton

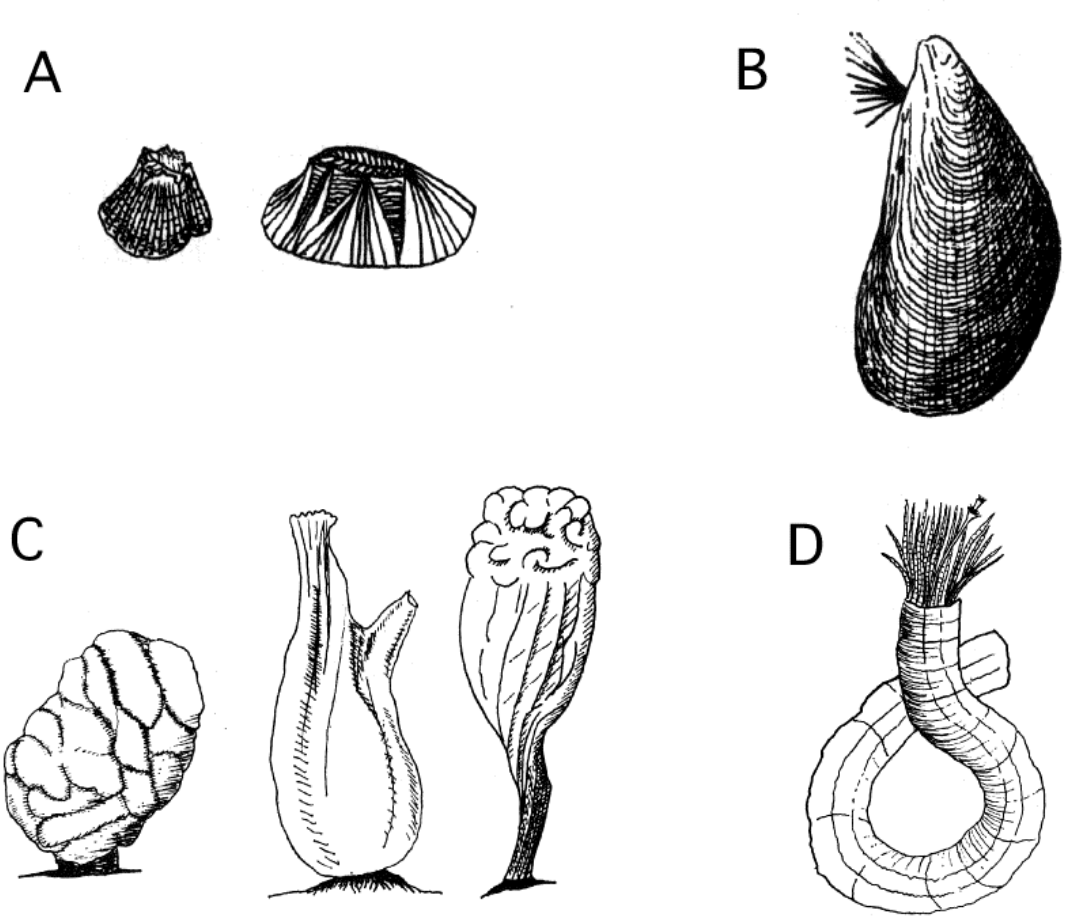


Figure 21: Other periphyton

A: barnacle, B: blue mussel, C: sea squirt, D: Hydroides elegans (related to lugworms)

13. Shellfish Toxins and Shipping Regulations

Bivalve mollusks such as scallops gather plankton, filter them from seawater, and consume them as food. However, when they eat plankton carrying toxins which live in the sea (shellfish toxin plankton), bivalve mollusks which are generally nontoxic store these toxins in their bodies and become toxic. This process of becoming toxic is called

"shellfish toxicity," and it is not fatal to affected bivalve mollusks.

In the case of scallops, shellfish toxicity is known to be primarily stored in the mid-gut gland. If a person eats scallops which contain toxins, symptoms such as paralysis or diarrhea may result, and in particularly severe cases, it can be fatal.

"Paralytic shellfish toxins" and "diarrheal shellfish toxins" are common types shellfish toxins. The toxin volume is expressed in "mouse units," and safe toxin amounts are determined for each type.

Harmful plankton surveys and shellfish toxin tests are regularly conducted in order to ensure that consumers can safely eat the scallops.

When testing detects shellfish toxicity in scallops exceeding safe levels, shipment restrictions are imposed.