

Original Research Article

THE CULTIVATION OF SCALLOP (*Patinopecten yessoensis*) IN HOKKAIDO, JAPAN

ABSTRACT

Scallop culture is a widely practiced aquaculture activity in Japanese waters that involves collecting wild scallop spat and then growing the spat to a marketable size. This study aims to determine how the cultivation system, technology, and transportation are applied in scallop aquaculture in Japan. This research was conducted from December 2022 to June 2023 at a family scallop farming business in Ishikari, Hokkaido, Japan, hereafter referred to as Company X. This research utilizes a descriptive method with literature exploration and direct observation methods with a case study at Company X. Based on the literature study and activities at Company X, the cultivation media used and transportation are important parts of the scallop culture activities. The cultivation media used at Company X include onion mesh bags, Pearl nets, and lantern nets. The current transportation technology of scallops is carried out in two areas, namely sea, and land, using the open dry system transportation method, exposure method, and oxygen method. Marine transportation uses Hydraulic Cranes for Shipboard Use (Marine Cranes) technology applied to two specialized vessels of 9.7 and 12 GT with truck-mounted crane classification. Land transportation for the delivery of young scallops uses plastic container baskets covered with wet rice sacks to prevent dryness and the scallops inside the baskets from biting each other. After that, the scallops are transported by freezer truck, while land transportation for shipping adult scallops uses a freezer truck filled with oxygenated seawater. The size of the wind blowing at sea, the time of pickup - delivery, and the number of scallops needed are important factors in transportation activities.

Keywords: Cultivation, Japan, Scallops, Transportation

1. INTRODUCTION

The scallop (*Patinopecten yessoensis*) is a cold-water clam that is widely distributed on the coastlines of Northern Japan, the North Korean Peninsula, and the Russian Far East [1]. The scallop ("hotate-gai" in Japanese), is cultivated in Japan for its good food quality and high productivity [2]. Over the past 30 years, scallop production has increased from less than 50,000 tons to 500,000 - 600,000 tons per year [3].

To sustain and achieve this level of harvest, the industry is evolving from a traditional wild fishery to an aquaculture-based one. The current development of the fishery is based entirely on intensive and directed efforts to collect wild scallop spat and then grow the spat to a marketable size using several culture techniques. Aquaculture mainly utilizes a combination of sowing culture and hanging culture techniques, with considerable success in both. Japanese scallop culture has developed into the most successful marine scallop culture enterprise in Japan [4]. Currently, more than 40% of scallop production in Japan comes from aquaculture [5]. The main region of scallop culture is Hokkaido (Lake Saroma, Sea of Okhotsk, and Funka Bay), where nearly 80% of production in Japan during 1991-2002 occurred [6].

Human needs cannot be obtained in any place, and human needs are not always in the same location or close to consumers, therefore transportation becomes a link between production areas, marketing areas, consumer areas, and raw material source areas [7]. In aquaculture, live fish transportation is moving aquatic biota in a living state by taking measures to maintain a high level of survival to the destination. The transportation of live fish is divided into two, namely transportation without water media or dry transportation and transportation using water media or wet transportation [8]. Therefore, in the aquaculture business, precisely the scallop, transportation is a crucial factor that needs to be considered.

Based on previous studies, many have discussed the cultivation of scallops and the transportation system applied. This study aims to determine how the cultivation, technology, and transportation systems are applied in the cultivation and sale of scallops in Japan. It is hoped that this paper can be used as a comparison and study material in the future development of shellfish culture in Japan, especially for the cultivation of scallops and transportation of marine fish commodities.

2. METHODOLOGY

The research was conducted from December 2022 to June 2023 at a family scallop farming business in Hamamasu, Ishikari City, Hokkaido, Japan, hereafter referred to as Company X. In this research, the method used is a descriptive method by exploring the literature such as Directory of Open Access Journal, Research Gate and Google Scholar. The keywords used for relevant discussion topics include scallop cultivation, transportation of scallop culture, scallop culture in Japan, and scallop. This descriptive research was conducted without any treatment or manipulation of the research sample. The purpose of descriptive research is to reveal the characteristics of the subject [9]. In addition, it uses direct observation methods with a case study at Company X. Thus, the theoretical framework can be arranged by the subject matter. This research is the result of an internship at the company.

Observations were conducted to identify the stages of scallop cultivation, the cultivation media used, and the types of transportation in scallop cultivation activities at Company X. The stages include conducting interviews with parties directly involved in scallop cultivation activities to find out the cultivation media used and the activity procedures in the transportation system. Then, measuring and documenting the equipment used in the implementation of cultivation and transportation activities. In addition, conduct a literature study to find out the basis of each treatment in transportation activities. Digital documentation processing using Oppo Camera software, iPhone Camera, and Microsoft Word from Microsoft Office 365 was used in the preparation of the report.

3. RESULTS AND DISCUSSION

3.1 Scallop Cultivation in Japan

Scallops are cultivated by hanging or sowing. They are transferred from the estuarine lagoon to the nearshore seabed when they reach 40-60 mm shell height after the "intermediate" culture stage. Scallops are cultured at a depth of 40 - 65 m and the cohorts are separated into four culture zones during 3 years of rearing culture [10]. In Japan, the sowing culture method has been practiced off the coast of the Sea of Okhotsk. This culture technique consists of several processes. First, scallop spat are caught in collectors suspended in the water column where spawning stock is kept. Next, the spat is reared in hanging cages until they reach a shell height of 30 to 50 mm and then released to grow in the sand. After three years, the scallops reach a marketable size with a shell height of about 120 mm and are harvested by dredging. With this culture technique, scallop survival between release and harvest is estimated to average 50%, although there is variation between different years and culture sites.

In 2017, the total production of scallop aquaculture in Japan was 174,000 tons throughout Japan. The prefectures with the highest order of production were Hokkaido 84,900 tons, Aomori prefecture 84,300 tons, and then Miyagi prefecture which can be seen in Table 1 [11].

Table 1. Total production of scallop aquaculture in Japan (Year 2017)

Year	2017
Hokkaido	84.900
Aomori	84.300
Miyagi	2.800

3.2 Scallop Cultivation Media

The culture method used in most areas is the hanging longline method (Figure 1) [11]. During the culture process, scallops grow by feeding on phytoplankton in the sea. However, the size of the scallops to be delivered, the delivery time, and the cultivation method vary depending on the sea area.

The location and method for scallop cultivation are determined by the Fisheries Cooperative Association (Gyokyo) and are rules that must be followed.

The media for the cultivation of scallops at Company X varies as follows, At the spat collection stage, the media used is an onion bag net (Bo Ami) which is a polyethylene net measuring 80 x 37 cm with a mesh size of 5 x 2 mm. The bag filling is usually large mesh monofilament or soft netlon according to the number of spat required per bag. At the intermediate culture stage, pearl nets are used, these are pyramid or cone-shaped nets with various mesh sizes available from 2 to 7 mm with 15 levels, while at the adult scallop rearing stage lantern nets are used. The most widely used structure is a lantern net with ten to twenty levels made of monofilament mesh (usually 12 mm or 21 mm foot size) enclosing a 50 cm diameter 5 mm plastic coated wire mesh loop, forming 15 cm high compartments. Each chamber has a lateral opening for inserting scallops. This structure with good flow characteristics is perfect for growing, the thin monofilament strands resisting heavy algae deposits and siltation. The system also has flexibility in the water and is compact for easy transportation, handling, and storage. It is a relatively inexpensive structure and has a service life of 4 - 5 years [12].

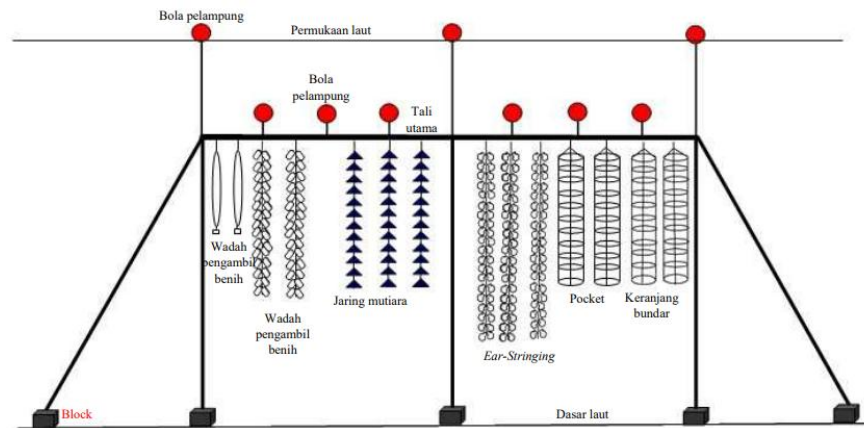


Figure 1. Scallop cultivation facilities at sea

3.3 Scallop Cultivation Cycle

The stages of scallop culture are simple in concept, consisting of collecting newly settled shelled larvae called "spat" in collecting bags and growing juvenile scallops in protected hanging cages (first pearl nets and then lantern nets) until they reach commercial size. An alternative way apart from this hanging culture after juvenile scallops (intermediate culture) is to sow 3 cm seeds from a pearl net in a protected sandy seabed area and dredge the scallops after 2 - 5 to 3 - 5 years.

Spat collection nets are installed in stages from mid-April to early May to collect scallop seeds in the sea. Then, the net will be lifted from the sea to remove the spat from the spat collection container, this process is done in July to August and is done in the morning. The spat that has been removed will be hung on the pearl net at sea for one year until they reach a size of 3 - 3.5 cm, after which the scallops will be removed from the sea. Thereafter, the 1-year-old scallops are used for final growth, which is carried out in lantern nets or on prepared seabeds where the scallops enjoy lower densities than in the native habitat for faster growth rates and better weight gain [13].

3.4 Problems Associated with the Scallop Cultivation

Aquaculture problems, which often result in mortality, can be classified as problems caused by nature or aquaculture. Natural problems arise from predation, parasites, and environmental problems from wave action, unsuitable substrates, and red tides. Problems caused by aquaculture are too many cages, too much stocking density, attempts to improve poor seed quality, and deterioration of water quality in the culture area [14].

There are control measures to prevent and reduce the impacts caused by these aquaculture maladies, namely (1) setting lower densities in the culture medium will result in higher growth rates and lower mortality by reducing the crowding effect; (2) shorter time for sorting scallops and replacing cages and cleaning them will reduce the shock to the scallops; and (3) stabilizing the longline facilities and hanging scallops will also reduce the shock caused by waves. Wave-induced shock damages the scallop mantle and leads to high mortality and slow growth.

3.5 Types of Scallop Transportation

3.5.1 Sea Transportation

At the harvest stage of scallop aquaculture, there is a marine transportation stage where scallops are transported from the aquaculture facility at sea to the landing site. At Company X, sea transportation transports harvested one-year-old scallops for shipment of young scallops and 3-year-old and 4-year-old scallops for shipment of mature scallops. Loading, unloading, and traveling should be scheduled at convenient times, and done as quickly as possible [15]. The transportation of scallops is carried out at the location of the rearing container nets that have been placed in the middle of the open sea, so special vessels are required for sea transportation. In Company X, two specialized vessels are used, which are 9.7 and 12 GT in size. In addition, the specialized vessels are equipped with Hydraulic Cranes for Shipboard Use (Marine Cranes) technology from the UNIC Ocean Crane company with the UBV500J series which is capable of lifting loads of up to 960 kg in one transport (Figure 2b). Based on a book issued by the Occupational Safety and Health Branch (2017) entitled Code of Practice for Safe Use of Mobile Cranes, this crane technology from the UNIC company includes truck-mounted cranes or cranes mounted on vehicles where the control engine is separate from the main vehicle [16].

In the transportation process, the ropes hanging from the aquaculture facility are collected and hooked onto one large hook, which is then transported by a ship's crane and finally, when the bottom of the crane wire is released, the scallops slide down to the deck of the ship (Figure 2a). In one transportation process, the crane can lift 10-20 ropes with a weight of about 30-60 kg/rope. The scallops are then brought ashore to be processed. This sea transportation system is included in the open dry system transportation. Dry system transportation is a transportation system that does not use water as a medium, but the environment or container used is made moist [17]. Dry transportation systems apply the principle of conditioning aquatic biota in a state of low metabolism and respiration so that endurance outside their living habitat is high [18].

After the sea transportation is landed, the scallops will go through a cleaning process from parasites attached to their shells [19]. After the oysters are processed, they will be shipped by land to reach the consumers.



2a



2b

Figure 2. (a) Nets that have been transported on the deck of a ship (b) UNIC Ocean Crane at Company X

3.5.2 Land Transportation

In addition to sea transportation, there is also land transportation of scallops that occurs during the process of delivering scallops to other parties, including consumers. The handling process in transportation activities is very important for fishery products, starting from the landing of the fish until it reaches the hands of consumers or the area of origin. There are two types of shipments made by Company X, namely, shipments of young scallops that are one year old with a size of 3.5 cm or more. In addition, shipments of adult scallops that are three years old with a shell size of 11 cm, weighing about 6 pieces/kg, and scallops that are four years old, weighing 3 - 4 pieces/kg.

Based on observations, land transportation for shipping young scallops at Company X uses plastic container-type baskets. The scallops are sold to fishing cooperatives in Sarufutsu and Esachi, and the cooperatives that purchase the scallops will release and grow the scallops into the sea, where they will be harvested after 3 years. The scallops delivered by this company are in their shelled form. Land transportation of young scallops in Company X is included in the exposure method using plastic container baskets covered with wet rice sacks to prevent dryness and the scallops in the baskets from biting each other. After that, the scallops are transported by freezer truck. All handling and transportation is done during the cold period. With this method, scallop survival can reach 80-90% [14].

In land transportation for the delivery of adult scallops at Company X, baskets are used first for handling and weighing the scallops. After that, the scallops will be put directly into the freezer hatch of the truck without using any container, the hatch has been filled with seawater. The adult scallops will be sold and shipped to South Korea. The land transportation of the adult scallops in Company X is included in the oxygen method by using a freezer truck that has been filled with oxygenated seawater [14].

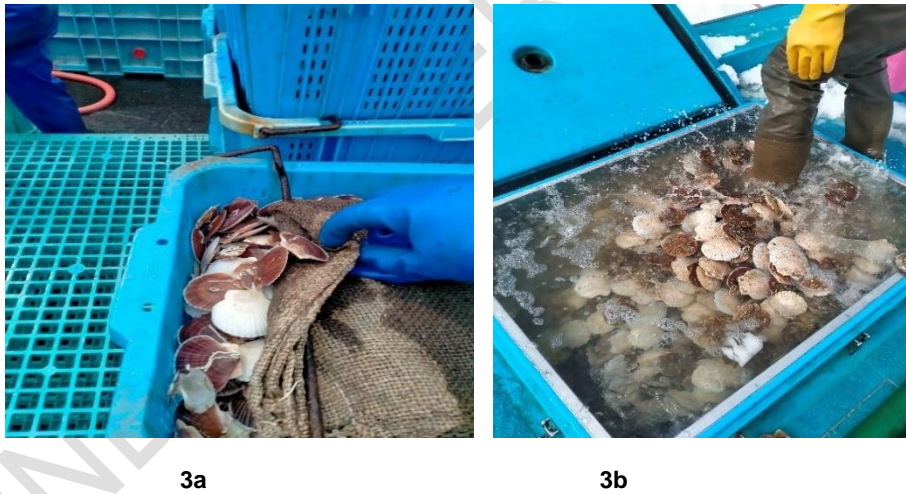


Figure 3. (a) Young scallops to be shipped (b) Adult scallops to be shipped



Figure 4. Putting young scallops into the freezer truck for shipping

3.6 Factors in Transportation of Fishery Products

Based on notes on sea transportation observation activities, it is known that sea transportation activities must pay attention to the time of collection, the size of the wind blowing, and the number of scallops to be processed (Table 2). In his research stated that there are crucial factors in the transportation of live marine fish, namely sea transportation, fasting, cooling, and oxygen supply. Then, on land transportation, the fulfillment of temperature, anesthetizing media, decreasing salinity, fish volume ratio, and media and oxygen [20].

Table 2. Important Factors in Sea and Land Transportation

Sea Transportation	Land Transportation
Temperature Fasting	Temperature Fasting
Wind Speed	Container/Carousel
Weather (Transportation Time)	Temperature Control
Number of Fish	Fish Ratio/Volume
Oxygen	Oxygen

4. CONCLUSION

Based on the results of research that has been conducted on "The Cultivation of Scallop (*Patinopecten yessoensis*) In Hokkaido, Japan" it can be concluded that:

1. The cultivation media used in scallop aquaculture activities vary according to the stage of cultivation. The cultivation media used are as follows, at the spat collection stage using onion bag nets (Bo Ami), at the intermediate cultivation stage using pearl nets, and at the adult scallop rearing stage using lantern nets.
2. The transportation system in scallop aquaculture in Japan is divided into two, namely sea and land. In marine transportation, the transportation activities use Hydraulic Cranes for Shipboard Use (Marine Cranes) technology installed on 9.7 and 12 GT vessels with truck-mounted crane classification. On land transportation, young scallops are delivered using plastic container baskets covered with wet rice sacks to prevent drying out and the scallops in the baskets from biting each other. After that, the scallops are transported by freezer truck, while land transportation for the delivery of adult scallops uses a freezer truck that has been filled with oxygenated seawater. Therefore, the transportation techniques in scallop aquaculture in Japan apply the open dry system, exposure method, and oxygen method. Wind speed, transportation time, and the number of scallops to be processed are crucial factors in transportation, quality, and processing.

REFERENCES

1. Hou, Rui, et al. Transcriptome sequencing and de novo analysis for Yesso scallop (*Patinopecten yessoensis*) using 454 GS FLX. *PLoS one*, 2011;6.(6):e21560.
2. Ito, H. Scallop culture in Japan. In; S.E. Shumway (Ed.). *Scallops, Biology, Ecology and Aquaculture. Developments in Aquaculture and Fisheries Science*. 1991;21:1017-1055.
3. Uki, Nagashisa. Stock enhancement of the Japanese scallop *Patinopecten yessoensis* in Hokkaido. *Fisheries Research*, 2006;80(1):62-66.
4. Shumway, Sandra E, PARSONS, G. Jay (ed.). *Scallops: biology, ecology, aquaculture, and fisheries*. Elsevier. 2016.
5. FAO. Fisheries global information systems. 2006. Accessed 31 July 2023. Available: <http://www.fao.org/figis/>.
6. Ministry of Agriculture, Forestry, and Fisheries. Statistics on Agriculture, Forestry and Fisheries. 2005. Accessed 31 July 2023. Available: <http://www.maff.go.jp>.
7. Lubis, Ernani Wiyomno, Eko Sri, Nirmalanti Mareta. Handling During Transportation of Landed Catches at Nizam Zachman Ocean Fishing Port: Biological and Technical Aspects. *Mangrove and coastal journal*, 2010;10(1):1-7.
8. Hidayat Taufik, Bramantyo, Muhammad Baiquni, Nurilmala Mala. Penerapan suhu pemingsanan dalam transportasi sistem kering ikan baronang *Siganus* sp. *Depik*, 2018;7(3):198-208.
9. Fraenkel, Jack R., Norman E. Walen, Helen H. Hyun. *How to design and evaluate research in education*. New York: McGraw-hill; 2012.
10. Paturusi, As' ad, Chiba Susumu, Goshima Seiji. The magnitude of natural recruitment in a cultured population of Japanese scallop *Patinopecten (Mizuhopecten) yessoensis* on Yubetsu seabed (Japan), Sea of Okhotsk. *Benthos Research*. 2002;57(2):69-75.
11. Japan Fisheries Association. Textbook for Fisheries Skills Test (Aquaculture). 1st ed. Japan; 2020.
12. Kosaka Yoshinobu. Scallop fisheries and aquaculture in Japan. In: *Developments in Aquaculture and Fisheries Science*. Elsevier. 2016.
13. Lagunova, D.D.; Gerasimova, E.A.; Chernetsov, V.V. Efficiency of scallop cultivation combined method (combination of suspended and bottom). *Sci. Work. Dalrybvtuz*. 2010;22:159-165.
14. Ventilla, R. F. The scallop industry in Japan. In: *Advances in marine biology*. Academic Press. 1982.
15. Sakai K. Scallop Culture in Japan. Suisan Hokkaido Kyokai, 1976.
16. Occupational Safety and Health Branch. Code of Practice for Safe Use of Mobile Cranes. Labour Department [Internet]. 2017. Accessed 20 July 2023.

Available: http://www.labour.gov.hk/eng/public/content2_8b.htm.

17. Kusyairi, Hayati N, Madyowati SO. Effectiveness of Transportation System Dry Closed Transportation System for Dumbo Catfish (*Clarias gariepinus*). *Agroknow Journal*. 2013;1(1):39-45.
18. Heriyati E, Kasman. Survival Test Survival Test of Tiger Grouper (*Epinephelus fuscoguttatus*) with the Low Temperature Immobilization Technique in Dry System Transportation. *Ziraa'ah Agricultural Scientific Magazine*. 2017;42(1):58-64.
19. Kawabe S., Murakami H., Usui M., Miyasaki T. Changes in volatile compounds of living Pacific oyster *Crassostrea gigas* during air-exposed storage. *Fisheries science*. 2019;85:747-755.
20. Imanto PT. Some Live Marine Fish Transportation Techniques and Facilities in the Marine Fish Trade in Belitung. *Journal of Aquaculture Media*. 2008;3(2):181-188.

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