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Inventory of Pests and Parasites in the Cultivation of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan

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Abstract

Hotate Shellfish is the largest shellfish cultivation in the world, but many pests and parasites are found. This research aims to inventory the types of pests and parasites found in the cultivation of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan. The objects used for this research were 54 Hotate shellfish, consisting of three life stages of shellfish, namely seed shellfish, juvenile shellfish, and adult shellfish. This research was carried out using observation and random sampling methods to determine the types and percentages of pests and parasites present during the research. This research was carried out for seven months from 13 April to 6 December 2022 at the Daisan Matsui Company, Ohama, Oshamambe, Hokkaido, Japan. The results of this research show that there are four types of pests, namely Starfish, Purple Shellfish, Crustaceans, and Sea Pineapples as well as two types of parasites, namely Annelid Worms and Barnacles which attack shellfish cultivation. The percentage of shellfish at three life stages that were attacked by parasites was 75.93%. There are several factors that control the attachment of pests and parasites, including substrate availability, nutrient availability, and environmental considerations. The surfaces and nutrients provided by hotate culture facilities provide adequate conditions for pest settlement and growth.

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Introduction

Hotate Shellfish (*Patinopecten yessoensis*) cultivation is the largest shellfish cultivation in the world (FAO, 2018). In addition, Japanese fishing businesses have produced the highest profits through exports since 2012 (Ministry of Agriculture, Forestry & Fisheries, 2021). More than 50% of Japan's shellfish are produced by mariculture activities along the coastline of Funka Bay, Hokkaido. Funka Bay is the main commercial production area of shellfish farming in Hokkaido, where most of the cultivation techniques used are hanging techniques.

Hotate shellfish are in great demand among local people because they taste delicious and delicious. Apart from tasting delicious and delicious, Hotate Shellfish also have quite high nutritional content and have

great potential for processing. The nutritional content of Hotate Scallops is muscle (72.4% protein, 12.1% carbohydrates and 6.1% fat) and gonads (61.6% protein, 19.5% carbohydrates and 10.8% fat) (Yudiati, 2002).

Hotate Shellfish were covered with multiple organisms on their surfaces (circling ropes, ropes hanging from the ceiling, pearl nets, baskets, and float balls) and on the surface of cultivation facilities (main ropes, hanging ropes). Apart from that, there are Purple Shellfish, Barnacles, Starfish, Hoya (*Ascidian*), and Annelid Worms, namely Hydroides elegans, as attachment organisms that stick to the surface of cultivation facilities (Japan Fisheries Association, 2020). Pests and parasites can damage Hotate shellfish and disrupt the sustainability of cultivation businesses, thus having a negative effect on shellfish. The clinical symptoms of shellfish that are infected with pests and parasites are that they appear smaller in size than healthy shellfish of their age, the shells are incomplete, have holes, are not symmetrical and are damaged (Gabaev, 2013). Parasites can attack or attach to the shell, causing a decrease in the shellfish's health and growth levels. Annelid worms consume shellfish eggs and larvae, which negatively affects shellfish survival (Aya et al., 2014).

Many researchers have investigated the pathogenic organisms and immune mechanisms of shellfish, because cultivating healthy shellfish is closely related to environmental factors (Song et al., 2022). Apart from environmental factors, Hotate clam cultivation is influenced by predatory pests. Current studies show that predation by muricid gastropods has been neglected in the management of Japanese shellfish fisheries (Chiba & Arai, 2014). Compared with *Asterias amurensis, Distolasterias nipon* continuously catches small shellfish and feeds on larger shellfish (Miyoshi, 2019).

Hotate Clam cultivation productivity can be affected by neglected pests and parasites in the cultivation environment. Available information regarding pests and parasites presents in Hotate clam cultivation in Funka Bay, Hokkaido is still limited. Based on these conditions, it is necessary to carry out research to inventory pests and parasites in one of the Hotate Clam cultivating companies in Ohama Village, Oshamambe, Hokkaido, Japan, namely the Daisan Matsui Company.

Materials and methods

Research Implementation

This research was conducted in April December 2022, at the Daisan Matsui Company located in Ohama Village, Oshamambe, Hokkaido, Japan. The objects used were 12 shellfish seeds, 23 juvenile shellfish, and 19 adult shellfish. The total number of Hotate Shellfish observed was 54 from cultivation in Funka Bay, Hokkaido, Japan. This research uses an observation method with random sampling techniques. Observation methods include observation, data collection (inventory), descriptive data analysis, and drawing conclusions.

Preliminary Investigation

A preliminary investigation was conducted to determine whether Hotate Shellfish (*Patinopecten yessoensis*) were subject to pests and parasites in Funka Bay, Hokkaido. While carrying out cultivation activities, the presence of organisms other than Hotate Shellfish (*Patinopecten yessoensis*) was observed. Apart from that, the stages of cultivated shellfish are known.

Sampling

After observations are made and it is found that there are pests and parasites, samples are then taken using gloves. Sampling was carried out randomly at three stages, namely seeds, juveniles and adults. Samples are collected on a tray so they can be observed.

Sample Cleaning

Samples collected in the tray were taken to be cleaned of dirt such as moss or sediment. Samples were cleaned using tap water. The collected samples were taken from the company to the dormitory for observation.

Documentation

The cleaned samples were photographed using a phone camera. Documentation aims to provide documents using accurate evidence. Documentation here is a record of events that have occurred, as well as a source of data used to complete information in research.

Observation and Calculation of Sample Number

The samples were observed and the numbers were counted. Shell samples were grouped based on the presence or absence of organisms attached to the shell. Pests and parasites that attack the cultivation of Hotate Scallops (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan were inventoried based on reference literature from the book written by Kosaka Yoshinobu in Chapter 21 entitled Scallop Fisheries and Aquaculture in Japan.

Data Analysis

The data obtained from the research results consist of data on the types of organisms present or attached to Hotate Shellfish and their cultivation facilities. Data is presented in tabular form, using pie charts, and documentation images and analyzed descriptively. Data compared with literature.

Results and Discussion

Types and Distribution of Pests

Research conducted on growing Hotate Mussel cultivation succeeded in finding several types of pests that attack cultivation facilities and shellfish. Pests found are taken randomly and observed. Based on observations, the pests found were Starfish, Barnacles, Purple Shellfish, Crustaceans, and Sea Pineapple Figure 1.

There are three types of Starfish found, namely *Asterias amurensis, Patiria pectinifera,* and *Distolasterias nipon*. Purple Shellfish and Asterias amurensis were found in all types of cultivation facilities. The type of pest that is not found in Floating Balls is Crustaceans. The type of pest that was not found attached to the basket and main rope was *Patiria pectinifera*. The types of pests found on Hanging Ropes are Starfish, Purple Shellfish and Sea Pineapples. These results

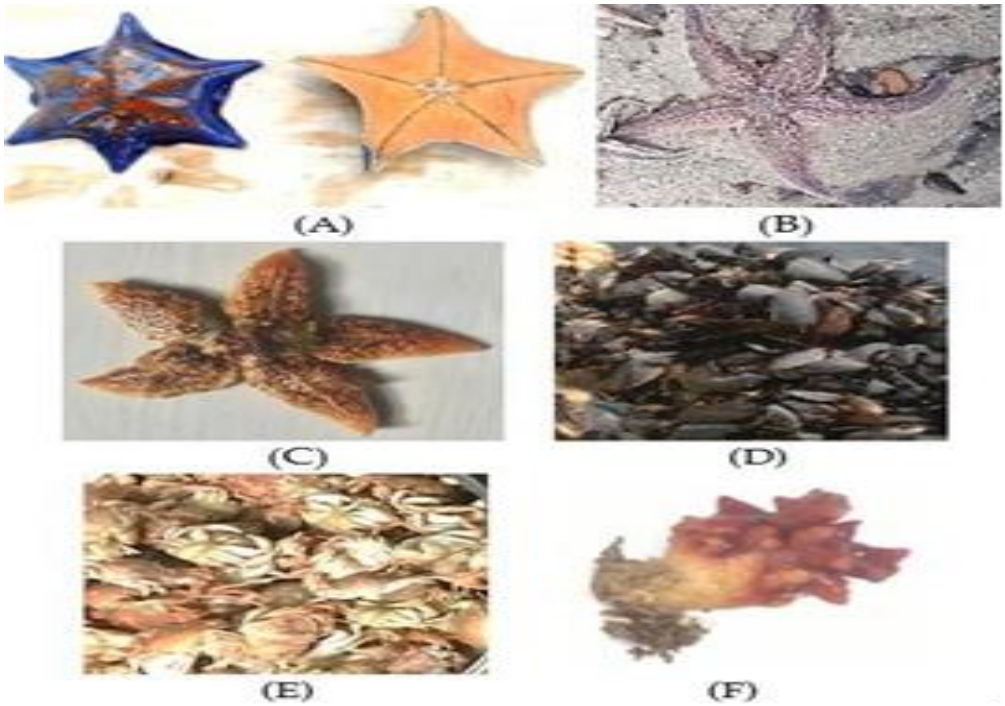

Figure 1. Pests found in Hotate Mussel cultivation (A) Starfish (*Patiria pectinifera*); (B) Starfish (*Distolasterias nipon*); (C) Starfish (*Asterias amurensis*); (D) Purple Scallop; (E) Crustaceans; (F) Sea Pineapple

Table 1. Types and distribution of pests in cultivation facilities in three life stages of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Japan

No	Types of Pets	Location	Life Stage		
			Seed	Juvenile	Adult
1	**Starfish**				
	Patria pectinifera	Float Ball		v	
	Distolasterias nipon	Float Ball		v	v
		Basket		v	v
		Main Rope		v	v
	Asterias amurensis	Calm shell	v	v	v
		Float Ball	v	v	v
		Basket	v	v	v
		Main Rope	v	v	v
		Hanging Rope	v	v	v
2	**Purple Scallop**	Float Ball	v	v	v
		Basket	v	v	v
		Main Rope	v	v	v
		Hanging Rope	v	v	v
3	**Crustaceans**	Basket	v	v	
		Main Rope	v	v	
4	**Sea Pineapple**	Float Ball	v	v	v
		Basket	v	v	v
		Main Rope	v	v	v
		Hanging Rope	v	v	v

are in accordance with research conducted by Kosaka (2016) that sea stars, other shellfish such as purple shellfish, crustaceans and sea pineapples are pests that commonly attack shellfish and cultivation facilities. Pests can indeed attack cultivation facilities, including those used for Hotate cultivation. Starfish can prey on and cause significant damage to shellfish populations. Sea Stars can thrive better in dense Hotate shell areas.

Patiria pectinifera and *Distolasterias nipon* remained the only pests not found to disturb Hotate seedlings, according to Table 1. All types of pests found attack Hotate at the juvenile stage. The only pests that were not found to disturb the Adult Hotate stage were crustaceans. This is in accordance with the opinion of Hardy (2020) who states that as Hotate grows, its vulnerability decreases because previous predator species will no longer be able to penetrate its thicker shell. Crustaceans have difficulty cracking the hard shell of Adult Hotate. The enemy becomes more specific. Starfish attack shellfish very slowly. Once the clam weakens, the Sea Star thrusts its stomach

into the clam and continues to consume its contents (Hardy & Athithan, 2020).

Small shellfish are prey for gastropods, octopuses, and crabs. The type of pest most often found attached to baskets is crustaceans. Asian shore crabs can invade, compete with shellfish and also eat shellfish (Sobieszczyk & Lawrence, 2022). Natural predators influence the survival and growth of Hotate Mussel seeds. For example, when moving young shellfish seeds into the sea during the crab recruitment period, it can result in crabs becoming trapped in shellfish nets (Sarkis, 2022). Small crustaceans can attack the gills and mantle of shellfish, causing decreased feeding in the shellfish, impaired growth, and increased susceptibility to other diseases. Severe crustacean infestations can cause mass die-offs in populations.

Hotate cultivation facilities, such as ropes, nets, or other structures, provide sufficient surfaces for pests to settle and colonize. Hotate cultivation facilities, especially those located in areas with good water flow patterns, can create conditions suitable for pest settlement and growth. Starfish and crabs can cause devastation to Hotate Clam populations if allowed to grow, so they must be removed (Kosaka, 2016).

There are two types of pests found attached to shellfish, namely Sea Stars and Purple Shellfish. The results showed that of the three life stages of shellfish observed, none were free from pests. Pests can have a negative impact on shellfish farming because they stick to shellfish shells, hindering their movement, reducing the feeding efficiency of shellfish and increasing the risk of infection. Additionally, the extra weight of attached organisms can hinder the growth and market value of shellfish. The presence of pests is one of the biotic factors that influence the survival rate of Hotate shellfish. Pests can cause a variety of detrimental effects on Hotate shellfish, including physical damage, stress, and competition for resources (Shapiro-Ilan, 2023).

Throughout Hotate's three life stages, shellfish can be susceptible to a variety of pests. In the seed phase, Hotate is microscopic and floats freely in the water column. At this stage, shellfish are vulnerable to predation by filter-feeding organisms, including some types of zooplankton, fish larvae, and other invertebrates. These predators may affect the survival and abundance of Hotate fry. In the juvenile phase, Hotate develops and settles in the substrate, under attack from pests that

grow together and adjacent to the shellfish habitat. Hotate that reach maturity, face various pests that can affect the overall health and productivity of shellfish (Grant & Larson, 2019).

According to Athithan (2020), many animal prey on or compete with shellfish. Examples are starfish, octopuses, crabs and fish. Predators such as starfish and crabs will be lifted along with shellfish cultivated in the sea. Crabs are capable of breaking shells and are potential predators. During bottom seeding, attacks are carried out by smaller and faster crabs such as Green Crabs (*Carcinus maenas*).

Purple Shellfish, which refer to the species *Mytilus edulis*, are generally not considered a natural pest organism for Hotate cultivation. Purple Shellfish tend to coexist naturally with Hotate and do not directly harm or damage the shellfish. Purple and Hotate Shellfish have similar food requirements, namely phytoplankton and zooplankton. Therefore, these two types of shellfish compete for the same food sources. However, this competition is usually not a serious problem in good Hotate cultivation, because each species is able to obtain nutrients from the food available in its environment (Eds et al., 1863). Purple Shellfish are generally considered to be companion organisms that live together with Hotate. Purple Shellfish can provide several benefits, such as providing protection or adding to the net structure or Hotate cultivation structure. However, it remains in the interest to monitor the population and control the growth of Purple Shellfish so as not to hinder the growth and health of Hotate (Shumway, 2016).

Sea Pineapple (*Acidia*) is a filter-feeding marine organism that is not usually known to attack or prey on Hotate (shellfish) directly. However, Sea Pineapples may indirectly impact Hotate populations or aquaculture operations. Sea pineapples have the ability to stick to various surfaces, including Hotate shells. The growth and accumulation of this organism on Hotate shells can lead to fouling, which reduces the shellfish's growth and mobility. This has the potential to affect the overall health and productivity of the Hotate population (Brand, 2016).

Sea Pineapple is a food filter that extracts food particles from the water column. In cases where Hotate and these organisms share the same water space, competition for available planktonic food sources can occur. If Sea Pineapples become too abundant, then the available food may run out, indirectly affecting Hotate's growth

and health. Although Sea Pineapple does not directly attack Hotate, its presence and growth can affect Hotate's overall health and growth. Sea pineapples are often found attached to rocks, shells, or other substrates in the intertidal and subtidal zones (Kutty, 2015).

Pests Control

So far, cultivators have been using countermeasures for years to clean up predators from nature, starting from using divers to remove them by hand and also specifically fishing for pests. Proper water filtration procedures, regular monitoring, selective breeding for disease resistance, and maintaining good biosecurity practices to manage and control pests and parasites in various phases of the Hotate life cycle. Collaboration with experts and compliance with local aquaculture regulations and guidelines are essential for effective pest management on Hotate farms (Goulletquer et al., 2011).

All of these efforts and methods have varying degrees of success, but the real problem is the fact that this can often happen again and persist. It is important for Hotate farmers to be able to control starfish populations, such as manual removal, physical barriers, or the introduction of natural predators. These steps can help prevent sea stars from damaging shellfish stocks and affecting production levels. One of the most successful methods for keeping Starfish numbers low is to place several lobster or crab pots in and around the bottom hatchery area (Hardy and Athithan, 2020). Starfish are caught and discarded from cultivation activities before seed sowing. Traps for catching Starfish are made of flat basket type hemp rope and baited. Predators and other competitors are left intact due to lack of suitable methods of economic factors.

Crab numbers can be kept down by fishing in the same manner as is used to remove Starfish. To reduce the impact of Sea Pineapple on Hotate cultivation, farmers employ various strategies such as regular cleaning and maintenance of Hotate shells to remove fouling organisms can help minimize the sticking of Sea Pineapple. Physical barriers include installing nets or partitions around the Hotate farming area to prevent the entry of Sea Pineapples. This barrier can help to reduce the presence of pests around the Hotate culture. As well as early intervention and routine monitoring of the Hotate population enabling early detection of fouling organisms (Wilcox & Jeffs, 2019).

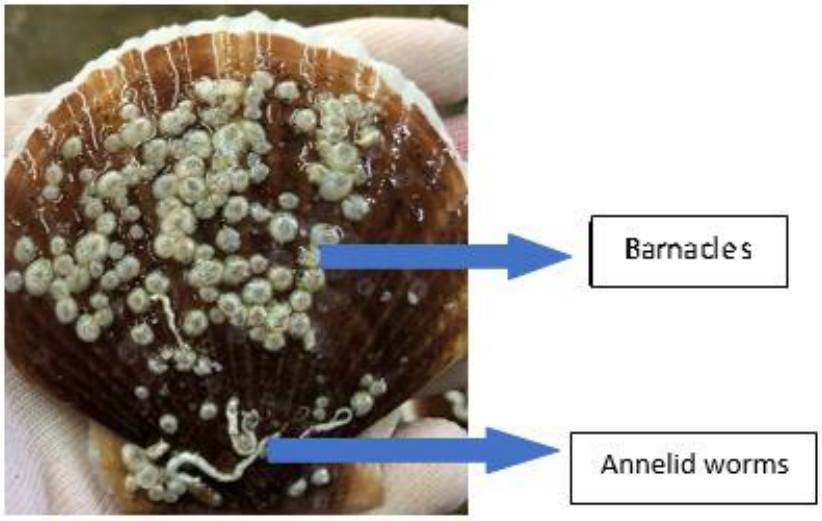

Figure 2. Parasites found in the cultivation of Hotate Shellfish

Habitat restoration and restoration of ecosystem health such as increasing the presence of natural predators help control pests in shellfish cultivation areas. Integrated pest management is a holistic approach to managing pests and parasites that focuses on combining multiple strategies to minimize their impact while minimizing environmental damage. This approach involves regular monitoring, using natural predators or biocontrol, optimizing cultural practices, and using chemical treatments only when necessary and with precision (Deguine et al., 2021).

Parasite

Types and Distribution of Parasites

Research that has been carried out on growing Hotate Shellfish has found two types of parasites that attack shellfish. Based on observations, the parasites found were annelid worms and barnacles. Parasites attached to the shellfish were taken at random and observed (Figure 2).

The presence of parasites will affect the survival rate of Hotate shellfish. Parasites live inside or attach to and depend on another organism, known as a host. Factors that influence the number of parasites attached to Hotate include substrate availability, nutrient availability, environmental conditions, predator-prey interactions and parasite control measures (Almón et al., 2022). Environmental factors, such as water quality, tidal currents and currents can influence the presence and distribution of Annelid Worms and Barnacles. Certain species may prefer certain stream conditions for feeding and reproduction. Barnacles dominate the

surface of cultivation facilities and shellfish (Goya & Youngsung, 2017).

According to Kosaka (2016), barnacles need a hard substrate to attach and grow. Barnacles thrive in areas with abundant nutrients, such as organic matter and planktonic food particles. Hotate cultivation facilities can serve as a source of food and nutrients, attracting barnacles to settle and feed on available resources. Barnacles prefer areas with water flow and moderate turbulence, as they help in filtering food and carry a constant supply of food. Clam shells provide the ideal substrate and texture for barnacles to settle and establish themselves. Shellfish act as filter feeders, collecting organic particles around their shells, which can attract larvae, creating suitable conditions for barnacles to get nutrition and supporting barnacle life.

Shellfish have limited mobility and cannot actively remove or prevent the settlement of barnacles on their shells. This immobility allows barnacles to settle and grow undisturbed on the shell surface. There are at least eight species of barnacles that commonly inhabit Hotate Clam cultivation, two of which are Balanus trigonus and Balanus rostratus which are most commonly found in shellfish. Barnacles attached to clam shells can disrupt the life of the shellfish and the cultivation method of

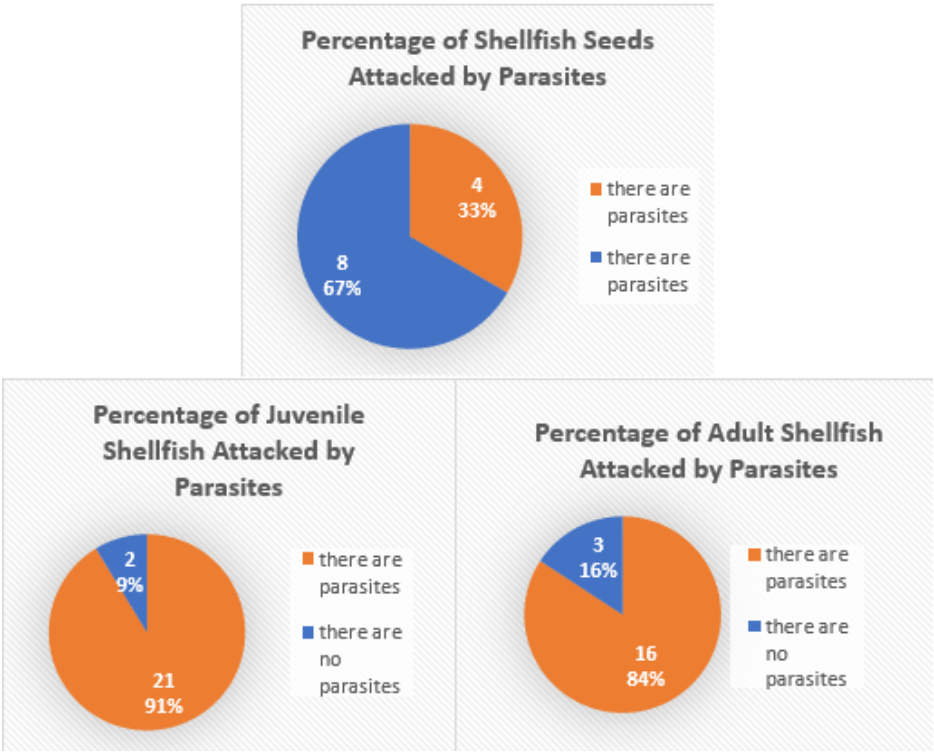

Figure 3. Percentage of Shellfish Attacked by Parasites at Three Life Stages

hanging them is on the shells' ears (Kosaka, 2016).

The presence of predators such as certain species of fish or crustaceans that can prey on annelid worms can reduce their numbers in the Hotate cultivation environment. The effectiveness of fouling control measures implemented in Hotate cultures, such as routine cleaning, physical removal, or use of anti–fouling coatings, may influence the attachment and abundance of annelid worms (Hoffman & Brown, 2019).

Results from observations of parasites in shell samples of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan amounted to 54 individuals. The types of parasites found on shellfish are annelid worms and barnacles. The stage most frequently attacked by parasites is juvenile shellfish, namely 91%. The stage that is least attacked by parasites is the Seed Stage, which is 33%.

This is in accordance with research conducted by Kosaka (2016) that Polychaeta grows and produces calcareous tubes on the surface of the shell. Polychaeta are the largest class of marine worms in the phylum Annelida (Eds et al., 1863). Annelid worms can produce lime or calcium carbonate. Annelida species, especially those in the class Polychaeta, have the ability to produce calcareous tubes or structures as part of their habitat or protective mechanism. Polychaetes build protective tubes made of calcium carbonate. These calcareous tubes provide the worm with protection from predators, help maintain its position in the substrate, and create a microenvironment suitable for feeding and reproduction (Vijayan et al., 2019). The ability to produce calcium carbonate structures is one of the adaptations of some annelid species and is an example of how various organisms use minerals and materials from their environment to enhance survival strategies (Qiu & Qian, 1997).

Polychaeta, a type of annelid worm that generally lives in the sea, is a parasite that usually attacks shellfish. Annelid worms dominate the surface of shellfish shells, because annelid worms grow and reproduce easily. According to Chiba (2014), polychaete worms can drill into the Hotate Clam shell, weakening its structure and possibly causing the shell to die or be damaged. According to Athithan (2020) there are various parasites that can affect Hotate, including Polydora Worms or Annelida and Flatworms. This parasite can attack mussel tissue or attach to its shell.

Annelid worms, like polychaetes, require a suitable substrate for mounting and burrowing. The availability of suitable surfaces, such as mussel shells may influence their abundance. If there are many surfaces to attach to, the number of Annelid Worms may increase. Annelid worms eat organic matter and planktonic particles in the water column. The availability of food sources, including nutrients and organic waste, can influence the growth and abundance of annelid worms in Hotate cultures. Nutrient-rich environments can support higher populations of these worms (Diez et al., 2013).

In Hotate cultivation, different life stages of Hotate can be susceptible to various parasites. The relationship between parasites in various Hotate stages starts from the Spat/Larva/Seed Stage, also known as veliger, microscopic in size up to 2 cm. During this stage, shellfish may encounter and be exposed to certain parasitic organisms in the water. Parasites, such as protozoa and other microscopic organisms, can attach to or infect larvae, potentially affecting their survival and development (Rollinson, 2017).

Juvenile stage, as Hotate larvae grow and develop, the shellfish eventually settle and attach to the substrate, transitioning to the juvenile stage. At this stage, shellfish are susceptible to various parasites, including those that can infect their tissues or shells. Parasites such as protozoa, bacteria, and worms can attack juvenile Hotate, affecting the shellfish's overall health, growth, and survival rate (Getchell et al., 2016).

The adult stage is a Hotate that has reached sexual maturity. Although generally more resilient than younger stages, adult shellfish are still susceptible to parasites. Parasites such as Perkinsus marinus, Haplosporidium nelsoni, Marteilia refringens, and Polydora websteri can affect the health and condition of adult Hotates, causing various diseases and potential death (Oliva & El-Tantawy, 2013).

Parasites Control

Susceptibility to parasites can vary depending on several factors, including environmental conditions, genetic traits of the Hotate, and overall management practices. Implementing appropriate biosecurity measures, regular monitoring and early detection can help identify parasite infestations in Hotate populations at any life stage and enable appropriate intervention measures to reduce their impact. A lack of adequate control measures may lead to barnacles breeding in Hotate cultivation facilities. Regular maintenance, cleaning,

and use of anti-fouling coatings or other management strategies can help minimize the attachment and growth of barnacles. It is important for Hotate cultivators to implement effective control measures to prevent excessive barnacle fouling, as this can have a negative impact on Hotate growth and overall production. Monitoring barnacle abundance and implementing appropriate management strategies based on local conditions can help control barnacle fouling at Hotate cultivation facilities (Hardy dan Athithan, 2020).

Hotate farmers and aquaculture researchers continue to work to develop strategies to minimize the risk of parasite infections, improving the overall health and productivity of the Hotate population at all stages of the shellfish life cycle. Genetic selection uses several kerrang breeding programs that combine genetic selection to develop parasite-resistant and pest-tolerant lines. Selecting individuals with better resistance to certain pests or parasites (Kutty, 2015).

Implement safety protocols to prevent the spread of pests and parasites, shellfish farmers are encouraged to implement strict Measures to control the distribution of equipment, personnel and stock between different farms or regions. Furthermore, remote sensing and technology have improved the ability to monitor the quality of water in addition to the above treatments. Early warning systems can help farmers take preventive measures to protect shellfish (FAO, 2023).

Sustainable aquaculture practices such as optimizing stocking density, and minimizing environmental impacts can indirectly contribute to reducing pest and parasite pressure in aquaculture settings. Ongoing research and collaboration between scientists, farmers and industry stakeholders is critical to understanding emerging pest and parasite threats and developing effective management strategies (Voorhees, 2023).

Conclusion

There are four types of pests found in the cultivation of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan. The types of pests found were Starfish, Purple Shellfish, Crustaceans, and Sea Pineapples. There are two types of parasites found in the cultivation of Hotate Shellfish (*Patinopecten yessoensis*) in Funka Bay, Hokkaido, Japan, namely Annelid Worms and Barnacles

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