The Culture of Japanese Scallops
(Patinopecten yessoensis)

Report of the Maine Delegation to Aomori Prefecture, Japan May 14-21, 1999

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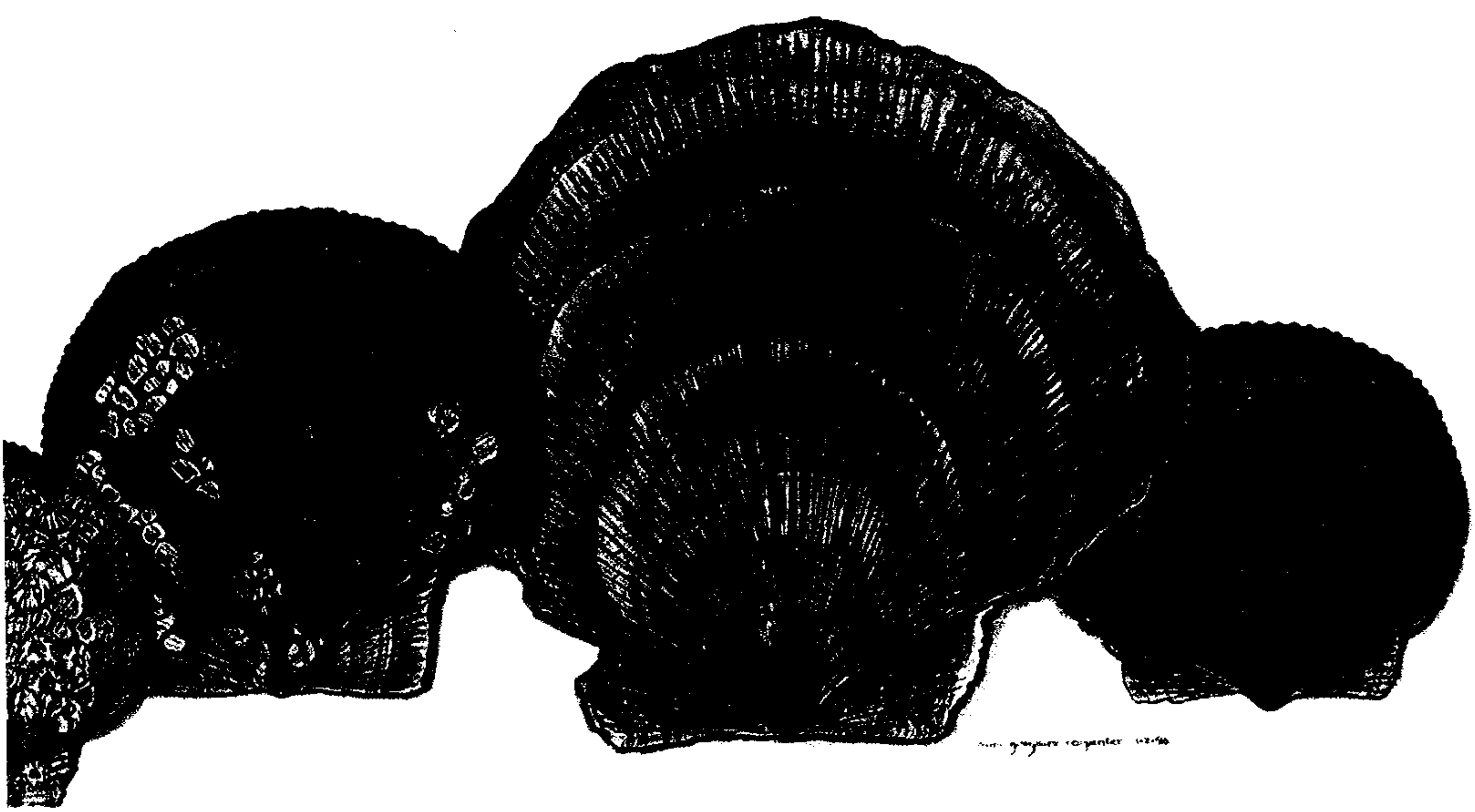

Cover -- "Scallops" by Mimi Gregoire Carpenter
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Mimi Gregoire Carpenter, a 1969 graduate of the University of Southern Maine at Gorham, was dubbed "Environmental Artist" by the Farnsworth Museum in Rockland, Maine. She is both artist and teacher, having shared the process of illustrating and writing with school children from York to Van Buren. Ms. Carpenter's delicate watercolor paintings might be termed "tide-pool art." The intricate designs depict the oft-overlooked sea creatures and objects cast up on Maine's craggy shoreline. For more information on the art of Mimi Gregoire Carpenter, visit her website: maineguide.com/giftshop/beachcomber, visit the Spruce Grove Gallery in Bar Harbor; or email her at: bchcmb@mint.net.

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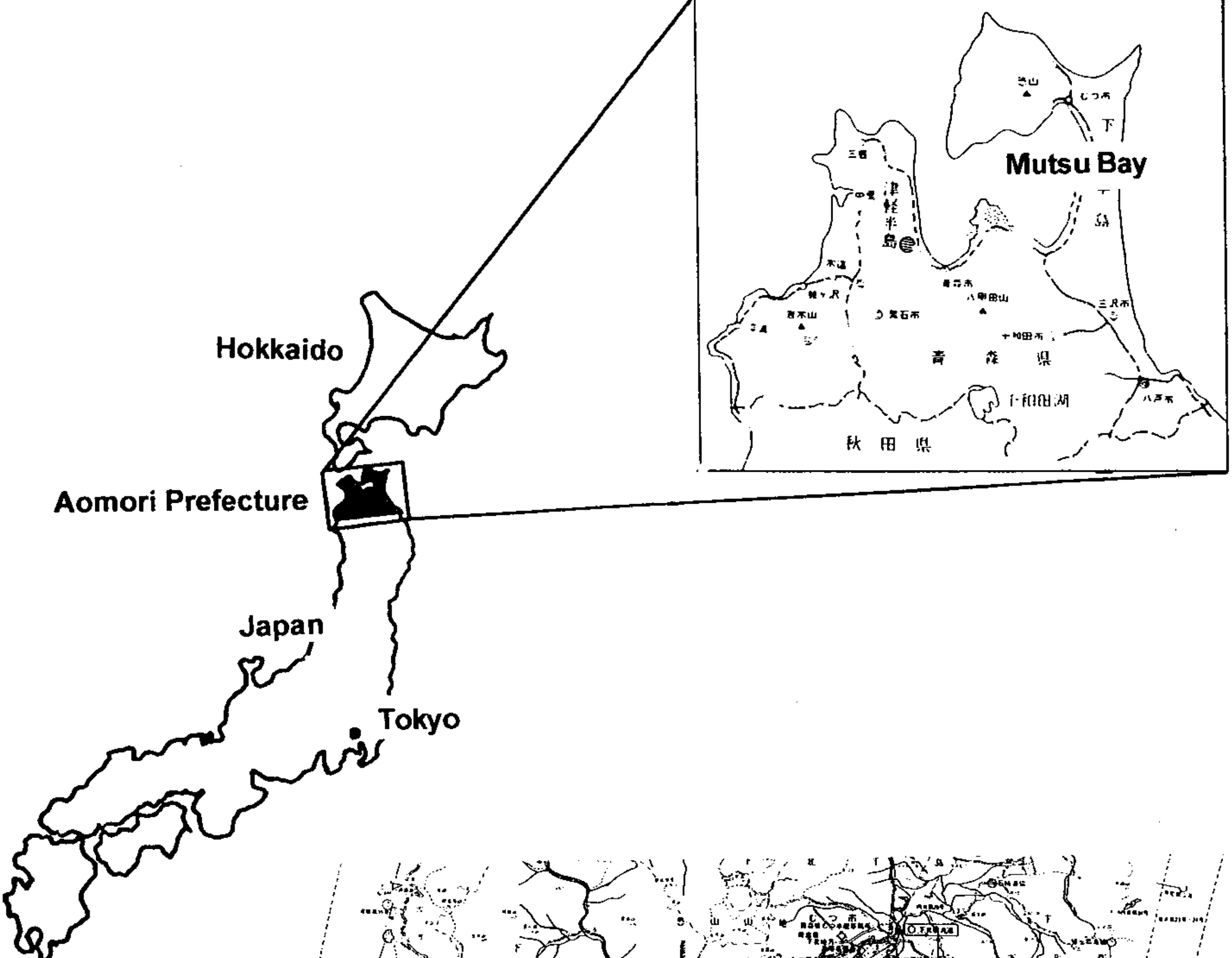


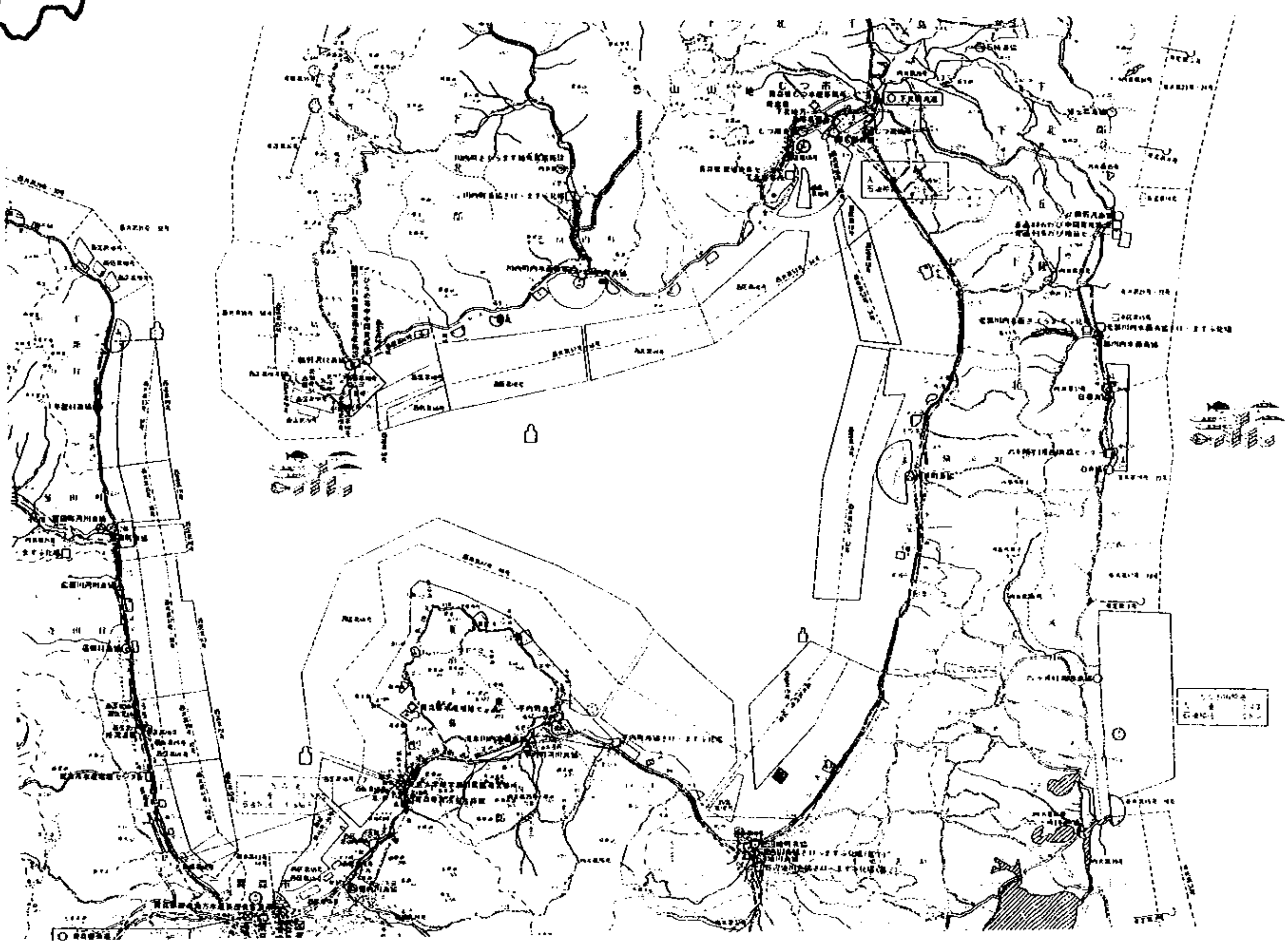


Chart of Mutsu Bay Showing Village Scallop Zones

Foreword

Scallop harvesting has played an important role in the lives, economies, and traditions of Maine's coastal communities for two centuries. Whether harvested by hand drag, commercial dragger, or hand-picked by divers, scallop harvesting continues to put food on the table and money in the bank. For some Maine families, Thanksgiving or Christmas dinner would be incomplete without a tasty dish of scallops while for others, making it through the winter would be very difficult without the scallop fishery.

Today, few Mainers disagree that the scallop industry is in serious trouble. Stocks are depressed, landings are down, and the number of license holders is low. For example, in 1997 only 400 metric tons (mt) of scallop meats were landed compared to 1981 when scallopers landed over 1,700 mt. In 1998 fewer than 600 people held scallop licenses in Maine, whereas in years past it was not unusual for the Maine Department of Marine Resources to issue over 1,000 licenses.

Management efforts in recent years have focused on resolving gear conflicts with lobstermen, establishing a uniform opening date for the scallop season along the coast, and increasing the ring size of the gear used so that scallops remain on bottom longer to grow and reproduce. While a great deal of effort has been expended on these and other traditional management efforts, the overall impact on scallop productivity has been undramatic.

The State of Maine has enjoyed a formal sister-state relationship with Aomori Prefecture, Japan since 1994. Several reciprocal exchanges of government officials, business leaders, and others have occurred during the past five years. Previous Maine visitors to Aomori reported the existence of a productive Japanese scallop (*Patinopecten yessoensis* vs. our sea scallop, *Placopecten magellanicus*) industry based in Mutsu Bay, and, because of our mutual interests, scallops became the focus of the most recent exchange with Aomori.

A Maine delegation was formed that had diverse interests and broadly represented various industry sectors, regulatory agencies, research interests, and geographic areas. The delegation included a scallop processor, a fishing industry writer, a commercial fisherman, a scallop farmer, two representatives from the Department of Marine Resources, a university professor, a Sea Grant extension agent, a community development specialist, and the director of Maine's Aquaculture Innovation Center.

The material that follows is a collaboration of the delegation. We hope this report of our fact-finding trip makes a useful contribution to considerations and discussions of how the health of Maine's scallop industry might be improved.

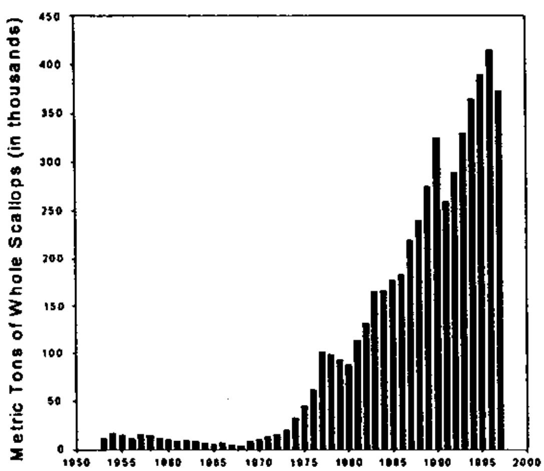
Introduction

Historically, Japan ranks among the top four nations in the world with respect to commercial fishing behind China, Peru, and Chile. Annual per capita fish consumption in Japan today is estimated at 81 pounds compared to 15 pounds in the United States (Fawzi, 1996; NFI, 1999). Between 1988 and 1993, however, Japanese fish and shellfish catch dropped by one-third, falling to its lowest level in 25 years (Fawzi, 1996). In 1997, Japan's total commercial fish and seafood landings of 7.41 million metric tons (mmt) worth $2.66 billion accounted for approximately 6.2% of global fisheries production of 120 mmt. The total potential harvest of marine fish and shellfish species by Japan is expected to decrease further or, at best, maintain its present level. The result is a major gap between production and consumption in Japan, which has been growing rapidly since 1989.

Aquaculture is growing in importance in Japan and is seen as the only feasible way to increase production of marine fish and shellfish (Fawzi, 1996). The importance of cultured fish and shellfish has increased slowly (from 4.8 to 15 percent of the Japanese total catch over the last 33 years) and is limited to relatively few species of algae, fish, and shellfish. In 1996, Japan accounted for approximately 4% of total world quantity of cultured organisms (compared to neighboring China which accounted for 68%). However, the culture of predominately high value marine finfish species such as the amberjack and shellfish such as the Japanese scallop and oyster more than doubled its world share in terms of value and made Japan the second largest global contributor of cultured products (Rana and Immink, 1997).

One of these species, the Japanese, yesso, or ezo scallop (*Patinopecten yessoensis* Jay 1856), has a particularly interesting history of exploitation and aquacultural development to fishermen, processors, marketing specialists, and others from the state of Maine, USA, where the giant scallop (*Placopecten* *magellanicus* Gmelin) is commercially harvested and, in 1997, ranked 7th in value of all commercial marine species landed with an average price per pound of $7.47.

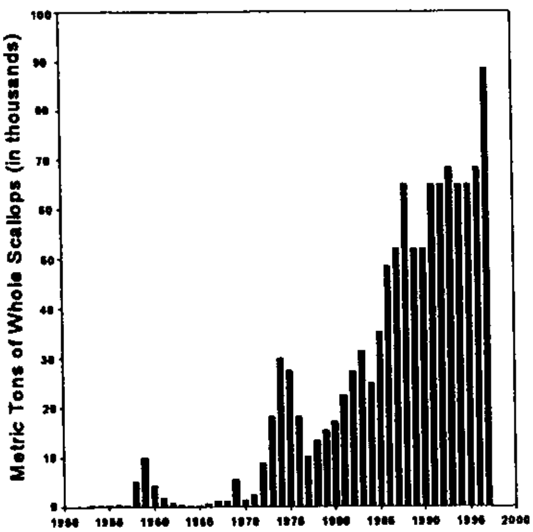
Figure 1. Annual Japanese scallop landings from Hokkaido



Production of *P. yessoensis* in Japan occurs primarily in the relatively cold waters between latitudes 40° N and 45° N (Ito and Byakuno, 1988). The northernmost island prefecture, Hokkaido, historically ranks first in annual production and accounts for 32% to 83% of the annual production in Japan (Ito, 1988). The northernmost prefecture in Tohoku (i.e., the six northern prefectures on the largest island of Honshu), Aomori, ranks second in production of Japanese scallops and is the birthplace (1965) of scallop culture in Japan. There, scallop landings are recorded in weights of whole animals because most of the soft tissue is processed (see below). Conversely, sea scallops landed in Maine and US waters are recorded in weights of whole meats, or adductor muscle which represents approximately 15-18% of the weight of the whole animal.

Production of the Japanese scallop (termed hotategai and pronounced "ho-tah-ti-guy" in Japanese) in Hokkaido and Aomori from the early 1900's to the late 1960's (Figs. 1 & 2) was entirely dependent on natural recruitment. That is, like the giant scallop fishery in Maine today (Fig. 3), catches were based on fishing efforts concentrated in high density areas where successful recruitment of scallop spat (see biology section) had occurred. Unlike the Maine fishery, however, the development of scallop culture techniques has catapulted production levels more

Figure 2. Annual Japanese scallop landings from Aomori

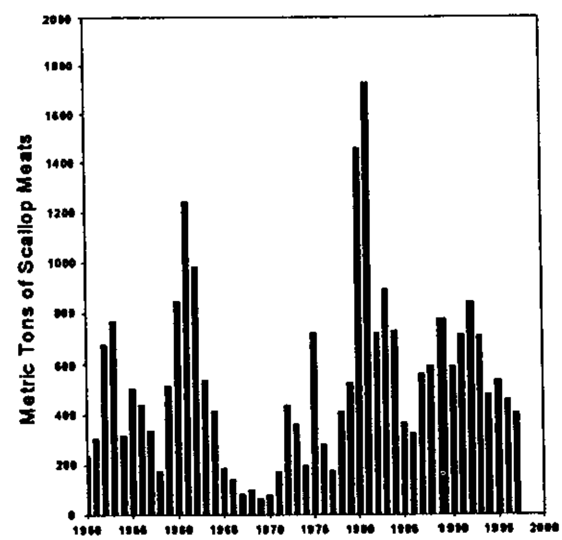


than 3000% in Hokkaido (21-yr average from 1952 to 1973 = 10,877 mt vs. 8-yr average from 1990 to 1997 = 343,497 mt)

and 2110% in Aomori (21-yr average from 1952 to 1973 = 3,032 mt vs. 8-yr average from 1990 to 1997 = 66,987 mt).

Because the technical development of scallop culture was first practiced in Mutsu Bay, a nearly enclosed body of water in the northern Aomori Prefecture, and, because the governments of the state of Maine and Aomori Prefecture entered into a sister-state relationship in 1994, a delegation of ten individuals from the state of Maine conducted a 4-day visit of the scallop culture fishery in Aomori Prefecture from 17-20 May 1999. This report focuses only on information specific to the Japanese scallop culture fishery collected by the delegation during that visit. The goal of the visit was to learn about Japanese scallop biology and culture as well as the historic, economic and social aspects of the scallop industry in Aomori Prefecture.

Figure 3. Annual Giant scallop landings from Maine



Although not all lessons learned from our Japanese counterparts are completely applicable to the Maine scallop fishery, many of the steps taken by Japanese fishermen, researchers, and government officials to better understand the mechanisms involved in increasing production levels can be duplicated if it is the will of Maine people.

Aomori Prefecture and the sister-state relationship with Maine

Aomori Prefecture, with a land area of 9,605 km^2 (Japan's 8th largest prefecture) is the northernmost prefecture on the island of Honshu. It is surrounded on three sides by water (the North Pacific Ocean to the east, the 250 km-wide Tsugaru Straits to the north that separates Honshu from the island prefecture of Hokkaido, and the Japan Sea to the west). The capital, Aomori City, lies at 40.8° N, the same approximate latitude as New York City. According to a 1995 census, approximately 1.5 million people live in Aomori Prefecture, which ranks 28th of the 47 prefectures, and 40th in population density (154.2 inhabitants/km^2). Aomori is rich in natural beauty and natural resources. There are four major mountains in the prefecture (Mt. Iwaki, 1,625 m [5,331 ft]; Mt. Odake, 1,584 m, Mt. Takada Odake, 1,552 m, and Mt. Idodake, 1,550 m) and a mountain range (Shirakami Mountains) that was registered as a World Heritage site in December 1993 (Anon., 1999a). The prefecture ranks 1st in the production of apples, yams, and garlic, 8th in both rice and lumber (67% of Aomori is forested), and 5th in commercial fish landings (371,000 mt in 1993 and 440,000 mt in 1997, which was about 6% of Japan's total 7,400,000 mt fisheries production). In 1997, two mollusk species provided more than 50 percent of landings in the prefecture. Aomori fishermen landed 154,000 tons of squid, the largest catch in Japan. They also harvested 88,362 mt of cultivated scallops--some 90 percent from Mutsu Bay where Japanese scallop culture began more than 60 years ago.

Before Japan's economic boom began in the 1950's and 1960's, Aomori Prefecture was considered isolated both geographically and culturally.

As land, air, and sea transportation systems were modernized through the 1970's and 1980's, the prefecture came to rely less heavily on the centralized social and economic structure of the Tokyo region. In the early 1990's, Aomori's government began looking inward and embraced the strengths of its natural and economic resources, its cultural diversity, and its geographic setting. Aomori introduced in March 1990, an intent to develop friendships, goodwill, and mutual understanding with foreign countries through international relations in hopes of opening the prefecture to the world. The prefectural government established the 21st century as the new age of "Human Renaissance" that will "provide a comfortable life for Aomori's residents and foster the ingenuity, creativity, and sensitivities of its people" (Anon., 1999b). To this end and to work towards building cooperation and a unified approach to internationalization, Aomori has established sister-state relationships with Santa Catarina, Brazil, Khabarovsk, Russia, and Maine, USA and actively promotes international exchange and cooperation in a wide range of fields such as education, culture, sports, industry, and economics. In addition, nineteen of Aomori's 67 cities, towns and villages have established sister-city ties with 24 cities in ten countries around the world.

The sister-state relationship with Maine has an historic beginning. Before dawn on 30 October 1889 the ship Cheseborough, registered at the port of Bath in the state of Maine, ran aground in the Sea of Japan off the shore of Shariki Village, in the north-western portion of Aomori Prefecture. At that time, in order to save the passengers and crew of the ship, the villagers from Shariki got into small boats for a desperate rescue mission. Villagers stripped the wet clothing from the foreigners, the first they had ever seen, and, by warming them, revived them (Anon. 1999c). Two youths ran the entire 64 kilometers to the Aomori Prefectural Office in 9 hours to report the accident. Based on this real historical event, the village has combined swimming and running into a "Swimming Ekiden" (a relay race of swimming and running) which is titled the Cheseborough Cup Long-Distance Swimming Relay and is held on the first Sunday of August. Along with reconfirming the courage and love of humanity of their ancestors, the village seeks to foster pride and community through the exchange with the people of Bath and the participants from all over Japan in this "Event that connects People and Nature and People and People" (Anon. 1999d).

Japanese Scallop Production in Mutsu Bay

Mutsu Bay, Aomori Prefecture

Mutsu Bay is the center of scallop culture in Japan and the world (Aoyama, 1989). It is a relatively shallow (38 m), nearly enclosed embayment (ca. 1800 km^2) that is connected to the Sea of Japan through a narrow (11 km wide) passage, Tsugaru Strait. The bottom is covered with sand and gravel along the shoreline and this grades into muddy sand toward the center of the Bay (Y. Kosaka, pers. comm.). Tidal amplitude is less than 1 m, wave heights average less than 1.2 m and tidal currents are very low. Seawater temperature ranges from 3° C to 25°C (37.4°F to 77.0°F) at a depth of 1 m and salinities are nearly oceanic ranging from 32o/oo (parts per thousand) to 34o/oo (Aoyama, 1989).

Biology

The filter-feeding Japanese scallop (*Patinopecten yessoensis* Jay 1856), and the giant scallop that occurs in Maine waters are in the family Pectinidae. In Japan, *P. yessoensis* extends from Tokyo Bay on the Pacific Ocean coast north to Hokkaido and can tolerate seawater temperatures from 5-20°C (ca. 40-68°F). The southern limit of the natural distribution in Japan is Toyama Bay in the Sea of Japan (Ito, 1990). The main mariculture areas are in Aomori and Hokkaido Prefectures.

As with other scallop species of this family, sexes are separate and males and females are easily recognized throughout the year by the color of the gonad (females = reddish orange; males = pale yellow to creamy white). Typically, females ranging in shell length from 120 mm to 150 mm (4.7 in to 5.9 in) each produce 8 to 18 million eggs (80µ [microns] or 0.003 in, diameter). Males generally produce two to three times as many sperm per individual as females produce eggs.

In Mutsu Bay and else where, periods of spawning correlate well with seawater temperature. Spawning occurs once a year in animals that are two years of age and older and usually begins in March (when seawater temperatures reach 6-8° C, or 42.8°-46.4° F), peaks in early April, and is complete by mid-April. The larval cycle (trocophore, veliger, pediveliger) is about 35-40 days (seawater temperatures during this period range from 7-12°C, or 44.6°-53.6°F). Metamorphosis and attachment to a solid substrate (seaweed, eelgrass, gravel, shells, etc.) by means of a byssal thread occurs when animals reach 280-300µ (0.011-0.012 in) in length (Aoyama, 1989). Immediately after metamorphosis, scallops are referred to as juveniles, or spat. After 4-5 months, when spat reach 8-10 mm (0.315-0.394 in), they lose their byssal thread and sink to the benthos where natural predation rates by starfish, bottom-feeding fish, and crustaceans exceed 90% (Y. Kosaka, pers. comm.).

After one year, animals that survive these bottom (benthic) conditions typically attain shell lengths between 20-50 mm (ca. 1-2 inches). After two years on the bottom, scallops grow to 50-90 mm (2-3.5 inches) and weigh 16-80 g. At age three, scallops range from 80-120 mm (3-4.5 inches). After three years, growth begins to slow down, but, some scallops reach 200 mm (7.8 inches) and may weigh 1 kg (2.2 pounds) after ten years (Ito, 1990). Shell growth varies seasonally with fastest periods of shell accretion occurring from April-May to October when seawater temperatures range between 10-15°C (50.0°-59.0°F). Gonad growth is also seasonal and occurs generally in autumn to winter when seawater temperatures dip below 10° C.

<u>Fishery prior to the late-1960's</u>

Although research into culture techniques (i.e., spat collection) began in the mid-1930's, it was not until 1968 that a culture fishery developed in Aomori and Hokkaido (Ito and Byakuno, 1988). Prior to this date, Japanese scallop production was based on the vagaries of reproduction, successful recruitment of wild spat to the bottom as well as high survival rates of these small individuals (i.e., the biological underpinning of the Maine scallop fishery today). As is typical of most wild fisheries, landings statistics prior to the 1960's (not shown here) recorded dramatic fluctuations in annual production.

From the late 1800's through the late 1960's, scallops were primarily harvested using various trawls (both hand and powered) and dredges. The most notable dredge type ("hotategai-keta-ami") caught between 15% and 70% of the scallops in its path depending on bottom conditions (Ito and Byakuno, 1988). The dredge was composed of a mesh bag with chains attached to front teeth that excavated partially buried scallops.

Culture History

Development of scallop culture was first practiced in Mutsu Bay and was related to technological advances in collecting wild spat from the water column. Beginning in the mid-1930's scientists working for the Aomori Prefecture began investigating meth - ods to collect wild spat for on-bottom enhancement purposes as well as rear larvae under culture systems in the laboratory. These lab and field trials were minimally successful but, a series of events during the spring of 1963-64 was to change the Japanese scallop fishery forever.

A fisherman in Mutsu Bay invented a spat collector by enclosing cedar branches within a mesh onion bag (Aoyama, 1989; Ito, 1990). This double-structure apparatus was innovative because until that time, only single-structure collecting material was used and most of the spat fell to the bottom before they could be collected due to weather-related events. The double-structure allowed relatively large surface areas (cedar branches) for the spat to recruit and "stick" using its byssal thread. Then, once animals lost their ability to attach to this substrate and fell from the branches, they would be stopped from dropping to the benthos by the onion bag net with its mesh size of about 5-8 mm

Therefore, the double-structure system took advantage of two important aspects of the early life history of the Japanese scallop. First, the branches within the onion bag acted as a substrate for attachment for the 300µ pediveligers. (Pediveliger is the name given to older larval, or swimming stage, scallops that developmentally possess both a swimming organ, the velum, and a foot that is used to probe the bottom. Pediveligers are shaped like tiny quahogs; that is, they are nearly round. At or near day 35-40, they undergo a change of shape, or metamorphosis, and take on the shape of a miniature scallop. At the same time, their foot develops the byssal gland that produces the sticky byssal thread used to attach to firm substrates, including cedar branches). Once settled on the branch material, scallops remain attached for a period of 40-70 days. Second, the onion bag, with its mesh size less than 8 mm diameter, prohibited the animals that had reached sizes greater than 10 mm from falling to the ocean floor.

Once this method of spat collecting was adopted by fishermen around Mutsu Bay (late 1960's and early 1970's), production of commercial size animals increased dramatically and, by 1973, the annual yield of scallops from Mutsu Bay had reached record proportions (Fig. 2). Spat collecting became so popular in a relatively short time that by 1971, 2.3 million spat bag collectors were deployed in Mutsu Bay that collected approximately 40 billion seeds, or 870/bag (Shaw, 1972).

Mass mortality of Japanese scallops occurred in Mutsu Bay from the summer of 1975 through the autumn of that year and this had tremendous repercussions on production during the next two years (Fig. 2). The symptoms were: deformed shells, abnormal coloration of the shell's inner surface, and slower than normal gonad growth (Ito and Byakuno, 1988). The problem had little to do with seawater conditions, increased levels of bacteria, or viruses, but was related to physiological stress due to unrealistically high densities of spat being cultured in pearl nets (see below).

> "After careful research into the phenomenon (i.e., the mass mortalities) it was discovered that scallops "bit" each other when placed in pearl nets at high density during intermediate culture. As a result, the mantle edge of the scallop was damaged and its mantle (shell-making gland) was partly destroyed. Scallops became deformed because of their inability to secrete shell material around the entire margin of the shell. The contant leakage of secretory fluid from the lesions results in significant wastage of energy, scallops having open blood systems. Scallops in this condition invariably died. Rough treatment of scallops and wave oscillation also caused the biting problem" (Ito and Byakuno, 1988).

From 1972-1975, studies conducted on the distribution and abundance of phytoplankton in Mutsu Bay by scientists at the Aomori Prefectural Aquaculture Research Center indicated that the carrying capacity of the Bay was limited to the introduction of 700 million spat each year. These limits were exceeded in 1975 because the majority of scallop growers around Mutsu Bay did not accept the scientific data (Ito and Byakuno, 1988). After the mass mortality event (which occurred at the same time outside the Bay in prefectures immediately south of Aomori -- Iwate and Miyagi, and two years later in Hokkaido Prefecture), enforcement of an upper limit of cultured spat ultimately has led to higher scallop land ings in the Bay (Fig. 2).

<u>Spat Collection</u>

Spat collection, the force driving the entire scallop industry in Mutsu Bay, is very much a numbers game. Fishermen deploy a sufficient number of spat collectors to be able to generate the amount of spat needed for intermediate and final growout scenarios. During the period from 1975 to 1985, average spat catch rate was approximately 34,000 individuals per bag

(Aoyama, 1989).

Spat collection occurs mostly on the eastern end of Mutsu Bay, most often in depths between 15 and 20 meters. Good spat collecting locations are also typified by having high plankton concentrations. Today, blue synthetic bags (approximately 2-feet long and 1-foot wide) with a mesh aperture of 5-6 mm (ca. 1/4-inches) have replaced onion bags as the outermost layer of the spat collectors. In addition, used monofilament gill netting (a piece typically measuring 6-feet x 3-feet, Y. Kosaka, pers. comm.) stuffed into each bag serves as the substrate of initial attachment instead of cedar branches. Another synthetic material, Netron, is used in place of gill netting in some instances. This spat collecting arrangement works well in areas of high larval densities such as occur in Mutsu Bay. In more offshore environments where larval densities are lower (as in the Okhotsk Sea in northern Hokkaido), the outer bag has a very fine mesh size (1-1.5 mm).

Deployment of spat bags, or collectors, is closely timed with spawning of the adults. Spawning is directly related to environmental conditions (temperature, phytoplankton abundance, etc.) and typically occurs when seawater temperatures reach 6-7° C in the late winter.

Scientists at the Aomori Prefectural Aquaculture Research Center in Moura, Hiranai-machi, on the shores of Mutsu Bay, closely follow environmental conditions in the Bay using an automated buoy system. They also collect information on scallop gonad index (a body condition index that is the ratio of the mass of the gonad to the mass of all soft tissues) and sample the water for larval abundances. These environmental and biological data enable scientists to forecast spat settlement reliably one month prior to its occurrence and help fishermen around Mutsu Bay determine when/where to place spat collectors in the water.

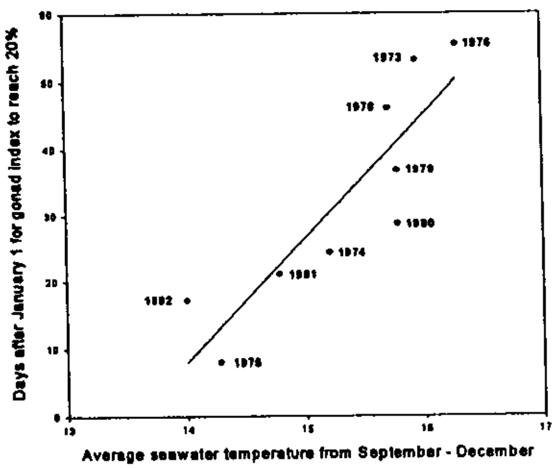
Bags are deployed approximately two weeks before scallop larvae are physiologically/ developmentally ready to settle onto any surface. Scallops appear to settle and attach better to new or clean bags (Y. Kosaka, pers. comm.).

Prefectural scientists forecast scallop spawning events and make recommendations to fishermen about when to deploy their spat bags by collecting real-time data (wind and current speed and direction, wave height, air and water temperature, salinity and dissolved oxygen) that is recorded hourly at several depths (1 meter, 15 m, 30 m and on the bottom) from a series of three oceanographic buoys located around Mutsu Bay. One is 6.4 km west of the Aquaculture Center, another is 2.5 km east of Tairadate Village near the northern, narrow opening of the Bay. The third is located 10 km south of Kawauchi Town, along the northern shore of Mutsu Bay. The entire monitoring, telemetry and display/recording system cost approximately $3 million.

Results from the telemetry data indicate that the best spat collection areas generally have sustained currents on the order of 6 cm/sec (ca. 1/10th of a knot). In addition, data from the three buoys indicate that the residence time of seawater in the Bay, which flows counterclockwise, is approximately 50 days. Strong and persistent winds affect currents within the Bay, and spat collection activities are adjusted accordingly.

Gonad index (GI), a measure of the the change in volume or size of the gonad through time, is also used to forecast spawning. This method allows a quick assessment of the ripeness of the gonads. In Mutsu Bay, information relating to gonadal index is collected from December through May. Spat can be expected to settle in bags approximately 40 days following a spawning event. Seawater temperatures are closely related to gonad maturation. It has been reported (Aoyama, 1989) that yearly gonad maturation through spawning is strongly correlated with water temperatures from September to December in the previous year (Fig. 4). When gonad indices approach 20%, spawning occurs shortly thereafter. This level of GI may occur as early as mid-January (1975) and

Figure 4. Relationship between seawater temperature the preceeding fall and gonad development (days after January 1 for GI to reach 20%).



as late as the last week of February (1976; Fig. 4). The data indicate that the higher the average fall temperature, the longer the period of gonad maturation and that spawning is likely to occur later (late February to March) of the following year. During the spring of 1999, scallops spawned later than normal (well into April; Y. Kosaka, pers. comm.), which would indicate that average fall (1998) seawater temperatures in Mutsu Bay must have exceeded 16°C (Fig. 4).

Another technique to estimate when spat bags should be deployed is that of using data gathered from larval abundance surveys (i.e., planktonic sampling of scallop larvae). Prefectural scientists have been monitoring abundance of scallop larvae from April through June each year since 1950. Fishermen wish to maximize the number of spat per bag. Since timing of deployment and location of spat collectors is critical, fishermen must have some understanding of larval densities and their spatial distribution throughout the Bay. To address this, as many as 50 sites within Mutsu Bay are monitored during both the day and night with the help of fishermen. Plankton tows allow estimates of the number of larvae per volume of seawater.

Until recently, maximum larval density observed in Mutsu Bay was 6,000 scallop larvae per ton of seawater (Aoyama, 1989). In recent years, however, some samples from Mutsu Bay have had as many as 20,000 to 40,000 larvae per ton of water. The general rule of thumb is that 100 larvae per ton of water should result in 400 scallops per collector, or bag. Once greater than 50% of the scallop larvae in the water column exceed a shell length of 200μ (ca. 1/5 mm or 0.008 inches), fishermen are encouraged to deploy their spat collectors (Y. Kosaka, pers. comm.). Since animals with a shell length of 280µ produce a foot (which contains the byssal gland) and are capable of settling onto various substrates, this gives fishermen enough time (about 2 weeks) to deploy enough spat collectors for the year. Collectors are usually hung as a vertical series of bags (longlines) 5-10 m below the surface of the water. The bottommost bag is 10-15 m above the benthos which reduces predation from crabs and starfish.

Starfish are perhaps the greatest threat to the spat collection system. These echinoderms typically spawn and settle after scallops do; however, nothing prevents these predators from recruiting into the same collector bag as the scallops. For this reason alone, spat bags generally deployed longer than four months usually have few scallops and many starfish. Therefore, it is critical that fishermen time precisely the harvesting of scallops from their spat bags so as to optimize the number of 8-10 mm scallops that are transferred to the next stage of the growout scenario: intermediate culture (see below).

Spatfall, recruitment, or settlement onto a surface, generally occurs each year during late May through July. Spat remain in the bags for about 3 months, or until they reach a shell height of approximately 10 mm (when byssal attachment ceases). At that time, spat are large enough to be transported to an intermediate culture system. When spat collectors are moved they are covered with wet newspaper to reduce stress and shock to the juvenile scallops.

The evolution and success of collecting spat for bottom and hanging culture (see below) is related to a predictable supply of larvae within Mutsu Bay. Since larval numbers are related directly to successful spawning of broodstock (adults), prefectural scientists have estimated the optimum number of adult scallops that spawn each year within the Bay to be approximately four billion. This mass of spawning stock ensures low interannual variability in spat collecting

(Y. Kosaka, pers. comm.).

Intermediate culture

Once spat have been harvested from the collectors (July and August), they are transferred to an intermediate growout system that uses pearl nets (a series of 8-10 pyramid-shaped nets with a 34 cm [ca. 13 inches] square floor and a height of 10 cm [4 inches]). These are so-called because they were originally introduced and used to culture various species of pearl-producing oysters in Japan. As with the spat collecting bags, pearl nets are hung vertically in series of levels (2-3 feet between nets) with the first nets approximately 15 m below the surface. A weight, or sinker, is attached to the bottommost pearl net which is 4-5 m (14-16 feet) above the ocean floor.

Between fifty and sixty 10 mm spat are placed in each pearl net. When this technique was first adopted in the late 1960's, fishermen tended to overstock the number of spat per net, placing nearly 100/net, and this resulted in the mass mortalities observed in 1975-1977 (Fig. 2). For best growth, nets should be stocked initially with 30 animals, but this would be cost-prohibitive in terms of the extra number of nets needed (Y. Kosaka, pers. comm.). Scallops remain in the pearl nets until the volume of each net occupied by scallops exceeds approximately 60% of the area of the net.

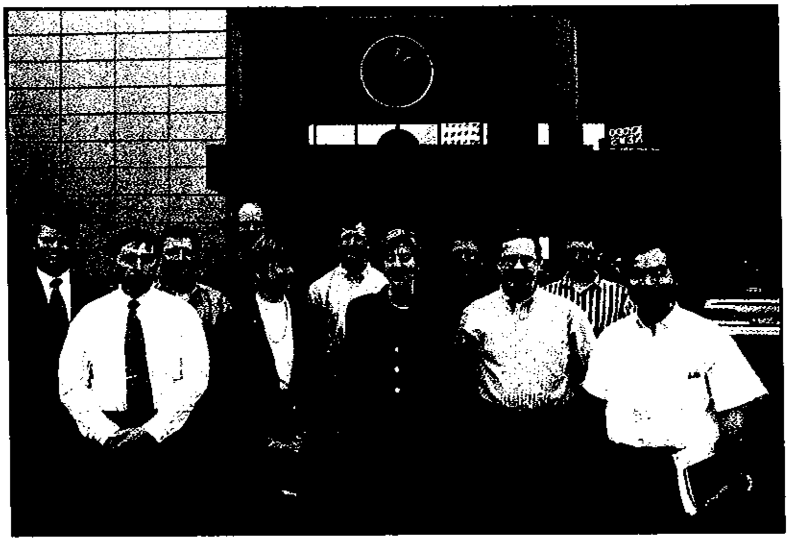
Pearl nets come in various mesh sizes. Fishermen generally use a mesh size which is one-half to three-quarters the size of the seed which is put into it. Individual pearl nets are not sewn shut along the seam; rather, they are sewn about 1/3rd of the length of the seam. Once nets are deployed vertically along the longline, their weight and the sinker weight helps keep the mesh taut and the seam closed. Few losses are incurred within the pearl nets in Mutsu Bay, even with the small gap in the netting. One reason fishermen can cut corners and adopt this type of labor savings has to do, in part, with the low current speeds in Mutsu Bay. Since current speeds are low, movement of the pearl nets in the water column is minimal which reduces the chances of scallops escaping through the small gap.

Hanging Culture

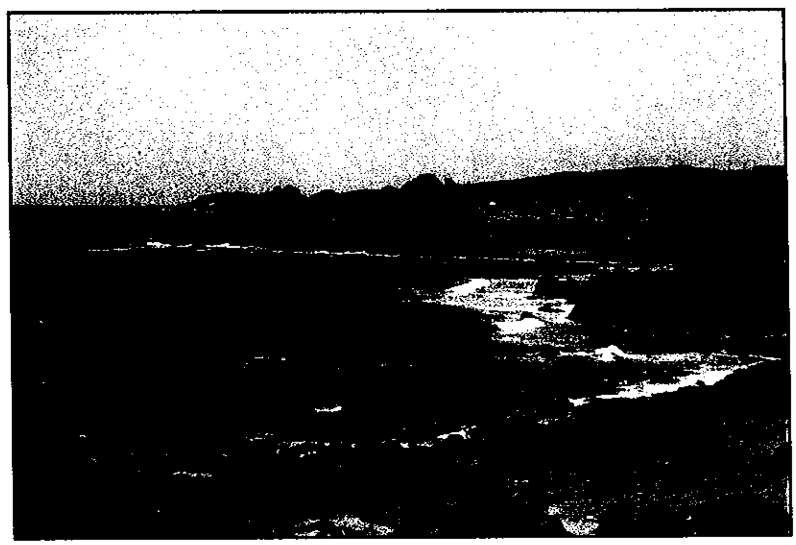
In roughly 10 weeks (mid-September through October), the 50-60 juvenile scallops within each level of the pearl nets reach a size of 20-30 mm (ca. 3/4- to 1 1/4-inches). Their densities are thinned and 15-20 animals are added to each level within clean pearl nets. (Like other scallop species, *Patinopecten* juveniles are fairly fragile organisms and do not react well to rapid changes in temperature, air drying, or rough handling. Aside from the fact that handling shellfish must be kept to a minimum for economic [labor cost] reasons, scallops are moved as little as possible so as to minimize stress, keep growth rates fast and mortality rates low. When seed is moved or transferred, it is wrapped in wet newspapers. Transfer of seed into pearl nets occurs at sea whenever possible, as well as subsequent grading. Proximity to shoreside facilities plays a large role in this ability, as deck space is limited; lower steaming times ensure that multiple runs to spat collection sites can be accomplished in a single working day, and much gear can be processed.)

Four to six months later (February to April), when scallops have reached 10 cm in shell height, they are once again thinned. This time either they are transferred to new pearl nets or lantern nets, or individuals are tied to polyethylene rope and are hung from the beak of the left valve (ear hanging). Animals placed back into pearl nets (with 9 mm aperture) are stocked at a density of 6/level (x 10 levels = 60 animals per set of nets). A lantern net is a series of ten cylindrical, collapsible units (12 - 22 mm mesh aperture). Each unit, or level, is 50 cm diameter x 18 cm high (19.5 inches x 7 inches). Units are stocked with ten scallops. Pearl nets and lantern nets are arrayed (as described above) along longlines.

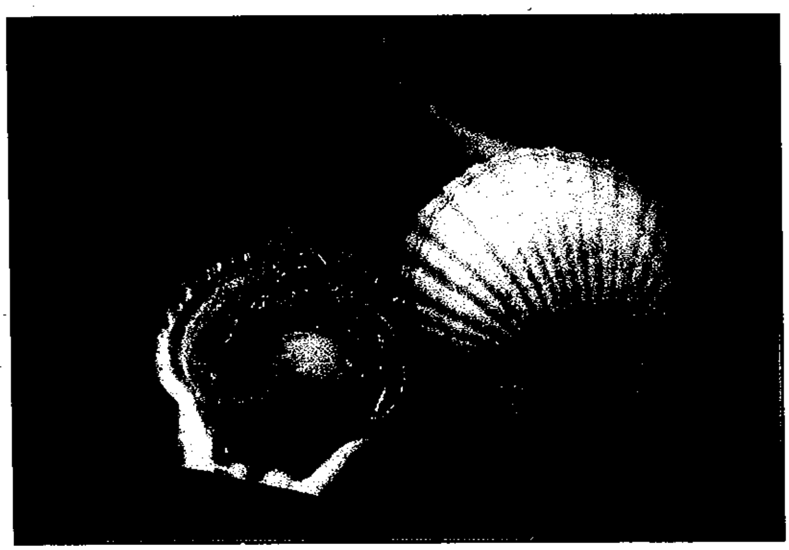
Ear hanging consists of "drilling a 1.3-1.5 mm hole at the front eared beak of the left valve about the right



The Maine Delegation at the U.S. Embassy, Tokyo. L to R: Keith Kirkham, Commercial Attache; Tom Pottle; Will Hopkins; Brian Beal; Sue Inches; Dana Morse; Laura Taylor; Jay Trenholm; Mike Hastings; Kristin Porter; Tomohiro Asakawa, Fisheries Advisor.

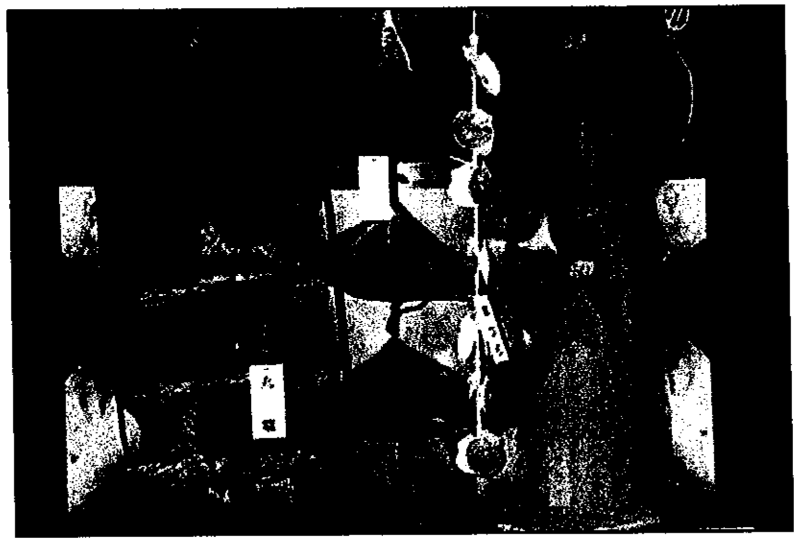


The coastline in Aomori Prefecture. *Photo by Brian Beal.*

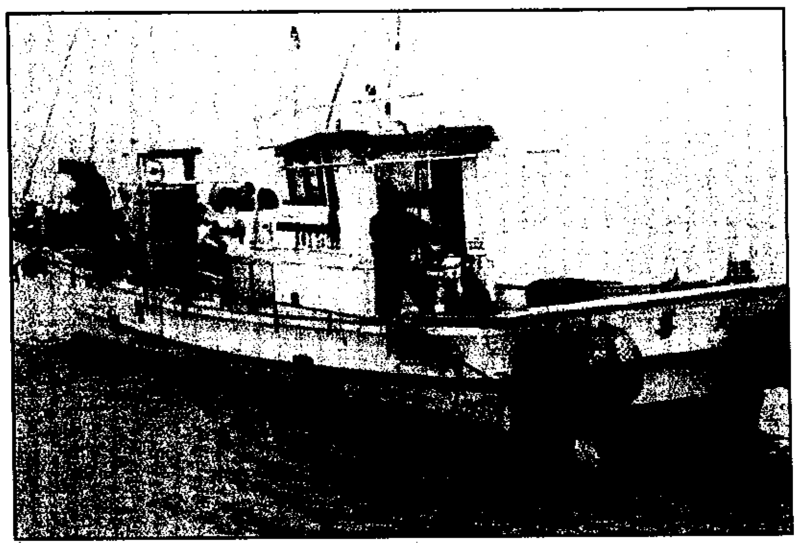


The Japanese scallop (Patinopectin yessoensis)
Photo by Brian Beal.

L to R: a lantern net; a pearl net; "ear-hanging" scallops; and spat collector bags. *Photo by Laura Taylor, 1999.*



Typical scallop harvesting vessel used in Mutsu Bay. *Photo by Dana Morse, 1999.*



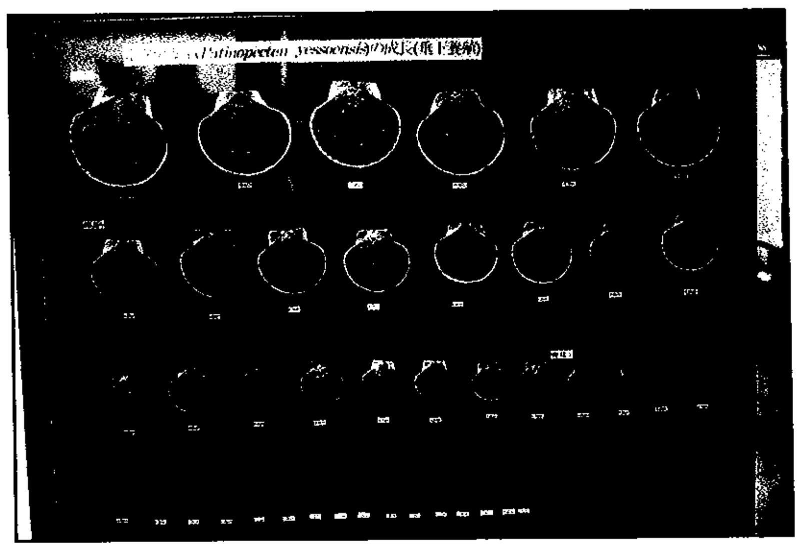
Cutler scalloper Kristin Porter shucks a Japanese scallop aboard the research vessel *Natsudomari*.

A fisherman cleans pearl nets at the dock. *Photo by Brian Beal.*

Unloading one farmer's harvest at a village cooperative on Mutsu Bay. *Photo by Laura Taylor.*

The shucking line at a modern scallop processing plant, built to HAACP standards. *Photo by Laura Taylor.*

An elaborate, computerized, grading machine at an Aomori scallop processing facility. *Photo by Laura Taylor.*



Japanese scallops in a display case. The top row represents the third year of growth. *Photo by Brian Beal.*

Japanese scallops come in many product forms. These canned scallops are sold with "the mantle on." *Photo by Brian Beal.*

valve notch or through both front ears near a byssal notch" (Ito, 1990). Pairs of animals are connected every 15 cm (6 inches) to a rope by a plastic pin that is forced through the hole of each scallop and twisted into the rope. One rope may contain as many as 130 individual scallops (65 pairs). Ear hanging is the most labor intensive culture method. Before ear hanging became more mechanized, in one day, one person could, on average, attach 2,000 scallops to ropes (Ito, 1990). Now that drilling machines are commercially available, 2,500-3,000 scallops can be drilled and attached to ropes in one hour.

The success of hanging culture is related to stocking densities. Lowering scallop density per unit area lessens negative effects due to crowding and ensures maximal growth rates and low mortality rates. Since stocking rates are relatively low at this last time of thinning, handling is nonexistent until the time of harvesting. This reduces shock and stress. Lastly, the physical arrangement of the longlines, which are anchored to the bottom (see Aoyama, 1989, p. 534), stabilizes the nets and ropes which lessens wave-induced stress to scallops (Ito, 1990). Hanging culture in Mutsu Bay occurs in about 50,000 hectares (123,500 acres) and it takes between 1.5 to 2.5 years for scallops to reach market size (meat weight = 100-130 g; shell height = 10-12 cm; Ito, 1990).

There is one aspect of hanging culture that tends to lower growth rates: fouling organisms (polychaete worms, other bivalves, small crustaceans such as barnacles and caprellid amphipods, tunicates, sponges, anemones, etc.). We observed fouling organisms on pearl nets that had been in the water about one year. Although the biomass of these organisms was not recorded, the density per individual pearl net was phenomenal, almost to the point where it was amazing that any scallop was alive within the nets. Since most of these organisms are filter-feeders, it is presumed that there must be an incredible amount of competition for phytoplankton between these fouling organisms and the cultured scallops.

<u>Bottom Culture</u>

Spat collected from bags that are not cultured in the water column are seeded on bottom usually during two times of the year (November to December at shell heights ca. 30 mm or in March of the following year when shell heights are about 50 mm). In Mutsu Bay, the majority of bottom cultured scallops are raised by staff from each Fisheries Cooperative Association (FCA, see below) in a total area of about 23,000 hectares (56,810 acres).

The biggest threat to the success of bottom culture is predation due to starfish. Before scallops are seeded on the bottom, starfish are removed by dredging (Ito and Byakuno, 1988). Growth rates of bottom cultured scallops are significantly slower than animals reared in the water column. For example, it will take, on average, 2.5 years for scallops in hanging culture to attain a live weight of 130 g, whereas it takes an average of 3.5 years to attain the same weight for animals growing on the bottom.

There are at least three reasons for this disparity in growth. First, animals reared on the bottom are generally in water depths greater than 40 m whereas scallops cultured in the water column are in depths from 15 -25 m where phytoplankton is more abundant. (This is the reason why stocking densities for bottom culture are low — $6/m^2$.) Second, scallops on the bottom are surrounded by sediments that can interfere, when resuspended, with the filtering of phytoplankton from the water column. Third, there are a host of predators, such as starfish, benthic fish, and crabs, that can, through their movements and attempts at capturing their scallop prey, cause scallops to escape. These flight responses tend to decrease the time scallops spend feeding. Bottom cultured scallops are harvested by diving or are dragged using the "hotategai-keta-ami," or "ketaami" drag. All scallops harvested from the bottom of Mutsu Bay in these manners are derived from spat collections. (In a meeting with scallop fishermen at the

Oshirogata Fisheries Cooperative in Aomori Prefecture, members of our delegation were asked how there were any scallops to be harvested in Maine if no spat collecting occurred. Many of those fishermen could not remember a time when their scallop fishery was not based on extensive culture using spat collectors.)

Public Health and Diarrhetic Shellfish Poisoning

The Aomori Fisheries and Environment Section within the Department of Fisheries regularly monitors water quality for fecal coliforms within Mutsu Bay. Water samples are taken monthly to assess seawater temperature and bacterial contaminants. There are 10 long-term monitoring sites within Mutsu Bay in addition to three electronic buoy systems and one telemonitor. The water quality testing equipment costs approximately $3,000,000.

Unlike Maine waters, Paralytic Shellfish Poisoning (PSP) is not a problem for the Mutsu Bay scallop fishery. However, the dinoflagellate, *Dinophysis fortii* Pavillard, which causes Diarrhetic Shellfish Poisoning (DSP) was discovered in the Bay in 1979 (Ito and Byakuno, 1988). Since that time, the Aquaculture Research Center regularly monitors toxin levels in scallops using a standard mouse bioassay. If DSP is present this does not affect harvesting because workers can remove the scallop's discrete digestive gland so that they may process the remaining portions (adductor and mantle). There is only one scallop processing plant in Aomori Prefecture which is HACCP approved (see below). That is, it is the only scallop processing plant that meets strict US Food and Drug Administration standards. Costs to achieve FDA-approval are prohibitive which is the reason there are no plans to bring other processing plants up to HACCP standards.

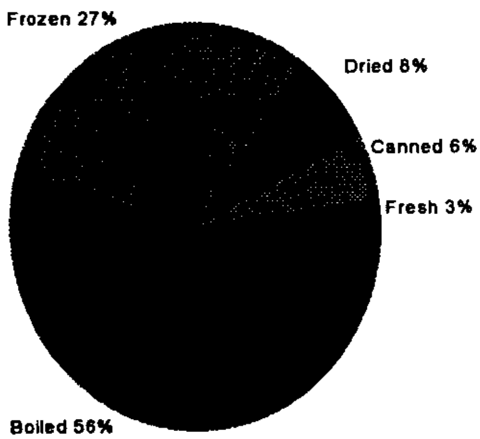
Price Structure and the Processing Sector

Since at least 1991, there have been four different prices paid for Mutsu Bay scallops depending on the method of culture and/or size of animals at harvest. These are: semi-adult, net hanging, ear hanging, and bottom. Scallops reared in pearl nets or lantern nets or harvested from ropes (ear hanging) demand the highest price whereas semi-adults and bottom-cultured scallops fetch the lowest prices. Semi-adult scallops (70 - 80 mm shell height with a meat weight of 65-70 g) are harvested before they are a year old. In 1997, the average price of semi-adult scallops was 113 ¥/kg (using 111.21 ¥/$1, this yields $1.02/2.2 pounds, or $0.46/pound). The average price of bottom-cultured scallops was ¥132/kg ($0.54/pound). Net and ear hung scallops were valued at ¥148 and ¥144/kg, respectively ($0.60 and $0.59/pound).

Today's price structure is about one-half of what it was in 1991 when net cultured scallops were worth 235 ¥/kg ($0.96/pound). Several reasons explain the declining price of Japanese scallops (Anon.,1999e) : 1) technological advancements in equipment and gear, navigation, materials, and ability to forecast spatfall, 2) mass production has surpassed market demand, 3) the occurrence of diarrhetic shellfish poisoning which reduces the amount of scallop tissue processed, 4) public health regulation of shipments of raw meats during summer months, 5) increased production of boiled, semi-adult scallops, 6) competition with China's cultured bay scallop industry. Nevertheless, revenues from scallop culture in Aomori Prefecture in 1998 totaled ¥14 billion ($126 million), which was second in economic importance to apples. (This is nearly 19 times the total landed value of sea scallops in Maine in 1997 -- $6.7 million.)

Scallop processing in Aomori in 1997 (Fig. 5) was unevenly distributed between fresh, canned, dried, frozen, and boiled products. Most processed scallops were boiled (56%) followed by frozen meats (27%). Boiled meats are processed from the smallest scallops (semi-adults) that have yet to reach reproductive maturity (i.e., less than 2 years old [Ito, 1990]). Frozen and dried scallop meats are produced using animals greater than 3 years of age. The distribution of

Figure 5. Processing production in Aomori Prefecture in 1997 (88,362 tons)



processed product (with fresh being the lowest of the five categories) is indicative of an industry at the mass production stage.

On 18 May, our ten-member delegation visited the newest and most modern scallop processing plant in Aomori Prefecture. The Seiho Shoji Co. scallop processing plant in Aomori City is a 7,000 square meter state-of-the-art plant which was built in 1997. The plant was built primarily to serve markets in the European Union and the United States and its operation and management is tightly controlled to conform to HACCP standards. Our tour of the plant was an eye-opening experience. After we were asked to don protective, sanitary outerwear, including hats with face guards, we entered the plant at the receiving station for the boiled scallop production line. Live scallops in the shell were piled on the floor and were fed into a steam line using a small "Bobcat-like" front-end loader. The product was first steamed and the entire meat (adductor muscle, mantle, gonad, digestive gland, etc.) was shaken out of the shell along a flume to a separation line. Processed whole meats comprise 60% of the plant's annual production. The meats were then mechanically maneuvered into large vats containing a chlorinated solution before being sent to an IQF room. Vats were then dumped into a tank with a feed conveyor which took the product to the IQF line. Freezing occurred along a conveyor which entered one of two 75-foot long x 6-foot wide freon-charged tunnels. Combined capacity of the tunnels was approximately 5,500 pounds of scallop meats per hour. After freezing, the product was stored in bulk trays in a storage freezer.

The plant was also producing an order for the US market during our visit. We entered a large shucking room (through sanitary foot dips and anti-bacterial fans) where approximately 80 women were shucking adductor muscles and performing a three-way grade. The primary grade was performed prior to freezing so freezing temperatures could be regulated properly. Next, we were shown a custom grading machine that was built primarily for servicing the US market (cost to the company was $1 million). This computerized grader processes 2,500 pounds per hour with an accuracy to 0.5 g. The company sells about 1,500 tons a year to US markets. The total production of this plant is 26,000 tons per year which are processed in about four months.

Scallop and Other Marine Research within Aomori Prefecture

The Aomori Prefectural government understands well the economic and social significance of the scallop industry. As such, the prefecture supports a formidable research establishment. The principal research facility for scallop cultivation and other fisheries is the Aomori Prefectural Aquaculture Research Center located in Moura, Hiranai-machi, on the shores of Mutsu Bay, about one hour from Aomori City. Founded in 1949, the Center moved to its present location and a new facility in 1967. In 1993, a new ¥3.003 billion complex opened to replace the older, outdated laboratory. Today, the Aquaculture Research Center encompasses some 175,500 square feet of buildings located on approximately 15 acres. Facilities include a 56,000 square-foot administration building, a 41,500 square-foot hatchery and some 36,200 square feet of modern laboratory space equipped with the newest research tools including a scanning electron microscope, DNA testing facilities and the capacity for real-time monitoring of data from the three automated oceanographic buoys (described above). With a staff of 33, including a Director, an Assistant Director and one off-site researcher, the center operates in five discrete "sections," one each devoted to scallops, other shellfish, marine fish, marine algae and the environment of the prefectural fishing grounds.

Oceanographic and environmental studies and survey of the fishing grounds located in the prefecture's coastal waters are conducted both in the laboratory and aboard the Center's 75-foot, diesel-powered research vessel "Natsudomari." The 24-ton vessel normally operates with a crew of eight, including two researchers, a captain and five deckhands. The scallop section, with a staff of five, is devoted to the study of the physiology and genetics of scallops as well as methods for culturing the animals, including both hanging and bottom culture methods. At present, genetic studies are being conducted to develop disease resistance in scallops. Last year, scallop scientists from the Aquaculture Research Center announced at a symposium on culture fisheries that they had discovered a disease in less than 1% of animals in Mutsu Bay that discolors the meats (a reddish color) and results in mortality prior to maturity. The section also studies Mutsu Bay to determine where spat collection efforts are likely to prove most effective and provides this information to the 22 Fisheries Cooperative Associations that are active on the Bay. Production of scallop seed also occurs at the Center and is sold to the cooperatives for stock enhancement. The shellfish section, with a staff of three, does similar work with an eye to enhancement of stocks shellfish other than scallops, such as abalone, surf clams, sea urchins and sea cucumbers, while the marine algae section studies methods to increase propagation of species such as kelp and to develop and expand cultured production of these species. The Center is also studying the use of natural predators to control starfish. The activities of the marine fish section reflect the prefectural government's strong commitment to "sea farming" through the enhancement of stocks of naturally occurring species. The Center has studied ways to increase stocks of such species as Pacific cod (*Gadus macrocephalus*,) black rockfish (*Sebastes schlegeli*,) marbled sole (*Pleuronectes yakohamae*) and the spotted halibut (*Eopsetta grigorjewi*.) The Center has released millions of juvenile cod into Mutsu Bay. The Center includes extensive facilities for the production of seed and the growout of these juvenile fish. In addition to a 30,000 gallon tank for the storage of filtered seawater, the center has six 4,500-gallon, eight 4,000-gallon and one 4,750-gallon outdoor cement tanks. Inside, there are one 7,500-gallon, one 5,000-gallon and four 2,500-gallon cement tanks, and seven fiberglass tanks ranging from 1,250-7,500 gallons.

The Prefecture supports two other major research facilities, both in the vicinity of the major fishing center of Hachinohe. The Fish Processing Research Laboratory operates with an annual budget of approximately $1.5 million and encompasses a small processing plant, laboratories and administrative facilities. Depending on projects underway, some portion of the laboratory's funding comes from the central government in Tokyo, but funding has been relatively flat over the past five years. Founded in 1978, the facility was modernized in 1995. The laboratory focuses its efforts on the development of new products for the fisheries industry and on improving preservation and packaging of fresh and processed fish products. Staff also offer guidance and consultation to fishermen and processors on these issues. The laboratory has a taste testing program that utilizes as tasters the wives of fishermen. The facility operates an educational outreach program, sending some of its staff of ten to cooperatives and processing plants. It also allows researchers from the processing industry to us its facilities.

The Prefectural Government also supports the operation of an Aquaculture Cultivation Center in Hachinohe. Founded in 1981, the Center is a shellfish and finfish hatchery primarily focused on the production of seed for abalone and, since 1990, juvenile flatfish, for stock enhancement programs. Juveniles are raised in tanks that are filled with seawater pumped from the Pacific Ocean which lies at the foot of the hill on which the facility is located. Annual budget at the Center, with a staff of twenty, is approximately $1.3 million. Approximately half the

Center's operating costs are funded by the flatfish and abalone industries--worth some $19 million combined. The balance comes from the Prefecture and the national government. Aomori Prefecture also supports a Freshwater Fisheries Research Center and the Aomori Marine Academy.

Fisheries Cooperative Associations

For centuries, Japanese fishermen have worked cooperatively to manage their fisheries. Today these groups of fishermen are legally organized into Fisheries Cooperative Associations (FCAs) as defined by the Fisheries Cooperative Association Law of 1948. Three types of fishing rights are managed by FCAs: those that 1) delimit aquaculture operations, 2) govern fixed gear, and 3) jointly cover all other fishing activities within the area controlled by the FCAs. Joint rights are distributed to all members of an FCA for access to space within the area controlled by the FCA. Aquaculture and fixed gear rights are given to fishermen only if there is suitable and available space for these activities (Pinkerton and Weinstein, 1995). FCAs regulate many aspects of local coastal fishing activities. Fishermen registered with a certain FCA are given rights to fish in only certain parts of the Association's zone. These rights, termed "sea tenure," have been part of Japanese fisheries law since 1901 and are considered to have the same legal status as land ownership rights (Pinkerton and Weinstein, 1995).

The geographic size of an FCA is determined by the regional Prefecture, but is generally based on town boundaries. (This is similar to how Maine's municipal clam management program works.) Each FCA also has well defined sub-areas that are used to separate the various gear types, or to provide separate zones in which different species are harvested.
Each FCA is composed of all the commercial fishermen of one or more communities who hold joint fishing rights to exploit all of the resources in a specific piece of ocean adjacent to the communities (Acheson et al., 1998). Fishermen within a particular association essentially manage the

fisheries within the geographic boundaries of the cooperative with minimal government (prefectural) intervention. Within the Mutsu Bay region of Aomori, the fishing grounds adjacent to the shore and out to the 40 m contour have been divided into cooperatives that rely heavily on scallops to sustain their coastal communities.

The Governor of Aomori Prefecture has the authority to establish geographical areas of the FCAs and develops broad policy that determines where harvesting occurs, the time of harvest (seasons) and size limits. The Prefecture has jurisdiction of the ocean up to two miles from the shore. The National government of Japan manages marine resources beyond this two-mile boundary. Once established, the FCA has a great deal of local control and decision-making. The current system of cooperatives in Japan is a way for fishermen to have a stake and a voice in managing their fishery. Fishermen decide, through their respective FCA, many aspects of how fishing is done and how the fishery is regulated, but one of the most important things that they decide is who can gain access to the fishery. Because belonging to a cooperative is the only way fishing is done in Japan, you must be accepted by the other members to be a fisherman. Much like a fraternal organization, acceptance is the key to entry into the FCA whether through family affiliation or application and acceptance. Fishermen are also designated specific areas within which to fish by the FCA. This creates a sense of pride among the membership and a feeling of security knowing that there will always be a place to fish and an equal opportunity to make a living among fisherman in the community.

Case Study: Oshirogata Fisheries Cooperative

The Oshirogata Fisheries Cooperative within Mutsu Bay has 65 members with a board of seven elected individuals. Board members hold three year terms which can be renewed indefinitely. To become a member of the Oshirogata FCA, one needs to wait for a space to open through attrition or inherit membership through the family. An initial contribution of ¥370,000 (ca. $3,325) is also required. Currently, it takes an estimated five years to become a member of the FCA. Not all members use fishing as their sole source of income. Some members farm rice paddies in addition to fishing. There is a growing concern among FCAs that the population is aging so the towns may need to merge to have a viable cooperative. As is the case in Maine, more young people are looking for jobs in the urban centers and leaving the coastal communities behind.

Within the Oshirogata Cooperative, the fishermen decide methods of fishing and carry out the cultivation of scallops using both hanging culture and bottom culture. The FCA is responsible for selling the scallops raised through hanging culture. The annual budget for the Oshirogata Fisheries Cooperative is $500,000 which covers an administrative staff of five, board salaries, and other overhead such as financing member's boat and equipment purchases. The FCA also pays approximately $300 in annual registration fees to the Prefecture. To cover the costs of administration, 5% of each fishermen's landed value of scallops goes to the FCA.

The scallop fishery has been very successful for the fishermen in the Oshirogata Cooperative. The total catch of scallops from Mutsu Bay in 1998 was 89,974 mt. The fishermen began fishing for scallops under direction of the Prefecture 30 years ago. Prior to that time, they had fished primarily for squid and sardines. Each FCA member receives twelve 1200 m lines (1200 m = 3,937 ft, or ca. 0.75 miles) with which to culture their scallops.

Members may choose which type of hanging culture method they wish (pearl, lantern, or ear-hanging). Currently, 75% of this FCAs fishing activity is centered on scallops because of their high profit- ability. The FCA has an estimated annual landed value of $4 million. For these fishermen, the key to their successful scallop cultivation program is spat collection. They have experienced a success rate of nearly 80% survival. Members of the FCA are paid to collect spat and disperse the seed. The FCA holds bottom tracts that are used solely for bottom culture of scallops. Seed sown on these bottom tracts are tended and harvested by FCA members who are paid for their time and expenses. Proceeds from the sale of scallops from the FCA's bottom tracts go toward the operating expenses of the FCA.

Within Mutsu Bay, there are 22 FCAs of which the Oshirogata Cooperative is one example. The Fishing Industries Promotion Association, organ - ized by the FCAs in Mutsu Bay, meets annually to discuss the catch for the Bay based on a management plan that considers the previous year's landing and other statistics from the Prefecture's research facilities. The number of scallops harvested in each cooperative is determined based on the size of the cooperative. The FCAs have relied heavily on the Prefecture's research to determine when to set spat collection nets and when to harvest the scallops. However, like most fishermen, scallop culturists also use information they obtain out on the water to make management decisions.

In Japan, fisherman from one fishery rarely encounter conflicts with those in other fisheries. Because subareas in the FCAs are designated for one certain type of fishery, conflicts between user groups (i.e., mobile gear vs. fixed gear) are avoided. Conflicts between members of the same fishery are also avoided because the area where individuals may fish is predetermined by the FCA. In conversations with the fishermen, we learned that minor conflicts concerning boundary lines between FCAs do arise, but the feeling was that this was uncommon. The combination of pride and security were evident in our brief encounter with Mutsu Bay scallop fishermen.

Through strong cooperation and accurate science, fishermen have developed a sustainable system of scallop culture and harvesting which provides economic stability for their communities. Thus, they seem very happy with their way of living and very confident that the sea will provide a living for them in the future. When asked what are the major problems facing them, their answer was surprisingly that they were concerned that the young people were not getting into fishing and the cooperatives in the area were losing members, so they may need to join with other FCAs. In contrast, many fishermen in the United States are not confident that the sea will provide for their future. Our fishermen also have a mistrust of the available science; thinking that scientists are working to put them out of business, not help them stay in business for the long term. The life of a Japanese fisherman is a secure one, working within a system which is well-honed by centuries of experience and untouched by other systems and ways of fishing. It is very evident that these fishers are satisfied with their way of life and hope to pass it on to future generations.

Marketing of Japanese Scallops and Maine Scallops

The vast majority of Japan's scallops are sold in Japanese markets; however, data provided by the US Embassy in Tokyo shows that 230 tons of scallops were exported to the U.S. in February 1999. Today, Japanese production of scallops in Aomori and Hokkaido Prefectures is at an all-time high, but prices are declining so there is an enormous incentive to locate international markets. It is doubtful whether Maine scallops could enter Japanese markets due to the wide disparity in price between the two species.

Conclusion

Realistically, there are limits to how policies and practices that work well in Japan translate to conditions here in Maine. For example, the scallops are a different species, Mutsu Bay tidal amplitudes, wave heights and current speeds are low compared to Maine's coastal waters, and cultural values have evolved and are rooted in unique social conditions.

Members of our delegation came away from the fact-finding experience with varied perceptions. Regardless of our personal interests, attitudes and areas of expertise, we all concur that the scallop fishery in Aomori, Japan works well. The sheer numbers of scallops landed, the processing capacity, the multitude of products (fresh and smoked meats, meats and mantles, dried mantles, live whole scallops, frozen, canned, boiled and dried) all attest to the success and productivity of the Japanese scallop industry.

Amidst the flurry of activity in all the different Japanese scallop industry sectors, there seemed to be a unity of purpose. Whether we spoke with prefectural government leaders, fishermen in the cooperatives, scientists at research facilities, or processing plant managers, there seemed to be a coordinated objective to maintain scallop production at sustainable and high levels. It was apparent that achieving this goal was the result of a well-planned funding infrastructure that supported basic and applied research, development of new growout techniques and outreach to transfer this and other technology to fishermen, monitoring efforts to determine best times for spat collection, and activities associated with controlling predators. In addition, state-of-the-art, HACCP-approved, processing facilities that meet demands of varied markets, management structures that provide local control and reward stewardship all contribute to a healthy industry.

It may well be this unity of purpose, more than any other single factor, that is responsible for the success of the Japanese scallop industry. Achieving a similar unity of purpose may be the greatest challenge to increasing the productivity of the

Maine scallop industry.

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