CLAM CULTURE IN JAPAN

UNITED STATES DEPARTMENT OF THE INTERIOR

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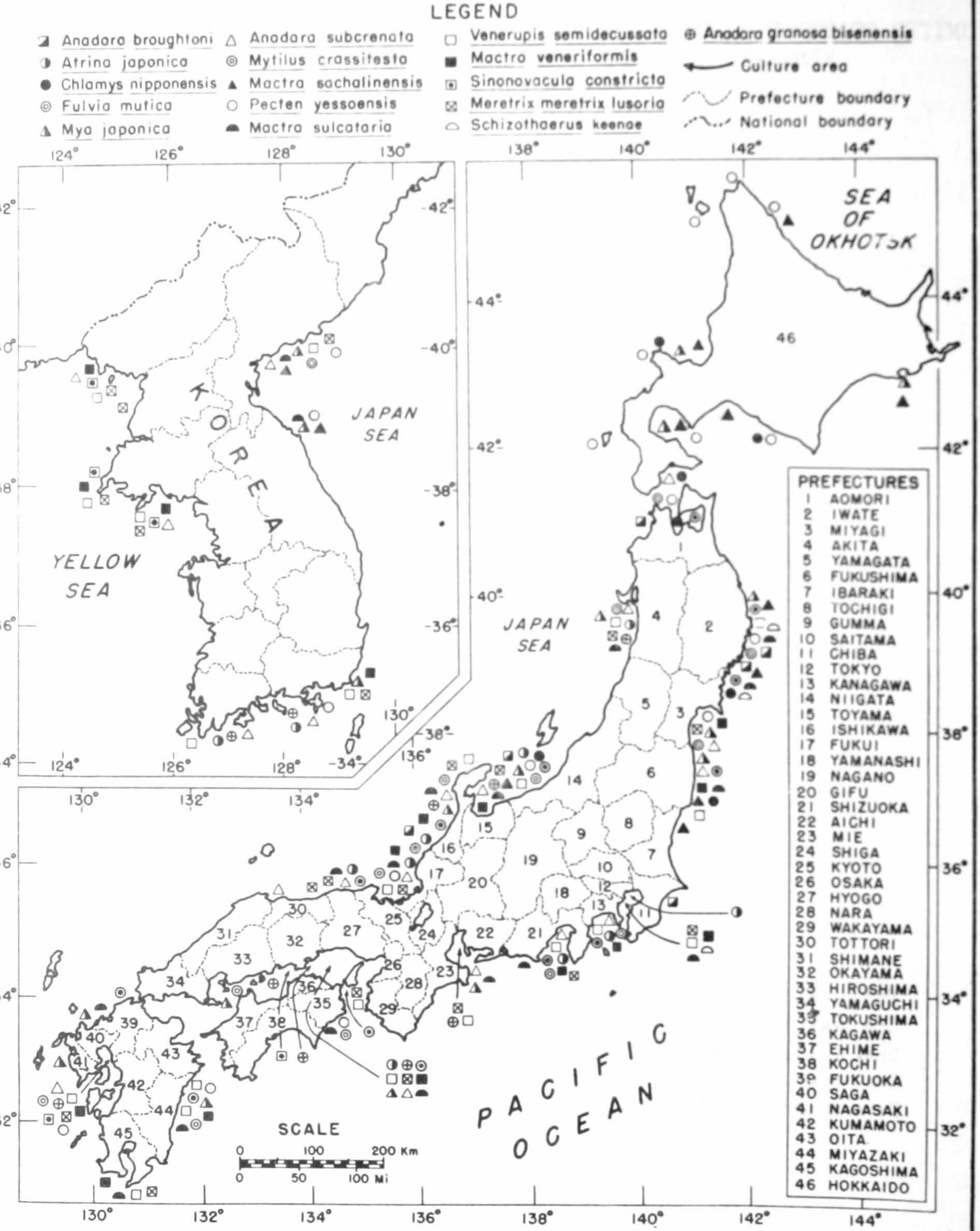
DISTRIBUTION OF IMPORTANT EDIBLE BIVALVES OTHER THAN OYSTER SPECIES



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by
A. R. Cahn

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SUMMARY

1. Clam culture is of ancient origin. The first mention of it in Japanese literature dates from 746 AD. Although this instance is merely the transportation of a species of clam from one place to another, such transplantings constitute a first step leading eventually to the more complicated and intensive methods of culture. Actual cultural methods came later but were practiced before oyster culture came into existence in Japan.

2. The innumerable shallow-water bays and inlets that indent the Japanese coast afford in many instances ideal localities for the practice of aquiculture. The utilization of the shallow coastal waters for the production of nutritious food is highly important to the health and welfare of a nation which derives approximately 85 percent of its animal protein from marine products. This becomes more important still when it is realized that animal protein represents only about 15 percent of the total protein food available to the human diet of the nation. Such aquicultural utilization of suitable water areas also constitutes the sole economic basis of many coastal villages wherein the population lives entirely on the results of its aquicultural activities.

3. Among the aquicultural pursuits of the Japanese in these shallow coastal waters is the culture of clams. Clams play an important role in the economy of the nation as they afford both food and a means of livelihood for many people. They are easily and cheaply cultured along much of the Japanese coastline. As the methods employed are simple and in many cases primitive, little equipment is required and hence shortages in material and gear do not affect production as is the case in more elaborate cultural procedures. Primitive as the methods may appear they are efficient as to production and well suited to the economic status of the people using them.

4. The methods employed in the culture and harvesting of 10 important clam species in Japanese waters are described in this report together with such variations as have been evolved to meet local conditions. The methods of harvesting 13 other slightly less important species, for which no cultural need thus far has arisen, are also reported. While these 23 species constitute the most important of the clams valued as food by the Japanese, many other species also are eaten, although in far lesser quantity and usually only locally. Such species have been merely listed for the sake of completeness.

5. Notes on the life histories of the important cultured species are given in some detail because the success of culture procedure depends in the last analysis on an understanding and appreciation of the inter-relation between environment and specific limitations to meet environmental change. Successful culture must be based on an understanding of specific life histories.

1/ This report was prepared by Dr A. R. Cahn, aquatic biologist, Fisheries Division. The drawings are the work of Messrs Saburo Satouchi and Katsuyuki Kita, technical consultants, Fisheries Division. The writer is indebted to Mr T. Ino and Mr F. Hasegawa for translating and briefing many Japanese publications and to Dr Tokubei Kuroda for assistance in problems of synonomy and nomenclature.

6. Statistics on clam production in Japan are both incomplete and confused, but such data as are available have been assembled. The total recorded production of clams in Japan during 1909-48 amounts to 5,842,833 metric tons, an annual average of 146,070 metric tons. In the peak year 1943, clam production yielded 4,378 grams per capita; at the rate of 32 grams of animal protein per kilogram, the production that year yielded 140 grams of animal protein per capita.

7. Many species of clams in Japanese waters are showing the effect of over-fishing, and in some instances the decline in production already has become serious. There is no reason to expect anything in the future except a further decrease due to the same cause, with more and more species being affected. For this reason protective measures are urged and improvement in culture technique through scientific investigation is needed in order to maintain production of this important marine food item.

INTRODUCTION

Japan is an insular nation. Its southern coast on the Pacific side is washed by the warm Kuroshio (Black Current 2/) flowing northward from the tropics; it turns northeastward just north of Chiba Prefecture and flows out into the open Pacific. The northern Pacific coast is under the influence of the southward flowing Oyashio (Mother Current). The entire Japanese coast of the Japan Sea is washed by the Tsushima current, a branch of the Kuroshio which flows north of the Ryukyu-retto (Ryukyu Islands) and passes through Tsushima-kaikyo (Tsushima Strait) between Japan and Korea. Japan's coastline is very irregular, being indented by innumerable bays, some large, many small. Many of these indentations afford large areas of shallow water, protected from the violence of the sea. In many such bays the shores are relatively low and the sea bottom is either sand, mud, or a mixture of the two. Such areas afford excellent shelter for marine life, especially for hundreds of species of mollusks 3/, and at the same time offer excellent opportunities for aquiculture.

One of Japan's major problems is that of the food supply for its 84,000,000 people. With a concentration of approximately 3,650 people per square mile of cultivated land (United States: 188 per square mile), it is not surprising that the people have turned to the sea as a source of steady food supply which furnishes them with 85 percent of their animal protein. The open sea supplies the larger species of marine fish such as bonito, tunas, albacore, spearfish, and sharks. The shallow water provides the smaller fish, crustaceans, algae, and a host of marine mollusks, both bivalves and gastropods. In order to augment the natural supply of food in the shallow water, or to obtain the wherewithall to buy food, the coastal populations have turned to systematic cultivation of these resources and have developed many phases of aquiculture, depending upon the environmental factors to determine the nature of such activities. In suitable localities noriculture, pearl culture, clam culture, oyster culture, and sea cucumber culture are undertaken. Although the production from these aquicultural activities may appear small compared with the total production reaped from the sea, they play an important role in the nutritional economy of the people and afford a livelihood as well as subsistence to innumerable small communities along the coasts. With the steadily increasing pressure of population, attention is being directed more strongly than ever toward enlarging aquicultural production. This focus of attention is leading to more intensive investigations of methods, improvement of techniques, and the opening of new areas to suitable aquicultural pursuits.

Although the cultivation of clams is very old even in terms of Japanese history the methods used today still are primitive, but they are surprisingly efficient. Clams afford a highly nutritious, palatable, and abundant source of food which is harvested relatively easily and inexpensively, and hence these mollusks play a real part in the economy of the nation. Urayasu, a town of 1,500 inhabitants in Chiba Prefecture, depends wholly

2/ See Glossary for list of Japanese generic terms used in this report.
3/ See Glossary for definitions of certain technical terms as used in this report and for an illustration of the shell features of a bivalve.

on the harvest of clams cultured at the mouth of the Edo-gawa (Edo River); the clams are the basis of its local economy. The same is true of many other communities along the Japanese coast.

That clams are extremely nutritious is indicated by the high protein content. In five important species the percentage of protein is as follows: Venerupis semidecussata 13.20; Corbicula spp. 18.40; Anadara broughtoni 15.79; Mactra sulcataria 11.08; Meretrix meretrix lusoria 13.19. A fat content in these five clams ranges from 0.45 percent in Anadara broughtoni to 0.8 percent in Corbicula spp.

This report deals with the various species of clams cultivated by the Japanese and also those which, while not actually cultured, are important items in the diet of the people. With the results of overfishing becoming apparent in many of the productive species, the Japanese are directing attention toward the possible cultivation of other species as well as toward the improvement of the techniques of culturing those already under domestication. The writer has studied the various methods employed in the field. They are reported herewith in an effort to bring together within a single small volume an account of the methods prevailing in different regions of Japan, in the hope that this information may make possible future improvements in techniques and an increase in production.

Considerable attention has been given to the problems associated with environment, life history, and development because these are important to anyone concerned with culture. An organism is an organic response to specific problems imposed by an environment and has definite and relatively nonelastic physiological limits of adaptation. The more closely these limits are approached the more serious becomes the penalty thereof. The environment is therefore of primary importance to the success of any culture project. As the organism cannot adjust to meet the requirements of an uncongenial environment, the environment for culture work must be selected with careful reference to the limitations of the organism if success is to be attained. To do this requires accurate knowledge of the life history as related to the environment. Such problems as temperature range, salinity tolerance, bottom composition, exposure during low tide, and similar environmental factors are of basic importance. They are dealt with here in some detail insofar as they are known to affect the various phases of the life history of the species. Success in any culture undertaking depends upon an understanding of the resistance and limitations of the organism involved and the intelligent application of that knowledge to culture procedure.

The present paper does not purport to be a taxonomic study, and time has not permitted a thorough taxonomic revision of the species discussed in this report. Such a revision would require consultation of literature not available in Japan, the examination of type specimens in London and elsewhere, and other aspects of malacological research which must be left to others. Considerable study would have to be devoted to determining whether the generic name Venerupis is valid, or whether Protothaca should be used instead. Cardium is used loosely; the proper identification of genera and subgenera in Japan of species going under this name is a challenge to local scientists. Research implies searching again, and in this area much more searching must be done by other workers before the classification of the animals considered herein is such as to receive the approval of all taxonomists.

HISTORY

That various species of marine mollusks have long served as items of human food has been proved repeatedly by the composition of innumerable shell mounds or kitchen middens excavated in many parts of the world. The coastal areas of the islands of Japan Proper are studded with prehistoric shell mounds, many of which have been studied and show a profusion of molluscan shells. While the number of marine bivalves found in the shallow waters easily accessible to these ancient people is large, the number of species they used as food, as evidenced by the contents of these mounds, is relatively small, indicating definite selectivity. Oysters are almost always present, and such clams as these people found available and pleasing to their taste are abundantly represented. The bivalves used as food greatly exceeded in both variety and quantity the gastropods eaten. As might be expected, the clams represented are those species found locally near the mound in which they are deposited. In only a few instances have molluscan species been found which are not indigenous to the vicinity of the midden, although some of these Japanese mounds are estimated to date back several thousand years. 4/ The ancient people of Japan depended greatly on the sea for their food, and they left their menus in their refuse piles as evidence of their diet.

The culture of clams probably began in the Far East, but much time-consuming research would be necessary in order to localize the first steps in the process. One of the earliest--if not the earliest--reference to primitive clam culture in Japan occurs in an ancient Japanese classic 5/. Here it is related that Yakamochi Otomo, a poet and warrior of the Imperial Household, took "Arisogai" 6/, a species of clam (Mactra spectabilis), with him when he was transferred from a post in Kii (now Wakayama Prefecture) to another in Etchu (now Toyama Prefecture) in 746 AD, and planted them in the waters of the latter region (Aikawa 1949). Clam culture of a sort was already established in China before the 17th century, for we find in ancient Chinese natural history books references to "Teiden" as farms where Sinonovacula was cultured and to "Kanden" where Anadara was cultured.

While the early inhabitants of the Japanese homeland simply used what they found locally, the Japanese of the 17th century began to improve on the providence of nature by culturing clams which they found particularly palatable, whether they occurred locally or not. As far as can be authenticated, the next man after Yakamochi Otomo to transport clams in Japan was Kenzan Nonaka (1615-63), one of the chief supporters of the Tosa feudal clan. In 1656 Nonaka was sent to Tokyo as envoy to aid in solving a controversy between neighboring clans. His mission accomplished, he decided to bring back to Tosa (Kochi Prefecture) some of the clams which he found so delightful on his Tokyo visit. He therefore piled one of his vessels high with adult clams and filled another with young of "Asari" (Venerupis) and "Hamaguri" (Meretrix) and sailed for home. The people of Tosa expected Nonaka to bring rich gifts back with him from Tokyo, and they were lined up on the beach to welcome him when he returned. As he came into Tosa-wan (Tosa Bay) Nonaka scattered his treasured clams in the shallow water, and the good people of Tosa went home in disgust. However, Nonaka was farsighted, for he planted a permanent profit instead of dispensing a temporal reward.

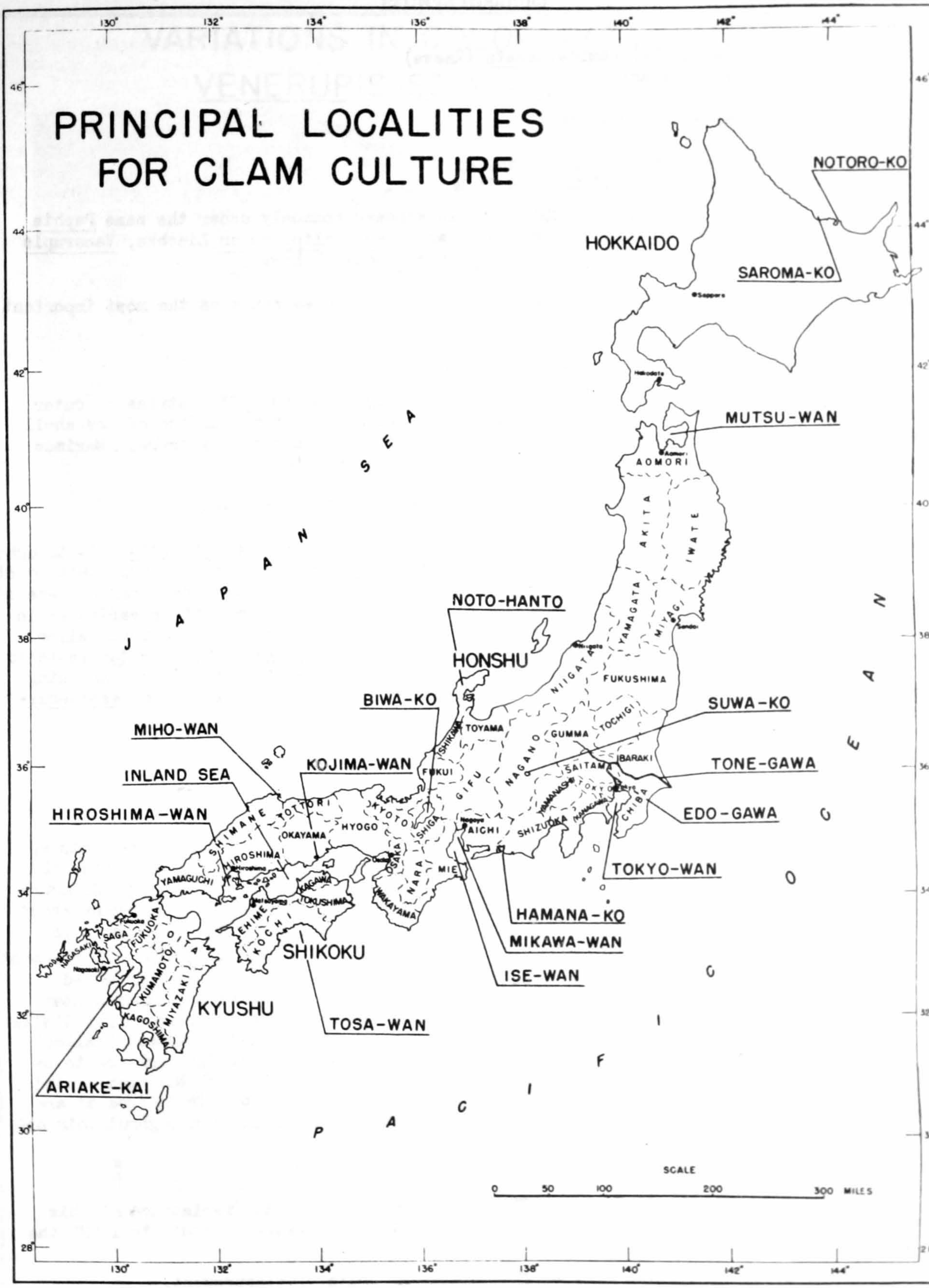
In 1673 Gorohachi Konishiya (Goroemon Kobayashi) was already raising clams in Kusatsu, Hiroshima Prefecture, and had his clam grounds fenced in with bamboo sticks. Here by chance he found that many young oysters were attached to his fence sticks, and one of the earliest of Japanese oyster culture methods sprang from his discovery (Cahn 1950). Thus it is clear that the actual culture of clams in Japan was already established when oyster culture was born.

Transplantation of clams from the Tokyo and Osaka areas to beds in the Toyama region was begun in 1858. The undertaking proved fruitless at first but later was successful. Fishermen of Kojima-wan, Okayama Prefecture (Figure 1) succeeded in acclimatizing "Agemaki" (Sinonovacula constricta) and "Sarubo" (Anadara subcrenata) brought from other regions to their home waters in 1859 and 1872 respectively. They also made a success of planting various other shellfish in later years. The culture of "Haigai" (Anadara granosa bisenensis) in the region of Kojima-wan, was started in 1859 by the brothers Ichisaburo and Yoshisaburo Maeda. As a result of these experiments, transplantation of mollusks of various species became common practice among coastal fishermen of Japan (Aikawa 1949). Some were successful, others failed because of uncongenial environmental conditions. The solution of the basic problem of successful transplantation remains the same today as at the time of these early experiments: a study of specific life histories in relation to environmental conditions. The problem of actual culture is more urgent now than at any previous period because of accumulating evidence that overfishing has reduced the available stock of clams.

4/ In an unpublished paper on the "Antiquity of Man in the Kanto Plain", Lt Col Hubert G. Schenck has recorded the analyses of two samples of radioactive carbon, early late Jomon in age, from the shell mount at Ubayama, Chiba Prefecture. He quotes the results of Prof W. F. Libby, Institute of Nuclear Studies, University of Chicago: "The age of one sample is 4546 ± 200 years, of the other 4513 ± 300 years." Colonel Schenck thinks that early man in the Kanto region has been eating shellfish since at least 3000 BC.

5/ Manyoshu, No 20: Poets From 313 to 759 AD.

6/ See Glossary for list of Japanese shell names with scientific name



NATURAL RESOURCES SECTION

Figure 1

1. Venerupis (Amygdala) semidecussata (Reeve)
Japanese Name: Asari

a. Synonomy and Importance

1864 Tapes semidecussata Reeve, Conch Icon, sp 67
1853 Tapes japonica Deshayes, Cat Conch Brit Mus, 181

In Japanese literature this species appears commonly under the name Paphia philippinarum Adams & Reeve, and less commonly as Tapes philippinarum Lischke, Venerupis philippinarum Adams & Reeve, and Venus philippinarum Adams & Reeve.

Along with Meretrix meretrix lusoria this species ranks as the most important of the Japanese edible clams found on sandy beaches.

b. Characteristics and Distribution

Shell ovate; umbo slightly bent anteriorly. Numerous fine striae on outer shell surface. Color pattern extremely variable (Figure 2). Inner surface of the shell white or yellowish. Cardinal teeth three. Pallial sinus comparatively large. Maximum size approximately 70 millimeters 7/ long by 50 millimeters high.

The distribution of this species is shown in the Frontispiece.

A closely allied species, V. variegata (formerly Paphia variegata), is thought by some taxonomists to be identical with V. semidecussata, but the current preponderance of opinion favors its separation. It is smaller and slightly longer, and the outer surface of the shell bears smaller and more numerous radiating ribs. The color pattern varies as in V. semidecussata, but the inner surface of the shell is sometimes pink or bright yellow. It is found on shores bordering the open sea, but not in bays, whereas V. semidecussata is found only in bays. The Venerupis of Hokkaido was reported by Kinoshita (1937) as being variegata, but afterward Kinoshita (1939c) recognized it as a local variety of semidecussata or intermediate form of both species.

c. Living Conditions

(1) Water Temperature

On the basis of present knowledge of its wide range in nature, this species is presumed to have a strong tolerance for temperature. Kitamura (1937) states the optimum is 23-24°C. In order to determine the optimum temperature for activity, Kitamura calculated the velocity of ciliary movement of the gills. A piece of gill filament about two millimeters square was placed in a glass dish, and the action of the cilia made the gill fragments "walk" on the bottom of the dish. The rate of movement of the gill fragment was directly proportional to the rate of activity of its cilia--the faster they moved the faster the fragment "walked". By varying the temperature of the water the experimenter found that the activity stopped at 0°C and at 36°C, these being the lower and upper limits of tolerance. The optimum proved to be 23.4°C at which point the gill fragment "walked" 2.39 centimeters per minute. While the experiment itself may seem at first glance to be trivial in nature, yet because the respiratory and feeding activities of the clam depend entirely on this same ciliary action, the implications and conclusions drawn from it are important to an understanding of suitable culture areas. The salinity throughout this experiment was 1.01812 at 15°C.

(2) Salinity

Kurashige (1942a) made the following report on the resistance of this clam to changes in the salinity of its environment. Within a range of 1.018 to 1.027 the

7/ See Glossary for conversion from metric to English units of measurement.

VARIATIONS IN COLOR PATTERN OF VENERUPIS SEMIDECUSSATA

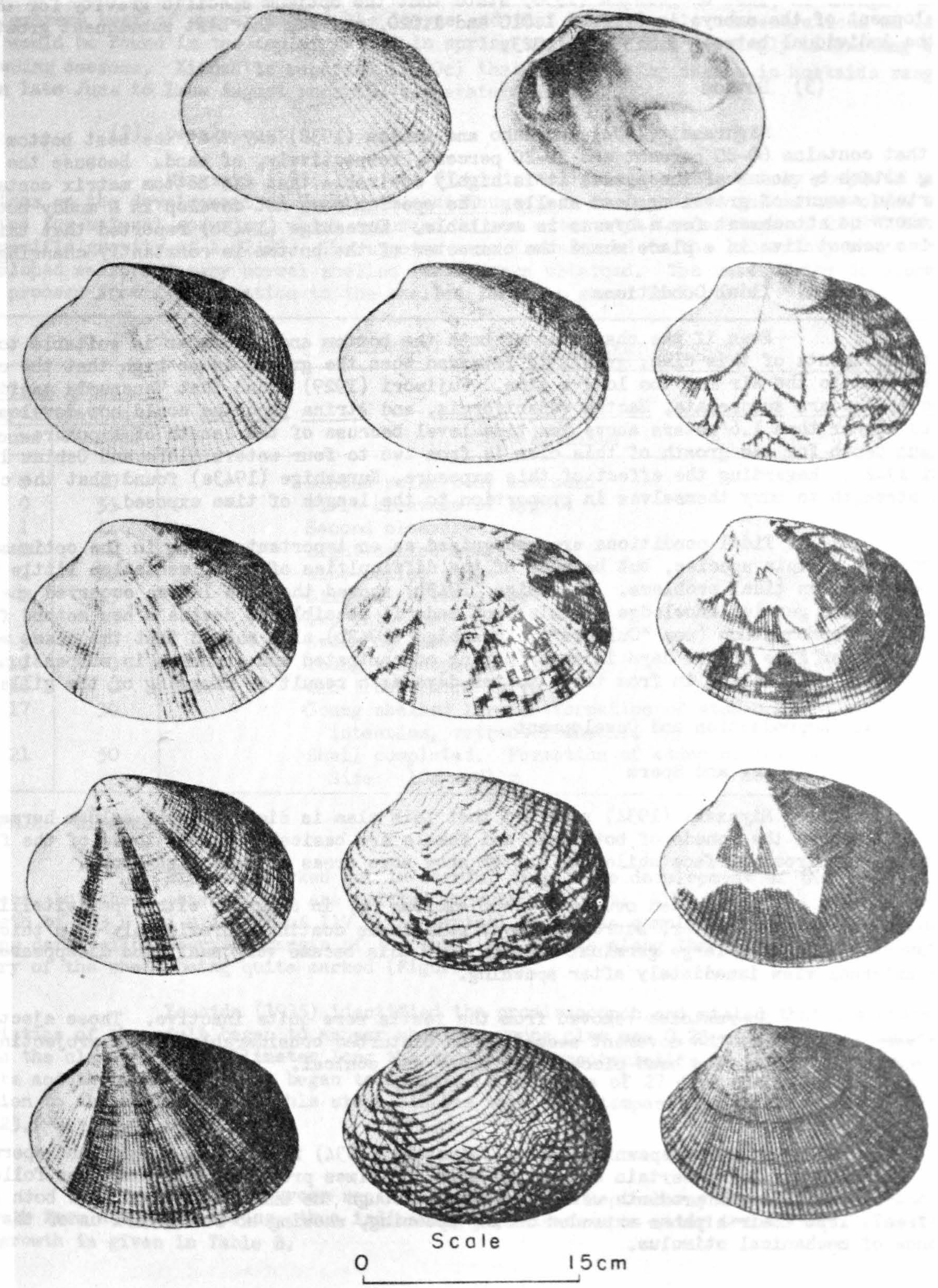


Figure 2

clam was unaffected to any visible extent. In water which was comparatively fresh, having a specific gravity as low as 1.005, most of the clams survived for two or three days but all died within eight days. Being fairly adaptable to high salinity, this clam survived for several months in water with a specific gravity as high as 1.092.

Icho and Oshima (1938) state that the optimum specific gravity for the development of the embryo is between 1.010 and 1.020, and for the best subsequent growth of the individual between 1.015 and 1.023.

(3) Bottom

Higurashi (1934) and Icho and Oshima (1938) say that the best bottom is one that contains 60-80 percent and 50-80 percent, respectively, of sand. Because the young attach by means of the byssus it is highly desirable that the bottom matrix contain a certain amount of gravel or dead shells. The species does not develop in a muddy bottom where no attachment for a byssus is available. Kurashige (1943b) reported that this species cannot live in a place where the character of the bottom is constantly changing.

(4) Tidal Conditions

Even if the character of both the bottom and the water is suitable to the requirements of this clam, growth is retarded when the ground is so high that the clams are exposed to the air for too long a time. Fujimori (1929) found that Venerupis semidecussata, Anadara subcrenata, Mactra veneriformis, and Atrina japonica could not develop in ground higher than 1.6 meters above low tide level because of the length of exposure. The optimum depth for the growth of this clam is from two to four meters (Icho and Oshima 1938; Ozaki 1942). Regarding the effect of this exposure, Kurashige (1943a) found that the clams lost strength to bury themselves in proportion to the length of time exposed.

Tidal conditions are recognized as an important factor in the optimum environment of this species, but because of the difficulties of experimentation little work has been done on tidal problems. Kurashige (1943b) showed that the larvae occurred where the current is gentle; knowledge of this fact made it possible to devise a new method for artificial reproduction (see "Culture"). Kurashige (1942b) also showed that the clams were weakened after five or six days in water having concentrated mud granules in suspension; many died of suffocation in from three to ten days as a result of clogging of the gills.

d. Reproduction and Development

(1) Egg and Sperm

Miyazaki (1934) reported that this clam is dioecious but seldom hermaphroditic. Although the gonads of both male and female are basically white, those of the former have a lustrous surface while the latter show some areas of yellowish-brown.

The ejected ovum was 63-66 microns (μ) in diameter with a perivitelline space 3.3-4.6 μ in diameter, surrounded by a gelatinous coating approximately 23 μ thick. The ovarian egg had a large germinal vesicle, but this became very small and disappeared from external view immediately after spawning.

Spermatozoa removed from the testis were quite inactive. Those ejected were very active, but the movement seemed to be disturbed considerably by the projecting and curved acrosome. The head-piece was slender and conical.

(2) Spawning

Studying spawning habits, Miyazaki (1934) reported that eggs and sperm were not extruded in any certain order, the eggs sometimes preceding and sometimes following the sperm. The sex products were discharged through the exhalent siphon, and both male and female kept their siphons extended during spawning, showing no retraction under the influence of mechanical stimulus.

Fujimori (1929) reported two spawning seasons, one in the spring from April to June, and a second in autumn from October to December. However, he discovered that the larvae could be found in the water all year round because late-spawned larvae, hatching in the fall, did not develop rapidly because of the cold temperature. Higurashi (1934) reported that the two spawning seasons occur in March-April and August-September. Yoshida (1935) believed that spawning was continuous from spring to fall; he thought that the extreme heat of summer damage the larvae and that consequently concentrations of larvae would be found in the cooler waters in spring and fall, thus seemingly indicating two spawning seasons. Kinoshita reported (1939c) that the spawning season in Hokkaido ranges from late June to late August when the temperature is 20-23°C.

(3) Development

Miyazaki (1934) was the first investigator to make fairly complete observations on the development of Venerupis semidecussata. He impounded the mature clams and waited for natural spawning, which occurred in sea water at a temperature of 22.8°C having a specific gravity of 1.02489. The zygotes were transferred to the laboratory where they developed well, and many normal shelled larvae were obtained. The rate of the developmental process from fertilization to the shelled larva is shown in Table A.

TABLE A. - DEVELOPMENT OF VENERUPIS SEMIDECUSSATA

Time After Fertilization		Stage Attained
Hours	Minutes	
0	40	Second polar body extruded
0	55	First cleavage of zygote
1	44	Second cleavage
2	0	Eight-celled stage
2	30	Nine-celled stage
2	45	Sixteen-celled stage
3	30	Two entoblast cells
5	30	Swimming larva
10	0	Young trochophore larva
16	0	Old trochophore larva
17	30	Young shelled larva. Formation of stomach, intestine, retractor muscle.
21	50	Shell completed. Formation of adductor muscle. Size: 104 x 81 u

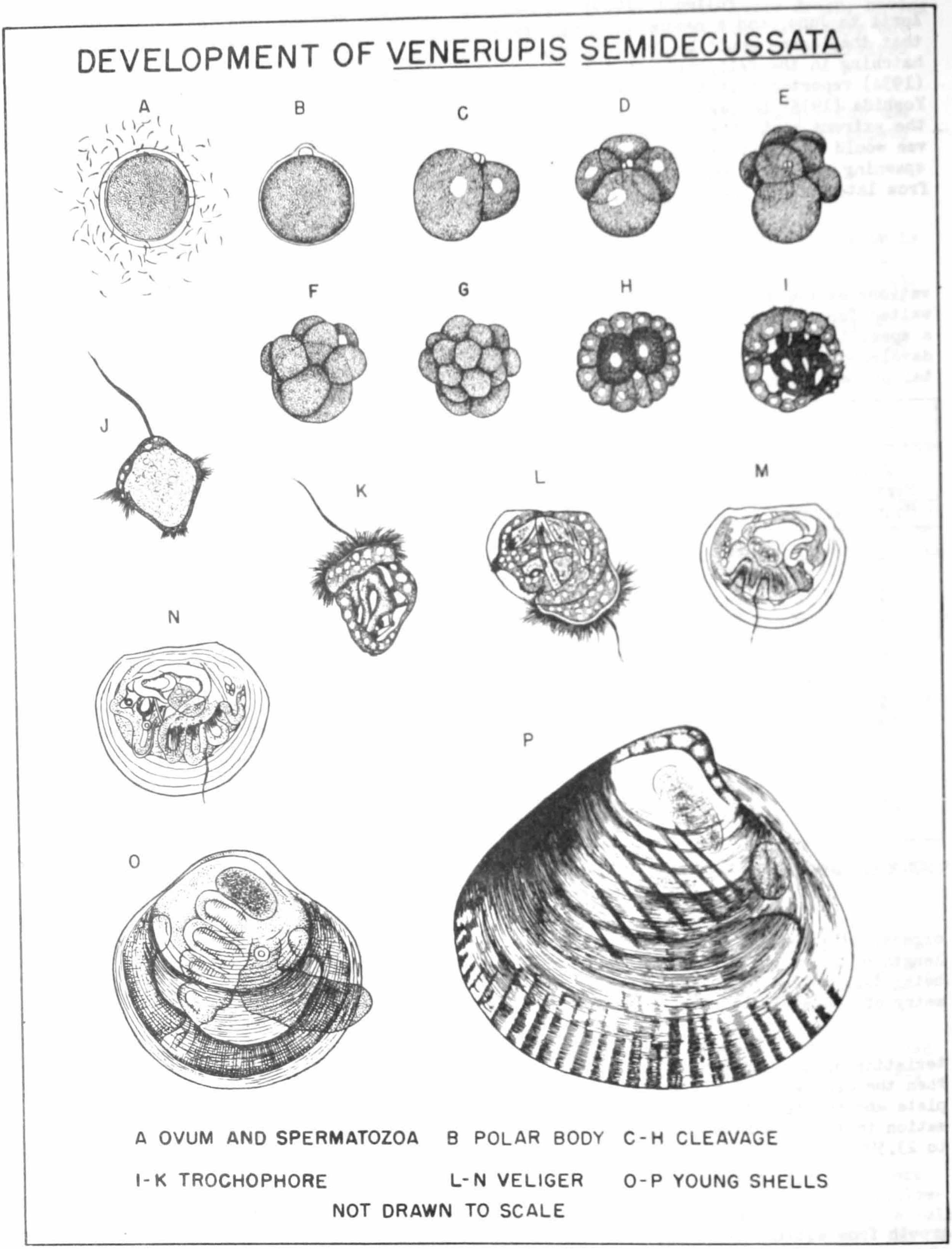
SOURCE: Miyazaki 1934

Miyazaki worked out in careful detail the development of the internal organs, but these observations are omitted from this report. When the shell attained a length of 133 u and a height of 117 u the typical larva was completed, the small clam then being dark yellow near the margin of the shell and purple along the hinge line, the asymmetry of the shell being quite marked (Figure 3).

Yoshida (1935) identified the prodissoconch and stated that the characteristics of the adult began to appear when the young clam was 0.28 millimeter in length. When the clam was 0.5 millimeter long the specific characteristics of the species were complete and the radiating ribs began to appear. An average of 27 days elapsed from fertilization to the attainment of this stage, in his work at a temperature varying from 18.0°C to 23.5°C.

(4) Growth

The Asari grows rapidly from April to September and practically ceases growth from autumn to spring, thus indicating dependence upon water temperature. The rate of growth is given in Table B.



NATURAL RESOURCES SECTION

Figure 3

TABLE B. - GROWTH OF VENERUPIS SEMIDECUSSATA					
Year	Date of Measuring	Length (cm)	Height (cm)	Weight (grams)	Months After Planting
1919	17 May	1.50	ND	0.37	0.0
	11 Aug	2.54	1.68	1.87	3.0
	22 Oct	3.63	2.37	7.12	5.0
	24 Dec	3.63	2.40	7.12	7.5
1920	1 May	3.79	2.40	7.12	11.5
	17 Jun	3.80	2.44	7.12	13.0
	14 Jul	3.96	2.60	9.75	14.0
	26 Sep	4.09	2.70	10.87	16.0
	26 Dec	4.12	2.73	11.25	19.0
1921	8 Feb	4.12	2.73	11.25	21.0
	9 Mar	4.12	2.77	13.12	22.0

ND: No data available
SOURCE: Fujimori 1929

Reporting on further growth studies, Fujimori summarized his work as follows: one year old, 2.6 centimeters; two years old, 3.8 centimeters; three years old, 4.8 centimeters; four years old 5.3 centimeters; five years old, 5.8 centimeters (Figure 4). The oldest specimen Fujimori reports is eight years old, having a length of 6.1 centimeters and a height of 3.2 centimeters.

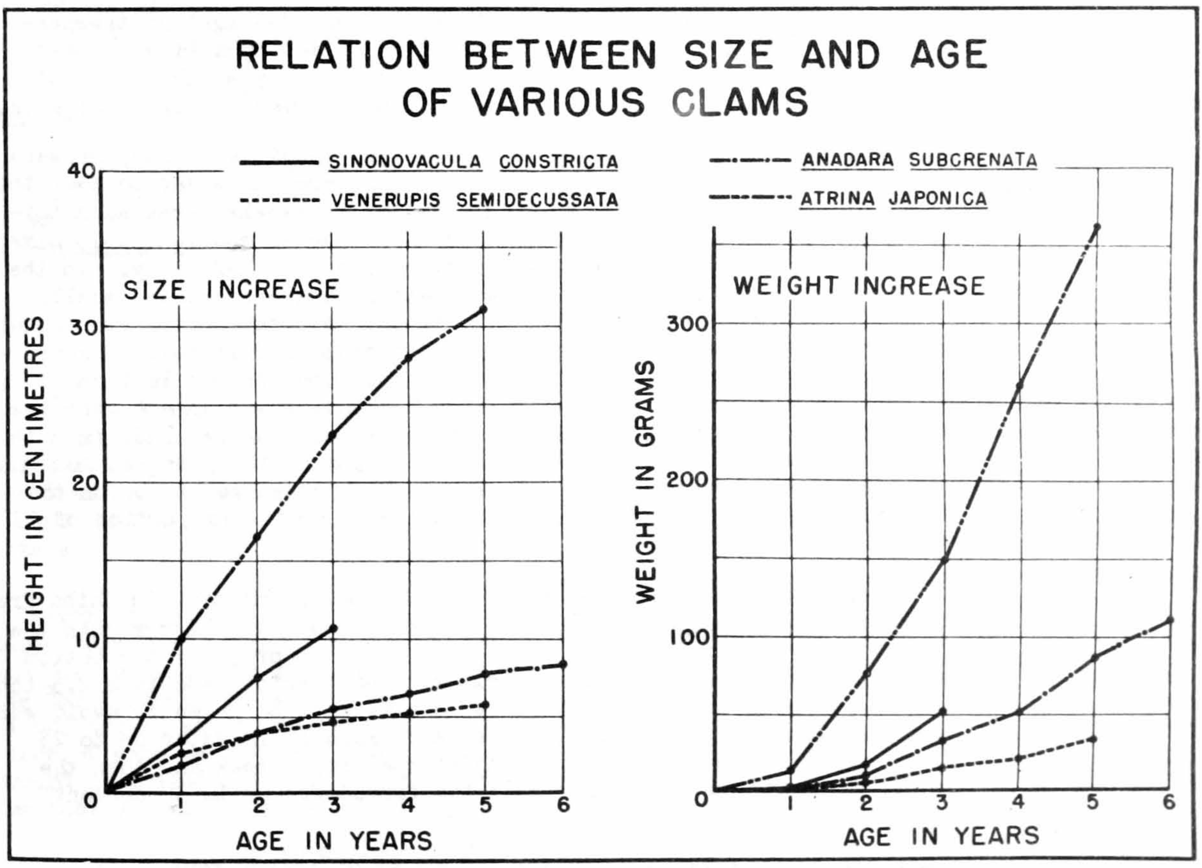


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Figure 4

e. Culture

(1) Culture Methods

According to Icho and Oshima (1938) the population of this clam in nature is usually very dense per unit area. If the young clams are permitted to remain in this overcrowded condition, shortage of food causes mortality and retards growth among the survivors. To increase production, the young seed clams must be gathered and transplanted to a culture area having optimum conditions. As a result of this procedure the clams grow remarkably and can be marketed after one or at most two years. Asari culture, therefore, consists of seed collecting and transplanting.

Seed can be transplanted in both spring and fall, but the spring planting is far more advantageous. Fall transplantation is followed by a period amounting almost to hibernation; owing to heavy fall storms, retarded activity, and depredations by ducks results are rather poor. On the other hand, clams transplanted in spring grow rapidly and become large enough so as not to suffer the damages resulting from fall planting by the time that season arrives. The amount of seed planted per unit area varies according to the size of the young clams. The standard amount to plant in the Ariake-kai (Ariake sea) is 1.5 to 2 sho 8/ per tsubo in early May, 2.5 to 3 sho in late May, 4 to 5 sho in June, and 5 to 7 sho in fall. Although the volume of the planted seed increases the number of individuals decreases because of the larger size of the clams.

Sowing is done at high tide ("shiomaki") or at low tide ("katamaki"). Growers have found that sowing during a strongly active flow or ebb tide is not advantageous. Planting done on an ebb tide is preferable because it gives workers an opportunity to level the ground after planting and to gather such predators as the snails Rapana thomasiana ("Akanishi") and Polynices didyma ("Tsumetagai"). An effort is made always to plant a uniform number of shells per unit area so as to get maximum growth, but the process cannot be exact because the clams are simply scattered broadcast on the bottom.

After sowing, the culture area is watched and guarded against trespass and thievery by human elements, and against invasion during high tide by molluscan predators. Sometimes the action of wind and waves crowds the clams together so that lack of food retards growth. When this occurs the clams are redistributed over the original area.

As the object of farming is maximum production in minimum time, growers often find it necessary to prepare the sea bottom in the culture area in order to meet the optimum conditions required to maximize the production. In the Ariake-kai area such bottom preparations began in 1917. At that time dead shells of barnacles and Venerupis mixed with cinders were scattered over the bottom, but the result was not satisfactory. In the summer of 1919 excellent results were obtained after scattering sand and crushed shells over the bottom. An experimental area was selected and divided into two parts, each covering 24 tsubo. The natural bottom here was a sandy mud, exposed for four to five hours at spring tide. All living shells were removed from both beds. One bed was left under natural conditions; in the other a mixture of sand and crushed shells was spread over the surface to a depth of 15 to 20 centimeters. Plantings of equal numbers were made in both beds, and these were harvested the following July. The production in the prepared bed was more than five times that of the natural bed, 941 clams being harvested per tsubo on the natural bed and 5,073 on the prepared bed (Icho and Oshima 1938), in the proportion of 23 sho to 124 sho per tsubo.

Another and very practical new method is now being employed in Chiba Prefecture. Here a machine is used to prepare the bed. A tractor drawing a harrow cuts the length and breadth of the culture ground and not only weeds but also prepares the bottom by breaking up the surface and getting rid of the detritus. The tractor used is a 2.5-ton, 27 horsepower machine. It can be used only at low tide as care must be taken to avoid wetting the machine with salt water, but it can be operated successfully in water up to 25 centimeters deep. After harrowing, the bed is left undisturbed for a week and then the seed is planted. Three months after sowing, growth in the farmed ground is 30 percent

8/ See Glossary for conversion from Japanese to English units of measurement greater than in the unharrowed beds. Not only were excellent results obtained in raising Asari but much improvement was also noted in Porphyra (seaweed) culture.

If adult clams are present, pelagic larvae occur over vast areas in every bay or river mouth. As a rule, however, most of these fail to set because the ground is not suitable for the development of the young. Although this clam is widely distributed in Tokyo-wan, in the entire area only one good seeding bed exists where the young clams can develop in quantities to be of commercial importance. This is at the mouth of the Edo-gawa near Urayasu, Chiba Prefecture. In other places the grounds are not suitable for the setting of the larvae and the subsequent development of the clams. In many places the difficulty appears to be that the tide is so swift the veligers cannot sink to the bottom at the proper time and establish a benthic life. Indications are that the pelagic larvae of V. semidecussata and other clam species are carried close to shore on the flow tide and that they sink to the bottom when the tide slackens and begins to ebb.

In line with this theory the Japanese have attempted several methods to slow the current artificially. Ota (1947) introduced a method, consisting of building bamboo fences against the tide current, which had given good results in Korea. This method is now under study at Nameishi, Kumamoto Prefecture, but the results are not yet available.

Taki (1949) conducted experiments based on the same general principle in the Urayasu area, using straw bags filled with sand instead of bamboo fences. At this time all that is known of the results is that the method has produced considerable amounts of benthic larvae where no such larvae occurred before. Storms and accumulating mud are elements working against these two methods.

Another method has been proposed by Niino (1949) who suggested boring wells in the tidal flats where no larvae occurred because of the high temperature of the water. The flowing wells are supposed to keep the bottom mud and shallow water at a proper temperature for the development of the clams. Whether this can be made practical in view of the expense of boring remains to be seen.

(2) Harvesting Methods and Gear

This species is harvested all year round, but the best seasons are autumn and winter.

The simplest and least important method used in Chiba Prefecture to gather the clams is a hand fork, hoe, or shovel which is used on exposed tidal lands or in water to a depth of one meter. This method is employed principally during the spring low tides and contributes little to the commercial production of the species.

The hand dredge ("Koshimaki") (Figures 5, 6) is of greater importance. This is a basket dredge about 60 centimeters wide, with a long bamboo handle. The basket is fitted with a series of long steel teeth which are worked through the sandy bottom and which separate the clams from the dirt. At low tide the koshimaki is pulled by a strap around the fisherman's waist. He wades backward in water up to one meter deep, pulling the dredge and working the handle back and forth to loosen the bottom material and to regulate the depth of penetration of the teeth. Workers sometimes use the koshimaki from an anchored boat in water 2.0-2.5 meters deep, by reaching out and then pulling the dredge toward the boat. This type of dredge gathers clams buried to a depth of 10 to 20 centimeters.

The most efficient method employs the "Omaki" or large dredge (Figure 6), a larger edition of the koshimaki basket dredge about one meter wide. The dredge is fastened to a boat by two ropes, and the long handle of the dredge sticks up at the bow of the boat so that the fisherman can work it back and forth to regulate the depth to which its teeth penetrate the bottom. The boat is pulled toward an anchor by a hand-operated winch, around which the fishing operations radiate. A marker is placed at the starting place of each pull toward the anchor, so that the same area is not fished twice yet no ground is missed. Twenty pulls are made each day and the average catch is about 85 liters per boat of two or three fishermen.

In some places (as at Futtsu, Chiba Prefecture) fishermen use a dredging net called "Ketaami", consisting of a rectangular wooden or iron frame and a net basket.

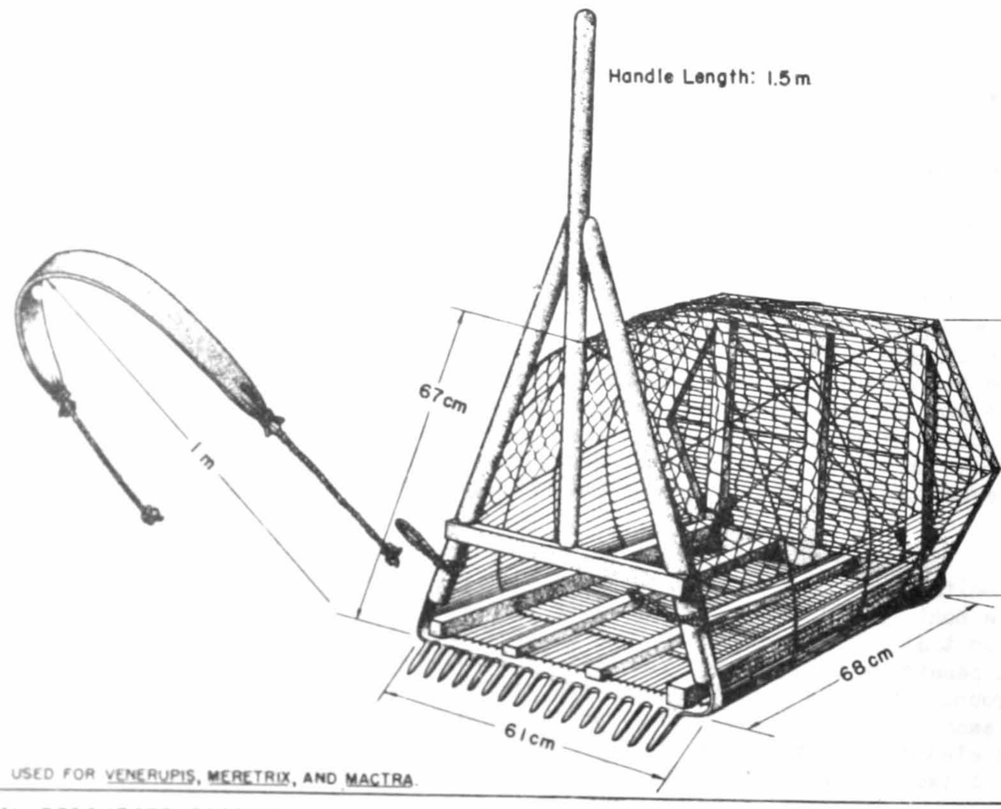
About 36 short iron teeth are arranged along the lower beam of the basket to dig into the bottom sand. Stones are added as weights at both ends of the bottom beam. This gear is practical on sandy-mud bottom in water from two to four meters deep. The dredge is lowered on the port side of a boat which then sails sideways about 300 meters; the dredge then is pulled up and the clams removed from the basket.

f. Enemies and Damage

In nature high wind and waves, floods, severe cold or heat, and submergence by detritus are enemies of this clam. The oxygen content of the water seems to be of less importance. Kurashige (1942b) reported that up to a certain point insufficiency of oxygen in the sea water did not visibly damage this clam. The Asari survived for three days in sea water containing less than 0.5 cubic centimeter of oxygen per liter. They began to show ill effects only after four or five days and died if exposed to this oxygen deficiency for 10 days. In sea water containing one cubic centimeter of oxygen per liter the clams lived normally for more than 20 days. Experimentally no damage was noticeable in water containing less than 0.5 cubic centimeter of oxygen per liter if the bivalve was transferred to well-oxygenated water for several hours each day.

Certain ducks, especially the "Magamo" (Anas platyrhynchos platyrhynchos) and the "Hajiro" (Aythia sp.), feed upon the young clams heavily from October to March. Once they find the culture grounds they seldom leave them. Saito (1936) studied the problem of damage by ducks to young V. semidecussata in the Urayasu area. Ducks collected on the culture grounds were found to have as many as 52 clams one to two centimeters long, totaling 28.2 cubic centimeters in volume, in the digestive tract. As the ducks seem to feed on the clams constantly for about 150 days from October to March, the damage done is considered to be very great.

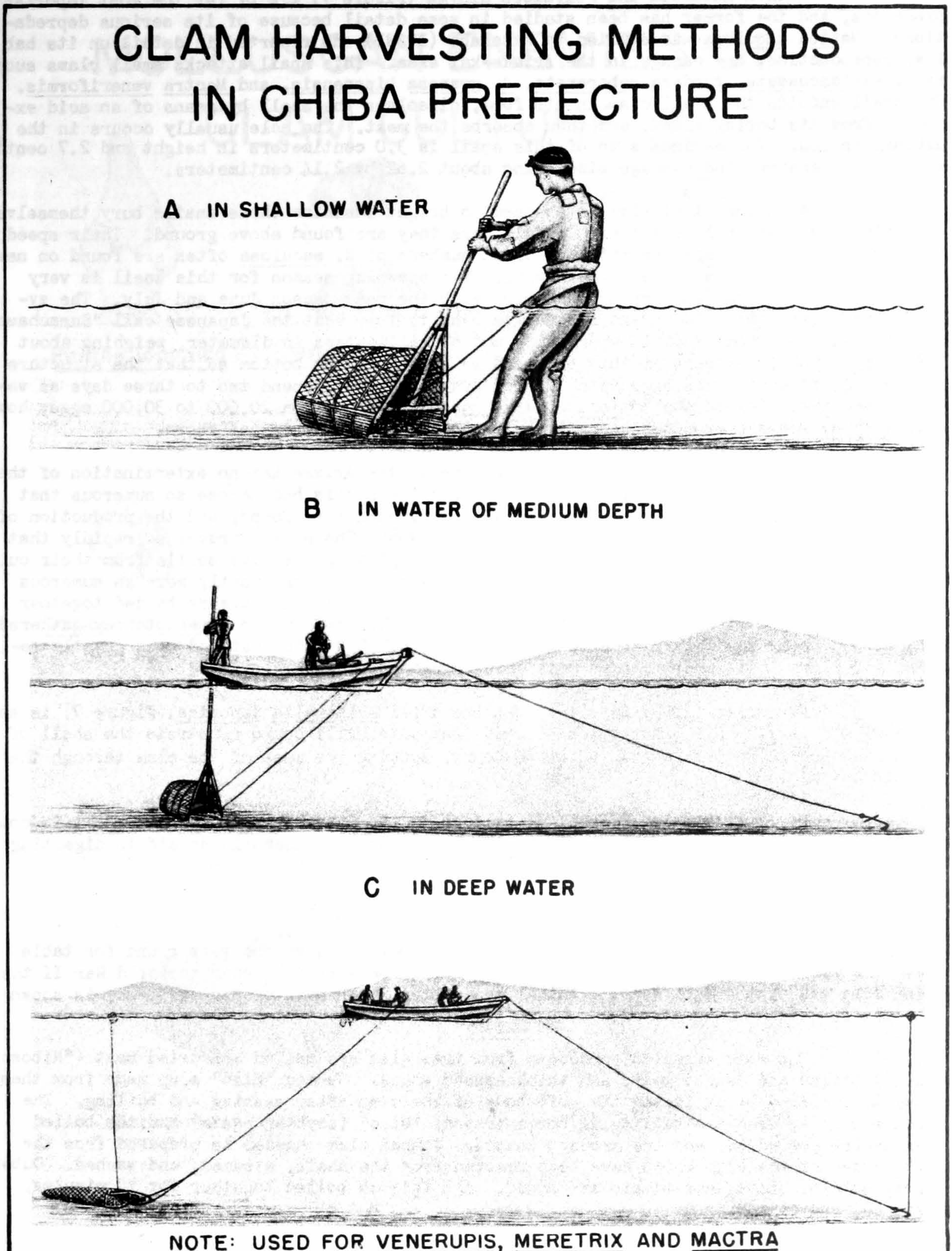
SHALLOW WATER DREDGE USED IN CHIBA PREFECTURE
(KOSHIMAKI)



NOTE USED FOR VENERUPIS, MERETRIX, AND MACTRA.

NATURAL RESOURCES SECTION

Figure 5



NATURAL RESOURCES SECTION

Figure 6

Natica maculosa and Polynices didyma (Figure 7) are by far the most important predators, and the former has been studied in some detail because of its serious depredations. Natica maculosa was studied by Watanabe (1938b) who reported in detail on its habits, reproduction, and damage in the Ariake-kai area. This snail attacks small clams such as V. semidecussata, Anadara subcrenata, A. granosa bisenensis, and Mactra veneriformis. The snail enfolds the small clam in its foot, dissolves the shell by means of an acid excreted from its boring gland, and then absorbs the meat. The hole usually occurs in the umbonal region. The maximum size of this snail is 3.0 centimeters in height and 2.7 centimeters in diameter, the average size being about 2.62 by 2.14 centimeters.

When the tidal flat is exposed to bright sunshine these snails bury themselves, and gathering them is impossible. On dull days they are found above ground. Their speed is about 26.4 centimeters per minute. Great numbers of N. maculosa often are found on new culture grounds only two days after sowing. The spawning season for this snail is very long, apparently from February to December, with the peak season June and July. The zygotes are covered with mucus and accumulate sand to form what the Japanese call "Sunachawan", a sand "tea cup" about 1 millimeter thick and 67 millimeters in diameter, weighing about 3.7 grams. The lower part of this egg mass is buried in the bottom so that the structure does not drift away. The eggs hatch in 15 days; the larvae spend two to three days as veligers and then sink to the bottom. One egg mass contains from 20,000 to 30,000 eggs; how many such masses are produced annually by a single individual is not known.

In the water off Fukuoka Prefecture in the Ariake-kai no extermination of the snails was attempted prior to 1935. At that time the snails had become so numerous that an average of 50 to 60 per square foot of culture ground were found, and the production of the area had been lowered 50 percent by their ravages. The snails travel so rapidly that the individual farmers found it impractical to attempt to gather the snails from their culture areas, because the next day the snails on their grounds apparently were as numerous as ever owing to the influx from neighboring areas. In 1936 the farmers banded together and petitioned the Fisheries Association for help. The Association agreed to buy gathered Naticas and their egg masses at five sen per sho. By 1939 this pest had been greatly reduced and since that time has been kept under reasonable control.

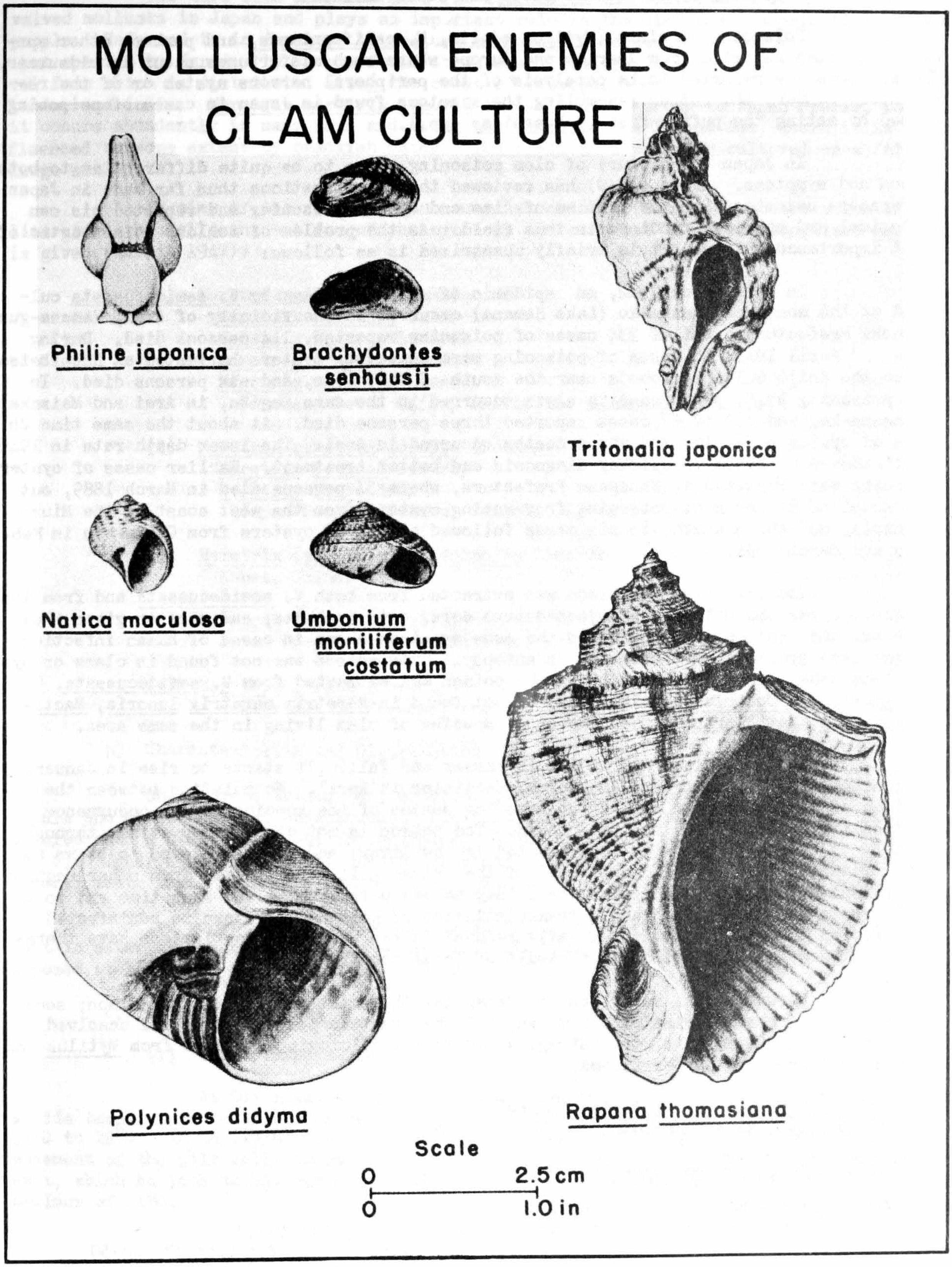
Kinoshita (1934) reported that the drill Tritonalia japonica (Figure 7) is an enemy of the Asari. His observations showed that this drill could penetrate the shell of an Asari 5.8 centimeters long in about 70 hours, sucking the meat of the clam through the drilled hole.

Philine japonica (Figure 7) belongs to the Opisthobranchia. The shell is completely internal, thin, and slightly spiral. The powerful gizzard is an aid in digesting clams.

g. Production and Utilization

The Asari is most palatable in spring but is taken the year round for table use. The meat is eaten raw, in soup, canned, dried, or salted. Prior to World War II the dried meat was exported to China. Annual production, both natural and cultured, is shown in Table 1.

The more important products from this clam are boiled and dried meat ("Niboshi Asari"), boiled and canned meat, and thick canned soups. Canned "Miso" soup made from these clams is prepared by utilizing the soft body of the clam after washing and boiling. The fluid resulting from the boiling is concentrated, "Miso" (soybean paste) and the boiled clam bodies are added, and the product canned. Canned clam chowder is prepared from the soft bodies of the clam which have been removed from the shell, steamed, and washed. Cubed bacon, potato, onion, and tomato are added. All this is boiled together for 10 minutes, flavored, and canned.



NATURAL RESOURCES SECTION

Figure 7

h. Poisoning by V. semidecussata and Other Mollusks

Poisoning by clams (Mytilus edulis, M. californianus, and perhaps other species) has been reported from America and Europe where such misfortunes occur in midsummer. The symptoms are reported to be paralysis of the peripheral nervous system or of the respiratory center, the latter resembling the symptoms found in Japan in cases of poisoning caused by eating the puffer fish (Sphoeroides spp.).

In Japan the picture of clam poisoning seems to be quite different as to both season and symptoms. Akiba (1949) has reviewed the investigations thus far made in Japan by Japanese scientists on the problem of clam and oyster poisoning and reported his own biological and chemical findings in this field. As the problem of mollusk poisoning is of great importance, his report is briefly summarized is as follows:

In late March 1942, an epidemic of mass poisoning by V. semidecussata cultured at the mouth of Hamana-ko (Lake Hamana) occurred in the vicinity of Arai, Hamana-gun, Shizuoka Prefecture. Out of 334 cases of poisoning reported, 114 persons died. During March and April 1943, 16 cases of poisoning were caused by oysters harvested at Hachibeise and on the Shijo culture grounds near the mouth of Hamana-ko, and six persons died. In 1949 poisoning by V. semidecussata again occurred in the same region, in Arai and Maizaka on Hamana-ko, and out of 67 cases reported three persons died. At about the same time 26 cases of oyster poisoning and three deaths occurred in Arai. The lower death rate in 1949 is attributed by Akiba to quicker diagnosis and better treatment. Earlier cases of oyster poisoning were reported in Kanagawa Prefecture, where 54 persons died in March 1889, out of a total of 81 cases of poisoning from eating oysters from the west coast of the Miura peninsula, and three deaths in six cases followed eating of oysters from Otawa-wan in February and March 1941.

The same type of poison was extracted from both V. semidecussata and from the oysters. After the poison was injected into dogs, cats, rabbits, and mice or given them by mouth, the test animals exhibited the same symptons shown in cases of human infection and the same symptoms were revealed in autopsy. This poison was not found in clams or oysters from other areas. In Hachibeise the poison was extracted from V. semidecussata, Ostrea gigas, and Dosinia japonica. It was not found in Meretrix meretrix lusoria, Mactra veneriformis, Batillaria sp., or any other species of clam living in the same area.

The poisoning rate is low in summer and fall. It starts to rise in January and reaches a peak in February and March, declining in April. No relation between the occurrence of the poison and either the breeding season of the species or the occurrence of the "red tide" (Cahn 1950) has been found. The poison is not distributed evenly through the body of the mollusk but is concentrated in the liver, and it is believed to be an abnormal rather than a normal constituent of the animal. If normal clams from other regions are transplanted to the Hachibeise area, they become poisonous at the same time and to an equal degree as the native clams. Transplantation of poisonous oysters to noninfected areas showed that the poison was greatly reduced in two weeks. Investigators have therefore concluded that the poison is a result of local conditions.

Work is still being done to determine the exact nature of this poison; some of the chemical characteristics are known, but the exact composition is still unsolved. It has been named Venerupin, to distinguish it from Mytilotoxin extracted from Mytilus and Tetrodotoxin from the puffer fishes.

2. Meretrix meretrix lusoria (Röding)
Japanese Name: Hamaguri

a. Synonomy and Importance

1798 Venus lusoria Roding, Mus Bolton; 180
1851 Cytherea lusoria Sowerby, Thes Conch 2: 620; pl 128, figs 40-42
1851 Cytherea formosa, C. meretrix, Sowerby, Thes Conch, 2: pl 129; figs 47, 48-50

The hard clam Meretrix meretrix lusoria is the most common of the edible bivalved mollusks in Japan and plays an important role in the diet and economic life of the people. Referred to in Japanese literature as Meretrix meretrix, it was separated from that species by Kuroda (1947) who found it subspecifically distinct from that more tropical form which is distributed along the coast of Formosa, South China, the Philippine Islands, and India. Meretrix meretrix lusoria is limited by Kuroda to Japan Proper, where it occurs abundantly in many bays and along the shore of the Inland Sea, where it is influenced to some extent by brackish water. The species is commonly cultured on a fairly large scale.

In view of the confusion in nomenclature which exists in modern scientific literature the following outline of the synonomy and range of the five recognized Meretrix is given (Kuroda 1947):

(1) Meretrix meretrix (Linne)
Meretrix castanea Lamarck
Meretrix zonaria Lamarck
Meretrix graphica Lamarck
Meretrix morphina Lamarck
Formosa, South China, Philippine Islands, India, etc

(2) Meretrix meretrix lusoria (Röding)
Meretrix formosa Sowerby
Meretrix fusca Koch
Japan Proper (Honshu, Shikoku, Kyushu)

(3) Meretrix (meretrix) petechialis Lamarck
Korea, China, etc

(4) Meretrix (petechialis?) lamarckii Deshayes
Japan Proper (Honshu, Shikoku, Kyushu), Formosa

(5) Meretrix lyrata (Sowerby)
West coast of Formosa, eastern India

b. Characteristics and Distribution

Shell ovate triangular; anterior portion short, posterior long. Umbo swollen; lunule and escutcheon not conspicuous. Ligament black, short but high. Surface smooth, covered with a semitransparent periostracum. Color and color pattern highly variable (Figure 8). Inner surface of shell almost white and pallial sinus small. Cardinal teeth two; lateral teeth two. Attains a length of 105 millimeters, a height of 76, and a width of 47.

The geographic distribution is shown in the Frontispiece. The clam is abundant in water of lower salinity in bays and inlets from the intertidal zone, where it is exposed at low tide, to water 12 meters deep.

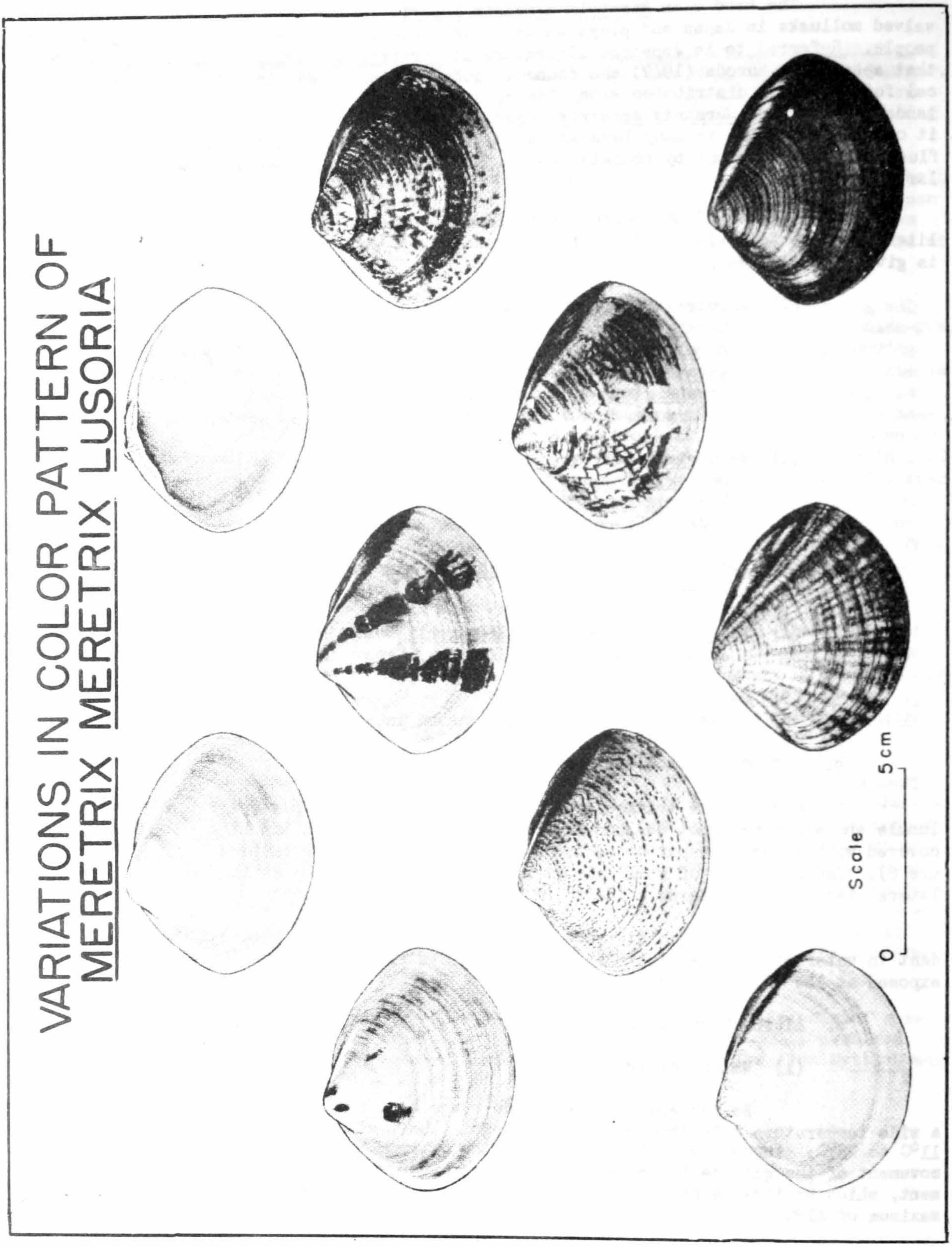
c. Living Conditions

(1) Water Temperature

As the species has a wide range both horizontally and vertically, it has a wide temperature tolerance range. Higurashi (1934) gives the temperature range as from 11°C to 28°C. Inoue (1938) found 25.5°C to be optimum in his experiments testing ciliary movement of the gill cells in relation to water temperature. He found that ciliary movement, which he took as his death indicator, ceased at a minimum temperature of 1.5°C and a maximum of 41°C.

(2) Salinity

Higurashi (1934) found that a specific gravity between 1.015 and 1.024 was essential to a suitable habitat. Experimenting with young shells he found that the



NATSURAL RESOURCES SECTION

Figure 8

young stages develop nearer to the river mouth that do young Venerupis while the adults inhabit deeper water. Venerupis and Meretrix are two of the most important edible clams in Japan and are closely associated as to habitat. Higurashi found Meretrix to be stronger in its tolerance of both temperature and salinity range than Venerupis.

(3) Bottom

Icho and Oshima (1938) show that a sandy mud bottom, composed of 60-80 percent sand, is the preferred habitat. Into this matrix the clam burrows to a depth of 3 to 13 centimeters according to the season of the year, going deeper in winter than in summer.

(4) Movement

Although this clam moves from place to place by action of the foot, movement sometimes is accomplished by the extrusion from the posterior portion of the clam of a string-like adhesive material. According to Uchida (1940) this material is spun into the current and inclines upward; the body of the clam is then carried along the bottom by tidal current aided by this "balloon". This secondary type of movement was found to be prevalent during the summer, when the young clams were growing rapidly, especially during August. Observers agree that young (larval) shells occur in the vicinity of the neap low tide level while the adult shells are found mostly in the zone of the spring low tide level.

d. Reproduction and Development

(1) Egg and Sperm

The gonads of both sexes are light yellow in color when the sex product is mature (Higurashi 1934). The eggs, according to Yoshida (1941), are spoon-shaped when in the ovary but change in sea water to spherical with a diameter of 0.06 to 0.08 millimeter. The eggs are enveloped in gelatinous matter. The head of the sperm is asymmetrical, being concave on one side. The head is 0.03 millimeter long and bears a long tail.

(2) Spawning

The spawning season for Meretrix varies with the locality. According to Fujimori (1929) spawning in the Ariake area takes place from mid-May to mid-July, the peak of spawning being reached during June. Icho and Oshima (1938) place the spawning in general terms as between May and September.

(3) Development

Yoshida attempted artificial fertilization and was successful in obtaining a few veliger larvae; he described the development of the larvae (Figure 9). Twenty-four hours after fertilization the shell covered the soft body completely; the organism was then yellow with a purple hinge line, the digestive system visible through it. One zygote attained 0.14 by 0.10 millimeter on the sixth day and 0.17 by 0.15 millimeter on the 12th day, at which time the organs within its soft body were almost completely formed. The size on the 17th day was 0.18 by 0.165 millimeter when foot movement began. Death followed on the 20th day. During this experiment the water temperature varied between 24.3 and 30.2°C. Yoshida also was able to collect veliger larvae of this clam and by culturing these made the following observations. The collected full-grown larva was 0.18 by 0.16 millimeter; anterior edge a little sharper than the posterior; shell peak not expanded; faint tooth-like protuberances at both ends of the hinge line. Color faint yellow except for the purple peak. Velum possessed a long flagellum. Two to six days were required for the full-grown veliger larvae to settle into the bottom stage of its history. This benthic larvae was found seldom to excrete a byssus. The color was transparent gray, and clear ring lines on the shell accompanied its growth. The interval from fertilization to the start of its benthic life was estimated at three weeks.

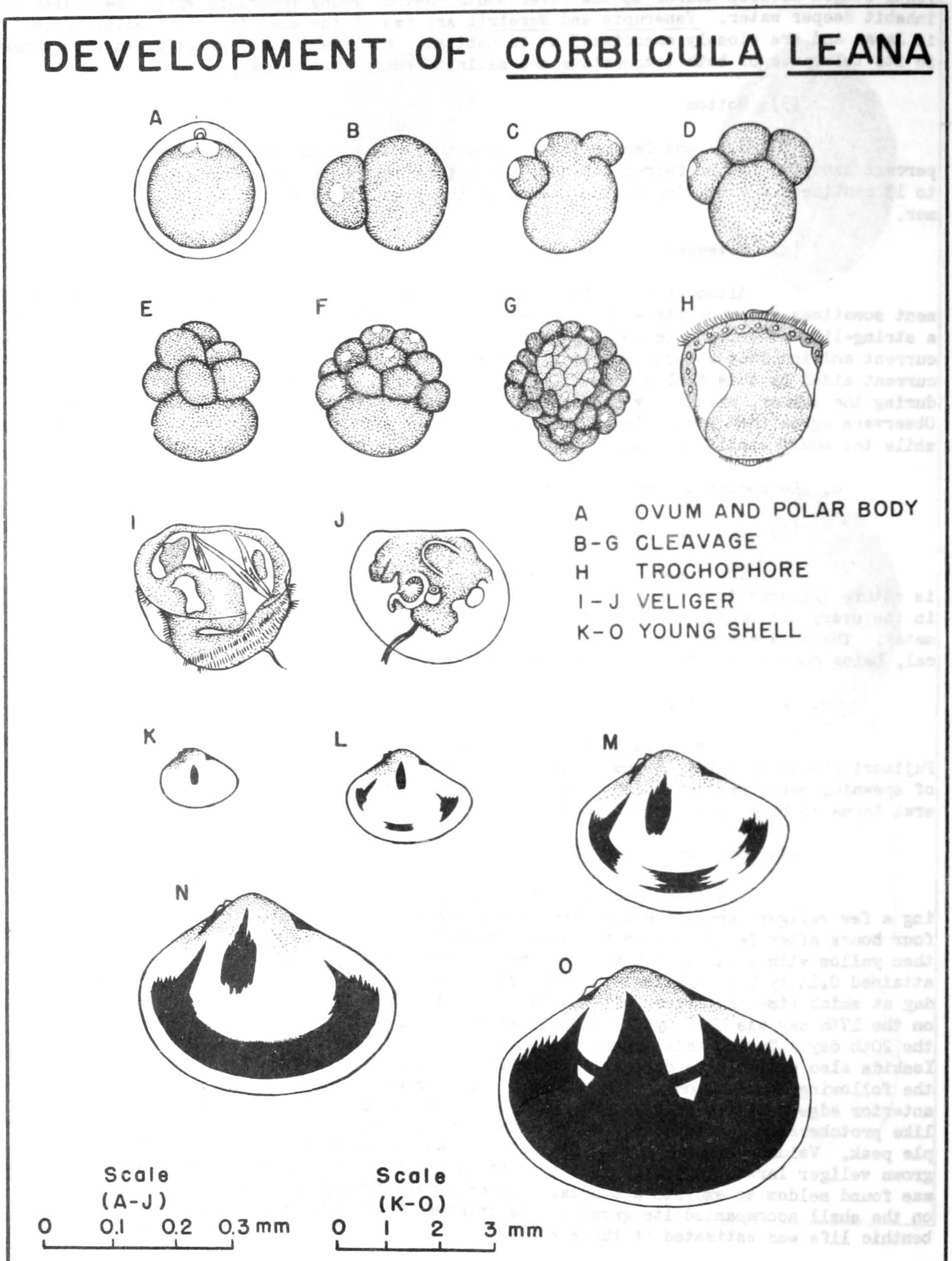

DEVELOPMENT OF CORBICULA LEANA
A
B
C
D
E
F
G
H
I
J
A OVUM AND POLAR BODY
B-G CLEAVAGE
H TROCHOPHORE
I-J VELIGER
K-O YOUNG SHELL
K
L
M
N
O
Scale
(A-J)
0 0.1 0.2 0.3 mm
Scale
(K-O)
0 1 2 3 mm

Figure 9

(4) Growth

The growth of Meretrix as found on culture grounds by Higurashi (1937) was as follows: length, one year, 2.0 centimeters; two years, 4.5 centimeters; three years, 5.0 centimeters. After three years the growth rate is very slow until a maximum size of about nine centimeters may eventually be attained at an unknown age. The growth rate of this species after planting on the culture ground in Chiba Prefecture (Table 2) shows that growth stops during the winter when the water temperature falls below 10°C and gradually increases as the temperature rises.

e. Culture

(1) Culture Method

In Chiba Prefecture practically all of the clam production results from artificially planted areas. The young clams used for seed measure two or three millimeters in length and are collected in a basket-type dredge having a lining of fine wire mesh which separates the tiny clams from the sifted sand. These seed clams are obtained only in shallow water near mouths of rivers because the low salinity and abundant food supply produces better sets in such places. The baby clams are taken by boat to the culture grounds, which are the deeper water regions of river mouths or between the deltas built by rivers; here they are spread over the bottom. According to Higurashi (1934) 0.6 to 3.6 liters of seed clams are used to plant one square meter of suitable bottom, and the planting is done during April and May or in October.

According to evidence from the Fukuoka Fisheries Experimental Station, the survival at the time of harvest is 25-35 percent of the number of clams planted.

The young clams bury themselves almost at once and are then left to grow in their new habitat for from one to two years. When the clams have attained a marketable size of five to six centimeters in length, the beds are dredged and the clams removed and sold. The weight of a marketed clam is about three times the weight of a seed clam planted two years before.

(2) Harvesting Method and Gear

As Meretrix and Venerupis are found together on the same beds and are harvested together, the same gear is used for both species. This gear has already been described in the discussion of Venerupis.

f. Enemies and Damage

The only serious enemy which Meretrix has in the Japanese waters is the large drill Rapana thomasiana (Figure 7) which may do considerable damage to young clams. Damage by ducks in winter is very slight because the seed generally is planted in May, after the spring migration from the area has taken place.

Among the elements, wind, waves, and flood are natural enemies of the species. Occasionally mud carried by flooded streams suffocates the clams, but the damage is generally less than that done to Venerupis because the ballooning" habits of Meretrix permit at least a limited degree of escape.

g. Utilization

Products (Table 1) include the following items:

Dried Hard Clam: The soft body is taken out of the shell, washed, and dried in the sunshine. Often they are impaled in a series on small bamboo spits and sold while still spitted.

Boiled and Dried Hard Clam: The clam is boiled in salt water until the shell opens. The soft body is then removed from the shell, washed, and dried in the sunshine.

Boiled and Seasoned Hard Clam ("Shigure"): The soft body is removed from the shell, washed, and boiled in fresh water flavored by ginger for one minute. It is then further seasoned by boiling in seasoning fluid for 15 minutes. Sugar, salt, soy, and sweet wine are used as condiments.

Canned Thick Soup: The liquid which remains after the Shigure hard clam has been boiled is cooked and then canned.

By-Product Clam Ash: The empty shells are piled in an oven and heated.

In olden times a game called "Kaiohi" involving shells of Meretrix meretrix lusoria was very popular among ladies of the "higher" classes. A pair of gold-lacquered octagonal boxes called "Kaioke" contained respectively the separated right and left valves of 360 Meretrix, the number symbolizing the days of the year. The inner surface of each valve was decorated with a beautifully painted picture; the same picture appeared on both valves of one shell but was not duplicated on any other shell.

When the game began the person in charge opened the box containing the left valves, removed 12 valves, and arranged them in a circle. Around this she arranged a second circle of 19 shells, continuing the circles with 26, 32, 40, 47, 55, 61, and 68 shells each, to complete the total of 360 shells. The nine circles represented the belief held by the Japanese astronomers that heaven consisted of nine layers, one above the other. All shells were placed with the pictured surface hidden, face down against the floor.

The players then took their places around the outer circle, and the keeper of the boxes took from the second box a single right valve which she placed face down in the center of the inner circle. Then each player in turn tried to match this lone shell. As all pictures were concealed the players could guide their judgment only by minor variations in the shape, size, or color markings of the valves. When a player succeeded in matching two valves, another right valve was brought out to be matched. The lady gaining the most matched shells won the game. As etiquette demanded modest decorum both in manner and in speech, the game was considered to be highly moral and very genteel. Up to the time of the Meiji Restoration these boxes and clam shells were considered essential articles that the bride of the higher social classes must take with her to her husband's home.

h. Regulations

The closed season and size limit set by the various prefectures for this species are shown in Table 3.

3. Fulvia mutica (Reeve)
Japanese name: Torigai

a. Synonomy

1844 Cardium muticum Reeve, Conch Icon, sp 32
1860 Cardium japonicum Dunker, Mal Blatt; 6:233
1861 Dunker, Moll Japan: 28; pl 3, fig 16
1904 Cardium anae Pilsbry, Proc Acad Nat Sci Phila; 56: 557; pl 40, fig 20 (immature)

b. Characteristics and Distribution

Shell considerably inflated and rather thin. Surface almost smooth but with 46-47 fine radiating ridges. Umbo smooth. External color yellowish-white, grading into pale pink at the umbo. Ligament short. Color of the inner surface reddish, gradually becoming deeper in tone toward the margin. Cardinal and lateral tooth one respectively. Average length 95 millimeters, height 95 millimeters, and breadth 63 millimeters (Figure 10).

This species is distributed from northeastern Honshu southward to Kyushu and southern Korea (Frontispiece). Ise-wan and Osaka-wan are notable regions for the production of this species.

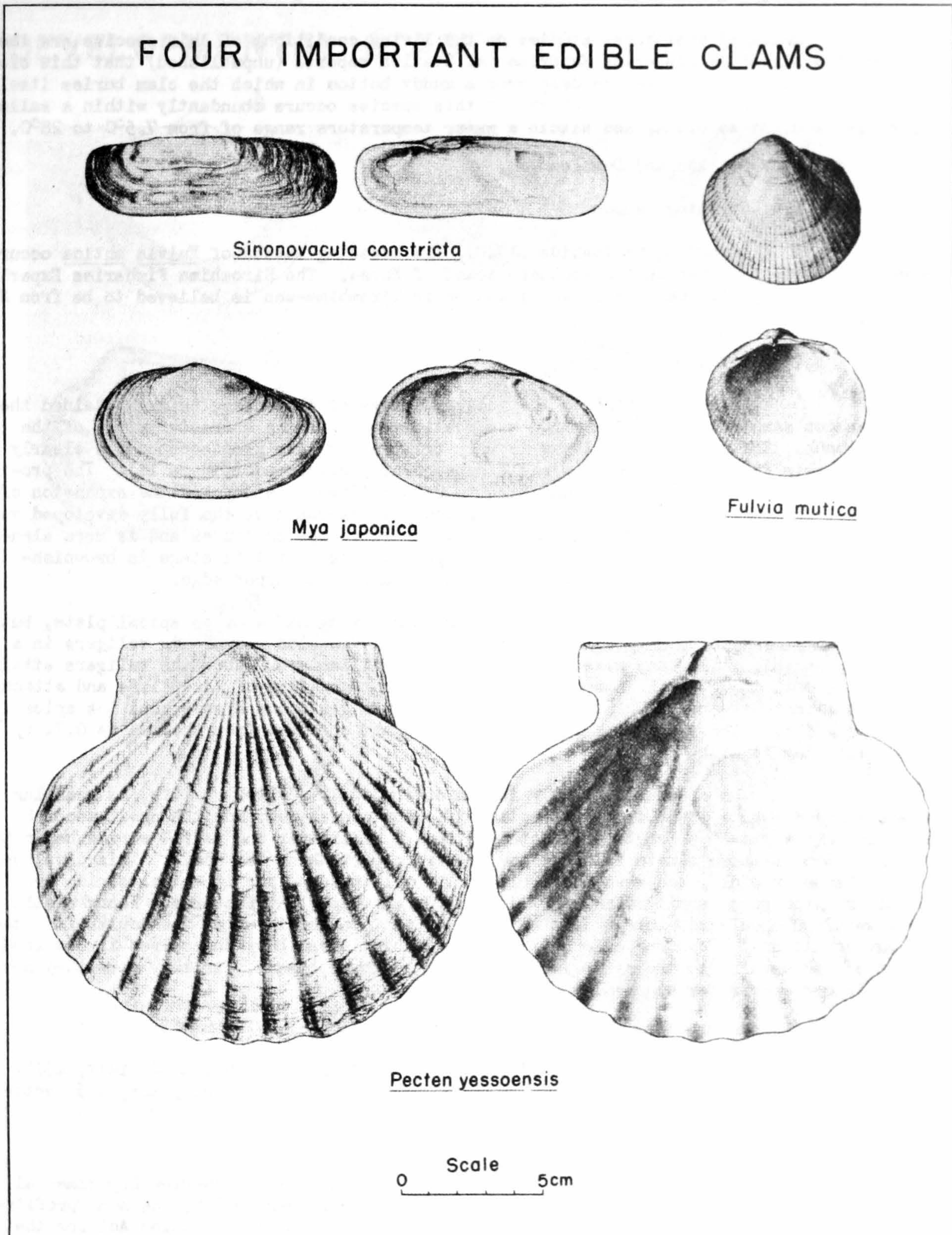

FOUR IMPORTANT EDIBLE CLAMS
Sinonovacula constricta
Fulvia mutica
Mya japonica
Pecten yessoensis
Scale
0
5cm

Figure 10

c. Living Conditions

Detailed ecological studies on the living conditions of this species are lacking, but the Hiroshima Fisheries Experimental Station reports (unpublished) that this clam prefers water from 6 to 40 meters deep over a muddy bottom in which the clam buries itself 5 to 15 centimeters deep. In Hiroshima-wan this species occurs abundantly within a salinity range of 0.015 to 0.024, and within a water temperature range of from 7.5°C to 28°C.

d. Reproduction and Development

(1) Spawning Season

According to Yoshida (1940), the breeding season of Fulvia mutica occurs between June and November on the southern coast of Korea. The Hiroshima Fisheries Experimental Station reports that the spawning season in Hiroshima-wan is believed to be from May to October.

(2) Development

Yoshida identified the veliger larvae of this clam, having obtained them from plankton samples. Indentification was possible through the characteristics of the prodissoconch. The shell of the larva is very brittle, and its prodissoconch is clearly distinguishable from the rest of the shell subsequently developed (Figure 11). The prodissoconch is 0.26 millimeter long and 0.24 to 0.29 millimeter wide, and the expansion of the umbonal region is notable. The length of the prodissoconch of the fully developed veliger larva is greater than its height, and the anterior edge protrudes and is more slender than the posterior edge. The color of the prodissoconch at this stage is brownish-yellow, with purple only at the umbonal portion and along the upper edge.

The fully grown veligers swim normally by means of an apical plate, but sometimes they crawl around by means of the tiny foot. Yoshida reared his veligers in a glass jar, at which time they measured 1.31 by 1.06 millimeters. When the veligers attain a length of 0.25 to 0.27 millimeter, they begin the bottom stage of their life and attach to the wall or to the bottom of the jar by means of the glutinous byssus, and the apical plate disappears. The smallest young shell Yoshida has obtained from the sea is 0.74 by 0.68 millimeter in size.

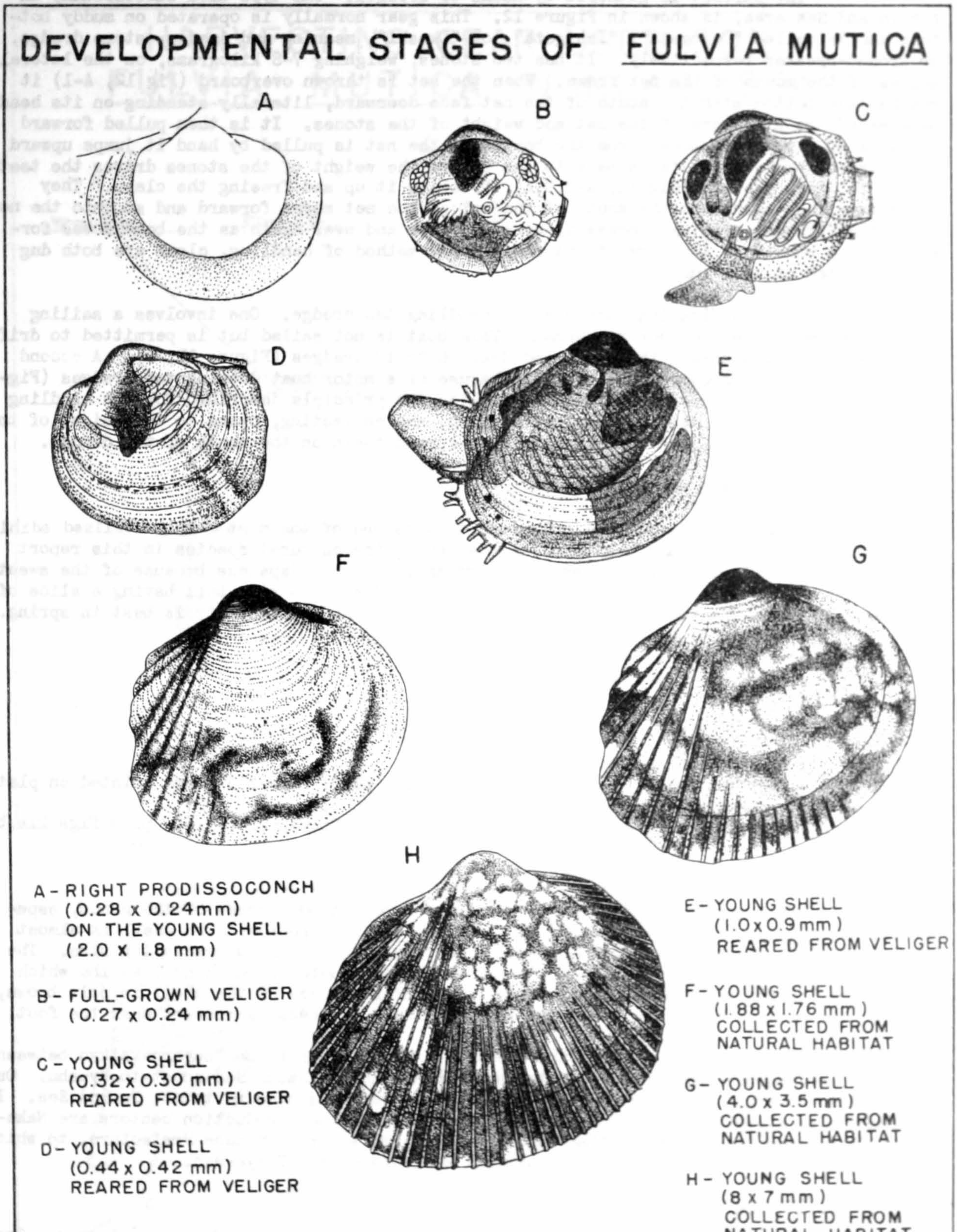
The dissoconch, newly formed during the early bottom life, is granular on the surface, which gives it a distinctly different appearance from the prodissoconch. When the larvae attain a length of about 0.75 to 1.0 millimeter the radial striae begin to appear as two or three minute folds at the posterior portion of the shell. This development continues rapidly, and when the shell is 8.0 millimeters long 46 radial striae are visible and the young shell resembles the adult in all important features. Young shells are always found on sandy bottom in shallow water, not on mud in which the adults find the optimum conditions. Yoshida believes that the benthic larvae bury themselves in the sand and attach themselves to the sand grains by means of their byssus. As they grow they move slowly into deeper water and seek a mud environment.

(3) Growth

The growth rate of Fulvia mutica to maturity (Fisheries Society, 1916, no locality given) is as follows: One year, height 0.8 centimeter; two years, 1.5 centimeters; three years (mature), 3.0 centimeters.

e. Harvest Method and Gear

According to the unpublished report of the Hiroshima Fisheries Experimental Station (1949b) the harvesting season extends from late December to May, the most profitable period being from January to March. The Hiroshima Prefecture Regulation Act for the protection of breeding marine animals prohibits harvesting of this clam from 1 August to 20 December, but in neighboring Yamaguchi Prefecture no regulations of any kind are in effect.



NATURAL RESOURCES SECTION **Figure 11**

The harvest is gathered by means of dredges. One type used successfully in the Inland Sea area, is shown in Figure 12. This gear normally is operated on muddy bottoms and is called "Dorogeta", "Ishigeta", or "Okoshi", meaning mud dredge, stone dredge, or ground-breaker respectively. It has two stones, weighing 7-8 kilograms, on the lateral angles of the mouth of the net frame. When the net is thrown overboard (Fig 12, A-1) it reaches the bottom with the mouth of the net face downward, literally standing on its head because of the structure of the net and weight of the stones. It is then pulled forward by means of a rope stretched from the boat. If the net is pulled by hand it jumps upward and forward, and when it falls back to the bottom the weight of the stones drives the teeth of the net into the mud (Fig 12, A-2,3,4), breaking it up and freeing the clams. They slide over the teeth into the mouth of the net as the net moves forward and so into the net bag. This jumping-digging process is repeated over and over again as the boat moves forward. As a result of the form of the net and the method of handling, clams are both dug and collected at each jump.

Two modifications are used in handling the dredge. One involves a sailing trawler manned by two to four fishermen. This boat is not sailed but is permitted to drift sideways, broadside toward the wind, and drags 6 to 10 dredges (Figure 12, B). A second modification, much more recent, involves the use of a motor boat drawing two dredges (Figure 12, C). Both of these modifications utilize the principle described for the handling of the single dredge: that of jumping, digging, and collecting, owing to the weight of the stones, their position, and the slightly down-curved teeth on the mouth of the dredge.

f. Production and Utilization

Although not actually cultured, this is one of the most widely utilized edible clams of Japan (Table 1) and has been included among the cultured species in this report for that reason. It is often called the "bird shell" by the Japanese because of the sweetness of its meat. The fresh meat is used in making "Sushi", a rice ball having a slice of clam meat on top. The meat also is dried and canned. The palatability is best in spring.

4. Anadara (Scapharca) subcrenata (Lischke)
Japanese name: Sarubo, Mirokugai, Mogai

a. Synonomy

1869 Arca subcrenata Lischke, Mal Blatt, 16: 107
1869 Arca subcrenata Lischke, Jap Meer Conch 1: 146, pl 9, figs 1-3 (Name Printed on plate as "nodosocrenata")
1906 Arca kagoshimensis Tokunaga, Jour Coll Sci Imp Univ Tokyo, 21 (2):59, pl 3, figs 21a,b

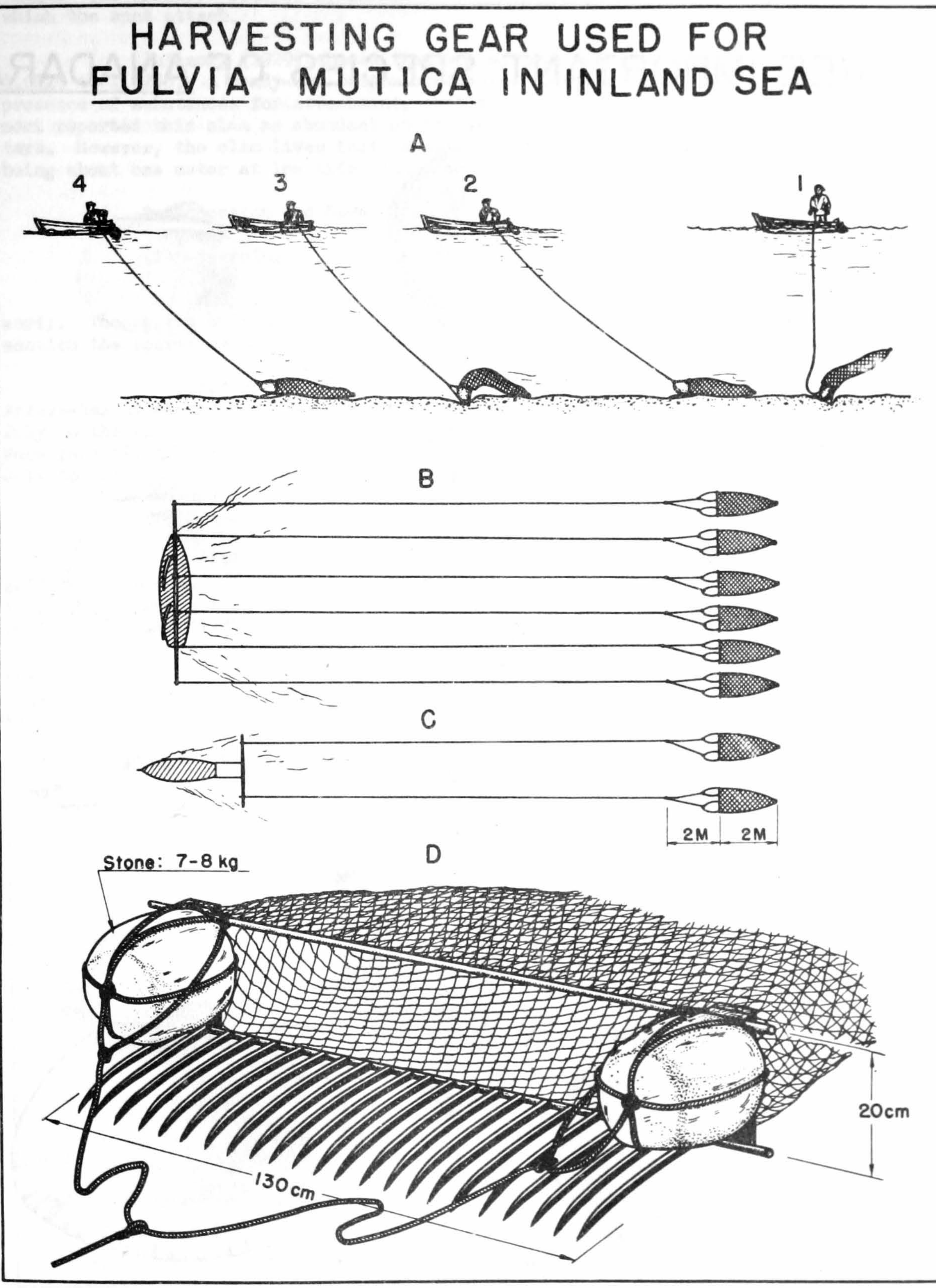
b. Characteristics and Distribution

This species bears a close resemblance to allied species of the genus, especially to Anadara granosa bisenensis and A. broughtoni (Figure 13). The shell is almost oval, inflated in shape, thick, and robust. Each valve has 32 or 33 radiating ribs. The left valve is slightly larger than the right and bears minute granules on the ribs which are lacking on the ribs of the right valve. The outer surface of the shell is pale brown, covered with coarse hair; the inner surface is white. A byssus is present near the foot.

The northern limit of the species in Japan seems to be Tsugaru-kaikyo between Hokkaido and Honshu. From here it extends southward on the Japan Sea coast to Kyushu. On the Pacific coast it is distributed from Miyagi Prefecture southward to the Inland Sea. It is found also along the entire coast of Korea. The principal production centers are Nakanoumi in Shimane Prefecture, Kojima-wan in Okayama Prefecture, Shimane Prefecture, to which it was introduced first Ariake-kai along Saga Prefecture, and Tokyo-wan.

c. Living Conditions

This clam inhabits brackish water which is usually abundant in eel grass, Zostera marina, and in this respect resembles Anadara granosa bisenensis. The Japanese name



NATURAL RESOURCES SECTION

Figure 12

THREE IMPORTANT SPECIES OF ANADARA

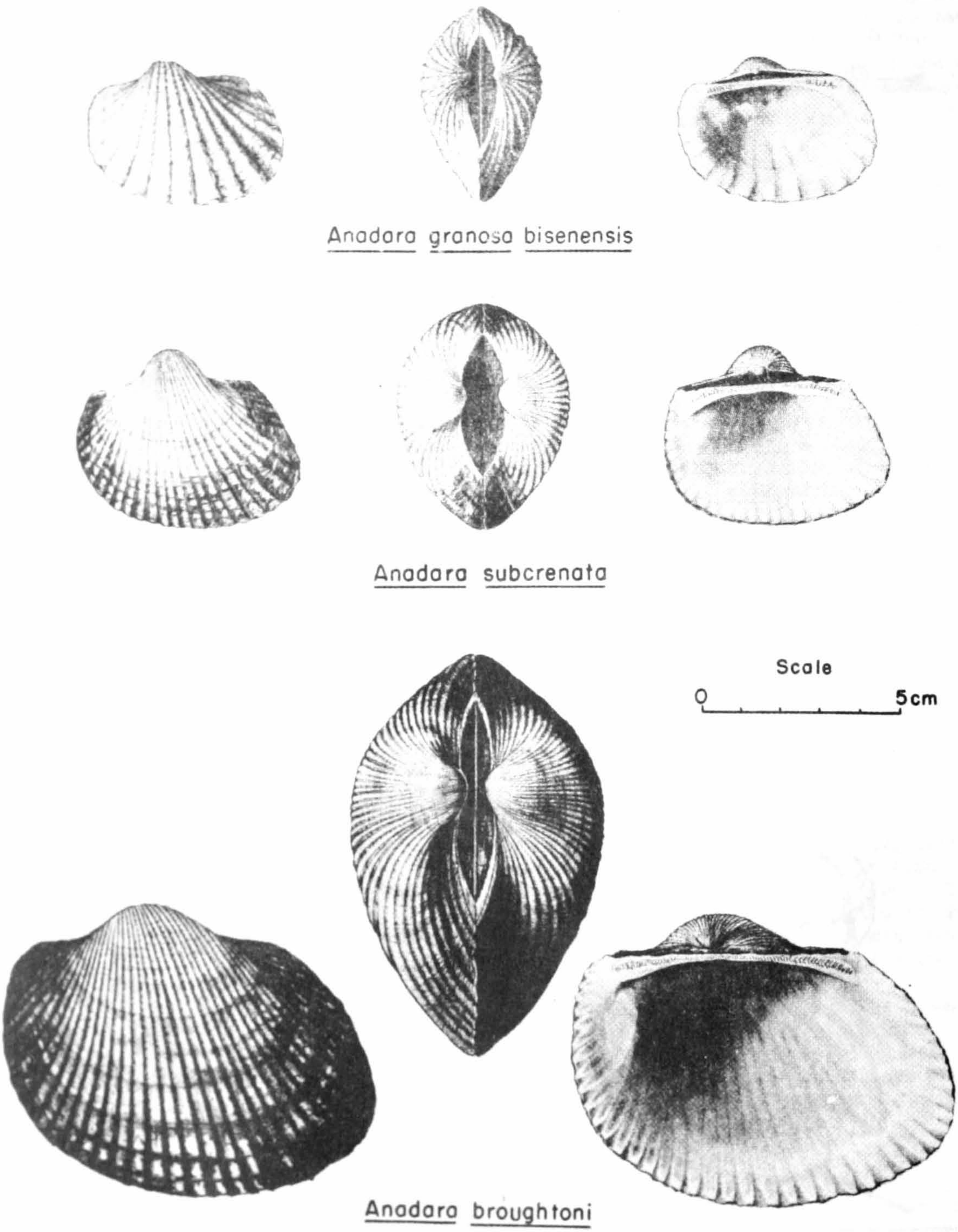


Figure 13

"Mogai" (literally, "seaweed shellfish") is due to this association with eel grass, to which the spat attach.

Fujimori (1929) showed that the optimum specific gravity for the species is 1.0220 to 1.0235. A sandy-mud bottom containing 50-80 percent sand is perferred, and the presence of substances for attachment, such as seaweed or dead shells, is essential. Fujimori reported this clam as abundant on the Ariake-kai tidal flats ranging from 0 to 2 meters. However, the clam lives best in water from 4 to 20 meters, the shallow water limit being about one meter at low tide (Icho and Oshima 1938).

d. Reproduction and Development

(1) Spawning

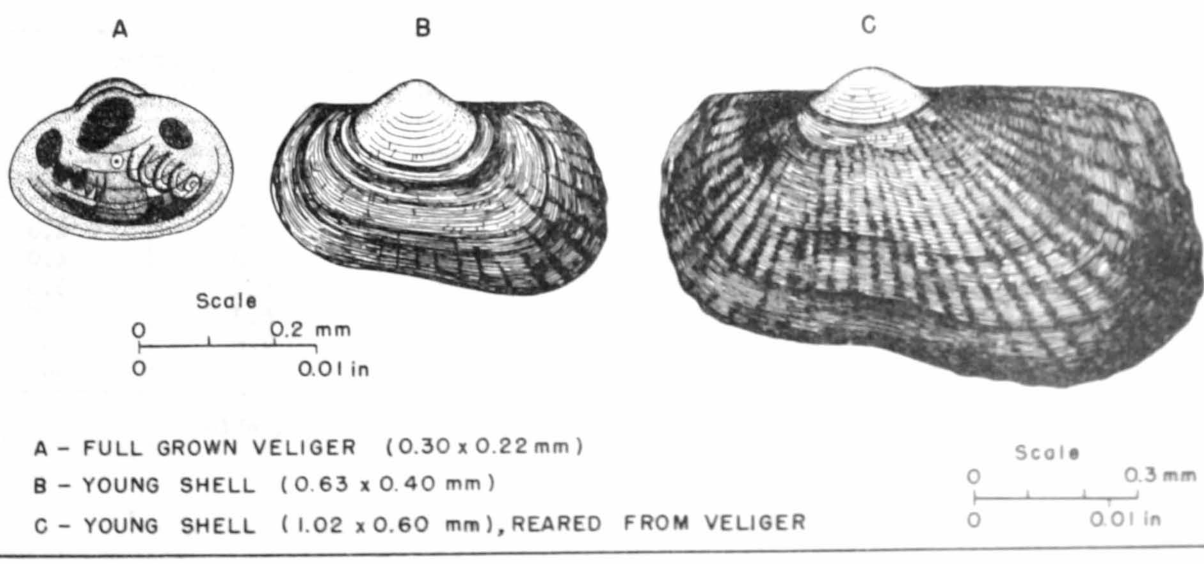
When mature the ovary is reddish in color, the testis yellowish (Fujimori). The egg is 0.05 millimeter in diameter (Higurashi 1934). The literature does not mention the spermatozoa.

Fujimori (1929) first reported the spawning season, saying that in the Ariake-kai it occurred between early July and early October, with the peak from the end of July to the end of August. At this time the water temperature ranged from 22.0°C to 28.5°C. More recently Icho and Oshima (1938) and Ozaki (1942) reported the breeding season as from July to September. Higurashi (1934) described it as from August to September.

(2) Development

Following fertilization the zygote sinks to the bottom and attaches itself to the seaweed or to other objects by its byssus. They separate themselves from this temporary attachment about one year after hatching and bury themselves in the mud of the bottom. Yoshida (1937) traced the development of the species and identified the veliger by tracing back the prodissoconch on the umbonal portion of the young shell. He collected samples by plankton net at Nakanoumi, Shimane Prefecture, which is a breeding ground of this species. In raising the larvae no special food was added to the aquarium. The smallest veliger traced was 0.11 by 0.09 millimeter. The fully grown veliger measured from 0.28 x 0.20 to 0.30 x 0.22 millimeter (Figure 14). Yellow in color, it had a few bristles and about 10 nearly concentric lines on its surface. In the laboratory it swam by means of its

DEVELOPMENTAL STAGES OF ANADARA SUBCRENATA



A - FULL GROWN VELIGER (0.30 x 0.22 mm)
B - YOUNG SHELL (0.63 x 0.40 mm)
C - YOUNG SHELL (1.02 x 0.60 mm), REARED FROM VELIGER

NATURAL RESOURCES SECTION Figure 14

apical apparatus or crawled by using its foot, or sometimes attached to the bottom material by its byssus. The apical plate gradually disappeared, and the larva began its benthic life attached to the bottom by its byssus and seldom crawled around. The dimensions at this state were about 0.28 x 0.20 to 0.32 x 0.22 millimeter. The veliger larva of A. subcrenata resembles that of the closely related A. broughtoni but can be distinguished by its sharper umbo, smaller number of concentric lines, and larger size. The new dissoconch which is formed after the larva has entered into its benthic existence is gray in color and distinct from the prodissoconch. When the young shell attained a length of about one millimeter, the radiating striae numbered about 30 and the shell acquired the main characteristics of the adult. Young shells are found attached to seaweeds, Bryozoans, dead shells, and other available objects by means of the byssus until they enter their benthic life and bury themselves in the mud.

(3) Growth

The growth rate of cultured Anadara subcrenata in the first eight months after sowing was determined at the Okayama Fisheries Experimental Station (Table C). The later development of the clam (Table D) was determined by the Fukuoka Fisheries Experimental Station. In a comparison of Tables C and D, the six months' difference in the sowing period should be noted.

Fujimori (1929) and Higurashi (1934) described the growth rate as shown in Table E. Fujimori reported the length of life at about eight or nine years with a maximum size of 8.3 centimeters in length and 6.2 centimeters in height (Figure 4).

TABLE C. - GROWTH OF ANADARA SUBCRENATA DURING FIRST EIGHT MONTHS (centimeters)

Date	Average Length	Average Height
20 Apr a/	1.30	1.20
14 Jun	1.60	1.40
14 Aug	2.58	2.18
22 Oct	3.24	2.64
14 Dec	3.30	2.65

a/ Date of sowing
SOURCE: Higurashi et al (1937)

TABLE D. - LATER GROWTH OF ANDARA SUBCRENATA

Date	Months After Sowing	Shell Length (cm)	Shell Weight (grams)
Oct 1912	0	3.53	6.8
May 1913	7	3.80	10.9
Feb 1914	15	5.08	26.6
Mar 1915	28	5.84	41.6

SOURCE: Higurashi et al (1937)

TABLE E. - ADULT GROWTH RATE OF ANADARA SUBCRENATA

Age (years)	Length (cm)	
	Fujimori	Higurashi
1	2.0	2.8
2	3.8	4.0
3	5.4	5.0
4	6.3	6.0
5	7.6	ND
6	8.3	ND

ND: No data available

e. Culture

(1) Culture Methods

The culturing on this clam is limited to seed collecting and transplanting, Nakanoumi in Shimane Prefecture being the center of the seed collecting activity. Here about 12,000 hectares of tidelands in Miho-wan are utilized for that purpose. This bay is connected to the sea by a narrow mouth and has an almost flat bottom covered by water up to eight meters deep, affording an ideal environment for the clams. The bottom is a gray-green mud about 1.5 meters deep, overlaid by a yellow-brown stratum composed mostly of decayed vegetation 6 to 16 centimeters thick.

Experimenting with planting seed of A. subcrenata, Higurashi (1937) recommended that 3 to 8 sho of seed having a length of 2.0-2.5 centimeters be planted per tsubo. This idea was modified by Oshima (1938) who recommended that from 500 to 600 sho of seed 6 to 9 millimeters in length be planted at the rate of 2.3 sho per tsubo. He obtained better results by planting more of the smaller seed clams. The planting season is August and September. Because of the difficulty involved owing to the depth of the water, neither experimenter gives figures as to the yield per unit area derived from their respective methods of planting; as A. subcrenata is not a shallow water species like A. granosa bisenensis making an accurate count within definitely known boundaries proved impossible.

Working on the problem of raising A. subcrenata in Okayama Prefecture on the Inland Sea, Icho and Oshima (1938) encountered areas heavily overgrown by seaweed which were in other respects good grounds for the species. Using a German aquatic weed-cutting machine mounted in a flat-bottomed boat, they mowed a portion of the area, cutting the seaweeds flush with the bottom. They then planted areas of three different types with seed of the clam, using the same number of seed per unit area in each type of environment. They found that the growth of A. subcrenata was poorest in the nondisturbed weed area, and best in the area free of seaweed. They also found that the mowing of the dense weeds greatly improved the growth rate, presumably by permitting a freer flow of current and the consequent increase of available food for the clams. The clams averaged 1.48 centimeters in length when sown in April. By mid-October, their average lengths in the three environments were: no seaweed, 2.67 centimeters; mowed seaweed, 2.47 centimeters; heavy seaweed, 2.27 centimeters.

(2) Harvest Method and Gear

Freshly planted areas are left undisturbed by immediate harvesting operations which reach their peak in April and May. The dredge used is "Mogaikaki" ("seaweed shellfish dredge") which is a slight modification of the koshimaki or hand dredge. The mouth of the dredge is triangular with a wooden framework of beams 0.8 meter long at each side and an iron beam armed with 25 teeth 18 centimeters long at the bottom. To this framework is bitted the net, and from the framework a wooden handle 8 to 10 meters long extends directly upward. The net is made of hemp string, with a mesh of 1.7 centimeters.

Two fishermen man the boat on the fishing grounds. One pushes the boat backward by means of a long bamboo pole, and the other works the net, keeping the teeth of the net in the bottom mud and regulating the depth of digging by means of his handle. As the boat is poled along the man in the stern who handles the dredge works it from side to side and forward, scooping up the clams as slow forward progress is made.

f. Enemies and Damage

As this clam inhabits relatively deep water (deeper than that in which A. granosa bisenensis is found) the damage by elements-- cold, heat, and flood--is relatively unimportant.

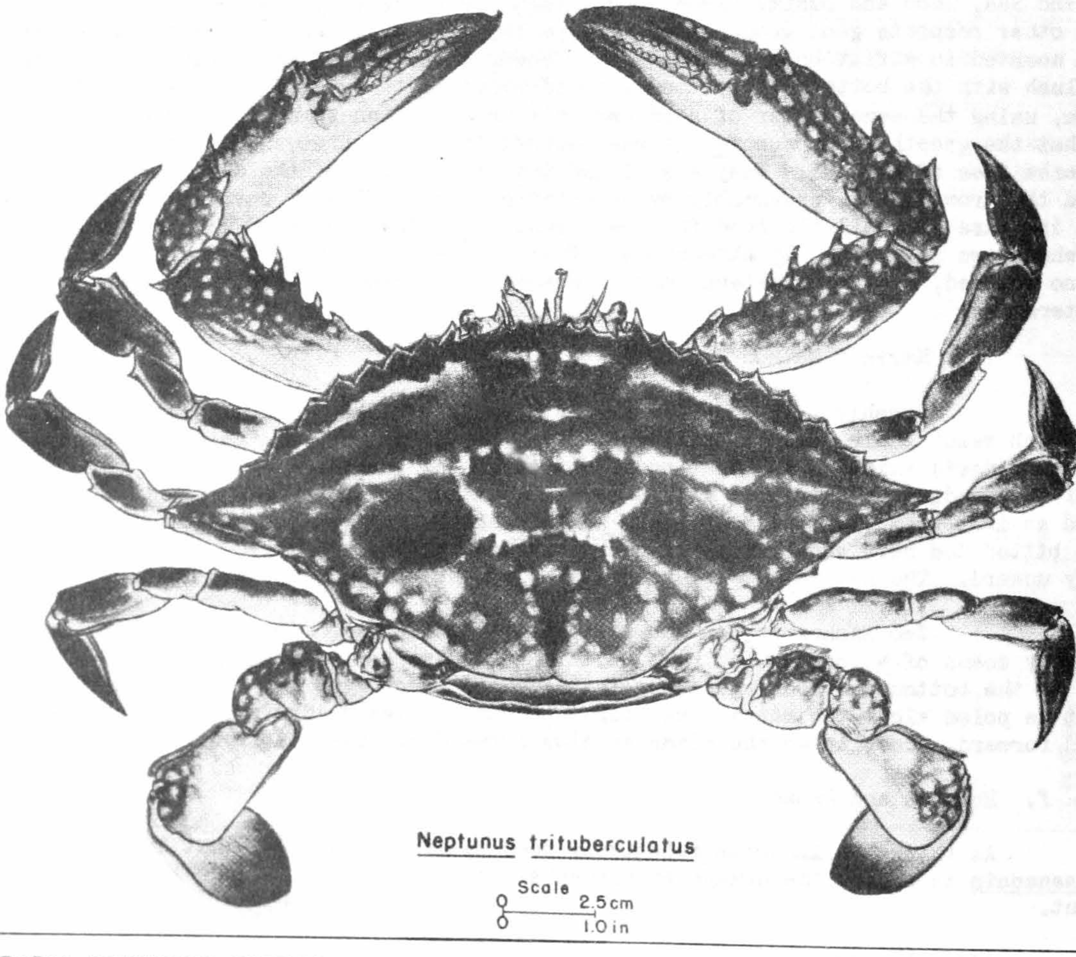
Among the animals which prey upon A. subcrenata can be listed ducks, octopus, crabs, and drills.

Among the ducks, the "Magamo" (Anas platyrhynchos platyrhynchos) and "Kikurohajiro" (Aythia fuligula) are the most important predators, causing damage from early December to late March in Okayama Prefecture. They feed at night, and in the shallower portions of the waters where this species is found the ducks can prey upon the mollusks without reference to tidal conditions. Investigation has shown that each duck consumes an average of one go of young clams per day. Once the ducks find the clam area they become regular visitors.

Both the common octopus ("Madako", Polypus vulgaris) and the smaller "Iidako" (P. fang-siao) prey upon the clams from late March to late October. The blue crab (Neptunus trituberculatus) (Figure 15) becomes an enemy during the late autumn, feeding on the smaller shells, most of them newly seeded. Protection against the crabs is afforded by spreading a net around the culture grounds.

The gastropod drill Rapana thomasiana attacks from late March to late October. Another snail, Natica maculosa, does most of its damage during the rainy season. Yet another harmful mollusk is the bivalve Brachydontes senhausii (Figure 7), which suffocates the clam by secreting a thick mass of byssus over the bottom.

CRUSTACEAN ENEMY OF CLAM CULTURE



NATURAL RESOURCES SECTION

Figure 15

g. Utilization

This clam commonly is sold fresh and alive in the markets throughout Japan, but the meat also is sold boiled and dried when removed from the shell. Drying is always accomplished by hanging or spreading the meat in the sun.

5. Anadara granosa bisenensis Schenck & Reinhart
Japanese name: Haigai, Fukurogai, Mogai, Chinmi, Unegai

a. Synonomy

1938 Anadara granosa bisenensis Schenck & Reinhart, Mem Mus Roy Hist Nat Belgique, (2) 14: 44; pl 4, fig 2; pl 5, fig 1

According to Dr Kuroda this Anadara may be retained as a local race of granosa from which the present form is probably transitional.9/

b. Characteristics and Distribution

Similar to A. subcrenata but bears 16-17 nodular radiating ridges. Ligamental area very wide and rhombic in shape. Both umbones swollen and widely separated. The folds on the ventral margin of the valves are comparatively strong (Figure 13).

This clam is distributed in southwestern Japan, the important culture grounds being Kojima-wan in Okayama Prefecture and Ariake-kai in Kyushu. It is living today also in Ise-wan. It has been identified from kitchen middens in northern Honshu (Groot, 1951).

c. Living Conditions

This clam prefers warm water and inhabits areas where the water is calm and approximately two to four meters deep. It buries itself about 26 centimeters in a muddy bottom. Incoming fresh water is desirable. Optimum conditions for larval occurrence are a lack of algae, exposure of the ground at low tide, an admixture of fresh water, and the bottom matrix composed of mud at least 0.3 meter thick. Growth is most rapid in sheltered bays having entering fresh water and a good tidal current, where the water is 2.5-3 meters deep at high tide but exposed at low, and where specific gravity is 1.008 to 1.014. A mud superstratum at least 1.5 to 2.0 meters thick is desirable (Icho and Oshima 1938).

d. Reproduction and Development

(1) Spawning

Almost nothing is found in Japanese literature regarding the life history of this clam. Higurashi (1934) states that the eggs have a diameter of 0.09 millimeter and that the gonad of the male is pale yellow while that of the female is pale red. Icho and Oshima (1938) give the spawning period as covering July to September.

(2) Growth

One-year-old clams have a length of 0.5 centimeter. Growth continues as follows: two years old 2.0 centimeters; three years old 3.0; four years old 4.2; five years old 4.7; six years old 5.3. The maximum life span is said to be about 10 years, and the greatest length attained is about seven centimeters (Kojima Shell Culture, Ltd, 1903).

e. Culture

(1) History of Kojima-wan Culture

For many years naturally grown A. granosa bisenensis have been harvested in Kojima-wan, Okayama Prefecture. It was in 1859 that Ichisaburo and Yoshisaburo Maeda

9/ For a full synonomy of some 60 titles see Prashad, B. (1932) Siboga Expedition Lamellibranchia.

tried to rear this clam for the first time, following the general plan used in oyster culture as practiced in the same bay. Their results were excellent from the start, and thereafter clam culture was undertaken by many people until in 1869 it developed into the principal business of the whole bay area. In 1873 Ichisaburo Maeda began exporting the cultured Anadara to China, and his success in this venture further promoted the development of the culture industry. But the rise of excessive competition among the clam culturists to sell to China, combined with the increasing difficulties of getting adequate seed clams to keep up the required supply, proved a serious handicap to the individual farmers. In 1885 Mototaro Fujiwara organized an association to control competition and to consolidate the industry, and in 1888 he organized the Kojima Shell Culture Co which had a complete monopoly on the clam production of Kojima-wan.

Since the early days of the Meiji Era (1868-1912) a program to fill in Kojima-wan had been under consideration. After numerous surveys the area was divided into regions and the work of filling was started in 1899. Despite repeated protests by the fishermen in the bay area the work of reclaiming the land went slowly but steadily forward. The Kojima Shell Culture Co fought the project consistently but at the same time worked intensively on the development of culture methods for A. granosa bisenensis. A. subcrenata from Shimane Prefecture and Sinonovacula constricta from Saga Prefecture were transplanted into Kojima-wan and their culture intensively undertaken.

However, difficulties soon began to appear. As the filling continued, not only were the culture grounds slowly reduced in area year after year, but those grounds which remained under cultivation were adversely affected by the nearby changes in environment. The tidal flow was reduced, and the deposition of mud began to prove an insurmountable handicap. The culture of A. granosa bisenensis in Kojima-wan should be finally abandoned in four or five years, according to the progress of the work. The progress of reclaiming the bay and the consequent reduction in area available for clam culture, according to the Inland Sea Fisheries Experimental Laboratory, 1950, was as follows: Region 1 (1899-1905) and Region 2 (1899-1912), 1,765 hectares; Regions 3 and 4 (1912-35), 1,215 hectares; Region 6 (1913-41), 925 hectares; Region 7 (1944-?), 1,650 hectares.

The culture activities in Kojima-wan consisted of two phases, the raising of seed clams and the culture of adult clams. Both were under the control of the Kojima Shell Culture Co, and the seed clams raised by one branch were purchased by the company for use of the second branch. The output of Kojima-wan in terms of seed produced and annual harvest is given in Table 4.

(2) Culture Methods

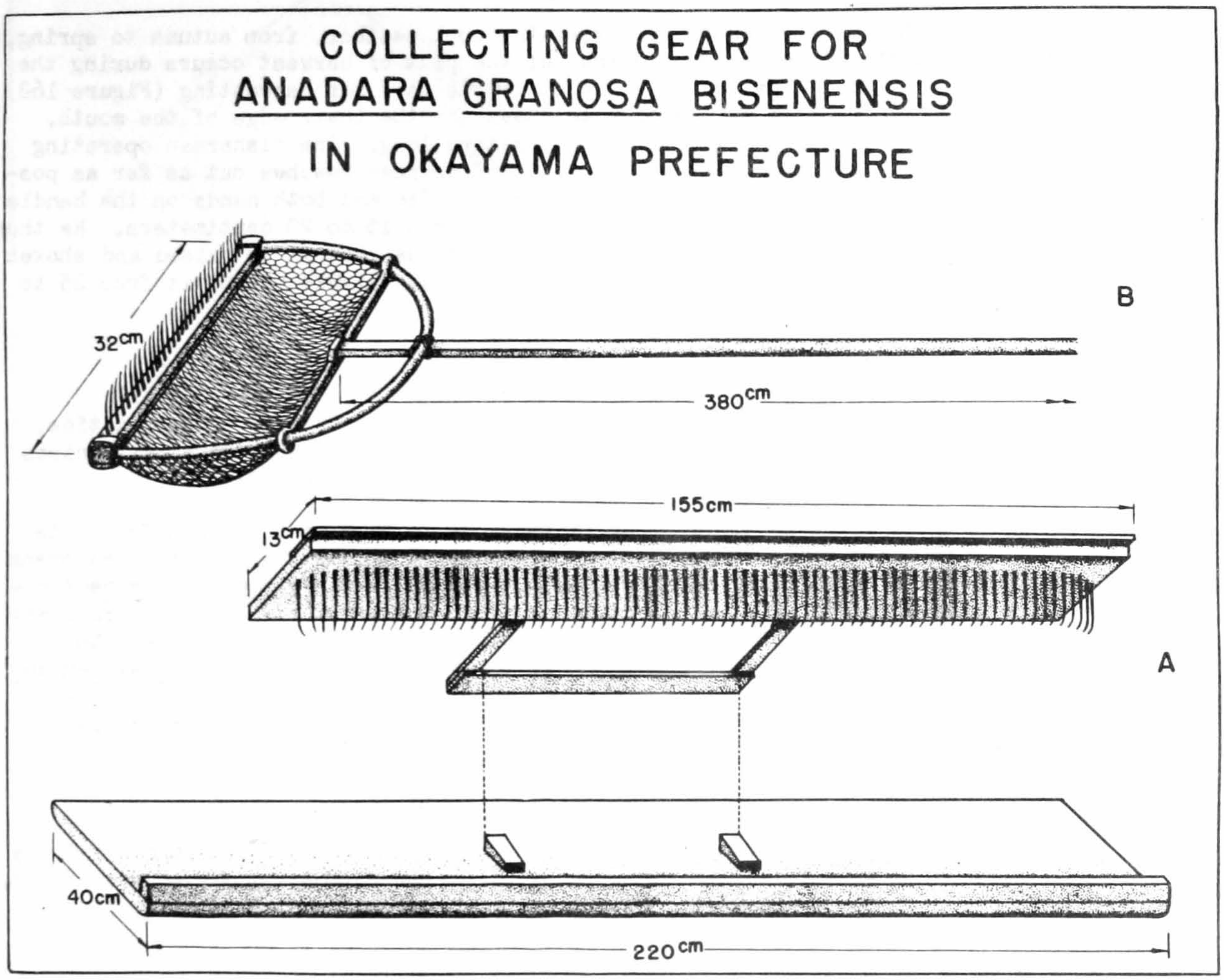
This Anadara is cultured only by the sowing method. Suitable culture conditions are described by Icho and Oshima (1938) as requiring an area free of algae, exposed at ebb tide, and having an admixture of fresh water and a soft bottom 15 to 30 centimeters in depth. The seed clams are collected during September and October, at which time they are approximately two months old and vary in size from 10,000 to 50,000 per sho. Approximately 2.1 koku of seed averaging 40,000 to 60,000 per sho are planted per tan. The relation between the size of the shells and the number per sho is as follows (Higurashi et al, 1937): shell length 6.6 millimeters, 40,000 per sho; 9.9 mm, 12,000 per sho; 19.8 mm, 1,000 per sho; 33.0 mm, 200 per sho; 46.2 mm, 120 per sho. The standard amount of seed to plant per tan in Kojima-wan varies with the size of the seed clams. This relationship is shown in Table F.

TABLE F. - SEED OF ANADARA GRANOSA BISENENSIS PLANTED (per tan)

Thousand per Sho	Sho Planted per Tan	Thousand per Sho	Sho Planted per Tan	Thousand per Sho	Sho Planted per Tan
80-100	110	9-20	300	1-3	1,200
60- 80	150	7- 9	600	0.8-1	1,350
40- 60	210	5- 7	750		
20- 40	240	3- 5	900		

SOURCE: Higurashi et al (1937)

When gathering seed clams the fishermen go to the seed culture grounds in small boats. While the tide is out the fishermen work on flat, wooden, ski-like sleds. Kneeling on the board, they push themselves along through the mud and shallow water with one foot (Figure 16A) and collect the seed clams by means of a short rake (Figure 16B). The gathered seed are placed in a bamboo basket on the front of the sled, and the mud and dirt removed from them by washing in sea water.



NATURAL RESOURCES SECTION

Figure 16

For sowing the seed on the culture grounds a flat-bottomed boat called "Hiratabune" is used. This is manned by three fishermen, one of whom poles the boat along slowly over the rearing bed while the other two men scatter the seed by means of a metal or wooden scoop, one operating on each side of the boat. Experienced sowers are able to plant rather accurately the amount of seed desired per unit area. They watch the environment carefully; if they encounter protected areas where the current is sluggish or areas of sand, they reduce the amount planted because growth will be slower owing to the less desirable conditions.

The seed is left as it falls during the first year. In the following spring the bed must be thinned according to the growth of the seed. This is done usually twice a year, in spring and fall, but if the crowding is not too dense it is undertaken only in the spring. A portion of the crop is removed and replanted in another bed. Thus the rearing ground gradually is increased in area. This method is called "Tokogae" (bed changing), "Makidashi" (sow out), or "Teire" (treatment).

When the clams reach a size equivalent to 300 per sho a final transplanting is undertaken, to somewhat deeper beds which are washed by a more rapid tidal current.

(3) Harvesting Method and Gear

The harvesting season is during the cool weather, from autumn to spring, but as the clams are most palatable in cold weather the peak of harvest occurs during the winter. A modified hand dredge called a "Mizuagetamo" is used for harvesting (Figure 16B). This woven metal basket net has a series of steel teeth at the lower edge of the mouth. The net is attached to a wooden handle four to six meters long. One fisherman operating a boat handles the gear. With the boat anchored, the fisherman reaches out as far as possible in setting the net. Placing the handle on his shoulder and both hands on the handle he forces the teeth to penetrate into the bottom matrix from 15 to 20 centimeters. He then works the net toward the boat. When the net is alongside the boat it is raised and shaken vigorously to wash out the mud and dirt. An average harvest by this method is from 25 to 40 liters of clams per hour.

f. Enemies and Damage

Among the environmental enemies of this species can be listed the red tide, floods, and excessive heat and cold. Floods result in lower salinity, severe heat raises both the temperature and the salinity, and cold produces a reverse effect.

Among the animal predators ducks, which come to feed on the clams from late autumn to early spring, are said to cause considerable loss. Among the fish the sea bream Sparus swinhonis and the Gobenoid fishes Taenioides rubicundus and Boleophthalmus pectinirostris, and the blue crab Neptunus trituberculatus prey upon the clams. If the sea bream become too abundant a gill net is spread around the culture area to exclude them. Molluscan enemies include the drill Rapana thomasiana, Natica maculosa, and Brachydontes senhausii. If abundant this latter mollusk interferes with the burying activities of the clam by spreading its threadlike byssus into the bottom matrix, making burrowing almost impossible.

g. Regulations

In Saga Prefecture the closed season is from 1 August to 30 September and the shell size is limited to animals larger than five bu. The regulations prohibit possession, sale, or collection of the species during the closed season.

6. Mactra sulcataria Reeve
Japanese name: Bakagai

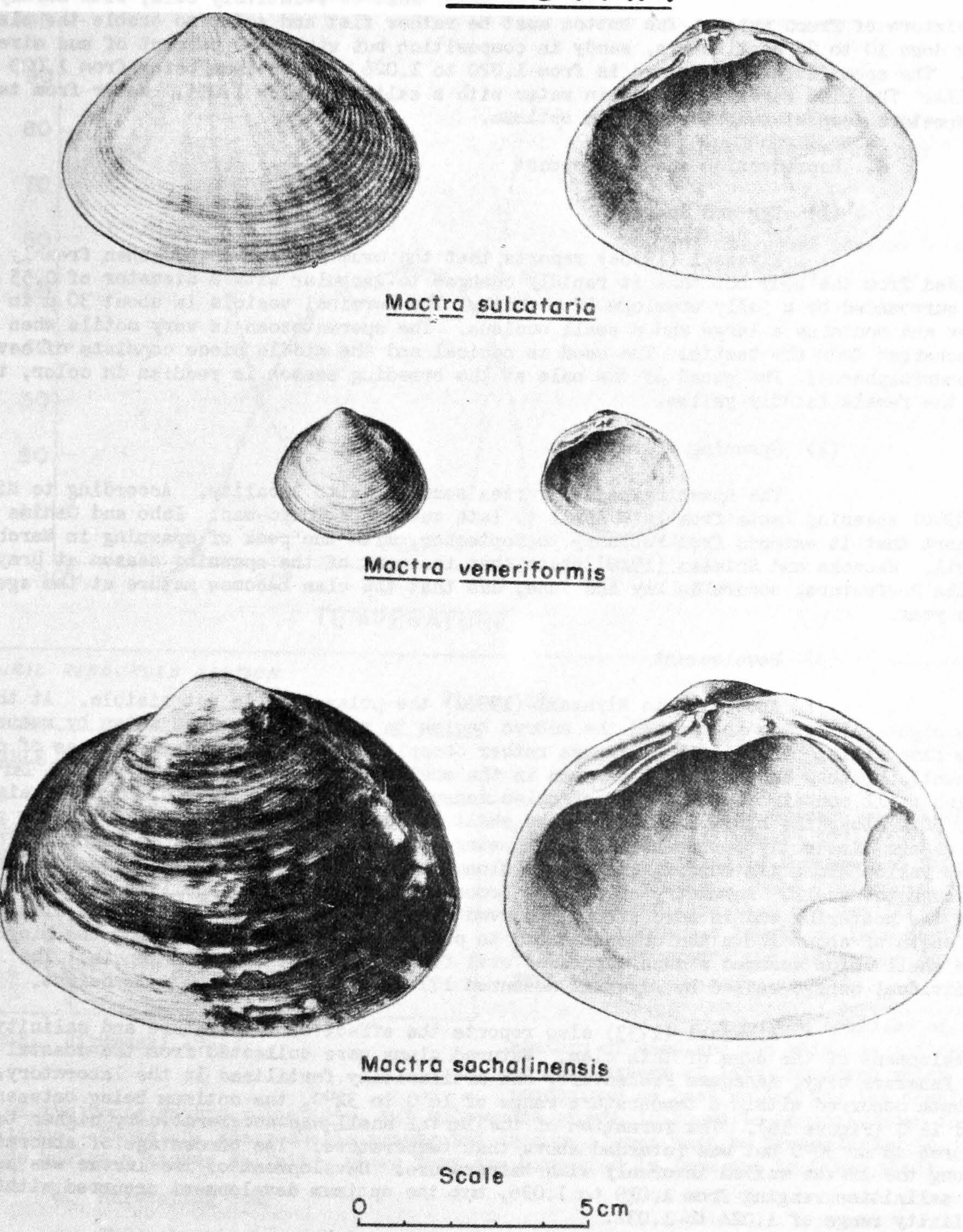
a. Synonomy

1854 (March) Mactra sulcataria Reeve, Conch Icon, sp 5
1854 (June) Mactra sulcataria Deshayes, Proc Zool Soc, 21 (1853)
1924 Tomlin, Jour Conch, 17: 153

b. Characteristics and Distribution

Shell very similar in form to that of Meretrix meretrix lusoria but more fragile, swollen, and considerably thinner. Concentric ridges gradually become clear near the ventral portion. Surface covered by a yellowish-brown periostracum. Several darker bands radiate from the umbo to the margin. Interior white, with a tinge of purple at the beak cavity and along the dorsal margin. Few lateral teeth, two on the right and one on the left side. Maximum size about 12.5 by 9.6 centimeters (Figure 17).

THREE IMPORTANT SPECIES OF MACTRA



NATURAL RESOURCES SECTION

Figure 17

The species is distributed abundantly in Tokyo-wan, Mikawa-wan, and in the Inland Sea but is uncommon in the Japan Sea. This distribution is shown in Frontispiece.

c. Living Conditions

Icho and Oshima (1938) have determined the environmental conditions needed for the suitable growth of this clam. The water must be relatively calm, with hardly any admixture of fresh water. The bottom must be rather flat and soft, to enable the clam to dig down 10 to 25 centimeters, sandy in composition but with 5-20 percent of mud mixed with it. The specific gravity range is from 1.020 to 1.026, the optimum being from 1.023 to 1.024. The clam rarely is found in water with a salinity below 1.015. Water from two to six meters deep at neap low tide is optimum.

d. Reproduction and Development

(1) Egg and Sperm

Miyazaki (1936a) reports that the ovum is pear-shaped when freshly extruded from the body but that it rapidly changes to globular with a diameter of 0.55 µ. It is surrounded by a jelly envelope 12 µ thick. The germinal vesicle is about 30 µ in diameter and contains a large and a small nucleus. The spermatozoan is very motile when freshly discharged from the testis. The head is conical and the middle piece consists of several chondriospheres. The gonad of the male at the breeding season is reddish in color, that of the female faintly yellow.

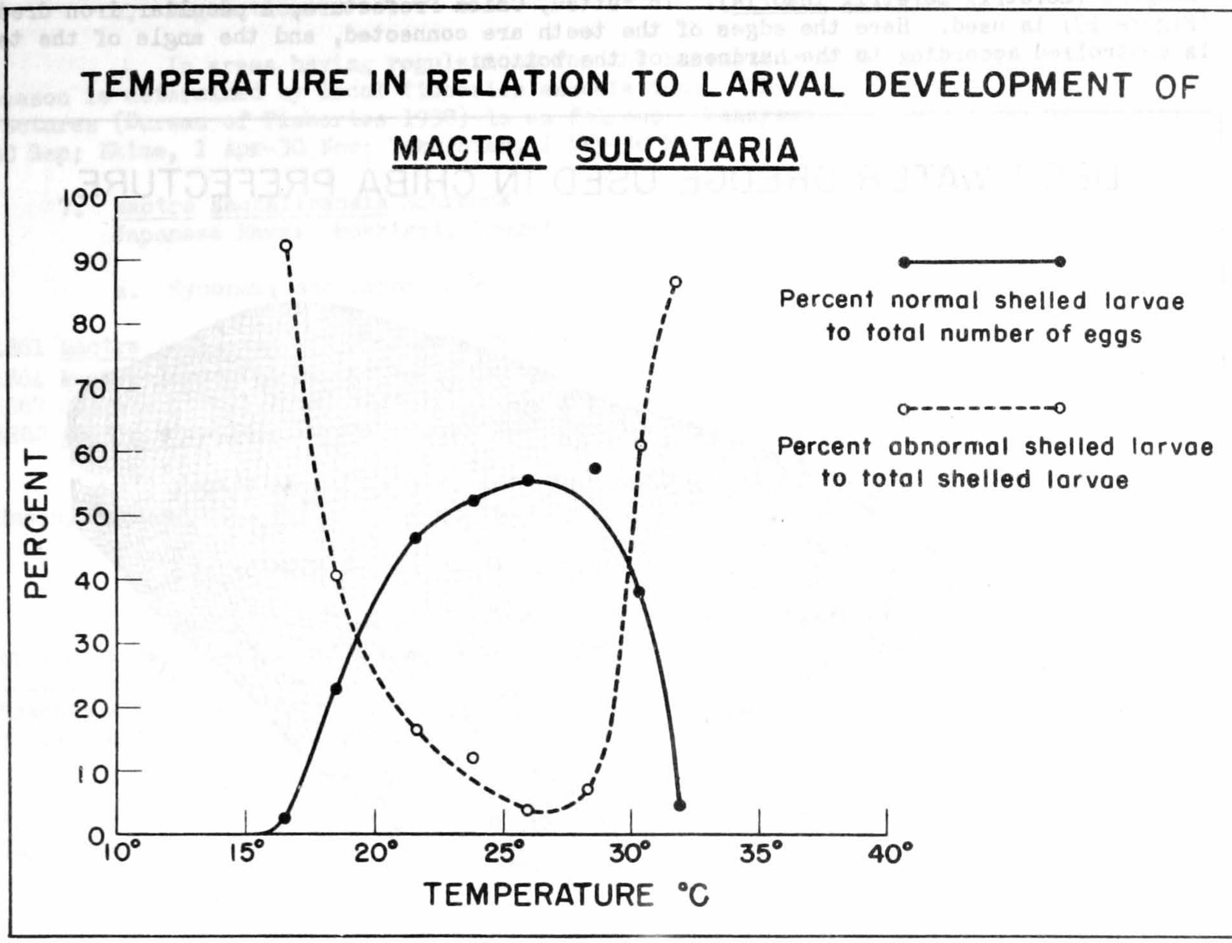
(2) Spawning

The spawning season varies somewhat with locality. According to Miyazaki (1936b) spawning lasts from late April to late autumn in Tokyo-wan. Icho and Oshima (1938) report that it extends from February to September, with the peak of spawning in March and April. Hanaoka and Shimazu (1949) state that the peak of the spawning season at Urayasu, Chiba Prefecture, occurs in May and June, and that the clam becomes mature at the age of one year.

(3) Development

According to Miyazaki (1936a) the polar lobe is not visible. At the time the eight-cell stage is reached the embryo begins to rotate in the sea water by means of its fine cilia. The apical cilia are rather conspicuous during the early stages of development, but they can no longer be seen in the shelled larva stage. Young shelled larvae which still contain abundant yolk granules measure about 80 µ in length, 60 µ in height, and 54 µ along the hinge line. When the shell is about 93 µ long and 78 µ high the growth lines are distinctly observable. At this stage the color of the shell is light yellow, deep yellow along its margin, and purple along the hinge. The yellowish liver can be seen through the shell. Asymmetry of outline becomes obvious when the shell is about 132 µ long, and the posterior end is more strongly curved than the anterior end. When the clam attains a length of about 140 µ the umbones begin to project. Teeth are seen along the hinge of the shell which assumed a much depressed oval form when about 163 µ in length. The largest individual embryo raised by Miyazaki measured 177 µ in length and 166 µ in height.

Miyazaki (1933) also reports the effect of temperature and salinity on development of the eggs of this clam. Matured clams were collected from the coastal water of Kanazawa city, Kanagawa Prefecture, and artificially fertilized in the laboratory. Growth occurred within a temperature range of 16°C to 32°C, the optimum being between 22°C and 28°C (Figure 18). The formation of the larval shell was accelerated by higher temperatures up to 30°C but was retarded above that temperature. The percentage of abnormalities among the larvae varied inversely with temperature. Development of the larvae was possible in salinities ranging from 1.019 to 1.036, but the optimum development occurred within a salinity range of 1.024 to 1.032.



NATURAL RESOURCES SECTION

Figure 18

TABLE G. - GROWTH OF MACTRA SULCATARIA (centimeters)		
Age (years)	Shell Length	Shell Height
1	3.3	2.3
2	4.8	4.2
3	6.4	5.2
4	8.2	6.0
5	9.7	6.7

SOURCE: Higurashi 1934

(4) Growth

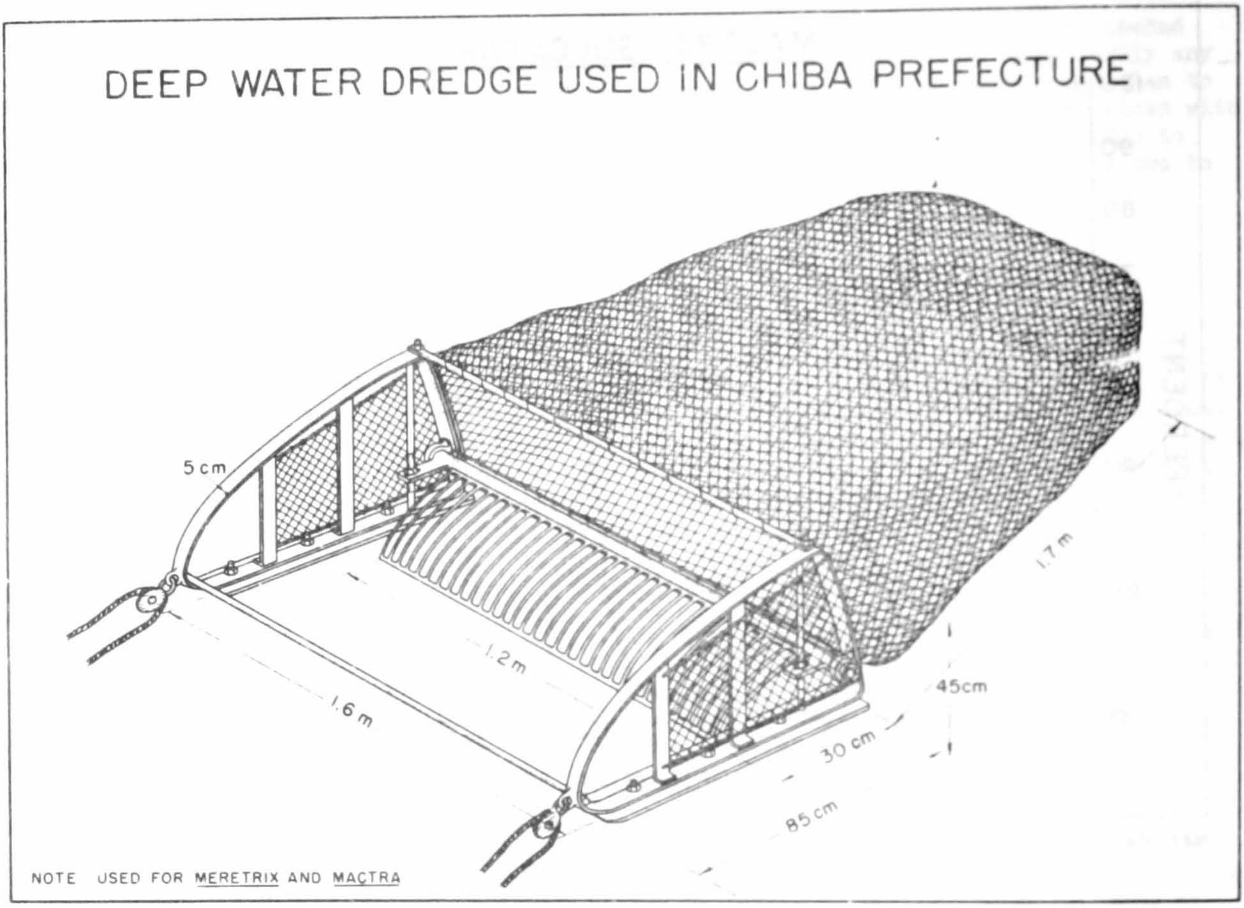
The average growth of Mactra sulcataria (Higurashi 1934) is shown in Table G. According to Hanaoka and Shimazu (1949), in Urayasu, Chiba Prefecture, this clam measures less than one centimeter in August , reaches a length of five centimeters in December, and thereafter grows very slowly.

A bottom composed of a mixture of sand and mud which is influenced to some extent at least by fresh water is recognized as best suited for the development of the young Mactra sulcataria, but subsequent growth is found to be poor under these conditions. Therefore young shells propagated in such places must be transplanted to other grounds having a higher salinity, where they are harvested in from one to three years.

e. Harvesting Gear

This clam is harvested in Chiba Prefecture from December to March or early April. The gear used is practically the same as for Asari (Venerupis semidecussata) and

Hamaguri (Meretrix meretrix lusoria). In Futtsu, Chiba Prefecture, a peculiar iron dredge (Figure 19) is used. Here the edges of the teeth are connected, and the angle of the teeth is controlled according to the hardness of the bottom.



NATURAL RESOURCES SECTION

Figure 19

f. Enemies and Damage

Any sudden chemical or physical change in water condition or properties causes damage to this clam, expecially to the young, which are rather delicate.

A host of animal enemies attack the pelagic larvae and the young clams just after settling down. They are fed upon by fishes such as the gobies, thread herring, flounders, and Enedrias nebulosus and by various shrimps. Starfish, octopus, drills (Rapana thomasiana), and the snails Polynices didyma and Natica maculosa are natural enemies the adult clams (Icho and Oshima 1938).

g. Utilization

The meat of Mactra sulcataria is sweet, and it is one of the more delectable of the Japanese clams. The clams are sold on the public market either raw or dried in the shell after boiling. The adductor muscle is especially flavorful and is prepared as "tempura" (fried in deep fat) or canned. The shells are used for chicken food and fertilizer after being piled in an oven, heated, and crushed into shell ash.

h. Regulations

In areas having regulations for the harvesting of M. sulcataria, the closed season is determined by local fisheries associations. The closed season for various prefectures (Bureau of Fisheries 1938) is as follows: Wakayama, 1 Jun-30 Sep; Hyogo, 1 Apr-30 Sep; Ehime, 1 Apr-30 Nov; Tokushima, 1 May-30 Nov.

7. Mactra sachalinensis Schrenck
Japanese Name: Hokkigai, Ubagai

a. Synonomy and Importance

1861 Mactra sachalinensis Schrenck, Bull Acad Imp Sci, St Petersb, 4(4): 412
1864 Mactra luhdorfii Dunker, Mal Blatt, 11:99
1867 Schrenck, Moll Amurl.: 575, pl 23, figs 3-7
1882 Mactra straminea Dunker, Index Moll Mar Japan: 183, pl 7, figs 5,6 (non Lamarck)

Mactra sachalinensis is an important edible clam in the northern regions of Japan, ranking with Pecten yessoensis.

b. Characteristics and Distribution

Shell ovate, thick, inflated. Outer surface smooth at umbo but with irregular growth lines on other surfaces. Shell covered by dark brown periostracum except at umbo. Inside of shell whitish, beak cavity deep. Pallial sinus elliptical. Tooth hard and low. Reaches a maximum size of about 100 millimeters in length, 85 millimeters in height, and 55 millimeters in width (Figure 17).

This species inhabits suitable environmental areas between Hokkaido and Chiba Prefecture on the Pacific coast of Japan, and between Hokkaido and Toyama Prefecture on the Japan Sea coast.

c. Living Conditions

This species lives in rather cold water which faces the open sea and which is not influenced by incoming currents of fresh water. It lives in a sandy-mud bottom where the water is shallower than three meters. According to Kinoshita et al (1935) the composition of the bottom is optimum for the species when it contains 30-80 percent fine sand, and unfavorable when there is more than 70 percent mud or more than 40-50 percent of medium coarse sand.

According to Kinoshita and Hirano (1934) the lower temperatures are best if this clam is to survive out of water. When exposed to air the weight decreases gradually until the animal dies; this death point is the loss of 25 percent of the body weight. The length of survival at various temperatures is important in relation to transportation and marketing. Experiment has shown the following survival periods: at 27.5°C, 34 hours; 19.2°C, 49 hours; 10.3°C, 145 hours; 5.6°C, 210 hours; -1.0°C, 522 hours.

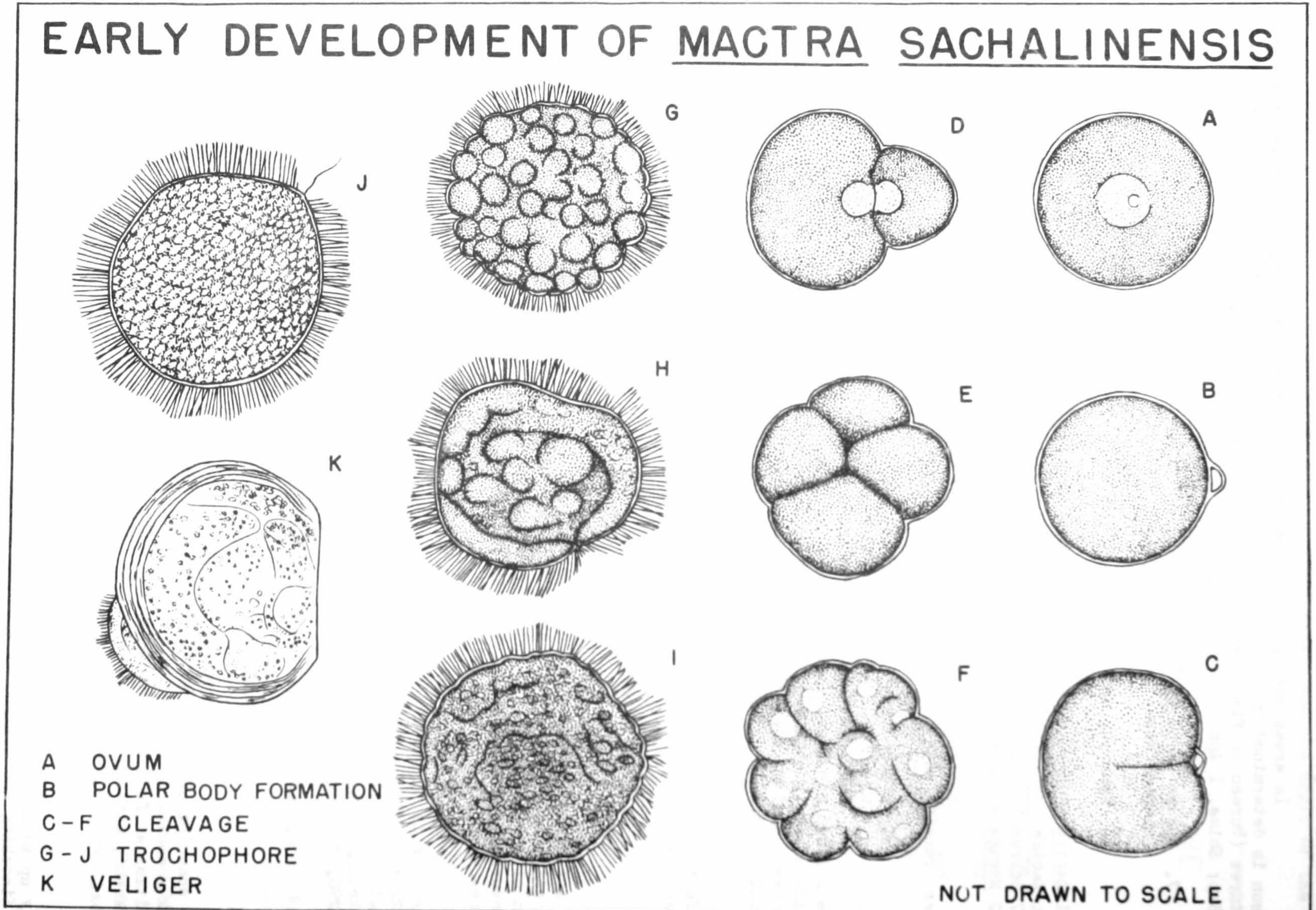
d. Reproduction and Development

(1) Spawning

According to Kinoshita and Hirano (1934) and Kinoshita and Shibuya (1940) the spawning of this species varies according to Hokkaido localities. The relation between peak spawning activities and temperature is cited by Kinoshita and Hirano for different localities as follows: Hakodate, mid-June, 15.7°C; Otaru, mid- to late June, 14.4-15.9°C; Oakkeshi, mid- to late August, 14.4-15.4°C; Shiraoi, mid-July, 18.2°C.

(2) Development

The development of Mactra sachalinensis is but poorly known, and this only up to 40 hours following fertilization. This early development, the result of work by Kinoshita and Hirano, is shown in Figure 20. The diameter of the egg is 50 µ and the



NATURAL RESOURCES SECTION

Figure 20

D-shaped larva is reached after 40 hours of development. The lower and upper limits of water temperature in which development can take place are 8°C and 28°C, with the optimum between 16°C and 23°C. The number of days required to form the shell, at different temperatures, is: at 8.5°C, 8 days; at 11.0°C. 4 days; at 13.4°C, 3 days; at 15.9°C, 2 days.

(3) Growth

The growth of this species according to Kinoshita (1939a) is shown in Table H.

TABLE H. - GROWTH OF *MACTRA SACHALINENSIS*	
Age (years)	Shell Length (cm)
2	3.5
3	4.8
4	6.4
5	7.2
6	7.6
7	7.9
8	8.1
9	8.2
10	8.3
12	8.5
14	8.7
16	8.9
18	9.1
20	9.4

SOURCE: Kinoshita 1939a

e. Harvesting Method and Gear

The sandy beaches from southern Miyagi Prefecture southward to Chiba Prefecture are the center of the dredge fisheries for *Mactra sachalinensis*. Fishing of this type is conducted in the open Pacific beyond the surf line and in water up to 15 meters in depth. The clams are harvested with dredges about 100 centimeters wide, equipped with digging teeth 50 centimeters long, spaced at intervals of four centimeters. The dredge digs to a depth of about 20 centimeters. Each boat uses two dredges. The aft dredge is dropped overboard first and the line payed out about 1,000 meters. This line, a bronze cable, is attached to a hand winch in the forward part of the boat. This completed, the forward dredge is dropped and enough line let out so that the dredge will operate properly yet not interfere with or tangle the aft dredge; the line then is attached to the winch, which pulls both dredges. Each boat has a crew of four or five men, usually including the owner. The boats average 10 meters in length and are equipped with four sweep oars for propulsion. The catch is divided between the crew, the owner taking two shares and the members of the crew one each.

The dredge used in Hokkaido (Figure 21) is very similar to the type used in the Miyagi-Fukushima area and the method of operation is almost the same. However, each boat has a crew of two but still operates two dredges. The time required for a single dredging operation is about 50 minutes, and from 100 to 380 clams per day can be gathered per boat in the Muroran district. The fishing season in Hokkaido extends from mid-August to mid-April, and the seasonal harvest varies from 5,000 to 12,000 clams per fisherman.

f. Production and Utilization

In the vicinity of Arahama, Miyagi Prefecture, these clams are harvested from 20 December to 30 April, an open season established by the local fisheries association to protect the resource. In 1948 the association at the village had 78 members, each one by regulation entitled to operate a single boat. The harvest in this town and the number of boats engaged in the fisheries are shown in Table I.

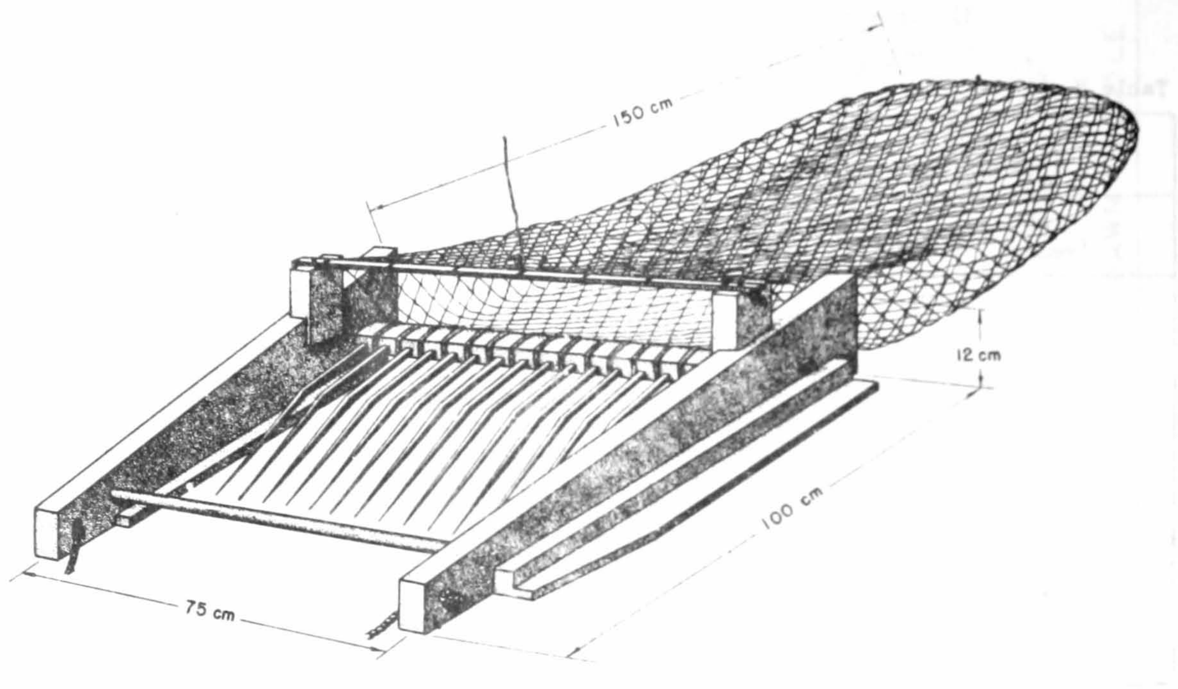
TABLE I. - HARVEST OF *MACTRA SACHALINENSIS* AT ARAHAMA, 1942-48

Year	Number of Boats	Production (kan)	Production (pounds)	Year	Number of Boats	Production (kan)	Production (pounds)
1942	17	4,790	39,565	1946	34	60,465	499,441
1943	33	19,966	164,919	1947	36	83,560	689,380
1944	24	33,529	276,950	1948 a/	41	42,550	351,463
1945	22	30,660	253,252				

a/ As of 27 March 1948; no further data available.

SOURCE: Glud (1947)

DREDGE USED FOR MACTRA SACHALINENSIS IN HOKKAIDO



NATURAL RESOURCES SECTION

Figure 21

The animals were sold in the shell at ¥240 per kan of meat (as of 1946). The shell weight is considered as one-third of the total weight. The average production is reported as about 20 kan of meat per boat per day. A few Meretrix are taken by these dredging operations but not in sufficient numbers to be of commercial importance.

Production is shown in Table 1. The meat is very sweet and is sold raw, dried, or canned. The shell is utilized as fertilizer after burning.

8. Pecten (Patinopecten) yessoensis Jay
Japanese Name: Hotategai, Akitagai

a. Synonomy and Importance

1857 Pecten yessoensis Jay, Perry's Narrat Exped Amer Squadron China Seas and Japan, 2:293, pl 3, figs 3,4; pl 4, figs 1,2
1861 Pecten brandti Schrenck, Bull Acad Imp Sci St Pete; 4:411
1862 (?) Dunker, Novit. Conch. (2(4)?): 61; pl 21
1869 Pecten yessoensis Lischike, Jap Meer Conch 1: 165, pl 10, figs 3, 4
1871 Lischke, l.c 2: 157, pl 13
1886 Kobelt, Conchy, Cab. 7(2):139 pl 38, fig 7; pl 39, fig 1

This species, the largest scallop in Japan, is the most important shellfish in the cold current areas of Hokkaido. In the Kitami and Nemuro coastal regions of this northern island the fisheries involving this shell can be compared in importance to that of the herring fisheries in Hokkaido.

b. Character and Distribution

Right valve swollen, the left almost flat. The two ears almost the same size, the ligamental line straight. Outer surface of the left valve pale purplish-brown with white radiating lines; inside white with a large muscle scar. Right valve white. At the center of the hinge line is a triangular pit. Kinoshita (1936) reports a wide variation in the number of radiating ridges among the Hokkaido shells, the right valve showing from 15 to 32 with 21 to 24 the most frequent, the left valve bearing 13 to 31, with 20 the average number. There seems to be no direct relationship between the number of ridges and latitude. Length 200 millimeters, height 190 millimeters, width 45 millimeters (Figure 10).

This species is distributed in the cold current areas between Hokkaido and Tokyo-wan on the Pacific side and between Hokkaido and the Noto-hanto (Noto Peninsula) on the Japan Sea coast.

c. Living Conditions

(1) Bottom

Nishioka et al (1948) cultured the spat of this scallop in three aquaria having different types of bottom conditions, gravel, mud, and a mixture of sand and mud. After four days of quiet and normal conditions during which growth and survival were normal, the bottom material and spat were gently stirred with a piece of rope. The aquarium having the gravel bottom became turbid but cleared again in 30 minutes. The other two aquaria required 10 hours to return to the original condition. The stirring of the latter two aquaria resulted in high oxygen consumption and a high death rate among the spat (Table J), but the survivors lived long enough to confirm the fact that spat can grow even on muddy bottom, especially if it is not disturbed. The disturbance produced no ill effect on the spat in the gravel-bottomed aquarium.

TABLE J. - EFFECT ON PECTEN YESSOENSIS SPAT OF BOTTOM DISTURBANCES

Aquarium Number	Bottom Type	Oxygen Content per Liter (cu cm)		Survivors
		Before Disturbance	After Disturbance	
1	Gravel	4.7	4.3	20
2	Mud	4.7	0.7	3
3	Sand-mud	4.7	1.0	4

SOURCE: Nishioka et al (1948)

Nishioka (1948) interpreted the above results as evidence of the importance of controlling trawl fisheries in order to promote scallop production and deduced that the depletion of scallops in Mutsu-wan was due to the over-use of this type of apparatus. This is contrary to his former (Nishioka 1943) conclusions, drawn from his study of the age composition of harvested scallops and yearly statistical records of production, that the depletion was due to reduction of larval occurrence resulting from periodic changes in physical and chemical character of the water rather than to overfishing.

Imai (1941) reported that the best bottom condition for this clam is one containing 40 to 60 percent gravel. Icho and Oshima (1938) and Ozaki (1942) state merely that sandy bottom is preferable.

The optimum depth was found by Icho and Oshima to be about 20 meters, within a range of 15 to 30 meters. Nagamine (1935) studied the scallop in Notoro-ko, an almost landlocked bay northeast of Abashiri, Hokkaido. Here he found the animal growing at a depth of 1.5 to 13.5 meters.

(2) Movement

The scallop has two methods of propulsion. To move forward it opens its shell and takes water into the mantle cavity, then squirts the water out oblique-posteriorly from the vicinity of the ear to force the shell ahead. To move backward the clam opens and closes the shell rapidly and repeatedly. Because of this clam's ability to move rather rapidly, the location of the fishing grounds changes from year to year and production is therefore uncertain.

Isahaya (1929, 1930, 1933) studied the problem as to whether or not this scallop migrates. In 1929 scallops were tagged with glass tags fitted on the shell by cement and were replaced in the sea off Mombetsu. Good results were obtained. In 1929, 296 tagged shells were recovered between 1 July and 30 September out of a total of 1,843 individuals tagged and liberated 21-29 May. The general movement was south, and the average distance travelled was five to eight miles. Results were similar in 1930. However, no definite information was obtained to show whether this was a migration or movement resulting from the ocean currents. Fishing for scallops ceased in September so nothing is known about movement after that time.

d. Reproduction and Development

(1) Egg and Sperm

According to Yamamoto (1943) the head of the spermatozoan is 5 µ long, triangular, and acutely angled at the top. The tail is 55-60 µ long. The mature egg is spherical and 0.09 and 0.10 millimeter in diameter.

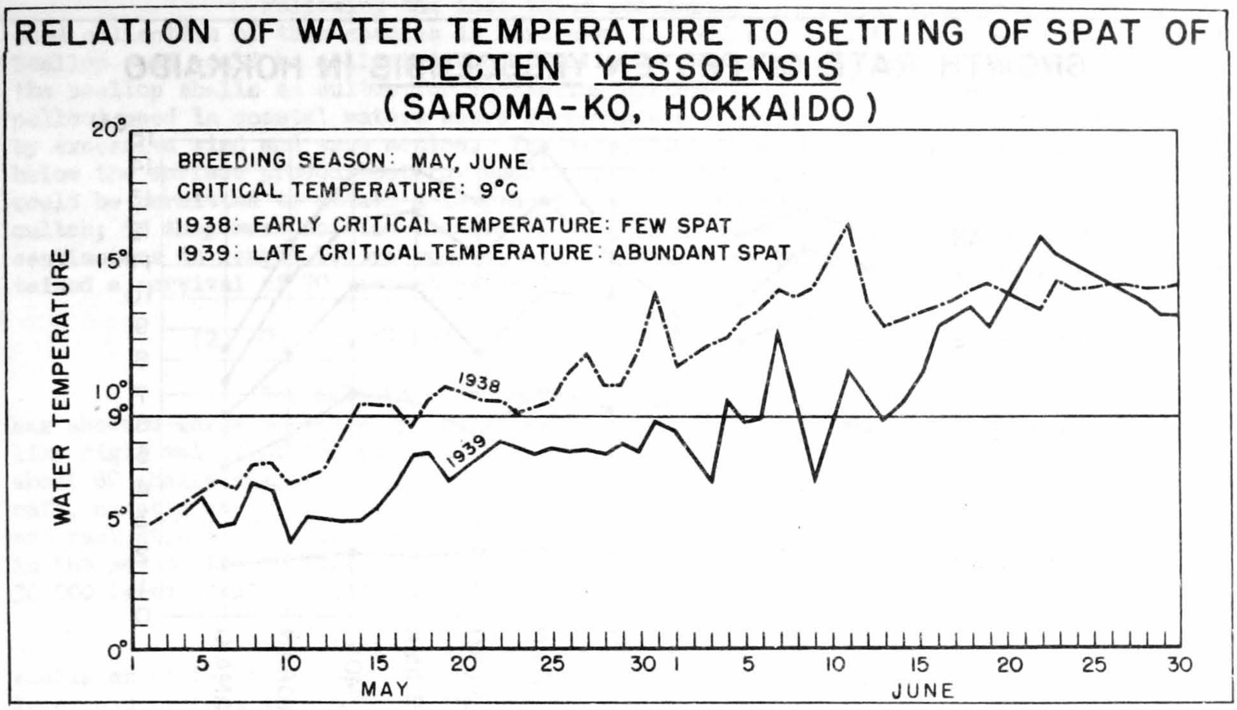
Despite the fact that European and American scallops are monoecious, this Japanese Pecten is dioecious. The sex of the individual cannot be told externally but cab be distinguished by the color of the gonads during the spawning season. At this time the testis is milky white, the ovary clear orange red. This condition is found in Mutsu-wan between December and late May or early June.

Nishioka et al (1948) studied fertilization in the laboratory and found that if the eggs were taken from the gonad and immediately fertilized, the percent of successful insemination was very low, averaging about three percent. However, if a period of time elapsed between the removal of the eggs and their insemination the rate of successful fertilization slowly increased in proportion to the period of lapsed time. Maximum fertilization was obtained when four hours had elapsed between the freeing of the eggs and fertilization, at which time 23 percent of the eggs were fertilized. No information is available as to this phase of development in nature, and further studies are needed to clarify the point.

(2) Spawning

Yamamoto (1943) reported that in Mutsu-wan mature ova and spermatozoa were present in the gonads from February to June and that the spawning was most active during April and May. He also found that the spawning season varies according to the locality by as much as 2 1/2 months, probably owing to differences in water temperature. This variation of the spawning season was described by Isahaya (1933) as follows: Soya, early May to late May; Mombetsu, mid-May to mid-June; Nemuro, mid-June to mid-July; Shibotsu-shima, early June to early July; Muroran (in harbor), early June; Muroran (beyond harbor), mid-June; Higashishimamaki, mid-April.

Kinoshita (1934b) reported that the local variations in the spawning season depended on local differences in temperature and that the minimum temperature for spawning is above 9°C. According to Kinoshita (1940), the variation in the amount of setting of seed depends on the occurrence of a rise in water temperature during the spawning season and the setting is heavier when the critical temperature occurs late in the spawning season and small when it occurs early (Figure 22).



NATURAL RESOURCES SECTION

Figure 22

Kinoshita (1943) experimented on the induction of spawning in this scallop. According to his experiment the spawning was induced by rapid artificial raising of the water temperature and pH. A rise of only one of these critical factors proved not to be effective, and the rise of both at the same time was necessary to induce spawning. Best results were obtained when a relatively low temperature was raised by 5°C and at the same time the pH raised from 8.2 to 8.4.

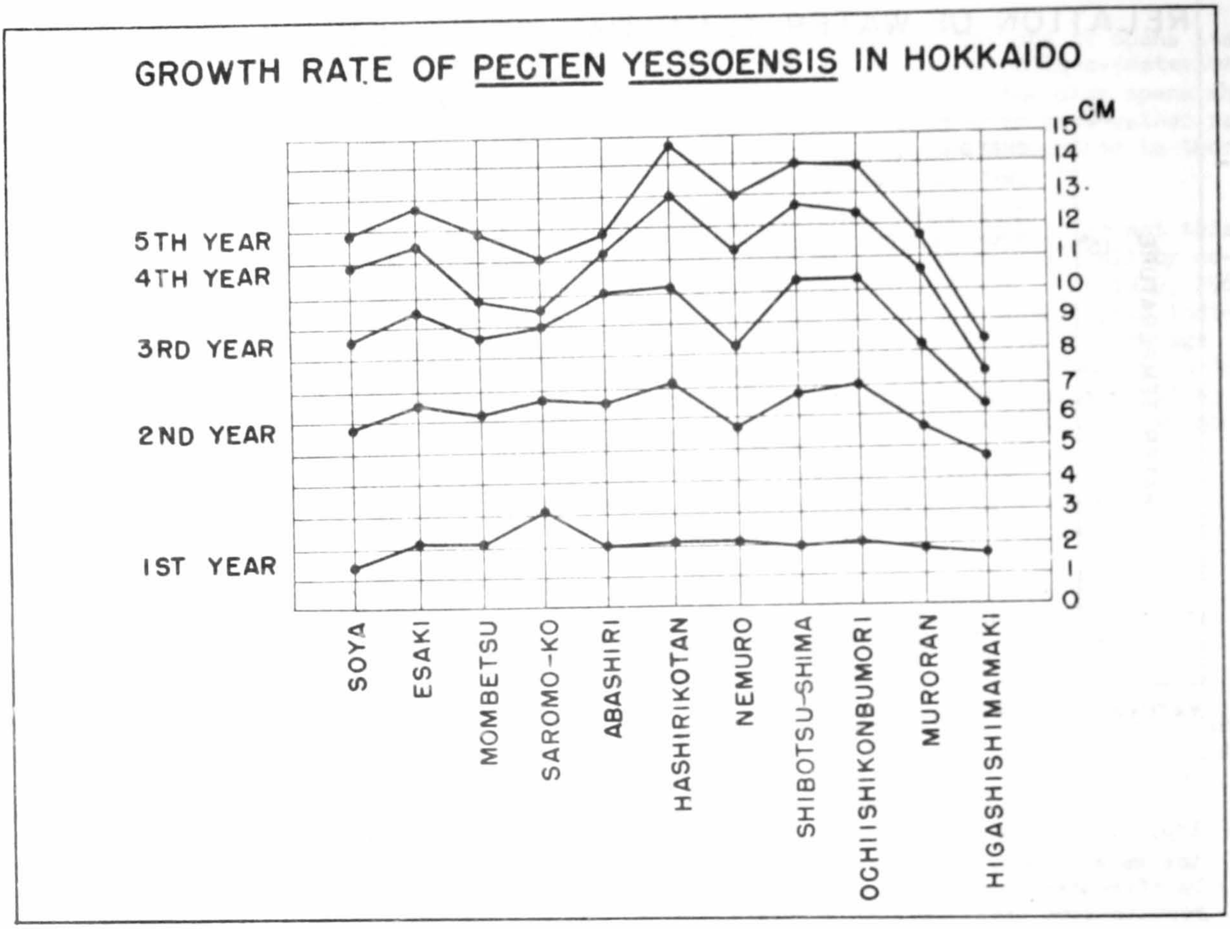
Nishioka et al (1948), experimenting on the same problem, succeeded in inducing spawning by keeping the scallop in water of lower temperature and lower salinity than normal for one or two days after collection and then returning the animals to the normal conditions of the habitat. Spawning ensued. This method seems to be more efficient than Kinoshita's alkali treatment as the eggs need not be washed after treatment.

(3) Development

Nishioka et al obtained a large quantity of ripe eggs by the method just described, inseminated them, and raised the larvae for three weeks. At this age the larvae had attained a shell length of 200 μ. From another experiment they concluded that the temperature range for development of the zygote is from 10°C to 15°C, with the optimum at 12°C. They found that larvae did not develop in a salinity lower than 1.0030 or above 1.0047, with an optimum salinity for development at 1.0037.

The relative growth rate over a period of five years in 11 localities in Hokkaido was given by Kinoshita (1934a) as shown in Figure 23. Icho and Oshima (1938) summarize the growth rate as follows but do not state the locality where observations were made: one year, length 3.3 centimeters; two years, 8.3; three years, 11.5; four years, 14.8.

The age of the scallop can generally be determined by counting the growth rings of the shell but sometimes pseudo-growth lines make an age determination difficult. Isahaya and Sakuma (1933) found that the growth lines as shown in a section of the triangular ligament which binds the shells together show exactly the age of the shell in years.



NATURAL RESOURCES SECTION

Figure 23

(4) Food

Kinoshita and Hirano (1935) obtained specimens of Pecten yessoensis from various localities in Hokkaido and examined the contents of the alimentary canals. A summary of their results shows that the ingested items included 33 species of diatoms and 19 species of protozoa, besides minute crustacea, Chlorophyceae, spores of algae, Echinoderm larvae, and a few other forms in lesser quantities. The bulk of the food consisted of diatoms and protozoa. Fragilaria spp. were predominant.

e. Culture

(1) Seed Collection

Only rather recently has artificial gathering of seed of this species been tried. The first seed collection was obtained experimentally in Saroma-ko, Hokkaido, in 1934 by the Hokkaido Fisheries Experimental Station. That first work was important because of the magnitude of the scallop fisheries, which in the shallow waters of Hokkaido is of importance second only to that of the kelp fisheries, and because the decrease in scallop production had already been recognized and attributed to overfishing.

Kinoshita (1934a) obtained the larvae of Pecten yessoensis accidentally on cultch for oyster seed set in Saroma-ko in 1933. These collectors were set 20 August 1933 and harvested 28 October.

Following the idea these accidentals gave him, Kinoshita (1935) tried seed collection of this species in Saroma-ko in 1934 and made the following observations. Scallop seed could be collected successfully by the usual hanging method which employed the scallop shells as cultch for collecting oysters (Cahn 1950). It was found best to collect seed in coastal waters where currents are sluggish and which are seldom ravaged by excessive wind and wave action. The water zone between 0.6 centimeter and 1.0 meter below the surface proved best for seed collecting. It was found that the young scallop could be permitted to attain a length of one centimeter before being removed from the cultch; if they were not too crowded on the cultch they could be permitted to reach three centimeters in length before removal without injury to the young scallop. Kinoshita obtained a survival of 70 percent after 70 days of rearing these young in metal baskets.

(2) Culture Method

For culture purposes collectors are set in the water when observation has shown a large number of pelagic larvae to be present (Kinoshita 1941). The deep, cup-like right valves of the scallop shells are pierced by a wire and strung back to back, with about 80 shells making one chain or series of collectors. The series is suspended from a raft, exactly as is done in collecting oyster spat (see Cahn 1950 for discussion of raft and rack structure). If the water is shallow the rack method is used, the rack being fixed in the sea bottom by stakes. One raft can suspend about 350 series and can gather about 30,000 larval scallops per series.

The attached shells grow rapidly. By the end of July colored larval shells about two millimeters long are found attached to the cultch that was hung in early June, and by late August these shells are 10 millimeters in length. The rate of seed harvest varies from year to year. In the 1939 harvest in Saroma-ko, which proved an exceedingly rich yield, one collector shell averaged 166 seed. On this basis a single raft of cultch produced 4,648,000 scallop seeds. In a poor year the harvest never fell below 1,000,000 seed per raft.

These collected larvae must be sown in August. They lack a byssus and enter the benthic life usually when they attain a length of about 10 millimeters. If the site of their transplantation is near, the seed scallops are transported attached to the collectors. If the transportation distance is great, the seed scallops are scraped off of the cultch and put into boxes especially designed and constructed for this purpose. The transportation box is made of wood and consists of an inner and an outer box. Eight wooden frames with wire net bottoms, on which the seed scallops are scattered, are piled one on top of another and placed in the inner box. The space between the outer and inner boxes is filled with ice to keep the inside temperature at about 10°C. The outer box is 1.2 meters long by 0.91 meter wide by 0.45 meter high; the inner box is 0.91 meter long by 0.6 meter wide by 0.45 meter high. One of these boxes can carry about 1,000,000 seed scallops. While the box is in transit ice is supplied and sea water sprinkled over the boxes at intervals of two hours.

The experimental seed collecting of 1934 founded the local culture program beginning in 1936. As of 1950, seed scallops from Saroma-ko were being transplanted to many Hokkaido culturing grounds both near and distant, including Muroran, Akkeshi, Noshappu, Shari, Abashiri, Tokoro, Yubetsu, Saruru, Esashi, Hamatonbetsu, Yuchi, Kishibetsu, and Shomubetsu. Prior to Warld War II they were shipped also to Kunashiri-jima, the southernmost of the Kurils.

Seed production in Saroma-ko during 1936-40 was: 1936, 32,000,000; 1937, 80,000,000; 1938, 59,000,000; 1939, 155,000,000; 1940, 550,000,000 (Kinoshita 1941).

Long-distance transplantation of seed was attempted by Nishioka _et al_ (1948) when they transported spat collected in Saroma-ko to Mutsu-wan. The spat were carefully packed and carried in the box previously described, and transported for 69 hours prior to planting. To complicate the problem, the experiment was begun on 24 August, the hottest period of the season. When the box was opened all of the spat were found to be quite healthy, and were clapping their shells vigorously. Subsequently, the water at Mutsu-wan proved to be too warm for survival, 20 to 26°C, and most of the spat died, but this does not invalidate the fact that the spat of Pecten yessoensis can be transported successfully for long distances.

f. Harvesting Methods and Gear

This large scallop usually is harvested in summer and autumn. Small-sized individuals are protected, and the fishing usually is closed during the breeding season (see "Regulations") because production is declining.

The gear used to harvest the scallop is known as "Hotate Ketaami" (scallop dredge). Its structure and the fishing methods are variable, but the following dredge and method of use found in the Abashiri district is typical. The front iron beam of the dredge is fitted with 21 heavy iron teeth about 0.3 meter long. Behind this is attached a hemp net about three meters long (Figure 24). At each side of the forward end of the net a U-shaped iron bar projects to act as a sort of runner to slide the net along on the bottom and to keep it from digging in. Six or seven fishermen in a 14 ton boat driven by a 40 horsepower motor drag two dredges slowly along the bottom. In some places the tide is used instead of a motor to propell the boat, in others a sail. The yield in the Abashiri district is between 800 and 1,000 barrels per month per boat, with from 170 to 200 shells per barrel for offshore shells and about 400 per barrel of the smaller coastal shells.

This method is effective only on clear bottom where no obstacles interfere with the proper dragging of the dredges. Where dredging is impossible other methods of harvesting the scallop are used, such as by spearing the shells with the help of a glass-bottomed "peep-show", or by using divers.

The spearing method is used in Mutsu-wan, Aomori Prefecture, but the depth at which this is possible is limited both by the transparency of the water and by practical difficulties. A very skillful fisherman under optimum conditions can collect shells to a depth of 20 meters, putting the speared shells in a bag hung from the ship into the sea. Scallops thus collected are inferior in quality because of the decreasing weight due to loss of body fluids through the incised wound (Nishioka 1943).

The diving method is prohibited in Mutsu-wan, but in Nemuro an 11-ton, 28-horsepower motor boat manned by a crew of six and two divers operates successfully. The depth of diving is usually from 15 to 30 meters. At 20 meters divers fish for three hour periods; at a depth of 30 meters they work for one hour. The catch averages about 2,000 to 3,000 shells per day per boat (Kinoshita 1949).

g. Enemies and Damage

Starfish, drills, and flounders are the major enemies of Pecten yessoensis. No study of either the damage done by the starfish or the means of controlling it has been made in Japan despite the fact that depredations are reported as severe. Flounders of the species Limanda schrencki have been found with their stomachs literally full of young Pecten yessoensis; this is especially true in midsummer. Among the mollusca, Natica janthostoma and Trophonopsis clathratus, both gastropods, are reported to do heavy damage (Kinoshita 1936). Kinoshita also reported damage done in the Notoro-ko region, by Stylochus ijimai, a Turbellaria, which eats the meat after invading the shell.

Kinoshita (1939b) studied this scallop in the Shari, Hokkaido, area, and found that a species of polychaete, Polydora ciliata, was parasitic on it. This worm drills holes in the shell and produces swellings inside the shell. Kinoshita discovered a very heavy infestation of this parasite, with almost every scallop over four years old infested. However, the infestation apparently did not lower the quality of the meat except where the drilling occurred near the adductor muscle.

DREDGE USED FOR PECTEN YESSOENSIS IN ABASHIRI, HOKKAIDO

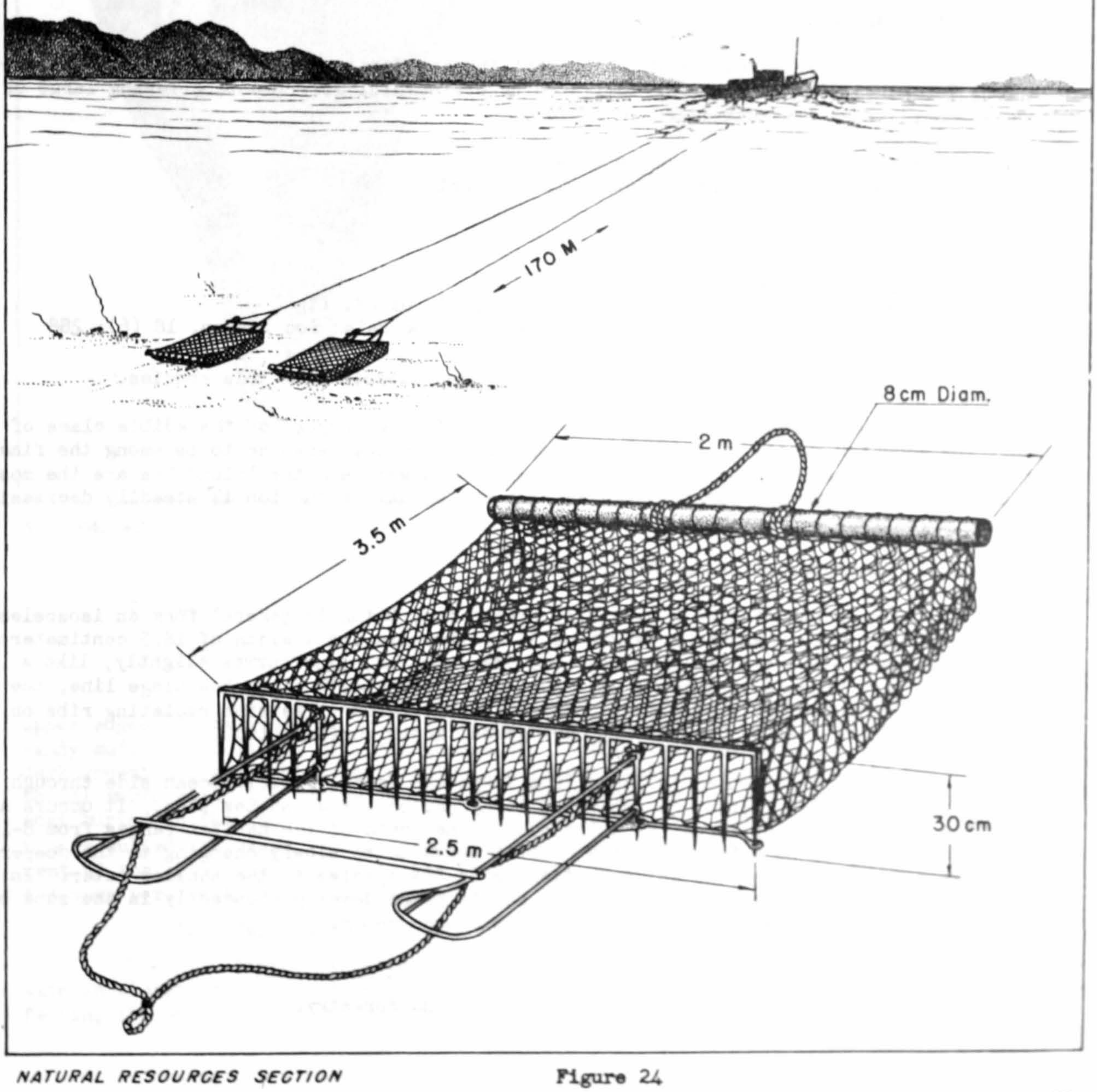


Figure 24

h. Production and Utilization

Since 1940 the production of Pecten yessoensis shows great fluctuation, and data are believed to be incomplete. No statistics on meat production are available, but Table 1 gives a basis for computing this factor. The shell production since 1941, in metric tons, is as follows: 1941, 21,531; 1942, 69,233; 1943, 39,366; 1944, 18,174; 1945, 2,032; 1946, 9,970; 1947, 18,498; 1948, 8,360. 10/

The muscle is widely used raw, dried, canned, baked, or fried. The dried meat was an important export to China. When boiled and dried, the muscle is removed from the shell, salted for one day, boiled in salt water, and then dried in the sun. Pressed muscle is prepared by steaming or roasting, followed by pressing, seasoning, and drying in the sun.

The body is not usually used as food but is dried and used as fertilizer. The shell is burned and the ash used as fertilizer. The natural valves are one of the most important components of the collector series for gathering spat of oyster. The cupped right valve is sometimes used as a dish or plate.

i. Regulations

To conserve the stock and prevent further decline in production various regulations for harvesting have been promulgated by prefectural governments covering large or local areas. These are summarized in Table 5.

9. Atrina (Servatrina) japonica (Reeve)
Japanese Name: Tairagi, Tairagai, Tachigai

a. Synonomy and Importance

1858 Pinna japonica Reeve; Conch Icon, sp 47
1891 Pinna lischkeana Clessin; Conchyl Cab 8 (1); 73, pl 28, fig 1
1929 Pinna (Atrina) pectinata japonica Winckworth, Proc Malac Soc London, 18 (6); 288

Kuroda (1947) synonomizes A. lischkeana Clessin with this species.

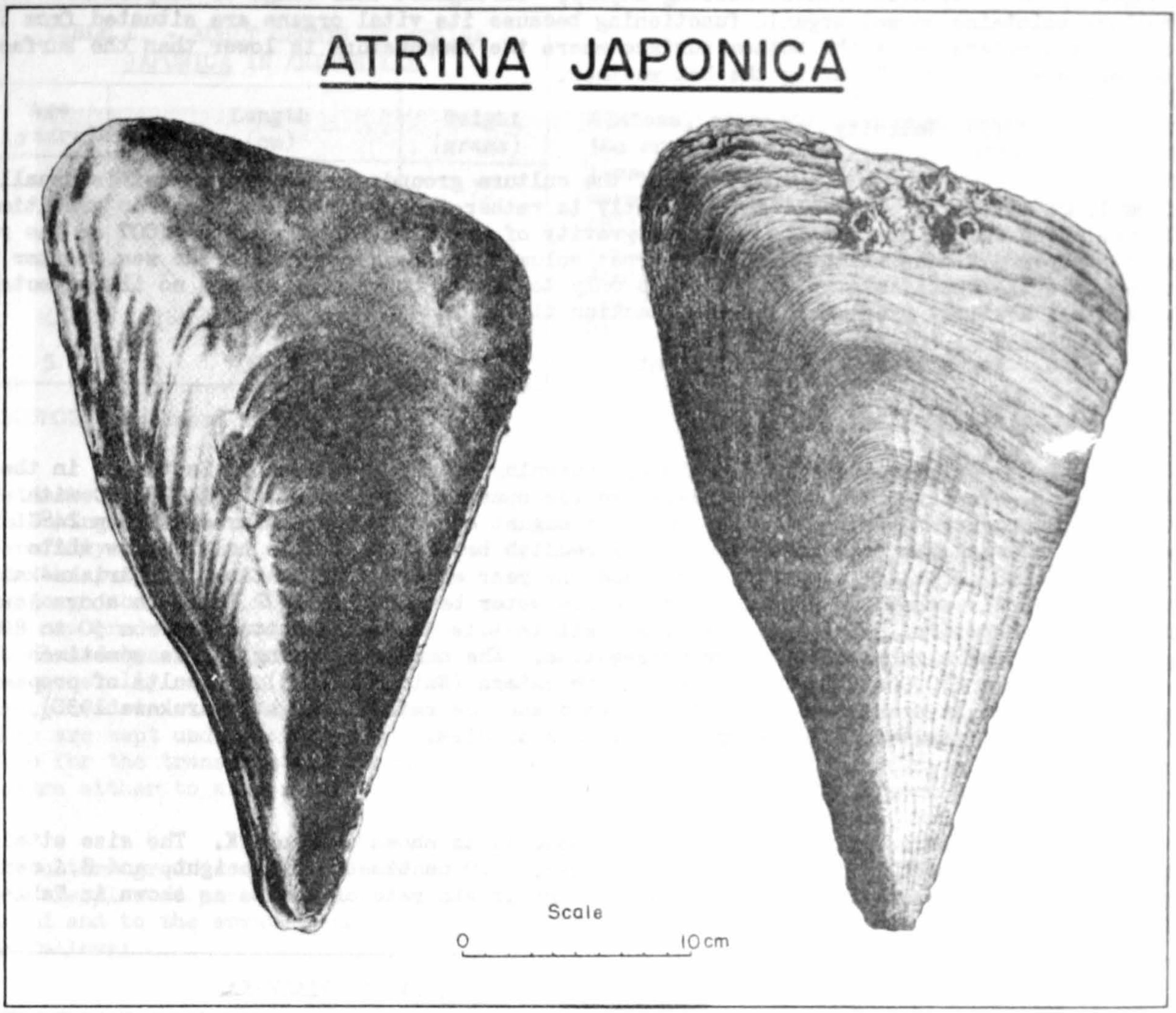
The fan shell (sea wing or pen shell) is the largest of the edible clams of Japan. The adductor muscle of this clam is considered by the Japanese to be among the finest of marine foods available to them. Ariake-kai, Tokyo-wan, and the Inland Sea are the most important fishing grounds for the species, but the annual production is steadily decreasing because of extreme over-fishing.

b. Characteristics and Distribution

Shell shaped like a partially opened fan, being in general form an isosceles triangle (Figure 25). Reaches a length of 37 centimeters and a width of 18.5 centimeters. Valves connected along the dorsal line; opposite (ventral) line curves slightly, like a bow. Shell very fragile, fractures as it dries out. No teeth along the hinge line, the valves being connected by a ligament. Growth lines crossed by several radiating ribs on the surface of the shell. Outer shell dark green, inner surface black.

It is distributed in Japan from Tokyo-wan on the Pacific Ocean side through Kyushu, and from Akita Prefecture southward to Kyushu on the Japan Sea side. It occurs also along the southern tip of Korea (Frontispiece). The depth of the habitat ranges from 8-10 meters to as deep as 60 meters, but the habitat seems to be slowly changing to the deeper waters as a result of the constant over-fishing of the species in the shallow water. In Ariake-kai off Fukuoka Prefecture the young shells often develop abundantly in the zone between low low tide and water ranging to a depth of one meter.

10/ Statistical Yearbook, Ministry of Agriculture and Forestry.



NATURAL RESOURCES SECTION

Figure 25

c. Living Conditions

(1) Bottom

This species buries itself vertically in the soft bottom, keeping the upper edges of the shell at or a little above the surface. The favored bottom is sand or sandy mud. The mollusks maintain themselves in their upright position with the aid of the dark greehish byssus which has a silk-like luster; this byssus attaches to the bottom material surrounding the ventral portion of the shell. During the summer the shells lie almost buried in the sand but in winter they work themselves upward so that only the ventral tip is buried (Marukawa 1930). According to the observations of Watanabe (1938a), 95 percent of the shells are buried in the same position in relation to the current, namely with the open portion of the shell facing toward the current.

(2) Temperature

Atrina japonica can resist a wide range of water temperature. During low tide in winter the temperature of the wet bottom may be as low as 1°C without adversely affecting the mollusk, and during low tide in summer the bottom surface temperature often ranges up to 39°C, also without causing injury, Throughout this range of temperature the mollusk maintains normal organic functioning because its vital organs are situated from 7 to 10 centimeters below the bottom surface where the temperature is lower than the surface temperature by 5 to 7°C during the hot weather.

(3) Salinity

The specific gravity of the culture grounds in the Ariake-kai is usually from 1.020 to 1.024, and the clam apparently is rather resistant to low specific gravities. In the rainy season of 1935 the specific gravity of the area fell to 1.005-1.007 as the result of severe floods which discharged great volumes of fresh water into the sea. After three days the specific gravity had risen only to 1.017, but Atrina showed no ill effects other than a slight slowing up of its reaction time.

d. Reproduction and Development

(1) Spawning

The species is dioecious, Spawning occurs from June to September in the Ariake area. The critical water temperature for spawning is from 22.0°C to 28.5°C with the optimum occurring from late June to early August at water temperatures between 24°C and 27°C. During the spawning the ovary is reddish brown, the testis pale yellow white (Watanabe 1938). Sexual maturity is reached one year after fertilization. In Ariake-kai the young shells sometimes propagate in shallow water between 1.5 to 2.0 meters above low water and 3.0 meters in depth at low tide. Within this range the bottom is from 50 to 80 percent sand and highly suitable for propagation. The number of young shells sometimes reaches between 2,000 and 3,600 per two square meters (Watanabe 1938). Results of propagation are best in years when the water is calm and the rainfall light (Marukawa 1930). There is no literature on the embryology of this species.

(2) Growth

The typical growth of this species is shown in Table K. The size attained by this clam is about 18.5 centimeters in length, 37.0 centimeters in height, and 8.4 centimeters in thickness, Fujimori (1929) reported the growth rate of adults as shown in Table L (also see Figure 4).

TABLE K. - GROWTH RATE OF ATRINA JAPONICA IN ARIAKE-KAI

Date of Measuring	Remarks	Shell Measurements			Size of Adductor Muscle	
		Length (cm)	Height (cm)	Weight (grams)	Long Diam (cm)	Short Diam (cm)
21 Apr 36	200 tsubo planted	12.1	5.3	23.2	1.9	1.3
19 Aug 36	4 months after planting	15.1	7.4	53.2	2.9	1.6
28 Oct 36	6 months after planting	18.5	9.4	86.2	3.6	2.0
13 Jan 37	9 months after planting	19.9	10.1	109.8	3.9	2.6
26 Jul 37	16 months after planting	21.4	10.4	112.8	3.6	1.6 a/

a/ Adductor muscle smaller despite increase in length, height, and weight of the shell because it is measured just after spawning.
SOURCE: Watanabe (1938)

TABLE L. - ADULT GROWTH OF ATRINA JAPONICA IN ARIAKE KAI		
Age (years)	Length (cm)	Weight (grams)
1	9.9	15
2	16.5	75
3	23.1	150
4	28.1	262
5	31.4	356

SOURCE: Fujimori (1929)

(3) Food

According to Watanabe (1938) diatoms, copepods, and protozoans constitute the normal food for this species. Food organisms ingested by Atrina japonica in Ariake-kai were identified as follows: Protozoa, Pulvinulina, rare: Copepoda, Calanus, rare; Diatoms, Stephanophixis and Conscinodiscus predominant, Asterionella, Triceratium, Rhizosorenia, and Navicula abundant, and Melosira, Biddulphia, Fragilaria, and Pleurosigma rare.

e. Culture

(1) Culture Methods

According to the work of Watanabe young shells spawned in June or July are gathered during March and April of the following year when they have attained a length of from about 10 centimeters. They are carefully pulled out of the mud either by hand or by the use of a pincher or clip developed for the purpose, and special care is taken to see that the fragile shell is not broken. Although the use of the hoe would be more convenient, the fishermen generally agree that its use produces a bad effect on the remaining seed shells by mechanical injury to both shell and byssus. The number of shells gathered varies with the conditions of the ground, but generally one man can gather between 2,000 and 4,000 Atrinas a day. The seed shells are placed in straw bags or in bamboo baskets and transported to the culture ground. Here they are kept under water by means of a weight on the container while waiting for the proper time for the transplanting operation, which occurs at low tide the next day. Prolonged exposure either to air or rain injures the vitality of the young shells.

The seed shells are gathered below the low low tide level and transplanted to culture grounds which are one to two meters above low tide level. Usually about 200 to 350 are planted per tsubo. Too dense or too sparse planting is disadvantageous both to the yield and to the eventual harvesting operations. The most effective method for planting is as follows:

Lines marked by red or white pieces of cloth spaced at intervals of 20 centimeters are stretched on the sowing ground, and an Atrina is planted at the spot indicated by each marker. An Atrina trowel is used for the planting of the shells, which are hand placed one by one. This trowel varies in shape with different localities but commonly it is an iron blade 20 centimeters long, 10 centimeters wide, and 1.65 centimeters thick, fitted with a wooden handle 3.3 centimeters in diameter and at right angles to the blade. Two or three helpers assist six or seven planters by delivering the seed shells for planting and by moving the marking lines as required. With shells planted at 20-centimeter intervals and lines spaced 10 centimeters apart, about 200 shells can be planted per tsubo. As the tidal current in Ariake-kai is rapid, 95 percent of the Atrinas orient themselves in a position parallel to the current. Therefore in artificial transplantation every effort is made to conform to the obvious preference of the species and they are oriented in a similar manner. The depth of planting is regulated with care also. If they are planted too shallow, the seed will be washed away by wind or wave action, and if too deep they are suffocated. In planting the upper edge of the shell is placed at or a little above the bottom surface. Usually the seed is planted when it attains a shell length of 10 centimeters, but occasionally some shells measuring 17 to 20 centimeters are used. When these larger shells are planted special care must be taken to see that the byssus is not cut when the shells are gathered, for cutting of these threads has an injurious effect on the visceral organs.

The shell of Atrina is very thin and fragile. Breakage near the adductor muscle is a death wound, but damage to the edges beyond the mantle is not serious and regeneration in this peripheral region takes place within a few days after planting. Young shells can live in air for a considerable time. Transportation from Fukuoka to Pusan, Korea, requiring four days, has been accomplished in late March at a temperature of 15°C. Although 25 percent of the shells suffered breakage, the remainder showed no appreciable effect of the journey and exposure.

The newly planted beds must be guarded against theft. If individuals die, they are removed immediately to avoid pollution and contamination of other individuals. The number of shells harvested represents about 80 percent of the original planting, the loss being attributed to carelessness in handling and to poaching.

Despite the fact that successful culture methods have been developed in Ariake-kai, no culture is practiced in Tokyo-wan, the _Atrina_-inhabited areas being left entirely to natural growth and development. In the water off Futtsu, Chiba Prefecture, some attempts were made to culture the shell according to the Ariake method but these failed, apparently because the transplanted shells did not establish themselves. No detailed information is available as to the cause of the failure. As the physical conditions around Futtsu differ considerably from those in Ariake-kai, some modifications of the Ariake methods are inevitable for successful results. The population of _Atrina_ in Tokyo-wan has fallen dangerously low owing to extreme overfishing, and investigations into practical methods for the culture of _Atrina_ in this area are needed immediately if the species is to survive on a commercial basis.

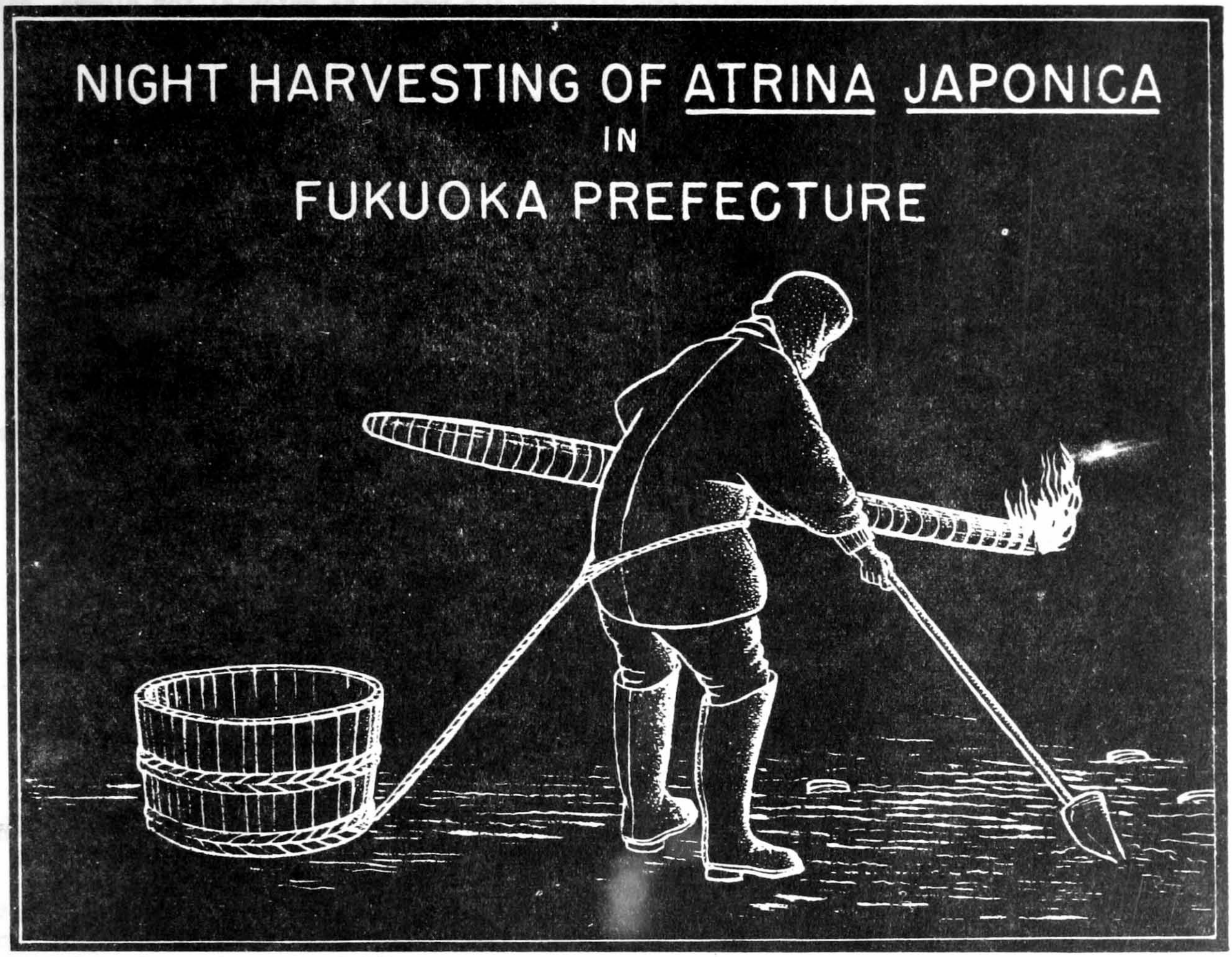
(2) Harvesting Method and Gear

The harvesting season is from October to March in Ariake-kai and from December to April in Tokyo-wan. The methods of harvesting differ in the two localities.

In Ariake-kai the fisherman walks over the fishing grounds at low tide at night, towing a pail in which to put his catch and carrying a torchlight to spy out the shells. This torch is a long stalk made of woven straw or pine wood, lighted at one end (Figure 26). A hook at the end of a stick is used to extract the shell, the hook being inserted between the gaping upper edges of the shell, twisted, and then driven through one side of the valve. An ancient legend refers to "Shiranuhi"--an enchanted light--which appears at night in this district. According to Jujimori (1929) the origin of this legend lies in the above mentioned fishing method. "Shiranuhi" is so famous that Ariake-kai is often called "Shiranuhi Bay". Sometimes dredging methods are used to fish for _Atrina_ when they occur in deeper water. This procedure has an advantage in that other edible shell species are gathered along with _Atrina_, but the disadvantage lies in the unavoidable damage done to _Atrina_ because of injury to the byssus attachments of the ungathered shells.

In Tokyo-wan the harvesting is done by divers operating from a boat. The boat is a three to seven ton craft with a crew of four or five men, including two divers. Clad in complete diving outfit and supplied by an air hose, the divers alternate in four to six hour periods, working in water about 20 meters deep. The diver carries a basket for his catch and is armed with either a hook or spear to gather his clams. The spear is the more convenient for it can be used to capture both _Atrina_ and _Schizothaerus_, which occur in the same area, whereas the hook can be used only on _Atrina_ because of the gaping shell. The spear is about 50 centimeters long and has an arrow-shaped barb at the tip. It enters between the valves in the area of the inhalent siphon and penetrates one valve of the shell. The clam is held by the barb as it is pulled out of the bottom matrix.

At Futtsu, Chiba Prefecture, _Atrina_ fishing has been carried on by diving since 1890. In those early days the shells propagated naturally and abundantly and were easily collected. In 1917 the shells were so abundant that the diver could not walk on the bottom without crushing _Atrina_ shells; the density was calculated as 330 shells per tsubo. By 1930 the density had decreased to only one shell per tsubo because of over-fishing (Marukawa 1930). Now the density is even less, and the shallow water stock is exhausted. Cases are on record of divers suffering from "diver's disease" as a result of having followed the clams into water of much greater depth.



NATURAL RESOURCES SECTION

Figure 26

f. Enemies and Damage

The most important biological enemy of the Atrina clams is Rapana thomasiana, the "oyster" drill. Rapana are thought to migrate into the Atrina beds after periods of heavy rainfall (Watanabe 1938). The octopus Polypus vulgaris is, to some extent at least, a predator upon Atrina.

Although the species has strong resistant powers to change in both water temperature and salinity, sometimes the clams are seriously damaged by accumulations of mud brought down by floods. The clam can wash out a thin layer of mud by opening and shutting the valves, but if the accumulated layer reaches two to three centimeters in thickness, death will follow.

g. Utilization

Nothing is wasted in the utilization of the catch of Atrina, every part being used for some purpose.

The posterior adductor muscle is the largest and most important and is brought to the market fresh. The flavor of this meat is best during the harvesting season when the fat content is greatest. In summer the taste is inferior and the quality sinewy. The clam meat, exclusive of the muscle, is brought in and sold either raw or as dried meat following boiling. It is a highly esteemed food.

The Italians reportedly have utilized the byssus as material for gloves, hats, and shawls after washing with soap and spinning. About 1920 an effort was made in Hyogo Prefecture to make cloth from byssus, but it was not successful.

The discarded shell is used as cultch for seed oysters and, when ground, as fertilizer.

h. Regulations

Small Atrinas are not taken, but this alone is not enough to safeguard the stock; cultural methods are necessary if the area is to maintain anything resembling maximum productive possibilities. The number of divers permitted to operate is determined and limited by action of local fisheries associations.

Saga and Fukuoka prefectures have a closed season 1 June-30 September and a size limit of 15 centimeters, Ishikawa Prefecture a closed season 1 May-31 August and a size limit of 15 centimeters, Kumamoto Prefecture a closed season 1-30 June, and Chiba Prefecture a size limit of 16 centimeters.

10. Sinonovacula constricta (Lamarck)
Japanese Name: Agemaki, Kamisorigai

a. Synonomy

1818 Solen constrictus Lamarck, Anim sans Vert, 5:455
1874 Solecurtus constrictus Sowerby, Conch Icon, sp 29
1882 Siliquaria constricta Dunker, Index Moll Mar Japon: 175, pl 7, fig 25
1924 Sinonovacula, Prashad, Proc Mal Soc London, 16:45, text figure

b. Characteristics and Distribution

Shell elongated, cylindrical. Anterior end rounded, posterior angular; both ends of the shell open. Umbo situated slightly anteriorly. Outer surface of shell with many coarse concentric lines. Shell covered by dark yellow periostracum; inner surface white. Main teeth two on the right and three on the left valve; no lateral teeth. Length 10 centimeters, height 3 centimeters. The body protrudes beyond the shell and the siphons attain a length of 45 centimeters (Figure 10).

This representative species of edible clam inhabits soft muddy bottom in shallow bays. The culture centers are in the Ariake-kai in western Kyushu and in Kojima-wan on the Inland Sea coast of Okayama Prefecture. The Kojima-wan site is the result of very successful transplantation of shells from the Ariake area during 1892-93. The species is also found along the Yellow Sea coast of Korea and on the coast of China.

c. Living Conditions

After studying the environment in which S. constricta thrives best, Icho and Oshima (1938) described the optimum environmental conditions for the survival of this clam as follows: (1) the sea calm and somewhat diluted by incoming fresh water; (2) a specific gravity between 1.005 and 1.015; (3) water temperature not lower than 2°C or higher than 30°C. The best bottom is composed of 1.7-2.6 centimeters of soft mud at the surface, below which lies 10-13 centimeters of a sand-mud mixture, and below this a substratum of 60 centimeters of mud. The bottom in which the clams are buried must be exposed for about three hours at normal ebb tide.

Fujimori (1929) experimented on the growth rate of this clam in aquaria having different specific gravities. Three large jars were prepared with suitable mud bottoms, and 30 S. constricta were planted in each. The jars then were placed at three different stations in water having different specific gravities. From results of this work (Table 6), Fujimori concluded that a specific gravity close to 1.01916 is optimum.

The time of exposure during ebb tide is extremely important. Even if the water and bottom conditions are suitable the clam's growth is retarded materially if the exposure during ebb tide is too long. Working at Miike, Kyushu, Fujimori studied this subject. Ten stations were selected in a line perpendicular to the water level. Fifty specimens of S. constricta, planted in October, were harvested the following April and the growth averaged at each station. From results of his work (Table 7) Fujimori concluded that growth was best at the lower levels where the clams were exposed for fewer hours at ebb tide, and that growth was inversely proportional to the number of hours of exposure. The relationship is probably associated with the hours required for feeding, which can occur only when the shells are covered with water.

Fujimori also proved the close relationship between bottom type and growth in S. constricta in a field experiment in the Ariake-kai. Young clams of the species, all the same size, were planted in five stations in a line perpendicular to the water level. The salinity of each station was similar, well within the optimum required range for growth. His results are shown in Table 8. Although the exposure time in the lower stations (Nos 4,5) should have produced the best results, the unfavorable bottom conditions prevented this, the best growth being obtained under the conditions of bottom represented in Stations 2 and 3. Thus the two factors of exposure time and bottom type play important roles in the growth rate of this species.

d. Reproduction and Development

No one investigator has traced the life history of S. constricta from fertilization to maturity, and the knowledge of the life history is of necessity pieced together from the investigations of several scientists. Even then it is very incomplete.

(1) Egg and Sperm

The mature gonad of the male and female of this clam is milky white in each sex according to Fujimori (1929). The egg has a diameter of 0.08 millimeter and is spherical. The spermatozoa is not described.

(2) Spawning

According to Fujimori the breeding season in the Ariake-kai is from late September to late October, with the peak of spawning activity normally falling between 10-20 October when the temperature ranges from 20°C to 25°C.

(3) Development

The eggs hatch out 10 days after fertilization (Icho and Oshima 1938). The larvae reach the trochophore stage five to six hours after hatching at a temperature of 20°C and in water having a specific gravity of 1.015 (Hamada 1922).

As a result of his investigations in the Ariake-kai, Fujimori concluded that the specific gravity of the sea water played a very important role in the development and life history of S. constricta but was intimately and inextricably associated with bottom type and exposure hours. In general he found that the rearing grounds for this clam are best within an area bounded by lines paralleling the tidal level at 1.5 meters above the low low tide and 4.0 meters above low low tide. However, within these optimum limits he found a very confusing variation of salinities, from 1.00 to 1.022 depending on the condition of the tide (spring or neap), the direction of its movement (ebb or flow), and the type of bottom. His only clear conclusion was that a salinity below 1.00500 was fatal to development or growth.

(4) Growth

S. constricta is extremely sensitive to the factors composing its environment. Hence the life history of the species is dependent upon and varies with the environmental conditions. As some of these are unstable, definite statements or figures describing the life history are difficult to obtain.

Studying the growth of this clam in the Ariake-kai first on natural grounds and then on the culture grounds, Fujimori proved the advantage of transplanting the young shells from a "natural" area to a selected culture area where conditions were optimum. He found that the best larval hatching occurred in water having a low salinity and that this was the preference of the young clams, in contrast to a preference of a higher salinity by the adults. As a result, in natural grounds the growth rate is slow because of this lower salinity factor. If the young clams are transplanted into areas of higher salinity which obtain on the culture grounds, more rapid growth is attained. This Fujimori shows by comparing the growth rate of clams on the natural ground with those transplanted to a culture area (Tables 9, 10).

Growth practically stops during the fall (spawning season) and winter and is most active from April to September (Table 10). Growth is most rapid during the first year, becoming slower each succeeding year (Figure 4). The maximum size is attained at about six years of age, with a length of 12.5 centimeters.

(5) Food

The work of Fujimori showed that the principal food of S. constricta consists of such diatoms as Biddulphia, Coscinodiscus, Melosira, Nitzschia, Pleurosigma, and Skeletonema, and other forms such as Navicula and Gramatophora.

e. Culture

(1) Culture Methods

As already indicated, the young shells develop on the higher ground in water of lower specific gravity, whereas growth is better at lower levels and higher specific gravities. This fact is the basis of the culture of S. constricta.

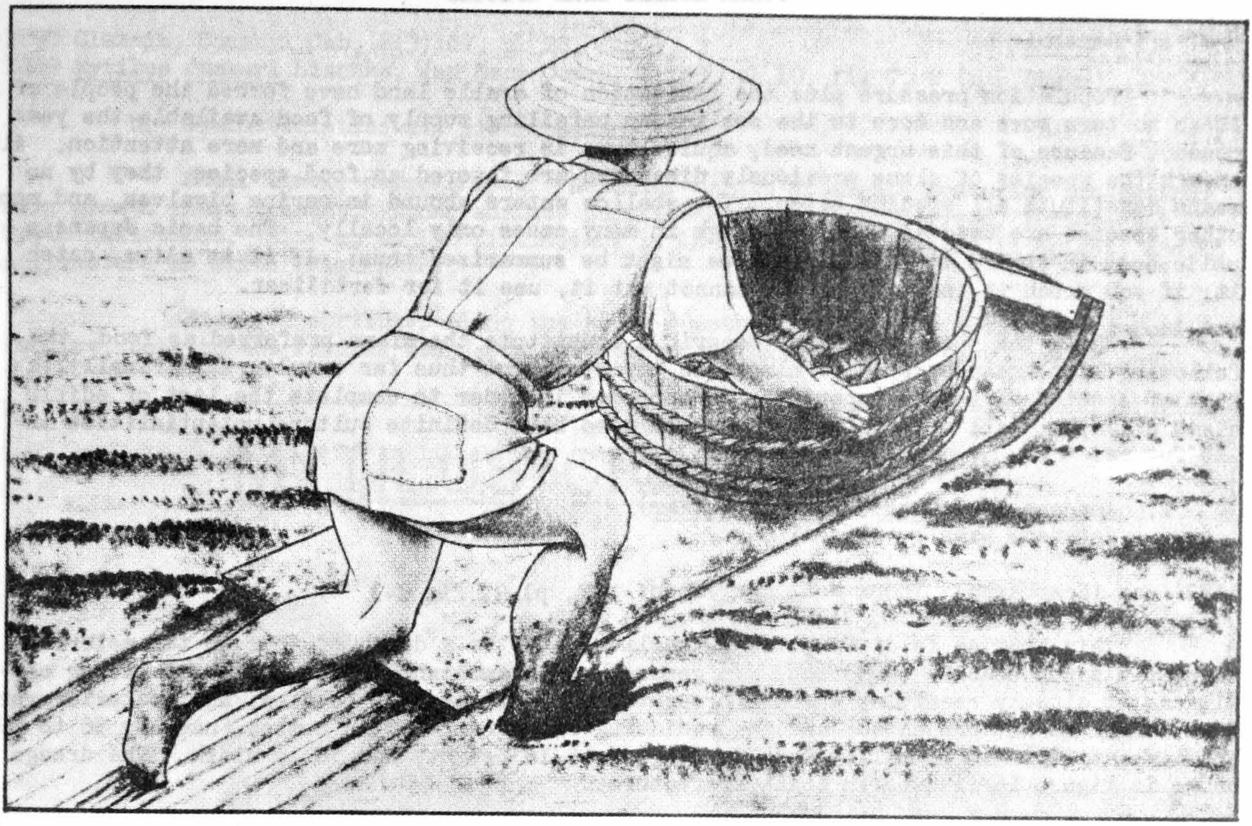
When about one year old the seed clams are suitable for transplanting and sowing (Icho and Oshima 1938). The sowing usually takes place from June to August. When transplanted to the culture grounds the seed is usually about 3.3 to 4.3 centimeters long and numbers from 600 to 800 per sho.

Gathering the seed is rather difficult because, although the natural seed ground is usually so high that the area is but slightly covered with water, the young clams bury themselves to a depth of from 20 to 26 centimeters. The fishermen go to the seed grounds at low tide equipped with a wooden pail ("Hangirioke") and a broad wooden board ("Hansita") (Figure 27). With one knee on the board, they push themselves over the soft mud with the other foot, the board acting as a sort of pontoon to keep them from sinking deeply in the semiliquid mud. The clams are gathered by picking by hand or by using a hoe. Although the density of the seed clams varies greatly, one skilled workman on a well concentrated bed can gather 27 to 36 liters on a single low tide. The gathered clams are kept wet by sprinkling repeatedly with sea water and are transported as quickly as possible to the rearing grounds where they are planted immediately, even though it may be at night or high tide. From two to three sho usually are planted per tsubo, but where the bottom conditions are best four to five sho can be planted with profit.

One year after sowing a mortality of from 40 to 50 percent is found, but the increase in size obtained through transplanting, as we have said, more than compensates for this mortality. While the mortality may be 50 percent, the increase in weight is four or five fold.

(2) Harvesting Method and Gear

In the Ariake-kai the harvesting season is from spring to autumn, but in other regions of the species range it is during the fall and winter. The same "ski-board" type of equipment as that used in gathering the seed clams is used to navigate over the grounds. The unskilled fisherman gathers the clams by hand, but the skilled workman uses



NATURAL RESOURCES SECTION

Figure 27. - Transporting seed of Sinonovacula constricta at Ariake-kai

a bamboo stick tipped with a hook. The men locate the respiratory hole made by the clam in the mud, enlarge it by inserting a finger, and pull the clam out by using the hook.

f. Enemies and Damage

As this clam is a low salinity species, if covered even for a few hours by water of high salinity it suffers great damage, especially when young. In the Ariake-kai propagation of this species rose rapidly from 1901 to a peak in 1905. However, it began to to suffer damage in 1906 and both the natural and artificially cultured Sinonovacula constricta were decimated thereafter by an unknown factor. The damage was greatest from late April to late June and again during October and November. According to Fujimori (1929), who made a chemical and biological study of the problem, increase in the specific gravity of the water was one factor responsible. He believed that ocean currents change locally for some reason, causing a rise in salinity; as this clam is especially sensitive to salinity; it was almost annihilated. The death rate was given further impetus by the decomposition of the many of dead clams, polluting the shallow waters.

Among animal enemies of this species Icho and Oshima (1938) list crabs (Neptunus trituberculatus), starfish, drills, and almost the same enemies which damage oysters. Also as this clam extends its foot through the shallow mud in movement it is easily preyed upon by two Gogynoid fish (Acanthogobious flavimanus, Taenisides rubicundus) and two herons, eastern gray heron (Ardea einerea jouyi) and egret (Egretta sp.).

g. Utilization

S. constricta is utilized mostly in soup or as a canned product. Prior to World War II the meat was dried after boiling and was then known as "Kantei". In this form it was exported in quantity to China. This export trade began early in the Meiji Era, and culture rose steadily until 1905 at which time the annual production had a value of ¥1,500-000. The last specific figure available is that of Fujimori for 1928 at which time he places the annual production value at ¥60,000. The production in Ariake-kai has never recovered from the chemical damage previously described.

OTHER EDIBLE CLAM SPECIES

1. General

Population pressure plus the limitation of arable land have forced the people of Japan to turn more and more to the sea for an unfailing supply of food available the year round. Because of this urgent need, aquiculture is receiving more and more attention. Although the species of clams previously discussed are favored as food species, they by no means constitute all species eaten. The shallow waters abound in marine bivalves, and many other species are used as food, although in many cases only locally. The basic Japanese philosophy in regard to life in the sea might be summarized thus: If it is alive, catch it; if you catch it, eat it; if you cannot eat it, use it for fertilizer.

While the species already described constitute the clams preferred as food, the following list includes species almost as important but thus far uncultured. Finally, a list of species of lesser importance is appended in order to complete the list of edible clams of Japan. All are of food value, and some have definite culture potentialities in the future.

2. Anadara (Scapharca) satowi (Dunker)
Japanese Name : Satogai

1882 Arca (Scapharca) Index Moll mar Japon: 233, pl 9, fig 1-3

This species is distributed in shallow water to a depth of four to ten meters along the sandy beaches of Honshu. In general appearance and in its choice of living conditions it closely resembles Anadara broughtoni. It is smaller in size, the posterior ventral margin is not projected, and the radiating ribs are fewer in number, usually 36 to 39. The size attained is 80 millimeters in length, 65 in height, and 58 in width. The dredge shown in Figure 16 is used in Chiba Prefecture.

3. Anadara broughtoni (Schrenck)
Japanese Name: Akagai

1867 Arca broughtoni Schrenck, Reis Amuir. Zool Moll: 578, pl 24, fig 1-3 (Oct)
1844 Arca inflata Reeve, Conch Icon, sp 30
1906 Arca tenuis Tokunaga, Jour Col Sci Imp Univ Tok 21 (2):58, pl 4, fig 1 a, b

Living at a depth of from 10 to 40 meters in calm inner bays having a muddy bottom, this species is distributed over a wide range from southern Hokkaido to Kyushu (see Frontispiece).

In appearance the shell closely resembles A. subcrenata, but in the adult stage it is very much larger. The umbo is highly projected; radial ribs number 42 or 43; surface of the shell is covered by a yellowish-brown coat except in the umbonal region, where it is white; many minute teeth are arranged in series. Adults frequently attain a length of 150, a height of 95, and a width of 70 millimeters. The spawning season is in summer. Harvesting is done by dredging.

The meat is purplish-red because of the presence of hemoglobin in the blood, an unusual condition among the mollusks. The meat is eaten fresh, with vinegar, or is canned.

The shell is utilized as the collecting gear of small octopuses (Octopus fangsiao) in Inland Sea. Two valves are bound to a long line and laid on the sea bottom as a common octopus pot. The octopus hides itself between the valves.

4. Mytilus crassitesta Lischke
Japanese Name: Igai

a. Synonomy

1868 Mytilus crassitesta Lischke, Mal Blatt, 15:221
1869 Lischke, Jap Meer Conch, 1:151; pl 11, fig 1, 2

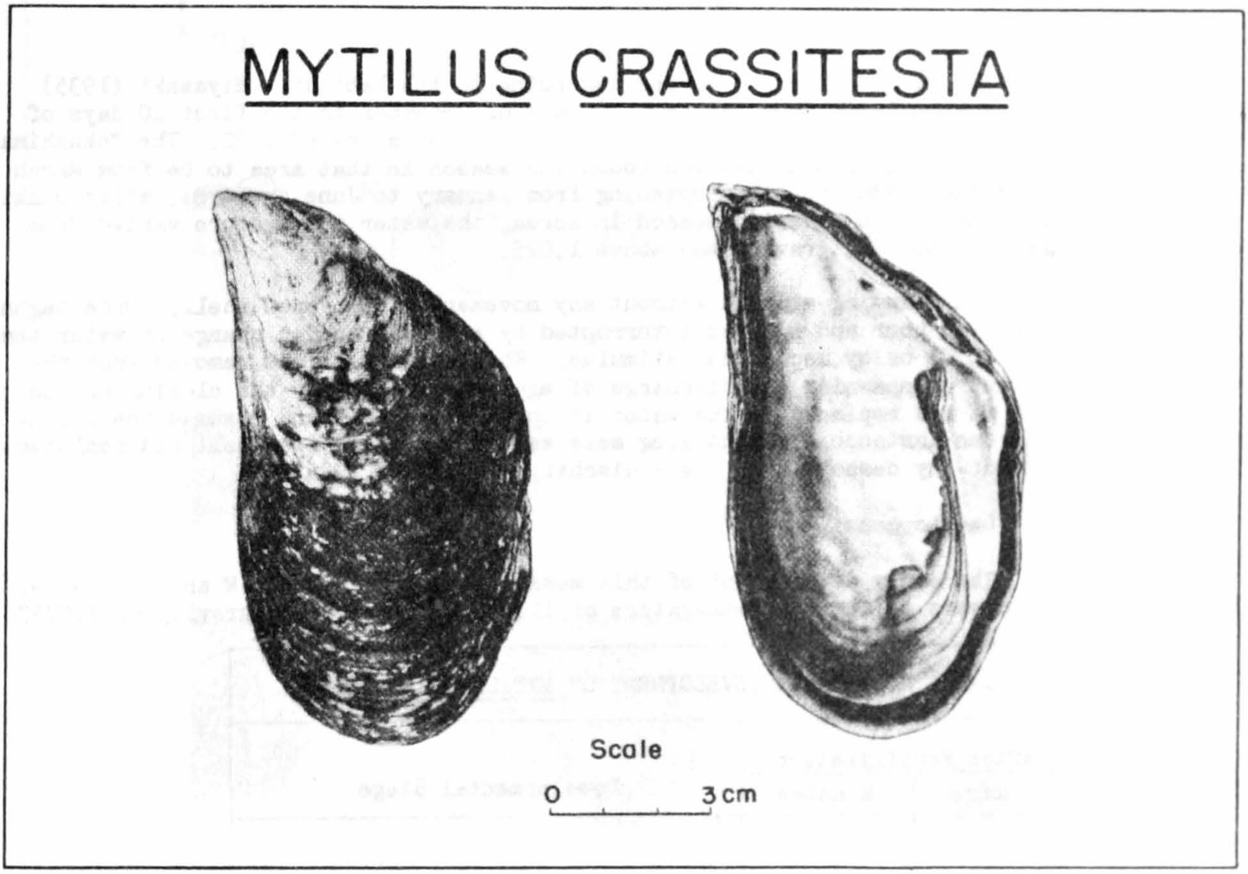
a. Synonomy (Cont'd)

1890 Clessin, Conchyl Cab, 8(3):67, pl 20, fig 1, 2
1869 Mytilus dunkeri Lischke, Jap Meer Conch, 1:153, pl 10, fig 7, 8 (non Reeve)

b. Characteristics and Distribution

Shell black, wedge-shaped. Anterior margin straight, posterior projecting; many growth lines present. Inner surface purplish-red or purplish-green, irridescent. Teeth indistinct. Size up to 130 millimeters in length, 60 millimeters in height, and 45 millimeters in width (Figure 28).

Widely distributed along the rocky coasts of Japan from Mutsu-wan, Aomori Prefecture, both on the Pacific and Japan Sea shores, in water from 10 to 20 meters deep.



NATURAL RESOURCES SECTION

Figure 28

c. Living Conditions

This gregarious species congregates on rocky shores, attaching itself to fixed surfaces by a byssus in areas that are well washed by clean sea water. To move, it extends its foot and secretes a mucous which flows through a groove in the foot, coagulates, and becomes a new byssus. The old byssus is then abandoned. Locomotion is therefore a slow process, as the byssus must be renewed several times in order to advance the animal 2.5 centimeters.

d. Reproduction and Development

(1) Egg and Sperm

When the ovum is extruded from the body it has a length of approximately 77 µ along its major axis and about 60 µ along the minor axis. The color is a pale yellow brown.

The head piece of the sperm is oval, terminating anteriorly in a conical protuberance and tapering posteriorly. It measures 5 µ in length and 2.6 µ in width. The middle piece is strongly refractive and consists of two chondriospheres. The tail piece is 60 µ in length. When freshly extruded from the testis the spermatozoa are immobile, active movement in sea water starting after a lapse of about 30 minutes at a temperature of 8°-9°C. The movement is a counterclockwise spiral. Artificial fertilization has not been successfully accomplished experimentally.

(2) Spawning

The spawning season varies according to its habitat. Miyazaki (1935) reported that the season lasts from the last 10 days of December to the first 10 days of April at Kánazawa, Kanagawa Prefecture, at a "trigger" temperature of 10°C. The Tokushima Prefectural Fisheries Experimental Station found the season in that area to be from March to September. Yoshida (1936) reported spawning from January to June in Korea, while Ozaki (1942) noted that during the spawning season in Korea, the water temperature varied from 10°C to 16°C and the specific gravity was above 1.025.

The spawning started without any movement of the open shell. Once begun it lasted for about an hour and was not interrupted by either a sudden change of water temperature (10°C to 30°C) or by mechanical stimulus. When the mussel was removed from the water during the act of spawning the discharge of eggs was stopped by the closing of the shell; as soon as it was replaced in the water it opened its shell and resumed the extrusion of eggs. In one instance a discharging male was removed from its shell and replaced in the water without any cessation of sperm discharge (Miyazaki 1935).

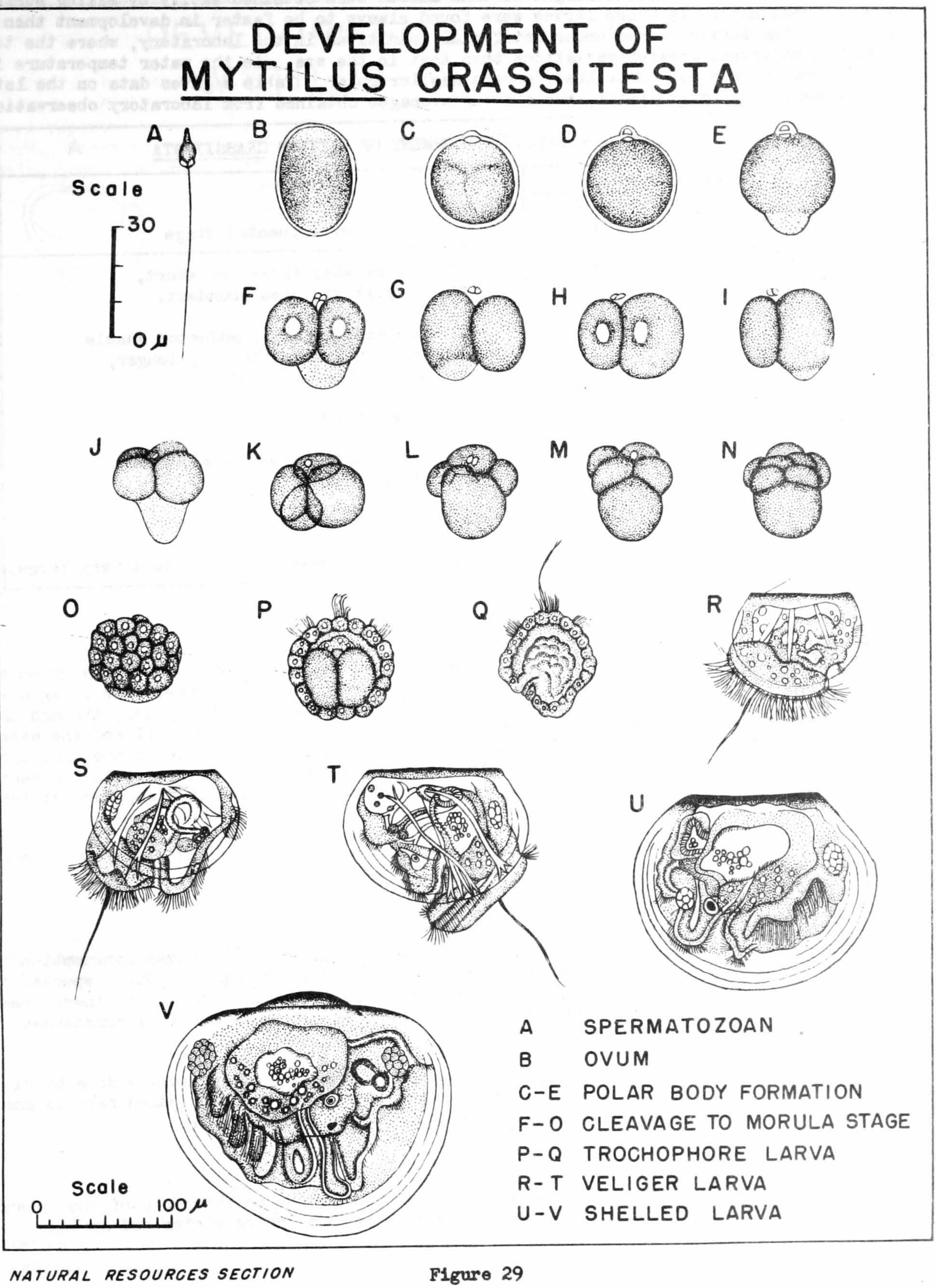
(3) Development

The early development of this mussel is shown in Table M and Figure 29. These developments were at a water temperature of 11.2°C and a specific gravity of 1.02330.

TABLE M. - EARLY DEVELOPMENT OF *MYTILUS CRASSITESTA*

After Fertilization		Developmental Stage
Hours	Minutes	
0	25	First polar body extruded
0	40	Second polar body extruded
1	20	First polar lobe appears
1	25	First segmentation begins
2	0	First polar lobe retracted
2	25	Second polar lobe appears
2	37	Second cleavage; second polar lobe retracted
3	20	Five-celled stage
3	30	Eight-celled stage
16	25	Embryo begins to rotate
53	50	Shell developing

SOURCE: Miyazaki (1935)



NATURAL RESOURCES SECTION **Figure 29**

Later developmental stages of this mussel were obtained easily by making surface tows. These naturally grown larvae were found always to be faster in development than corresponding larvae reared under artificial conditions in the laboratory, where the temperature underwent greater variations than that in the sea. As the water temperature in the laboratory was not controlled, growth was irregular. Table N gives data on the later development of M. crassitesta, these being averages obtained from laboratory observations.

TABLE N. - LATER DEVELOPMENT OF MYTILUS CRASSITESTA

After Fertilization		
Days	Length (μ)	Developmental Stage
3	95	Hinge straight; intestine short, thick; yolk granules abundant.
6	107	Transparent; anterior adductor muscle appears; intestine thinner, longer, looping on the left side.
12	114	Hinge yellowish
34	129	Liver visible; posterior adductor muscle appears.
72	173	Statocyst appears
86	203	Umbo stage; eye-spot formed; foot very large.

SOURCE: Miyazaki (1935)

Yoshida (1936) studied the development of the veligers. When the fully grown veligers attained a length of 0.28-0.32 millimeter the velum became reduced, the pelagic veliger stage ended, and the mussel entered its benthic existence. Thereafter, through the more rapid and broader growth of the ventral-posterior portion of the shell and the assumption of the dorsal-anterior portion of an acute angular form, the change in the direction of the axis of the shell is attained and the adult form results. During growth the teeth on the dorsal-posterior rim of the shell become reduced and eventually disappear but those on the dorsal-anterior rim never disappear (Figure 30).

The clam reached a length of nine centimeters during the first year and became sexually mature in three years (Icho and Oshima 1938).

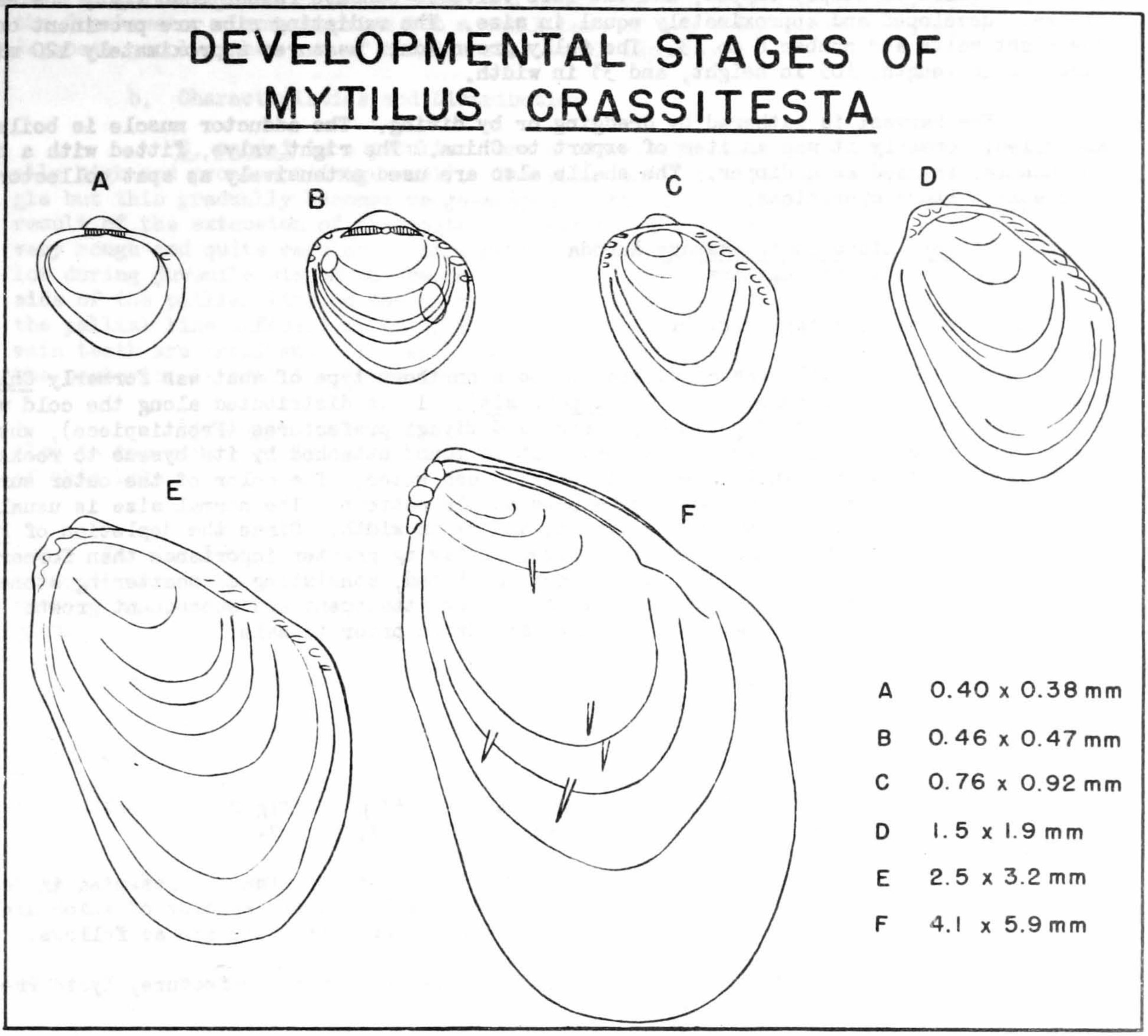
e. Culture and Harvest

Because so many more favored bivalves are available for human consumption in Japan, this species is not cultured nor has its culture been attempted. Other species of the genus Mytilus are cultured in Europe, especially in France and Italy, and there seems to be no reason why similar culture could not be carried out in Japan if circumstances warranted. This is not the case at this time.

In those areas where M. crassitesta is harvested this is usually done by divers because of the depth of water involved. Where practical a long-handled rake is used. The harvesting season is from December to March (Icho and Oshima 1938).

f. Utilization

In Japan this species is used as food only in the neighborhood of the Inland Sea. The meat is red in color, and best for eating purpose during winter and spring.



NATURAL RESOURCES SECTION

Figure 30

Formerly the meat was boiled and dried into "Tansai" and exported to China. For home consumption it is used in soup. Much of the harvest is utilized as fertilizer. The shell is worked up into buttons and other decorative products, or crushed to make calcium. It is also used as cultch for the collecting of oyster spat.

5. Pecten (Pecten) albicans (Schroeder)
   Japanese Name: Itayagai

1842 Pecten laqueatus Sowerby, Thes Conch, 1:46, pl 15, fig 101
1844 Pecten antonii Philippi, Abbild Besch, 1:99, pl 1, fig 1
1922 Pecten excavatus Yokoyama, Jour Coll Sci Imp Univ Tokyo 44 (1):183, pl 15, fig 6, 7 (Non Anton)

This is the species commonly referred to in literature as Pecten laqueatus Sowerby.

This species inhabits sandy bottom in water from 20 to 40 meters deep and is distributed along most of the coast of Japan where environmental factors are favorable. In general form the shell resembles Pecten yessoensis, but the valves are smaller and thinner.

The right valve is deeply cupped, and the left valve is concave rather than flat; the ears are well developed and approximately equal in size. The radiating ribs are prominent on the right valve and number 8 to 13. The fully grown adult measures approximately 120 millimeters in length, 105 in height, and 35 in width.

The harvest is gathered by dredging or by diving. The adductor muscle is boiled and dried; formerly it was an item of export to China. The right valve, fitted with a bamboo handle, is used as a dipper. The shells also are used extensively as spat collectors in oyster culture operations.

6. Chlamys nipponensis akazara Kuroda
   Japanese Name: Akazara

1932 Kuroda Venus 3(2) appendix: 91

This clam usually was considered to be a northern type of what was formerly Chlamys farreri nipponensis Kuroda (now C. nipponensis). It is distributed along the cold water coast of western Hokkaido, Aomori, Iwate, and Miyagi prefectures (Frontispiece), where it inhabits water from 4 to 10 meters deep. It is found attached by its byssus to rocks and pebbles in areas not influenced by incoming fresh water. The color of the outer surface is purplish-brown with an indefinite pale purple pattern. The normal size is usually about 70 millimeters in length, 80 in height, and 32 in width. Since the depletion of Pecten yessoensis this species has been recognized as having greater importance than formerly. In Aomori Prefecture a simple culture has been developed, consisting of scattering stones in water of the proper depth to afford a location for attachment and subsequent growth (Icho and Oshima 1938). The muscle is boiled and dried prior to sale.

7. Corbicula sandai Reinhardt
   Japanese Name: Setashijimi

a. Synonomy and Importance

1878 Corbicula sandai Reinhardt, Jahr Deut Mal Ges, 5, 187 pl 5, fig 2
1907 Corbicula biola Pilsbry, Annot Zool Japan, 6:158; pl 7, figs 7-10

The genus Corbicula is a group of small fresh-water clams represented in Japan Proper by four species and three varieties (Kuroda 1938), three species of which are used as food by the Japanese. These, with their general distribution, are as follows:

(1) Corbicula sandai Reinhardt 1878: Biwa-ko, Shiga Prefecture; Kyoto Prefecture.

(2) Corbicula leana Prime 1864: Honshu, Shikoku, Kyushu.

(3) Corbicula japonica Prime 1864: Honshu, Shikoku, Kyushu.

   (a) C. japonica atrata Reinhardt 1878: Kyushu, Shikoku, Honshu.

   (b) C. japonica sadoensis Pilsbry 1901: Hokkaido, Sado-shima.

   (c) C. japonica transversa von Martens 1877: Kanagawa Prefecture, Honshu; Nagasaki and Saga prefectures, Kyushu.

A fourth species, Corbicula awajiensis Pilsbry, also is found in northern Kyushu and the southern half of Honshu, but as it is seldom used for food because of its small size, it is disregarded in this report.

The three species above listed are the only fresh-water clams regularly eaten by the Japanese. Their culture is relatively crude. The species C. japonica will be discussed as a whole and will not be subdivided into its component varieties, as these are not recognized by the clam fishermen and hence are not separated subspecifically. While the fresh-water clams comprise but a small part of the total molluscan food supply of the Japanese people, they are of considerable local importance.

b. Characteristics and Distribution

C. sandai is a peculiar form of Corbicula inasmuch as the umbones are unusually high and prominent (Figure 31). The young shell has the shape of an isosceles triangle but this gradually becomes wedge-shaped as the clam approaches the adult stage, as a result of the extension of the posterior region. The concentric rings on the shell are very rough and quite regular in arrangement. The outer surface of the shell is orange yellow during juvenile stages but becomes lustrous black with age and maturity. The area outside of the pallial line on the inner surface of the shell is dark purple, the area within the pallial line suffused with light purple. The hinge line is thick and strong and three main teeth are prominent. The angle of both groups of lateral teeth is less than 90° and the posterior lateral teeth are long.

Corbicula sandai originally was found only in Biwa-ko, but now it is found also in the waters of Kyoto City and in other nearby districts which belong to the system of this lake.

This Corbicula had been transplanted from Biwa-ko to Suwa-ko in Nagano Prefecture. Kuroda (1936) reported that the form changed from the original triangular to round, owing to the influence of the environment. The clams did not propagate in spite of the success in transplantation, and their flavor was inferior to that of original Biwa-ko Corbicula.

c. Habit and Habitat

This Corbicula inhabits bottoms composed of sand having an admixture of pebbles and shows a marked distaste for muddy areas. A weak current is also a requirement. The clam buries itself from two to six centimeters deep during the winter, reappearing at the surface in late March or early April.

The life history and development is unknown, but Miyazaki (1936) reports C. sandai to be dioecious. According to Kawabata (1931), this Corbicula reaches its maximum fatness during April and May "when the wisteria flowers open" and suddenly decreased in meat weight in June "when the wisteria blossoms fall". He states that spawning occurs during these months. During the period June to September the weight is light and the flavor poor. To illustrate the relative quality of the clams at various seasons Kawabata gives the following figures on the volume of unshelled clams (gallons) required to produce one gallon (4.4 liters) of meat: Oct-Dec, 14-15, quality bad; Jan-Mar, 12.5, quality good; Apr-May, 7-10, quality best; Jun-Sep, 13.5, quality not good. Kawabata also pointed out that the quality varies with the habitat. Clams inhabiting muddy places are poor in quality and taste, while clams from sandy or sandy-pebbled areas where the water is clear and fast flowing are superior in quality.

d. Harvesting Methods and Gear

Two types of dredges are used to gather this species. In the deeper parts of Biwa-ko the "Kaihikiami" is used while in the shallower Seta-gawa which flows from the southern end of the lake the "Shijimikaki" is used. The Kaihikiami is a simple dredge made with a wooden or metal frame and fitted with a net. It is drawn from a rowboat at the end of two towing lines. The Shijimikaki is a hand dredge used from a rowboat. It consists of a dredge fitted with a thick cotton net, from which a vertical bamboo pole rises as a handle. The fisherman in the boat pushes the gear into the bottom and, by using the side of the boat as a fulcrum, rakes back and forth with it as the boat moves or drifts slowly along.

e. Production and Utilization

In Biwa-ko the clamming operations are carried on throughout the year, except for a closed season in late spring. At Seta on the Seta-gawa, the Shijimikaki is used the

TWO IMPORTANT SPECIES OF CORBICULA

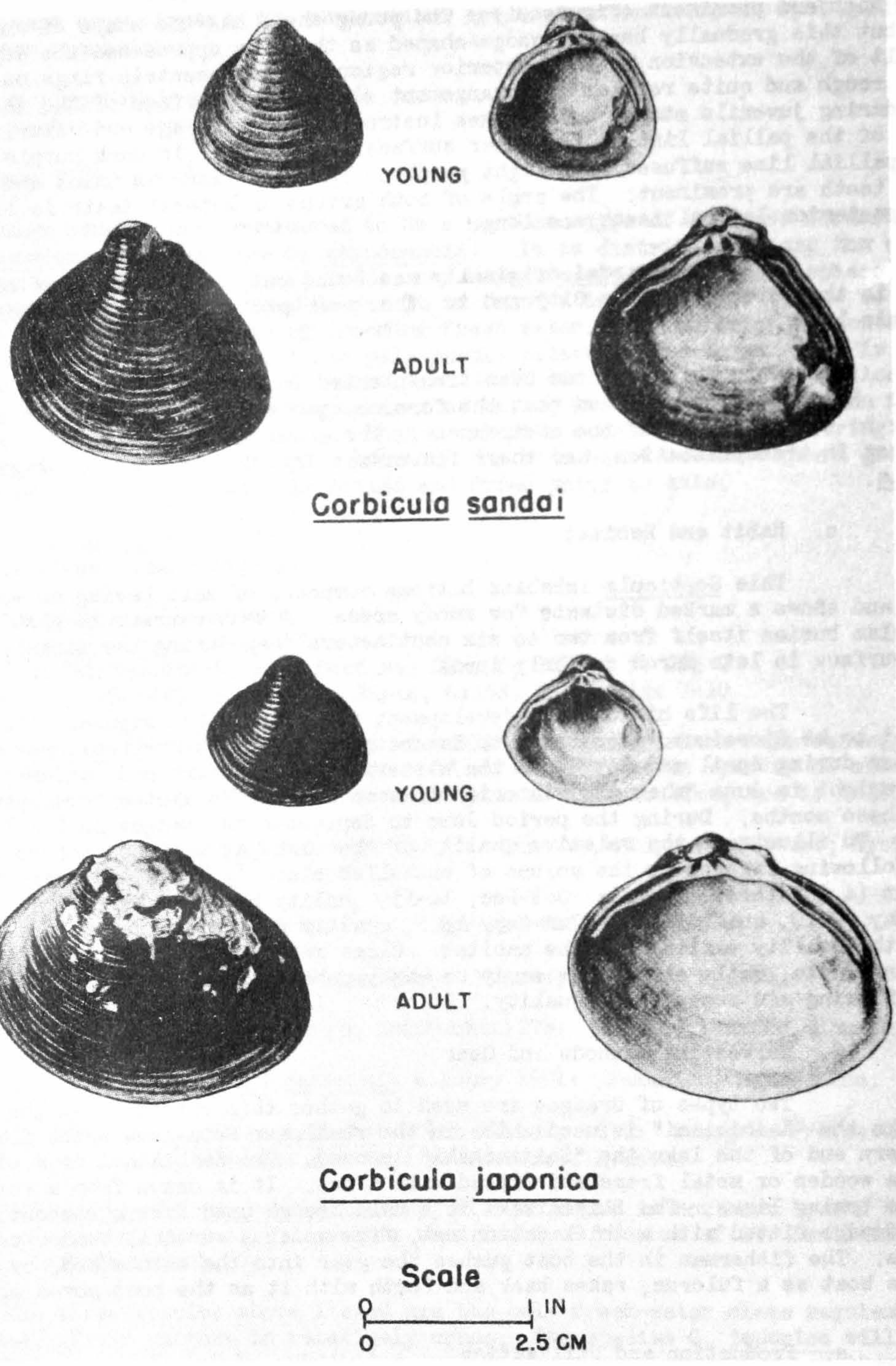


Figure 31

year round with no closed season. One person is able to gather from 53 to 95 liters of clams per day. The total of this species taken in Biwa-ko during 1942-48 is given in Table 11, and the amount caught in the Seta-gawa area during 1947-49 is shown in Table 12. The meat of this species has the best flavor just before spawning; therefore the harvest is usually large during February-early May and largest in April.

The shelled clams are sold fresh in the Kyoto and Otsu markets under the name of Kawashijimi. By another method, in use for some 150 years, the clams are placed in running fresh water for one night to eliminate the sand in the alimentary canal. They are then boiled, and the meat is separated from the shells by straining through a bamboo basket and is sold as "Shigureni". The shell is powdered after burning.

f. Regulations

The Fishing Regulation Act of Shiga Prefecture prohibits the taking of Corbicula sandai from 15 May to 30 June, and the taking of young shells less than 1.5 centimeters in length at any time. The Seta-gawa area is, however, specifically excluded from this law, so that no closed season is in force on C. sandai there. How long such a limited area can support an annual harvest such as is indicated in Table 12 without the aid of culture activities is an open question.

g. Influence of Water Level on Production in Suwa-ko

In Suwa-ko, Nagano Prefecture, the distribution of the shellfish Corbicula is limited to a depth of 50 centimeters when the water level is 759 meters above sea level (Miyasaka 1949). Water around two meters with sandy bottom is best for the breeding of this shellfish. Since the construction of a dam, all sorts of fishes in this lake have been depleted, presumably owing to the fluctuations of the water level which range within about one meter. The water level often falls in winter, and this coincides with the spawning of Corbicula. The depletion of Corbicula production (Table 13) may possibly be the result of this fluctuation, although other factors such as over-fishing must yet be investigated before a definite answer can be given.

8. Corbicula leana Prime
Japanese Name: Mashijimi

1864 Prime, Ann Lyc Nat Hist New York, 8:68; fig 14
1878 Corbicula pexata Reinhardt, Jahrb Deutsch Mal Ges, 5:193; pl 5, fig 6
1907 Corbicula orthodonta Pilsbry, l.c.p 156, pl 7; fig 1, 2, 5, 6

This species is distributed in Honshu, Kyushu, and Shikoku, where it inhabits areas with sandy bottom. Anterior and posterior margins are almost symmetrical, the umbo forming a rounded projection. The surface is glossy black and covered with rough, regularly concentric lines. The young shell is faintly yellowish-green with an irregular brown pattern. Inner surface is bluish-purple. There are two main teeth on the right and three on the left valve, with a long lateral tooth. The size usually attained is 43 by 37 by 22 millimeters. The ovary of the mature animal is grayish, the testis grayish-white. Young shells attain a length of one centimeter at the age of one year, two centimeters at the age of two years (Icho and Oshima 1938).

This clam is one of the most common of the Japanese fresh-water species and inhabits clear brooks and ponds. The spawning season extends from June to October (Icho and Oshima 1938). According to Miyazaki (1936) this clam is monoecious and incubates its young, the inner gill lamellae being differentiated structurally for marsupial purposes. The early larva is furnished with a velum which is useless for swimming. The D-stage larva within the mother shell attains 237 μ in length and 193 u in height. When compared to the same stage of marine bivalves, it shows more advanced development in its general organization, the larva already having well-developed functional gills, a foot, and a byssus (Figure 32). Immediately after the discharge from the mother shell the larva enters the bottom life, and when it reaches a length of 1.5 millimeters brown pigment appears on the outer surface of umbo (Miyazaki 1936b).

DEVELOPMENT OF MERETRIX MERETRIX LUSORIA

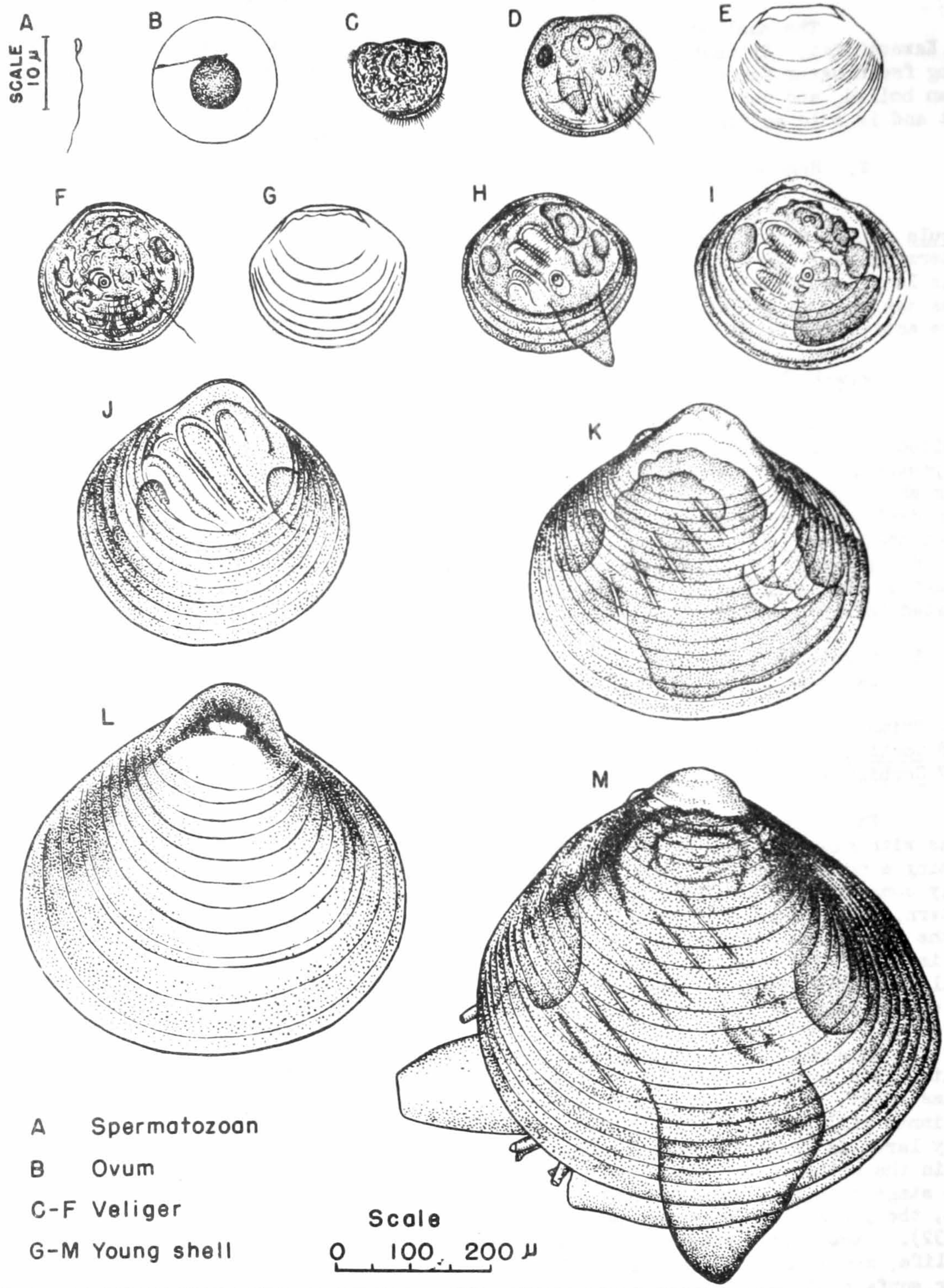


Figure 32

The meat is seasoned and eaten fresh or is canned. The shell is frequently used for making shell toys or is made into fertilizer.

9. Corbicula japonica Prime
Japanese Name: Yamatoshijimi

1864 Prime, Ann Lyc Nat Hist New York; 8:68; fig 15
1877 Corbicula biformis Reinhardt, Sits Ber Ges Nat Freunde Berlin, p 70

This clam prefers the brackish water of river mouths and is found in Honshu, Kyushu, and Shikoku at a depth of about eight meters on a bottom 70 percent sand and mud. As compared with Corbicula leana, the umbonal region is larger and the ventral margin forms more nearly a straight line. The outer surface is glossy black and usually bears a radial patten. Young shells are yellowish-brown. Concentric lines are rough and sometimes obscure, the anterior lateral tooth longer than posterior lateral tooth. The inner surface is pale purple, blending to milky white in the deepest part of the valve. The size is usually 40 millimeters in length, 35 in height, and 22 in width. Miyazaki (1936b) reports that this species is dioecious and non-incubatory.

The most intensive fishing for this species occurs in the mouth of the Tone-gawa, at Shiishiba, Chiba Prefecture. Here two methods are used, both involving the same gear, which consists of an iron rake, a basket, and a bamboo pole (Figure 33). In one method the dredge is held by hand at the stern of the boat and the boat is moved by means of a 100-meter loop attached to a winch and fixed to a pole planted in the bottom. In the second method two dredges are held by hand at the stern of the boat, and the boat is moved by means of a "water sail" measuring three by three meters. This sail is of canvas or other material, with a weighted frame below and a bamboo pole above to act as a float. Submerged, it drifts with the current, pulling the boat slowly along. The direction and speed is controlled by a dragging anchor.

Fishing is engaged in during the entire year, but as the table quality of the clam is best in winter the peak of the harvest occurs during that season. The Japanese believe that soup made from the meat of this species is an effective remedy for jaundice.

10. Meretrix lamarckii Deshayes
Japanese Name: Chosen-hamaguri

1853 Meretrix, Cat Conch Brit Mus: 39

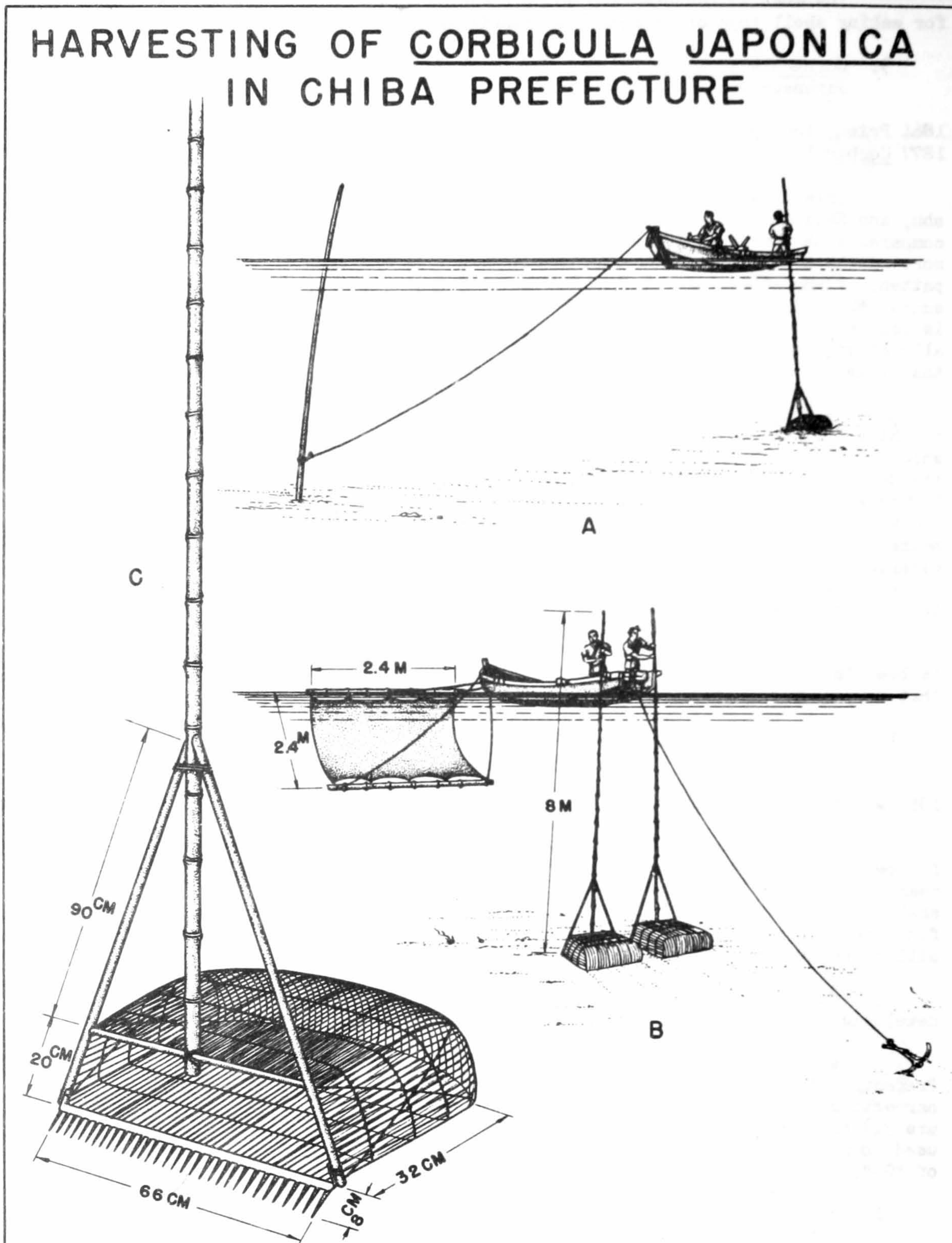
This clam is very similar to Meretrix meretrix lusoria but differs from it in the following details: the shell is larger, thicker, and heavier, the ventral margin is more nearly a straight line, and the width is somewhat less in proportion to the length of the shell. The distribution is limited to the open ocean shores, whereas M. m. lusoria is found in bays and similar sheltered localities. An individual of normal size measures 100 millimeters in length, 75 in height, and 45 in width.

The breeding season is from June to August, but nothing is reported regarding its development or growth.

Along the open ocean coasts of Ibaraki and Chiba prefectures on Honshu and Oita Prefecture in Kyushu the shell is especially abundant, and these areas afford excellent harvesting grounds. The harvesting is accomplished either by a deep-water dredge (Figure 34) or a hand dredge (Figure 35). The meat is greatly desired as food. The shell is used to make high grade buttons and the white "stones" used in the popular Japanese game of "Go".

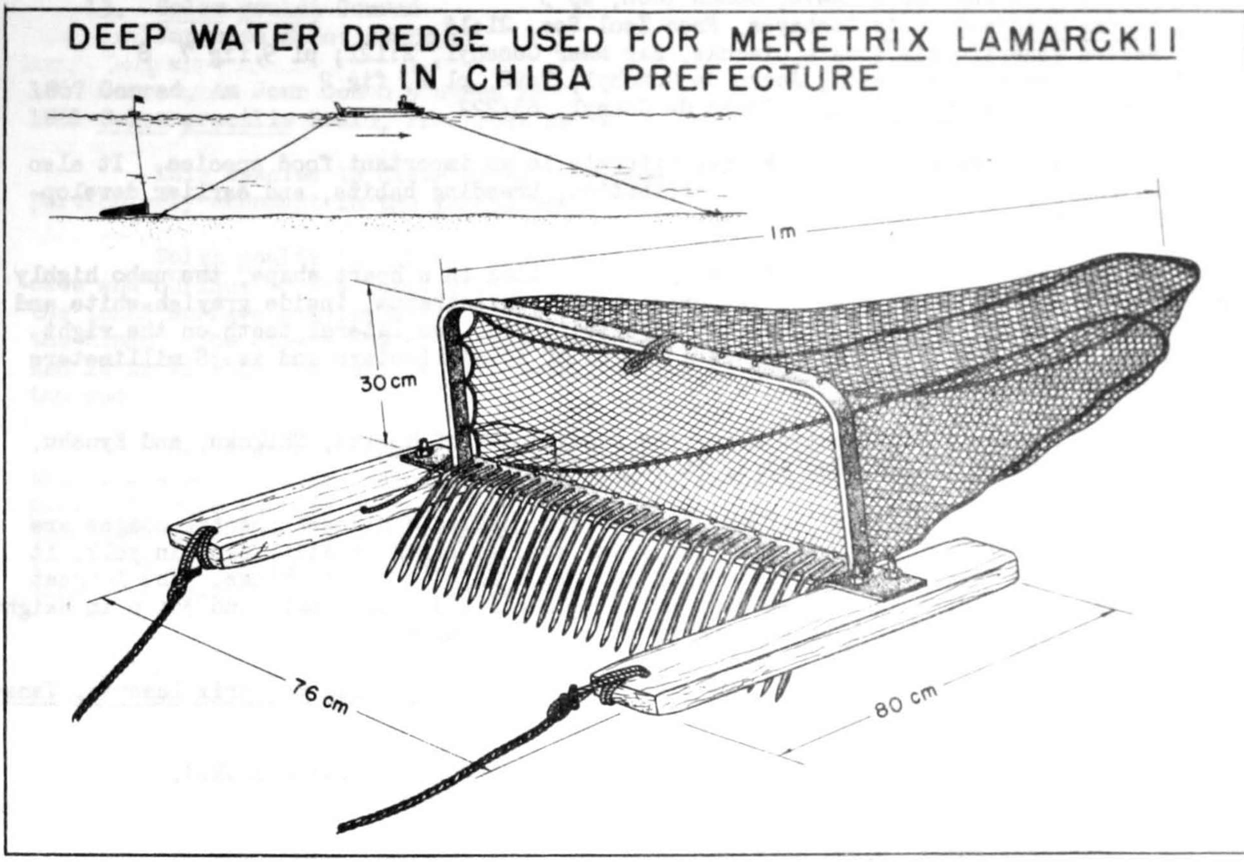
11. Mactra veneriformis Reeve
Japanese Name: Shiofuki

1854 (April) Reeve, Conch Icnon, sp 2
1854 (June) Mactra veneriformis Deshayes, Proc Zool Soc, 21 (1853); 15



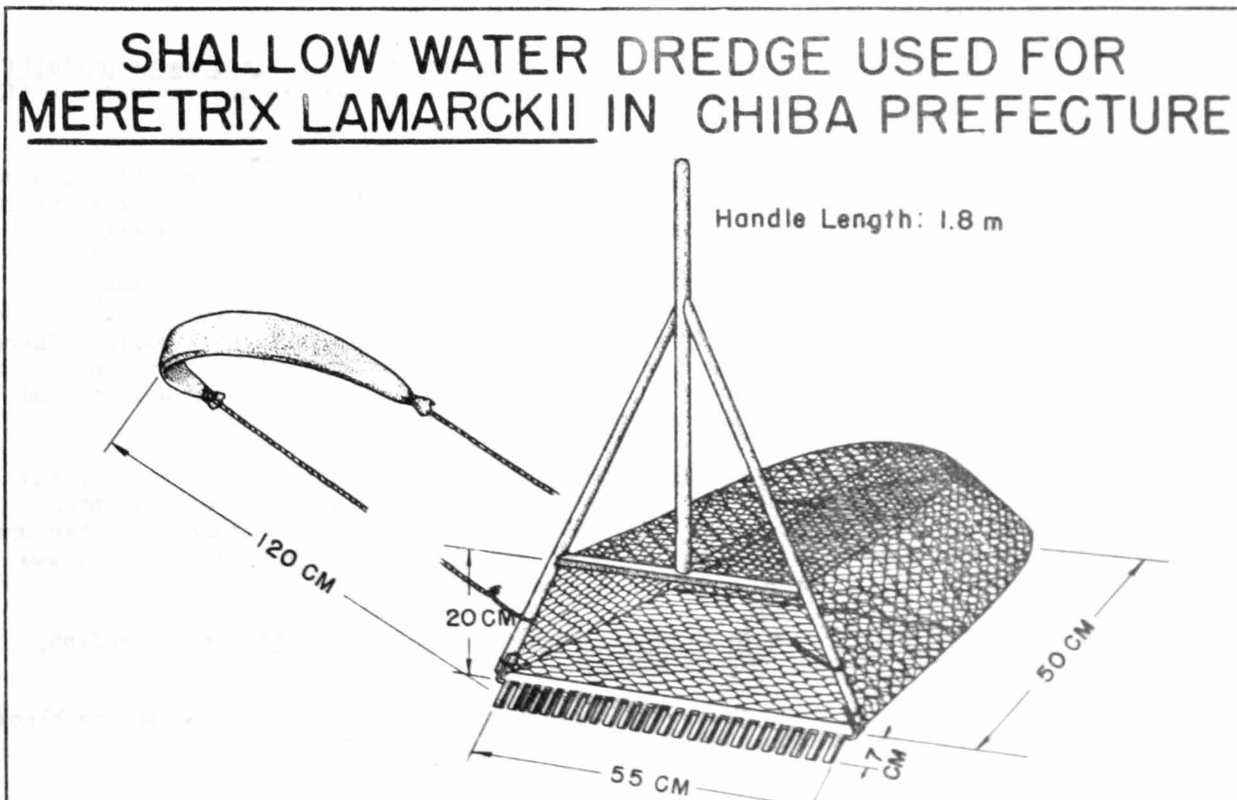
NATURAL RESOURCES SECTION

Figure 33



NATURAL RESOURCES SECTION

Figure 34



NATURAL RESOURCES SECTION

Figure 35

1854 Mactra quadrangularis Reeve, Conch Icon, sp 3
1854 Mactra quadrangularis Deshayes, Proc Zool Soc, 21:15
1871 Mactra veneriformis zonata Lischke, Jap Meer Conchyl, 2:121; pl 9, fig 7, 8
1858 Mactra bonneaui Bernardi, Journ de Conchyl, 7:92, pl 2, fig 2
1917 Mactra quadrangularis Lamy, Journ de Cochyl, 63:222

Like Mactra sulcataria, M. veneriformis is an important food species. It also closely resembles the former in its distribution, breeding habits, and earlier developmental stages.

The shell is triangular and very much swollen in a heart shape, the umbo highly pointed. The shell is covered by yellowish-brown periostracum, inside grayish-white and purplish at ventral margin. It has one cardinal tooth, two lateral teeth on the right valve and one on the left. It reaches a length of 45 millimeters and is 38 millimeters high and 26 millimeters wide.

It is widely distributed along the sandy coast of Honshu, Shikoku, and Kyushu. The spawning season ranges from April to July (Taki 1933).

According to Miyazaki (1936a) its breeding habits and developmental stages are much like those of Mactra sulcataria. The young shelled larva is still rich in yolk; it measures 84 µ in length and 68 µ in height and has a faintly purple hinge. The largest form raised by Miyazaki is a young spat which measures 403 µ in length and 354 µ in height; the umbonal region is dark blue and the liver brown in color.

This clam is collected by the same gear used for Meretrix meretrix lusoria, Venerupis, and Mactra sulcataria.

The meat is used raw after shucking or is fried or otherwise cooked.

12. Schizothaerus keenae Kuroda and Habe
Japanese Name: Mirukui, Mirugai

1950 Kuroda and Habe; Ill Cat Jap Shells, No 4, May 10

This is the species referred to in Japanese literature as Schizothaerus nuttalli (Conrad) 1837, which is an American species. The Japanese species was not separated until 1950 by Kuroda and Habe.

Distribution is in Honshu, Kyushu, and Shikoku, and the clam is particularly abundant in Tokyo-wan and in the Inland Sea. The shell is thick. Because of the curvature of the valves there are two openings, at the anterior and the posterior margin, where the valves fail to make contact. The posterior opening is large, and a big siphon projects from it. The Japanese name Mirukui ("Codium eating") is derived from the fact that the posterior margin of the shell often is covered by Codium, a green alga. The outer surface of the shell is covered by a thick dirty white coating; the inner surface is white. There is one V-shaped tooth on each valve, and two lateral teeth on the right but only one on the left valve. The size generally attained is 120 millimeters in length, 85 in height, and 54 in width. Some of the largest reach a length of 150 millimeters.

In Tokyo-wan the spawning season is normally from late March to early April and the harvest season from December to April. On the advice of the prefectural government fishing usually is not carried on during the spawning season, although there is no law preventing it. The fishing gear is the same as that used for Atrina japonica because these two species are taken during the same season on the same grounds.

Juveniles are preyed upon by Rapana thomasiana, Natica maculosa, and starfish, but the octopus is the only enemy of the adult.

The big siphon protruded from the valves is eaten raw or is fried after the black skin has been removed. The Japanese consider it a delicious food.

13. Solen gouldi Conrad
Japanese Name: Mategai

1867 Conrad, Am Jour Conch 3 apped 28
1861 Solen gracilis Gould, Proc Bost Soc NS 8:26

This species is distributed in Honshu, Shikoku, Kyushu, and south Korea. It is particularly abundant in the Inland Sea.

Solen gouldi is a long, slender clam having thin valves. The front edge is truncate and oblique to the longitudinal axis of the shell. The outer surface is dirty yellow, the inner surface grayish-white. The ligament is long and black. One main tooth is in the hinge. The dimensions of an average adult are 120 millimeters in length, 15 in height, and 12 in width. The foot is well developed and is used effectively in digging in the bottom mud.

The usual environment is a mud bottom under 4 to 20 meters of water. At low tide the clam's presence is indicated by the hole it keeps open to the bottom surface. If a pinch of table salt is dropped into this hole the clam literally jumps out of its burrow. This method is used for low tide harvesting. The clam is also gathered at low tide by inserting a slender bamboo splint into its burrow and piercing it. On grounds which are not exposed a gear furnished with hooks is used from a boat.

The meat is delicious, particularly in autumn and winter, and is served with vinegar and bean paste (miso). It is also used as bait in angling. The dried product was formerly exported to China.

14. Mya (Arenomya) japonica Jay
Japanese Name: Ônogai

a. Synonomy

1857 Jay, Rept Jap Exped Comdr Perry, 2:292; p 1, fig 7, 10
1875 Mya acuta Sowerby, Conch Icon, sp 12 (non Say 1822)
1898 Mya intermedia Dall, trans Wag Free Inst, 3:857

This is the clam repeatedly referred to as Mya arenaria Linne or as Mya arenaria japonica in Japanese literature. Mya arenaria is found along the northern coasts of the Atlantic and Pacific oceans on the American continent and is not the same shell as that which Jay described from Japan. Mya arenaria is commonly known as the soft clam, soft-shelled clam, long-necked clam, etc, and is highly valued in America as a food species. In Japan, however, Mya japonica is not used to any great extent as food. Reports concerning it are few, and data meager.

b. Characteristics and Distribution

Shell oblong-ovate, the left valve slightly smaller than the right. Anterior and posterior ends open, the anterior rounded, the posterior protruded. Shell covered by a thin dark gray periostacum, the inner surface white. Pallial sinus extremely large. Chondrophore flattened, situated just under the left umbo. Both siphons are thick and long, and together are bound in a chitinous sheath. Length 90 millimeters, height 53 millimeters, width 32 millimeters (Figure 10). An extremely large specimen measures 170 millimeters in length.

The species is distributed around the entire coastline of Japan from western Hokkaido to southern Kyushu, on both the Japan Sea and Pacific Ocean sides. It is apparently absent from the northern coast of Hokkaido in the Sea of Okhotsk. It also occurs on the Japan Sea coast of Korea (Frontispiece).

c. Living Conditions

According to a survey by the Hiroshima Fisheries Experimental Station (1949a) Mya japonica is widely distributed on sandy mud bottom in water which is somewhat brackish. The tidal zone inhabited is that which is exposed four hours after the spring high tide. It prefers a bottom type which is somewhat more muddy than that inhabited by Venerupis or Meretrix. It buries itself deeply in the bottom matrix, the depth of burial varying with the size, season, and bottom type. Clams two to three centimeters in length are usually found buried from five to six centimeters deep, while clams eight centimeters in length are found at a depth of from 0.4 to 1.8 meters.

d. Reproduction and Development

Yoshida (1938) reported the spawning season to be from May to June in Chinkai-wan, Korea. According to the study by the Hiroshima Experimental Station (1949a) the season for spawning in Okayama Prefecture is believed to be from April to October but no conclusive evidence was obtained to narrow the season more closely.

Yoshida (1938), working in Chinkai-wan, Korea, identified the young of this species (Figure 36) by the characteristic features of the prodissoconch during the breeding season from May to June. Numerous veligers were obtained from hauls with plankton nets. The young shell is thin, fragile, grayish-white, and semitransparent. The veligers were raised in the laboratory to the end of metamorphosis. At this time one of the larger individuals measured 3.2 millimeters in length and 1.8 millimeters in height. The swimming larvae, which are from 0.24 to 0.30 millimeter long, begin their bottom life by attaching to the substratum with the glutinous threads of the byssus, and the apical plate disappears. As an indication of their habitat choice, no specimens were found among seaweeds of the genera Enteromorpha, Ulva, or Sargassum.

The growth rate of Mya japonica in the Hiroshima region has been given by the Hiroshima Fisheries Station (1949a) as follows: one year old, 4-5 centimeters long; two years old, 6-7 centimeters; three years old, about eight centimeters.

e. Culture and Harvest

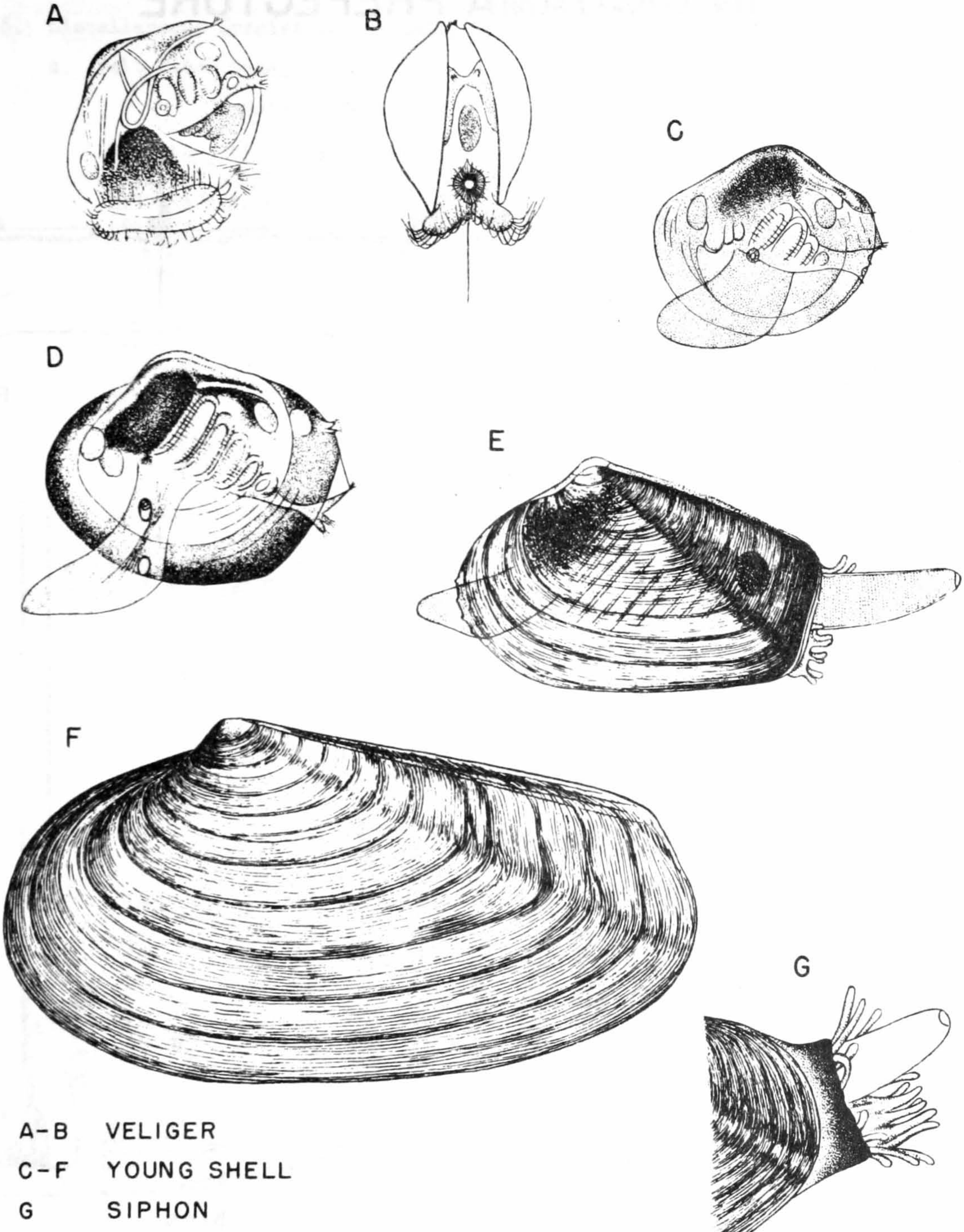
The culture of this clam thus far has not been considered because of the abundance of better known species already under culture, but the Hiroshima Fisheries Experimental Station believes that this species could be cultured successfully and that it has valuable possibilities in the future.

At Otoshima, Okayama Prefecture, harvesting is carried on as a joint operation by the local population under direction of the local Fisheries Association and about 230 men annually engage in this task. In 1945-46 one person could harvest an average of 30 kan per day, but the catch has become reduced to five kan per person per day because of overfishing.

At low tide the clam is dug by means of a hand hoe called "Taguwa". On areas where the clams are abundant a harvesting method called "Jinotoribori" (fort digging) is practiced. Earthen banks are constructed around the harvest grounds at low tide to prevent water from entering the area, and then the clams are dug out carefully.

In deeper water a specially designed gear (Figure 37) called the "Oukogi" is used from a boat. A six-toothed iron fork is attached to a pole six to eight meters long by a ratchet-like apparatus operated from the other end of the pole by means of a pull line. The fork is inserted into the bottom with the teeth vertical, and the pull line working on the ratchet raises the teeth through the bottom stratum to a position at right angles to handle (Figure 37 A-E). The four middle teeth are set at an angle slightly below the level of the outer teeth at each end, thus forming a sort of shallow basket which contains the clams dug and prevents them from slipping out sideways when raised to the surface. The teeth, being curved, prevent the shells from slipping out over the tips of the fork. This type of gear has been in use since 1944. By this method two or three fishermen in a boat harvest from 10 to 15 kan per day. This method is used principally from November to March.

DEVELOPMENTAL STAGES OF MYA JAPONICA

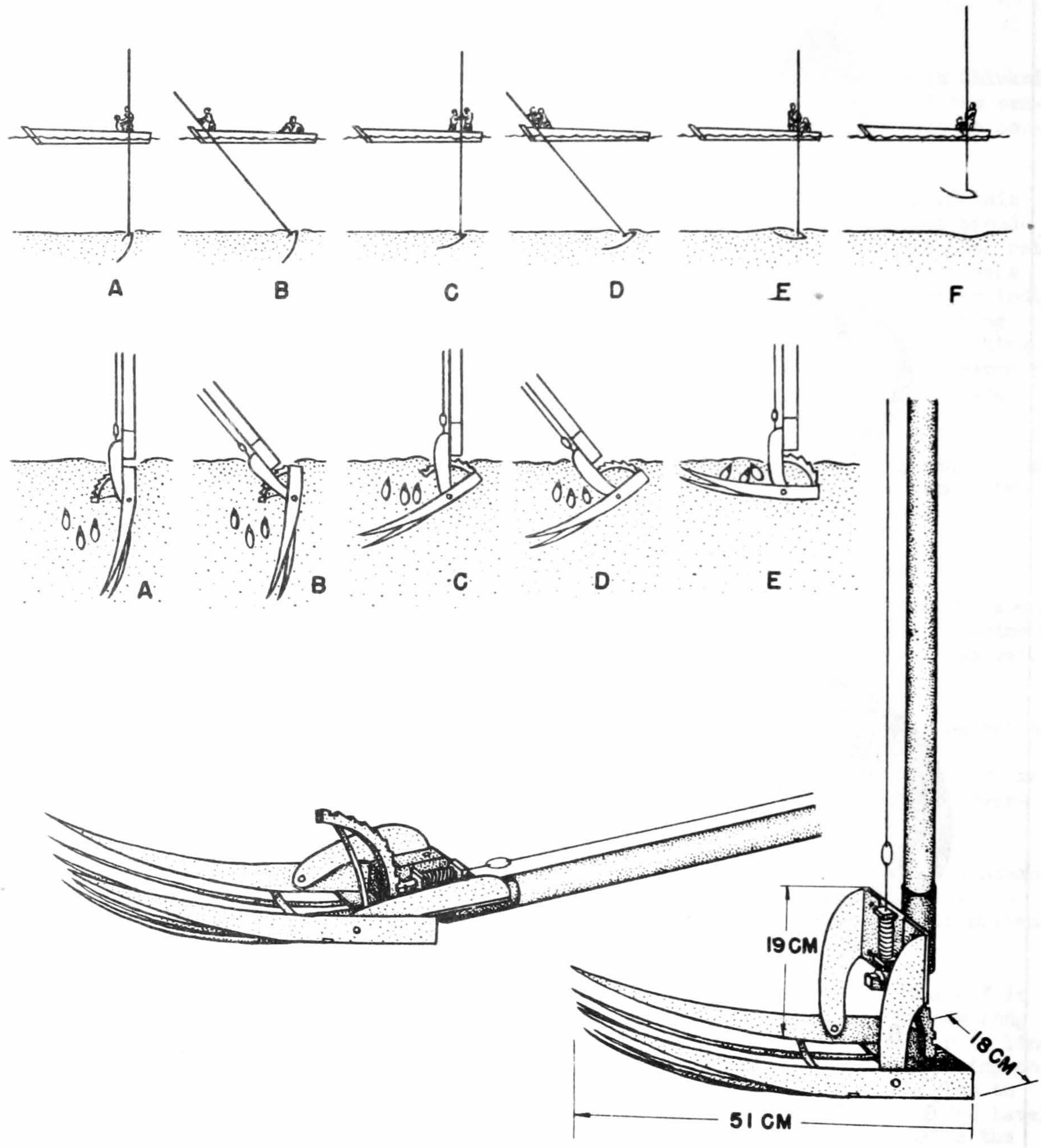


NOT DRAWN TO SCALE

NATURAL RESOURCES SECTION

Figure 36

HARVESTING GEAR FOR MYA JAPONICA IN OKAYAMA PREFECTURE



NATURAL RESOURCES SECTION

Figure 37

Local association rules prohibit the taking of clams under six centimeters long, and harvesting is prohibited during the spawning season which is from April to October. Despite regulations, however, the annual harvest is declining sharply. Almost no detailed production records are available; however, at Otoshima, Okayama Prefecture, the Hiroshima Fisheries Experimental Station reports that the harvest in 1945 was 776 metric tons while that in 1947 was only 86 metric tons.

15. Miscellaneous Species Occasionally Used as Food

a. Salt-Water Species

Scientific Name	Japanese Name
Barbatia obtusoides (Nyst)	Kariganegai
Trisidos tortuisa kiyonoi (Makiyama)	Byobugai
Anadara scapha (Menschen)	Ryukyusarubo
Anadara trisenicostata (Nyst)	Hagoromo
Chlamys erythrocomata (Dall)	Kamionishiki
Volsella difficilis Kuroda & Habe	Ezohibarigai
Volsella metcalfi (Hanley)	Kokegarasu
Volsella trailli (Reeve)	
Lithophaga curta (Lischke)	Ishimate
Pinna attenuata Reeve	Habokigai
Amusium japonicum (Gmelin)	Tsukihigai
Glycymeris vestita (Dunker)	Tamakigai
Chama reflexa Reeve	Kikuzaru
Cardium burchardi Dunker	Zarugai
Cardium enode Sowerby	Nagazarugai
Cardium californiense Deshayes	Ezoishikagegai
Dosinia japonica (Reeve)	Kagamigai
Dosinia bilunulata (Gray)	Hinagai
Cyclina sinensis (Gmelin)	Okishijimi
Gagrarium divaricatum (Gmelin)	Kemangai
Circe stutzeri (Donovan)	Shiraogai
Callista chinensis (Holten)	Matsuyamawasure
Callista brevisiphonata (Carpenter)	Ezowasure
Sunetta menstrualis Menke	Wasuregai
Pitar sulfurea Pilsbry	Iwohamaguri
Venus puerpera L.	Nunomegai
Saxidomus purpuratus (Sowerby)	Uchimurasaki
Gomphina melanaegis Roemer	Kotamagai
Gomphina aequilatera (Sowerby)	Okiasari
Chione squamosa (Linne)	Shioyagai
Mercenaria stimpsoni (Gould)	Binosugai
Paphia euglypta (Philippi)	Sudaregai
Paphia amabilis (Philippi)	Satsumaakagai
Paphia schnelliana (Dunker)	Ohsudare
Paphia vernicosa (Gould)	Awasudare
Paphia variegata (Sowerby)	Himeasari
Protothaca jedoensis (Lischke)	Oniasari
Protothaca adamsi (Reeve)	Ezonunome
Arcopagia diaphana (Deshayes)	Ichoshiratori
Macoma tokyoensis Makiyama	Goisagi
Tellina venulosa Schrenk	Saragai
Gastrana yantaiensis Crosse & Debeaux	Shiratorimodoki
Sanguinolaria olivacea (Jay)	Isoshijimi
Sanguinolaria adamsi (Reeve)	Murasakigai
Sanguinolaria boedinghausii (Lischke)	Fujinami
Solen gordonis Yokoyama	Akamategai
Solen grandis Dunker	Ohmategai
Mesodesma striatum (Gmelin)	Isohamaguri
Mactra maculata Gmelin	Ryukyubakagai
Mactra antiqua Spengler	Arisogai

b. Fresh-Water Species

Scientific Name	Japanese Name
Lanceolaria oxyrhyncha (Martens)	Sasanoha
Unio douglasiae nipponensis Martens	Ishigai
Unio biwae Kobelt	Tateboshi
Inversidens reiniana (Kobelt)	Otokotateboshi
Inversidens hirasei (Haas)	Setaishigai
Inversidens japonensis (Lea)	Matsukasagai
Pseudodon omiensis Heinburg	Katawagai
Hyriopsis schlegeli (Martens)	Ishigai
Cristaria plicata spatiosa (Clessin)	Karasugai
Anodonta japonica (Clessin)	Tagai
Anodonta lauta Martens	Numagai

TOTAL CLAM PRODUCTION

An attempt to arrive at satisfactory statistics regarding annual production of the various species of edible clams discussed in the preceding pages is both difficult and confusing. This is due to two factors: (1) the annual figures are in themselves very incomplete; (2) the Japanese fisherman does not distinguish between many of the species collected and hence various species are grouped together and classified merely as "Others". During some periods a given species may be reported annually and consistently; then for no apparent reason it suddenly appears lumped together and reported under the heading "Others". Thus annual production for many of the species utilized for food cannot be determined, even when they are produced in considerable quantity. Statistics are relatively complete for only two species, the Asari (Venerupis semidecussata) and the Hamaguri (Meretrix meretrix lusoria), which are two of the principal species from an economic point of view. Complete figures exist for the Torigai, Fulvia mutica, from 1909 to 1944, after which time it appears inseparably under "Others". Statistics are available for Hokkigai (Mactra sachalinensis) for 1922-48, but prior to 1922 this species was lumped with "Others". In many instances no separation is made in the Japanese statistics between clams raised "naturally" and clams which are "cultured", and beyond the available printed figures there is no way of ascertaining further information or breakdown.

Using all available Japanese data, Table 1 has been compiled to show the annual production of edible clams in Japan 1909 through 1948.

Production reached its peak in 1943, when 323,883 metric tons were produced, the second largest harvest being 305,865 metric tons produced in 1942. These figures indicate the pressure that was being applied on the people to provide food during the late war years. As the population of Japan in 1943 was 73,980,000, the production of that year yielded 4.38 kilograms of clams as food per capita. Taking the figure of 32 grams of animal protein per kilogram, the production in 1943 yielded 140 grams of animal protein per capita for that year.

During the post-Surrender period the annual harvest has returned to about that of the best normal prewar years. For the total 1909-48 period, the harvest of clams amounted to 5,842,833 metric tons, for an annual average production of 146,070.78 metric tons.

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GLOSSARY

1. Technical Terms

The following definitions of technical and semi-technical terms are offered as an aid to the reader. Each term is defined in the sense in which it is used in this report, not in the all-inclusive sense found in a dictionary or in a biological vocabulary. The shell features of a bivalve are illustrated in Figure 38.

acrosome	A minute body at the anterior end of the spermatozoan.
adductor muscle	The powerful muscle extending between and attached to the two halves of a bivalved mollusk shell, the contraction of which closes the shell.
apical plate	A group of nervous or sensory cells found at the anterior end of the larvae of mollusks.
aquiculture	Culture of things that inhabit water.
benthic	Living in the sea bottom.

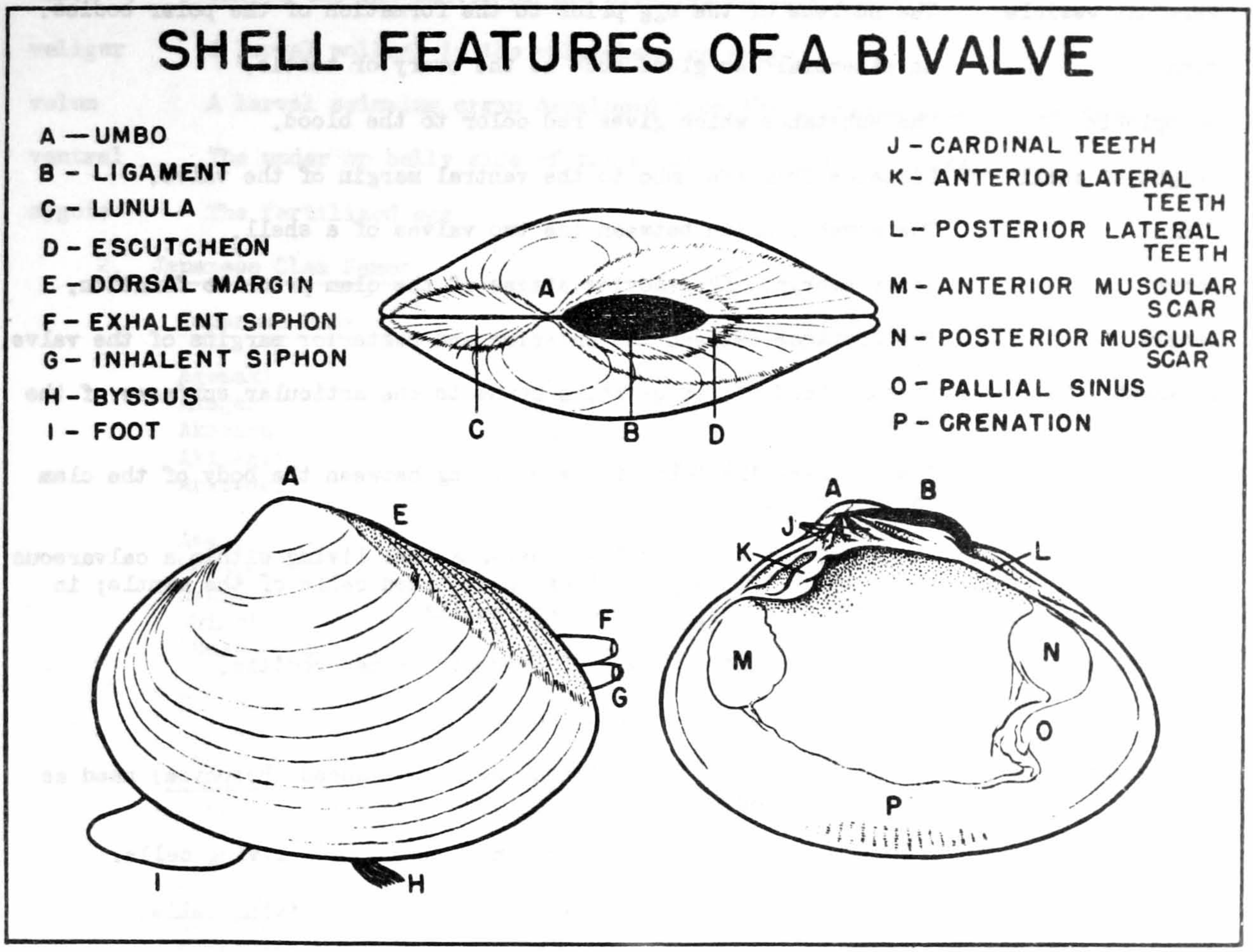

Figure 38

byssus — A group of tough filaments secreted by a gland in the foot of a bivalved mollusk by which the animal attaches itself to some fixed object.

chondriospheres — Large or aggregated spherical bodies composed of minute granules present in the cytoplasm of cells.

chondrophore — A cavity or process of the shell of a bivalved mollusk which supports the internal hinge cartilage.

cilia — Hairlike processes found on many cells, capable of vibratory or lashing movement.

collector — Any material such as shells, laid down on a breeding ground to provide attachment for spat; cultch.

cultch — Collectors for spat.

dioecious — Opposite sexes located in different individuals; an individual which is dioecious is either male or female.

dissoconch — The larval shell of a bivalved mollusk in the veliger stage.

dorsal — The back, or pertaining to the back of an animal.

gastropod — A mollusk in which the shell is a single coiled unit; snail.

germinal vesicle	The nucleus of the egg prior to the formation of the polar bodies.
gonad	An essential sex gland such as the ovary or testis.
hemoglobin	The substance which gives red color to the blood.
height of shell	Distance from the umbo to the ventral margin of the valve.
hinge	The movable union between the two valves of a shell.
larva	Early embrynic free-moving stages of the clam prior to fixation.
length	The distance between the anterior and posterior margins of the valve.
ligament	A tough band of tissue which connects the articular surfaces of the valves.
mantle	The curtain-like fold of tissue lying between the body of the clam and the shell.
mollusk	A soft-bodied salt- or fresh-water animal living within a calvareous shell which is the product of specialized cells of the mantle; in this report clams, oysters, and snails.
monoecious	Two sexes within a single individual; hermaphroditic.
neap tide	The least tide in the lunar month.
noriculture	Culture of "nori", a gelatinous reddish seaweed (<u>Porphyra</u>) used as food by the Japanese.
nucleolus	A rounded body found within the nucleus of most living cells.
nucleus	An essential agent of life processes found in living cells.
ovum	The egg or female germ product.
pallial line	The line or scar made by contact of the mantle with the inner surface of the valve.
periostracum	A chitinous layer covering the outer surface of a mollusk shell.
Polar body	A minute cell which separates from the egg in the early stages of its maturation.
prodissoconch	The rudimentary or embryonic shell of a bivalved mollusk.
spat	Veliger larvae of the clam (and oyster) which have attached themselves permanently to an object.
spermatozoan	The active male sex cell; sperm.
teeth	Articulating projections on the hinge of the valve which interlock and prevent slipping. They bear no relation to mammalian teeth in either structure or function.
trochophore	A free-swimming larval stage of mollusks having a peroral ciliated ring and in which the shell has not yet begun to form.
umbo	The lateral prominence just above the hinge of the bivalved mollusk shell; the beak or shoulder. It is the first part of the shell to be formed. (Plural: umbones)

valve	One of the two halves of the bivalved mollusk shell.
veliger	A larval mollusk in the velum-bearing stage.
velum	A larval swimming organ developed from the ciliated ring of the trochophore.
ventral	The under or belly side of the animal; opposite to dorsal.
zygote	The fertilized egg.

2. Japanese Clam Names

Japanese Name	Scientific Name
Agemaki	Sinonovacula constricta
Akagai	Anadara broughtoni
Akazara	Chlamys nipponensis akazara
Akitagai	Pecten yessoensis
Arisogai	Mactra spectabilis
Asari	Venerupis semidecussata
Badagai	Anadara broughtoni
Bakagai	Mactra sulcataria
Chinmi	Anadara granosa bisenensis
Chosen-hamaguri	Meretrix lamarckii
Fukurogai	Anadara granosa bisenensis
Haigai	Anadara granosa bisenensis
Hamaguri	Meretrix meretrix lusoria
Hokkigai	Mactra sachalinensis
Hotategai	Pecten yessoensis
Igai	Mytilus crassitesta
Itayagai	Pecten albicans
Kamisorigai	Sinonovacula constricta
Karasugai	Mytilus crassitesta
Mashijimi	Corbicula leana
Mategai	Solen gouldi
Mirokugai	Anadara subcrenata; A. broughtoni
Mirokki	Anadara broughtoni
Mirugai	Schizothaerus keenae
Mirukui	Schizothaerus keenae
Mogai	Anadara subcrenata; A. granosa bisenensis
Onogai	Mya japonica
Sarubo	Anadara subcrenata
Satogai	Anadara satowi
Setashijimi	Corbicula sandai
Shiofuki	Mactra veneriformis
Tachigai	Atrina japonica
Tairagai	Atrina japonica
Tairagi	Atrina japonica
Torigai	Fulvia mutica
Ubagai	Mactra sachalinensis
Unegai	Anadara granosa bisenensis
Yamatoshijimi	Corbicula japonica

3. Japanese Generic Terms

gai (kai)	shell
-gawa (-kawa)	river
-gun	subdivision of a prefecture
-hanto	peninsula
-jima (-shima)	island
-kai	shell
-kaikyo	strait
-kawa	river
-ko	lake
-retto	islands
-shima	island
-shio	current
-wan	bay

4. Units of Measurement

a. Metric Units

Metric		English		Metric		English
1 micron	=	0.000039	inch	1 cubic centimeter	=	0.061 cubic inch
1 millimeter	=	0.039	inch	1 gram	=	0.035 ounce
1 centimeter	=	0.394	inch	1 kilogram	=	2.205 pounds
1 meter	=	3.281	feet	1 liter	=	2.113 pints
1 kilometer	=	0.621	mile	1 metric ton	=	2,205 pounds
1 square meter	=	10.764	square feet	1° centigrade	=	5/9 (°Fahrenheit - 32)
1 hectare	=	2.471	acres			

b. Japanese Units

Japanese		Metric			English	
1 bu	=	0.303	centimeter	=	0.119	inch
1 sun (10 bu)	=	3.030	centimeters	=	1.193	inches
1 tsubo	=	3.306	square meters	=	35.583	square feet
1 tan (300 tsubo)	=	991.7	square meters	=	0.245	acre
1 go	=	0.180	liters	=	11.008	cubic inches
1 sho (10 go)	=	1.804	liters	=	0.4765	US gallon
1 koku (100 sho)	=	180.4	liters	=	47.654	gallons
1 kan	=	3.75	kilograms	=	8.267	pounds

TABLE I. - ANNUAL PRODUCTION OF EDIBLE CLAMS IN JAPAN, 1909-48
(metric tons unshucked clams a/)

Year	Venerupis semidecussata "Asari"		Meretrix meretrix lusoria "Hamaguri"		Fulvia mutica "Torigai"	Anadara Spp. "Akagai" b/	Mactra sachalinensis "Hokkigai"	Pecten yessoensis "Hotategai" c/	Others		Total
	Natural	Cultured	Natural	Cultured	Natural	Natural	Natural	Natural	Natural d/	Cultured e/	
1909	14,178	9,188	7,102	ND	9,517	f/	f/	f/	33,531	ND	73,516
1910	18,255	14,410	5,670	ND	8,066	f/	f/	f/	44,750	ND	91,151
1911	18,450	13,862	6,645	ND	7,095	f/	f/		43,664	ND	89,716
1912	20,141	13,521	6,300	ND	7,458	f/	f/	f/	42,482	ND	89,902
1913	11,400	6,151	5,336	ND	7,143	f/	f/	f/	45,456	ND	75,486
1914	21,660	20,188	5,280	ND	8,178	f/	f/	f/	60,691	ND	115,997
1915	23,932	16,657	5,151	ND	10,203	f/	f/	f/	65,762	ND	121,705
1916	24,847	17,626	3,937	ND	8,013	f/	f/	f/	48,438	ND	102,861
1917	26,940	18,686	3,742	ND	4,601	f/	f/	f/	42,631	ND	96,600
1918	28,556	21,782	4,507	ND	6,982	f/	f/	f/	46,244	ND	108,071
1919	27,412	19,628	7,042	ND	6,840	f/	f/	f/	64,177	ND	125,099
1920	30,573	19,281	7,102	ND	8,628	f/	f/	f/	66,189	ND	131,773
1921	29,876	19,543	5,707	ND	15,236	f/	f/	f/	56,787	ND	127,149
1922	9,307	22,599	3,461	ND	16,488	1,931	2,347	f/	30,889	ND	87,022
1923	11,505	20,483	5,374	ND	2,977	2,017	2,921	f/	25,944	ND	71,221
1924	9,356	18,239	5,088	ND	2,006	2,280	4,901	f/	30,043	ND	71,913
1925	19,376	24,285	6,033	ND	3,232	3,157	2,373	f/	35,409	ND	93,865
1926	12,821	19,702	7,005	ND	2,992	2,426	3,990	f/	75,982	ND	124,918
1927	18,172	25,615	6,986	ND	2,475	3,431	3,945	f/	71,332	ND	131,956
1928	17,868	30,445	6,228	ND	2,606	5,475	4,736	f/	84,258	ND	151,616
1929	15,866	31,164	5,096	ND	1,646	6,963	7,136	f/	76,215	ND	144,086
1930	16,725	24,596	5,628	ND	2,051	5,557	3,840	f/	66,401	ND	124,798
1931	16,346	28,432	6,643	ND	2,658	5,010	5,265	f/	59,613	ND	124,167
1932	19,323	29,530	10,192	ND	15,131	4,470	4,860	f/	48,450	ND	131,956
1933	21,176	35,275	11,452	ND	6,382	3,495	4,338	f/	67,747	ND	149,865
1934	16,983	38,522	12,817	ND	5,981	4,451	5,253	f/	111,566	ND	195,573
1935	48,750	43,840	10,683	ND	6,086	3,292	5,501	f/	104,565	ND	222,717
1936	18,776	42,598	8,400	ND	6,037	2,647	6,123	f/	85,065	ND	169,646
1937	17,977	61,723	6,667	ND	10,792	1,237	6,097	f/	77,872	ND	182,365
1938	19,503	51,767	5,636	ND	12,348	1,076	6,900	f/	55,301	ND	152,531
1939	19,601	55,084	4,833	ND	8,872	1,597	5,617	f/	55,541	ND	151,145
1940	20,688	59,822	3,937	ND	6,457	1,488	5,955	f/	120,367	ND	218,714
1941	41,377	64,766	11,032	10,673	1,503	3,465	12,678	21,531	59,074	12,357	238,456
1942	34,072	62,418	10,976	11,465	7,151	6,881	11,467	60,233	79,146	22,056	305,865
1943	70,117	73,846	11,175	11,832	12,311	5,156	4,005	39,366	86,269	9,806	323,883
1944	76,078 g/	57,934	h/	16,018	f/	f/	1,722	18,174	73,626	9,742	253,294
1945	69,766 g/	30,569	h/	14,028	f/	f/	1,243	2,032	20,368	6,936	144,942
1946	f/	27,087	f/	11,798	f/	f/	2,754	9,970	108,163	10,887	170,659
1947	f/	29,933	f/	37,348	f/	f/	4,618	18,498	90,043	16,586	197,026
1948	f/	23,148	f/	6,568	f/	f/	4,458	8,360	97,865	19,209	159,608
TOTAL	937,749	1,243,945	239,063	119,730	246,142	77,502	135,043	178,164	2,557,916	107,579	5,842,833

a/ Weight of meat is considered about 1/15 of the weight of the unshucked clams.
b/ "Akagai" includes Anadaras in general.
c/ Pecten albicans is included, although less important.
d/ Includes Venerupis semidecussata (1946-48); Meretrix meretrix lusoria (1946-48); Fulvia mutica (1944-48); Anadara spp. (1909-21, 1944-48); Mactra sachalinensis (1909-21); Pecten yessoensis (1909-40); Atrina japonica; Mya japonica; Schizothaerus koenae; Anadara subcrenata; Anadara granosa bisenensis; Chlamys farreri; Anadara subcrenata, etc.
e/ Included Pecten yessoensis; Anadara granosa bisenensis; Chlamys farreri; Anadara subcrenata, etc.
f/ Included in "Others (Natural)"
g/ Includes Meretrix meretrix lusoria (1944-45)
h/ Included in Venerupis semidecussata (1944-45)
ND: No data available
SOURCE: Statistical Yearbook, Ministry of Agriculture and Forestry, and Espenshade (1947).

TABLE 2.- GROWTH OF MERETRIX MERETRIX LUSORIA ON THE CHIBA CULTURE GROUNDS

Year	Date of Measuring	Days After Planting	Length (cm)	Width (cm)	Weight (grams)
A	Apr 28	0	2.00	1.75	2.20
	May 27	29	2.10	1.80	2.60
	Jun 28	61	2.27	1.94	3.31
	Jul 21	84	2.47	2.12	4.18
	Sep 9	123	2.88	2.42	6.36
	Oct 8	153	3.10	2.59	7.82
	Nov 8	184	3.17	2.68	8.40
	Dec 9	215	3.18	2.71	8.51
B	Jan 7	244	3.19	2.71	8.52
	Feb 5	274	3.19	2.71	8.56
	Mar 8	303	3.19	2.71	8.39
	Apr 18	345	3.20	2.71	8.77
	Jun 28	414	3.62	3.03	12.21
	Aug 29	476	4.06	3.32	16.06
	Oct 10	518	4.30	3.48	18.64
	Dec 12	572	4.39	3.53	19.32
C	Feb 24	646	4.41	3.55	19.69

SOURCE: Higurashi et al (1937); measurements by Chiba Fisheries Experimental Station.

TABLE 3. - CLOSED SEASON AND SIZE LIMIT FOR MERETRIX MERETRIX LUSORIA a/

Prefecture	Closed Season	Size Limit (cm)
Aomori	None	4.0
Miyagi	1 Jun-31 Jul	3.0
Fukushima	1 May-30 Jun	6.0
Ibaraki	1 May-30 Jun	5.0
Chiba	None	1.5
Tokyo	None	1.5
Kanagawa	None	1.5
Shizuoka	None	4.5
Aichi	None	3.0
Mie	1-31 Jul	
Wakayama	1 Jun-30 Sep	None
Osaka	None	3.0
Hyogo	None	3.0
Okayama	1 Aug-30 Sep	3.0
Hiroshima	None	3.0
Yamaguchi	None	3.0
Ehime	1 May-31 Aug	None
Tokushima	1 May-30 Nov	3.0
Oita	1 Jun-31 Aug	None
Kumamoto	1-30 Jun	3.5
Saga	1 Jun-31 Jul	3.0
Fukuoka	1 Jun-31 Aug	None
Shimane	None	3.0
Ishikawa	None	3.0
Toyama	None	4.5

a/ Meretrix lamarckii is also included, although it is far less important.
SOURCE: Bureau of Fisheries 1938

TABLE 4.- ANNUAL PRODUCTION OF ANADARA GRANOSA BISENENSIS IN KOJIMA-WAN, 1891-1936 (liters)

Year	Seed Clams Produced	Adult Clams Produced
1891	158,621	235,345
1892	34,338	419,827
1893	365,431	571,460
1894	ND	296,957
1895	ND	1,572,207
1896	ND	2,682,756
1897	69,357	3,056,337
1898	657,897	2,897,312
1899	1,317,082	3,263,021
1900	59,417	2,583,552
1901	124,258	2,883,108
1902	108,237	553,773
1903	203,833	1,995,264
1904	58,508	1,739,104
1905	3,482	1,436,823
1906	45,969	1,278,984
1907	19,755	1,258,573
1908	14,078	1,100,583
1909	33,707	1,327,426
1910	18,847	1,922,930
1911	18,342	1,649,336
1912	5,273	1,114,283
1913	31,260	615,385
1914	42,487	729,980
1915	39,132	809,807
1916	ND	ND
1917	47,533	644,324
1918	28,283	592,274
1919	69,105	299,430
1920	44,935	464,383
1921	14,835	256,665
1922	21,698	267,009
1923	107,202	322,036
1924	51,267	268,548
1925	32,143	238,449
1926	43,269	323,070
1927	37,063	398,760
1928	9,158	298,118
1929	61,612	341,791
1930	87,447	358,972
1931	64,009	92,998
1932	16,778	140,657
1933	11,101	319,967
1934	ND	303,946
1935	ND	254,091
1936	ND	285,604
TOTAL	4,176,749	44,465,225

ND: No data available
SOURCE: Records of Kojima Shell Co

TABLE 5.- REGULATIONS FOR HARVESTING PECTEN YESSOENSIS

Prefecture	Minimum Size (cm)	Closed Season	Gear Regulations
Iwate	9.0	None	None
Aomori	10.0	1 Mar-31 Jul	Diving prohibited
Hokkaido			
Toshima	10.6	1 Apr-15 Jun	Teeth of dredge must be wider than 3.6 sun
Shribeshi	10.6	1 Apr-15 Jun	
Ishikari	10.6	1 Apr-15 Jun	
Teshio	10.6	16 Apr-30 Jun	
Iburi	10.6	16 Apr-30 Jun	
Kushiro	10.6	1 May-15 Jul	
Tokachi	10.6	1 May-15 Jul	
Nemuro	10.6	1 Dec-30 Jun	
Chishima	10.6	1 Dec-30 Jun	
Kitami	8.2	1 Apr-30 Jun	Teeth of dredge broader than 2.8 sun

SOURCE: Bureau of Fisheries (1938)

TABLE 6.- RELATION BETWEEN GROWTH OF SINONOVACULA CONSTRICTA AND SPECIFIC GRAVITY

Period	Length (cm)	Height (cm)	Thickness (cm)	Weight (grams)
At time of planting	5.4	1.7	1.3	6.3
After three months in:				
Specific gravity 1.01358	7.2	2.2	1.4	12.8
Specific gravity 1.01916	8.2	2.5	2.0	27.8
Specific gravity 1.02257	7.9	2.4	2.0	20.3

SOURCE: Fujimori (1929)

TABLE 7.- RELATION BETWEEN GROWTH OF S. CONSTRICTA AND EXPOSURE AT EBB TIDE a/

Station	Elevation Above Low Low Tide	Average Shell Length (cm)	Exposure at Ebb Tide a/ (hours)
1	4.62	ND	ND
2	4.22	1.1	3185
3	3.89	1.3	2660
4	3.46	1.4	2230
5	3.13	1.4	1893
6	2.80	1.7	1553
7	2.57	1.8	1320
8	2.41	2.0	1153
9	2.21	2.5	940
10	1.65	ND	ND

a/ Total exposure between time of planting in October and harvest in April
ND: No data available
SOURCE: Fujimori (1929)

TABLE 8. - RELATION BETWEEN GROWTH IN S. CONSTRICTA AND BOTTOM TYPE

Station	Height Above LLT (meters)	Shell			Percentage of Sand			
		Length (cm)	Width (cm)	Weight (grams)	At Surface	16 Cm Below Surface	33 Cm Below Surface	Boring Depth (cm)
At time of planting a/	NA	4.32	1.32	3.75	NA	NA	NA	NA
At time of harvest b/								
1	3.23	5.94	1.84	7.87	0	0	19	39
2	2.51	6.89	2.17	12.75	17	29	30	50
3	1.95	6.86	2.21	12.37	21	27	31	46
4	1.65	5.31	1.75	5.52	43	50	ND	21
5	1.06	5.34	1.74	4.40	47	47	ND	22

a/ September
b/ October
NA: Not applicable
SOURCE: Fujimori (1929)

TABLE 9.- GROWTH OF S. CONSTRICTA ON NATURAL GROUNDS IN ARIAKE-KAI

Year	Date of Measurement	Length (cm)	Weight (grams)	Months After Hatching
1921	19 Apr	1.71	0.19	7
	4 May	2.50	0.47	8
	5 Jun	2.97	0.56	9
	2 Jul	3.33	2.06	10
	26 Aug	5.01	4.75	11
	15 Sep	5.37	5.74	12
	19 Oct	5.44	6.00	13

SOURCE: Fujimori (1929)

TABLE 10. - GROWTH OF S. CONSTRICTA ON CULTURE GROUNDS IN ARIAKE-KAI

Year	Date of Measurement	Length (cm)	Weight (grams)	Months After Hatching	Months After Sowing
1921	6 Aug	4.78	3.19	10	0
	31 Aug	5.61	7.50	11	1
	3 Oct	7.09	11.90	12	2
	2 Dec	7.55	12.40	14	4
1922	28 Jan	7.55	15.10	16	6
	25 Apr	8.08	22.50	19	9
	25 May	8.26	24.00	20	10
	2 Sep	8.90	29.60	23	13
1923	4 Jan	9.32	31.40	27	17
	10 Aug	10.89	51.13	36	26

SOURCE: Fujimori (1929)

TABLE 11. - PRODUCTION OF CORBICULA SANDAI IN BIWA-KO, 1942-48
(metric tons)

Year	Unshucked	Meat	Total in Terms of Unshucked a/
1942	217.1	34.8	739.1
1943	476.6	25.5	859.1
1944	327.6	4.5	395.1
1945	185.8	17.4	446.8
1946	214.8	39.7	810.3
1947	178.4	27.6	592.4
1948	106.8	18.8	388.8
TOTAL	1,707.1	168.3	4,231.6
Average	243.8	24.0	604.5

a/ Weight of unshucked clams is calculated here as 15 times the weight of the meat, based on experimental evidence.
SOURCE: Shiga prefectural government statistics

TABLE 12. - HARVEST OF SHUCKED C. SANDAI AT SETA, BIWA-KO, 1947-49
(metric tons)

Month	1947	1948	1949
Jan	11.5	3.7	12.2
Feb	4.0	9.0	24.6
Mar	11.0	22.3	57.6
Apr	47.7	40.3	64.7
May	11.1	32.0	34.3
Jun	6.6	50.5	30.6
Jul	8.1	57.5	27.7
Aug	8.2	44.0	22.1
Sep	23.0	53.8	44.5
Oct	18.7	35.8	21.0
Nov	5.2	6.7	57.1
Dec	0.2	28.2	35.0
TOTAL	155.3	383.8	431.4

SOURCE: Statistics of Seta Fishing Assn

TABLE 13. - PRODUCTION OF CORBICULA IN SUWA-KO, 1917 - 48
(metric tons, unshucked)

Year	Production	Year	Production
1917	66.9	1935	22.8
1918	49.3	1936	22.9
1919	43.5	1937	34.8
1920	12.6	1938	36.6
1921	18.2	1939	46.1
1922	19.0	1940	41.3
1923	30.3	1941	18.5
1924	29.3	1942	15.0
1925	30.9	1943	3.3
1926	34.9	1944	34.8
1927	34.1	1945	0.8
1928	24.9	1946	0.2
1929	25.2	1947	ND
1930	20.3	1948	0.3
1931	8.2		
1932	8.0		
1933	26.4		
1934	32.9		

ND: No data available
SOURCE: Miyasaka (1949)