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BREEDING OF THE OLYMPIA OYSTER IN TANKS AND CULTURE EXPERIMENTS IN JAPANESE WATERS*

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The Olympia oyster, *Ostrea lurida* is the native oyster of the Pacific Coast of the United States and Canada, and has gained the reputation of the highest quality. Several works have been reported on the general biology of the oyster as well as on the ecological analysis of its natural bed. Among them such works as of Stafford (1) and Hopkins (2) are well worth mentioning. Since the introduction of the seeds of Japanese oyster, *Ostrea* (*Crassostrea*) *gigas*, into the Pacific Coast, the natural production of the Olympia oyster has declined (Galtsoff) (3) This decline has partly been due to the drill menace, interspecies competition and poor spawning (Galtsoff) (3) (Chapman and Banner) (4). Under such circumstances the maintenance of production of seed has become the main concern of the people in the industry.

First success of artificial breeding of the Olympia oyster is due to Hori (5) who transported the species into Japan and succeeded in rearing the larvae to metamorphosis in small dishes. He claimed that the larvae were fed on ground sea lettuce (*Ulva*). Later on Davis (6) succeeded in rearing larvae, which were obtained by inducing gonad maturation and spawning in warm sea water, on a mixed food culture of green phytoplankton, consisting chiefly of a species of *Chlorella*.

We succeeded in rearing them in tanks by means of the method of non-colored naked flagellate and could obtain many spat on cultch. Furthermore, the spat were experimentally cultured under rafts by the hanging method in several culture beds in northern Japan, where the low water temperature during summer would never allow the Japanese oyster, *O. gigas*, to spawn to bring the natural set. The experiment was carried on as a part of a test to develop a new type

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of oyster which can propagate naturally even in cold waters. Other species including *O. edulis*, crosses between *Gryphaca angulata* and *O. gigas*, several races of *O. gigas* and their crosses were also cultured at the same time. The results of comparative culture will be reported in another paper. Here we report the results of tank breeding and the culture experiment on the Olympia oyster.

We express our hearty thanks for the cooperation of the Hokkaido Fisheries Experiment Station in the experimental culture of the oyster in Hokkaido.

Transplantation and Culture

In December of 1948, forty three specimens of two- to three-years-old Olympia oysters with an average shell length of 3.5 cm were packed in a metal case protected from dessication with wet cotton wool, were shipped from Seattle to Tokyo by North West Airline and then were transshipped to Onagawa by train.* It took nearly 50 hours for transportation. The oysters were placed in a bamboo basket and hung under a culture raft. They were used for breeding experiments during 1950 and 1952.

Thirty three oysters were living at the time of first breeding experiment in June, 1950, while twenty seven were left alive at the time of second experiment in June of 1952. The mortality was respectively 23 and 37 per cent of the number transplanted. Shell showed only a little growth during the culture. The average shell height was 4.0 cm and 4.3 cm in June of 1950 and 1952 respectively.

Breeding Experiment

When the water temperature reached around 15°C, the oysters were transferred from the culture raft in the bay to the outdoor tank of Onagawa Laboratory. In the tank, the oysters were laid on a bamboo mat in the middle layer of water, ca 50 cm down from the surface. Bay water was run into the tank for about

Table 1. Records of swarming of larvae of Olympia oyster in tanks in 1950.

Number of swarming	1	2	3	4
Date	June 17–20	June 22–23	July 2–5	July 5–8
Temperature (°C) of tank water	17.8–18.5	18.5–18.9	not recorded	not recorded
Number of larvae liberated	1,160,000	280,000	1,540,000	490,000
Average size of larvae at swarming in μ (Height × Length)	162.6 × 183.1	153.8 × 177.4	not recorded	not recorded

* We wish to express our hearty thanks to Mr. Cedric Lindsay, Shellfish Laboratory, Quilcene, Washington, for the shipment of Olympia oysters.

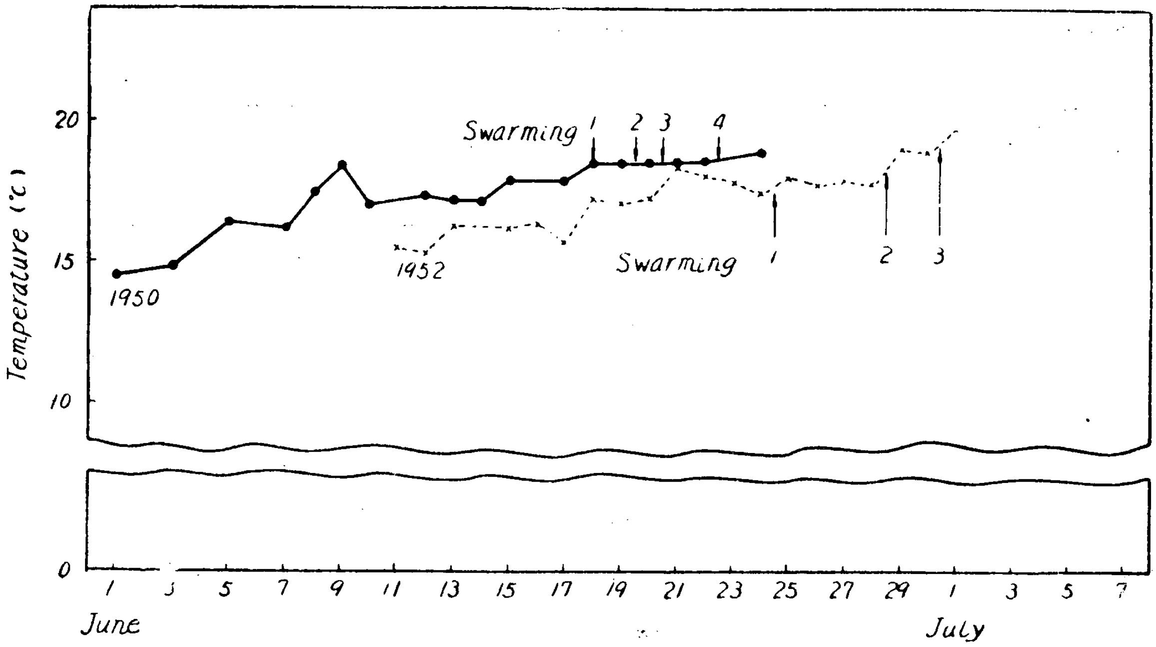


Fig. 1. Record of water temperature and swarmings in tanks, in 1950 and 1952.

four hours daily. In 1950, twenty six oysters were transferred to the tank on June 1st, and, in 1952, twenty seven oysters were placed in the tank on June 10th. Records of swarming of veliger larvae in the tank for 1950 are shown in Table 1 and Fig. 1.

Four swarmings were recorded and, in total, three and a half millions of larvae were liberated in the tank. Records of swarming in 1952 are shown in Table 2 and Fig. 1.

Table 2. Record of swarming of larvae of Olympia oyster in tanks in 1952.

Number of swarming	1	2	3
Date	June 24–25	June 28–29	June 30–July 1.
Temperature (°C) of tank water	17.5–18.1	17.9–19.1	19.0–19.8
Number of larvae liberated	220,000	400,000	590,000
Average size of larvae at swarming in μ (Height × Length)	149.4 × 174.6	152.8 × 179,1	164.2 × 189.0

Three swarmings were recorded and, in total, one million and two hundred thousands of larvae were liberated in the tank. Number of liberated larvae in both of these years were much smaller than what we expected from the brood size indicated by Hopkins (2). But no further swarming was observed with the groups during the seasons. The records indicated that the swarming occurred

Table 3. Results of breeding experiment of Olympia oysters in tanks in 1950.

Culture number	1	2	3	4	5
Tank number	D-5	D-3	C-1	C-3	C-2
Capacity in litre	2,900	2,900	8,900	8,900	8,900
Number of larvae set in tank	150,000	170,000	730,000	300,000	430,000
Tank water conditions- Temperature (°C)	19.5 (18.3-21.0)	19.7 (18.5-21.5)	19.7 (18.5-21.2)	20.0 (18.7-21.0)	20.4 (20.0-22.5)
Chlorinity (‰)	16.2-16.7	16.6-17.6	16.4-18.2	16.8-17.8	17.6-17.8
pH	8.22-8.25	8.23-8.28	8.23-8.29	8.25-8.30	8.28-8.30
Number of *Monas* per cc	500-3,500	600-2,300	900-3,400	1,000-3,600	100-2,700
Grams of cane sugar added (date of enrichment)	2 (4) 2 (10) 2 (15) 2 (19)	2 (4) 2 (10) 2 (15)	2 (8)	5 (10)	5 (6)
Estimated number of grown larvae	30,000	40,000	130,000	50,000	210,000
Percentage of survivals	20.0	23.5	17.8	16.7	48.8
Minimum duration of pelagic life in days	15-16	14-15	13-14	11-12	10-11
Number of spat on cultch	1,200	424	4,500	4,600	14,100
Average number of spat on single shell	31	8	40	57	51

Table 4. Results of breeding experiment of Olympia oysters in tanks in 1952.

Culture number	1	2	3
Tank number	D-5	C-4	C-3
Capacity in litre	2,900	8,900	8,900
Number of larvae set in tank	220,000	690,000	590,000
Tank water conditions, Temperature °C	19.0 (17.7-20.7)	19.4 (17.8-20.4)	19.4 (18.0-20.5)
Chlorinity ‰		17.6-17.9	17.6-18.0
pH	8.22-8.29	8.23-8.27	8.25-8.28
Number of *Monas* per cc	1,000-6,500	700-2,400	400-4,500
Grams of starch added (date of enrichment)	5 (4)	5 (10) 5 (14)	5 (4) 5 (12) 5 (17)
Estimated number of grown larvae	30,000	270,000	130,000
Percentage of survivals	20.0	23.5	17.8
Minimum duration of pelagic life in days	17-18	13-14	15-16
Number of spat on cultch	1,500	4,300	36,300
Average number of spat on single shell	16	32	158

on days when water temperature rose up 0.4°C to 1.2°C in a day. The possible induction of larval swarming caused by such a slight rise of temperature was also noticed in the case of the European flat oyster, *O. edulis* (Imai et al.) (7).

It was observed that the average shell size of larvae varied considerably at every swarming. Average shell height extended from 149.4μ to 164.2μ while that of shell length from 174.6μ to 189.0μ. But no uniformity was noticed in the trend of shell size at swarming in successive liberations as was noticed in *O. edulis* (Imai et al.) (7).

The straight hinge larvae thus liberated were used for rearing in tanks. The method of culture was practically the same as already reported in the case of *O. edulis*. Soon after being pumped into the tank, the water was inoculated with the non-colored naked flagellate, *Monas* no. 34 and enriched at intervals with

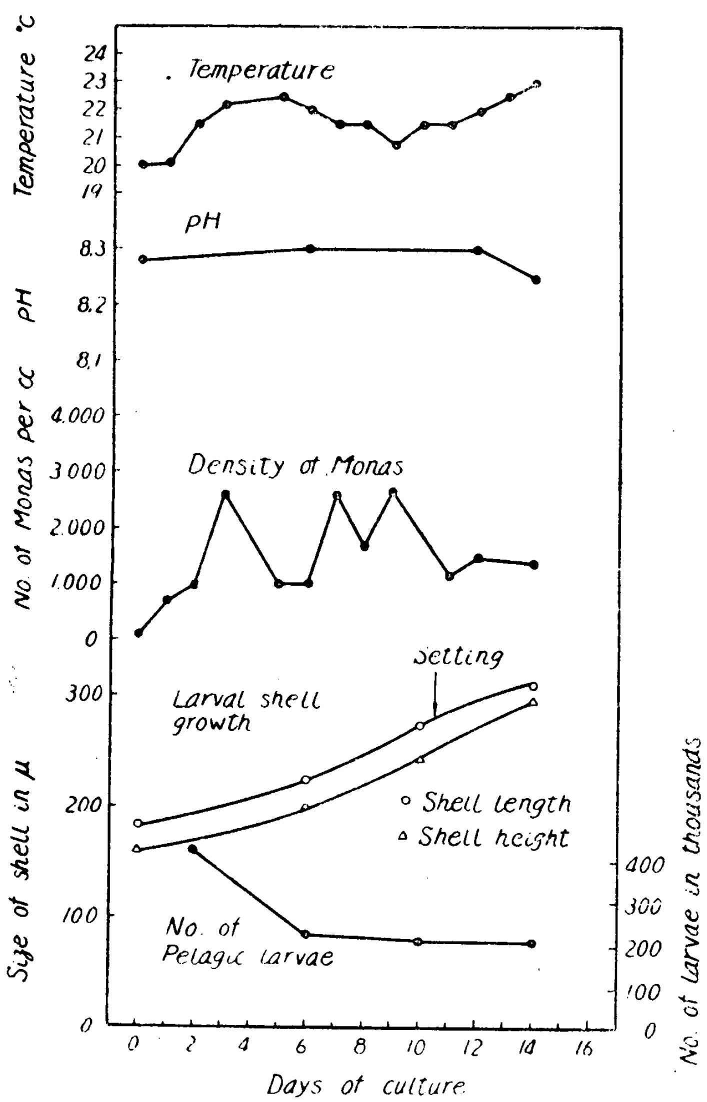


Fig 2. Records of tank breeding in culture No. 5 of 1950.

a few grams of cane sugar or cooked soluble starch in order to maintain the *Monas* population at the level of a few thousands (1,000 to 2,000) per cc. Records of culture of 1950 and 1952 are summarized in Table 3 and 4.

Fig. 2 and 3 show the records of environmental conditions and larval shell growth in culture No. 5 of 1950 and No. 3 of 1952.

The shortest duration of pelagic life was observed in the culture No. 5 of 1950, where the larvae reached fully grown size and began to set on cultch on the 10th or 11th day of culture under the water temperature of a range between 20.0 and 22.5°C (Average 21.8°C). While the longest duration of pelagic life was recorded in culture No. 1 of 1952, where the temperature was the lowest with

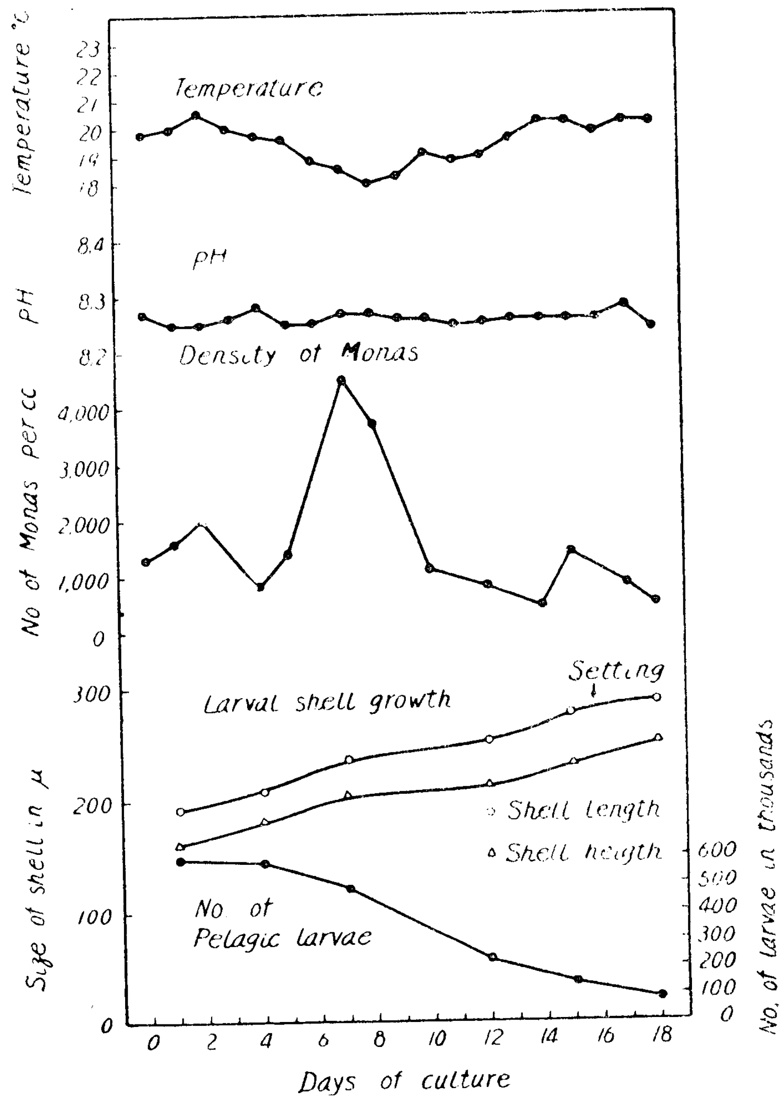


Fig. 3. Records of tank breeding in culture No. 3 of 1952.

a range of 17.7 and 20.7°C (Average 19°C).

It can be noticed from these data that the duration of pelagic life of Olympia oysters was close to that of *O. edulis* (Imai et al.) (7) and much shorter than 30 days which was estimated by Hopkins (2). It was even shorter than 22 days which Hori (5) found in his rearing experiment at 20°C.

On being liberated, the black-sick larvae were D-shaped with more or less straight hinge. After three to four days of culture when the shell length reached around 200 μ, the umbone began to appear. And when the shell height reached around 260 μ, the foot developed and the larvae began to crawl on the substratum. Soon they began to set on the cultch. Developmental stages of the larvae in tank culture are shown in Fig. 4.

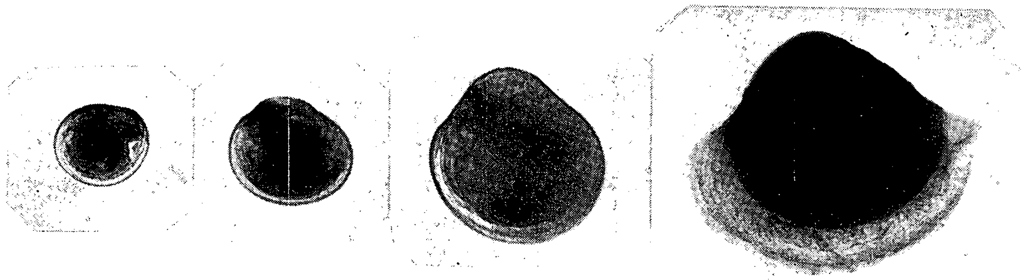
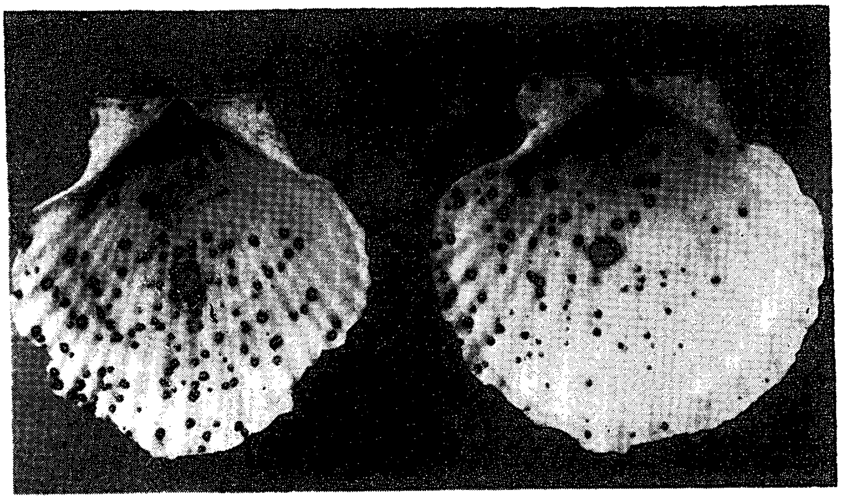


Fig. 4. Developmental stages of Olympia oyster in tank culture.
1. Pelagic larva at liberation. 155×177μ.
2. Pelagic larva with umbone developed. 225×261μ.
3. Fully grown larva. 324×328μ.
4. Spat one day after settlement. 391×468μ.

Table 5. Percentage of population in 0.01 mm size group in tank culture.

Culture number	No. 5, 1950				No. 3, 1952				
Size \ Date	July 5	11	15	19	July 2	8	13	16	19
0.14mm	20								
15	40								
16	30				90	10			
17	10				10				
18		50							
19		20	10			20			
20		20				10			
21		10				20	10	10	
22			20			20	40		
23			10					10	
24			20			10		20	
25			30			10			20
26							40	10	
27			10	20					
28				20			10	40	50
29				30					20
30								10	
31				10					
32				20					10

Table 5 shows the percentage of population in 1 μ size group of larvae at various stages of cultures. The size of larvae at metamorphosis was slightly larger than in the case of *O. edulis* where no larvae over 300 μ in shell height was observed.



1

2

Fig. 5. Showing the seeds of Olympia oyster collected on shell.

1. 15 days old.
2. Two months old.

The number of grown larvae in the tank on the first day of setting was estimated to be between 13.6% (Culture No. 1 of 1952) and 48.8% (Culture No. 5 of 1950) of the total larvae with which the culture was started. A comparatively small part of them were actually caught on the cultch and the rest of them set heavily on the wall and bottom of the tank.

For spat collection in the tank, the *Pecten* shells were used as cultch which were strung through the hole in the center of the shell by cotton rope. Therefore, the shells were held horizontally with the ridged surface up or down. Observations were made as to the intensity of set on either surface of the shells as well as on upper and under surfaces of the cultch. The results are summarized in Table 6.

Table 6. Ratio of spat catch on upper and under surfaces, and on ridged and smooth surfaces.

Culture number	Upper surface			Under surface		
	Ridged surf.	Smooth surf.	Total.	Ridged surf.	Smooth surf.	Total.
1	596	65	661	774	663	1,437
2	68	61	129	145	128	273
3	329	257	586	317	265	582
4	82	28	110	156	148	304
Total	1,075	411	1,486	1,392	1,204	2,596

The set was heavier on the under surface than the upper surface (36.4 : 63.6). And the ridged surface always collected more spat than the smooth surface.

Culture of Olympia oyster by hanging method.

Seeds of Olympia oysters thus obtained were kept in tanks for nearly two months and were transferred to Onagawa bay after it had been confirmed that there was no danger of natural set of native oysters in the bay.

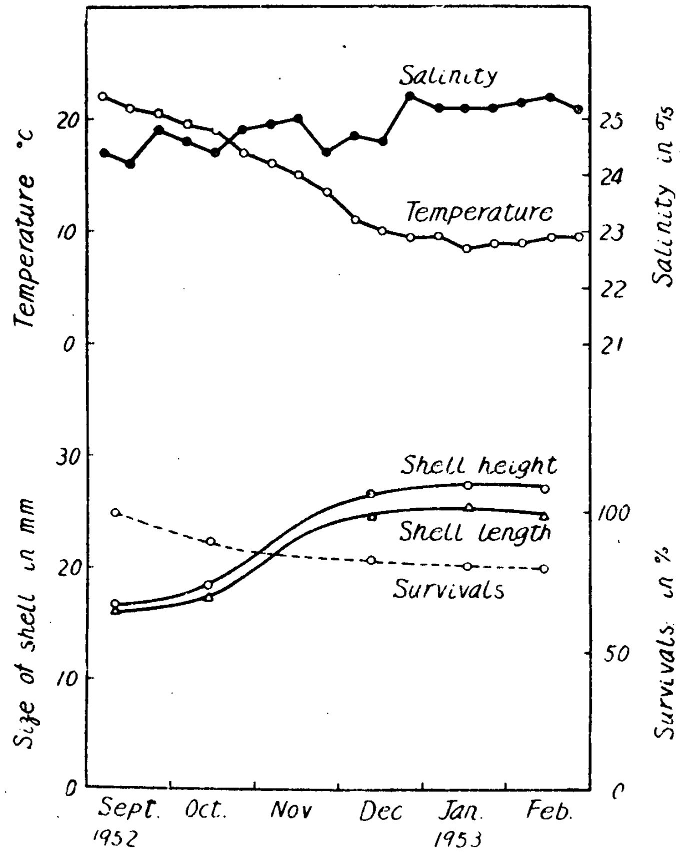


Fig. 6. Survivals and growth of Olympia oyster seeds in Onagawa Bay.

In 1950 the seeds were translaid on the hardening racks in Mangoku-Ura, where all of them died of freezing during winter. In 1952 the seeds were kept under rafts during the winter in Onagawa Bay. Figure 6 shows the survival and growth of the seed oysters which were held in a wire basket under the raft in Onagawa bay before they were transferred for the culture experiment.

In May of 1953, a large part of them were transplanted to Saroma and Usu Bays in Hokkaido and the rest were left in Onagawa Bay for a culture experiment. For culture, six to eight collectors with ten to fifty seeds per shell were connected to a rope two to three meters long at 30 cm intervals and hung under the float. Location of the beds are shown in Fig. 7.

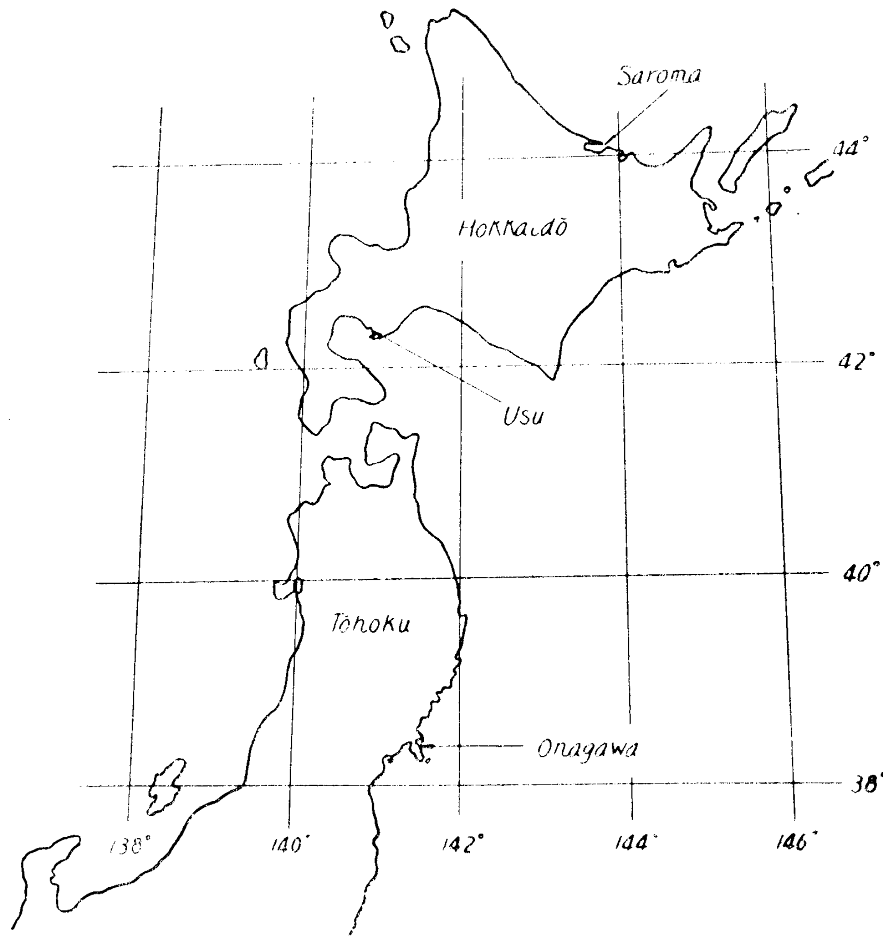


Fig. 7. Map of northern Japan showing the locations of the experimental culture beds.

Survivals and shell growth of the oyster and the changes of water temperature and salinity during the culture at each bed are shown in Fig. 8.

The results of detailed observations made after six to eight months of culture are summarized in Table 7.

Mortality was nearly twice as high as that of *O. gigas* at each bed but such

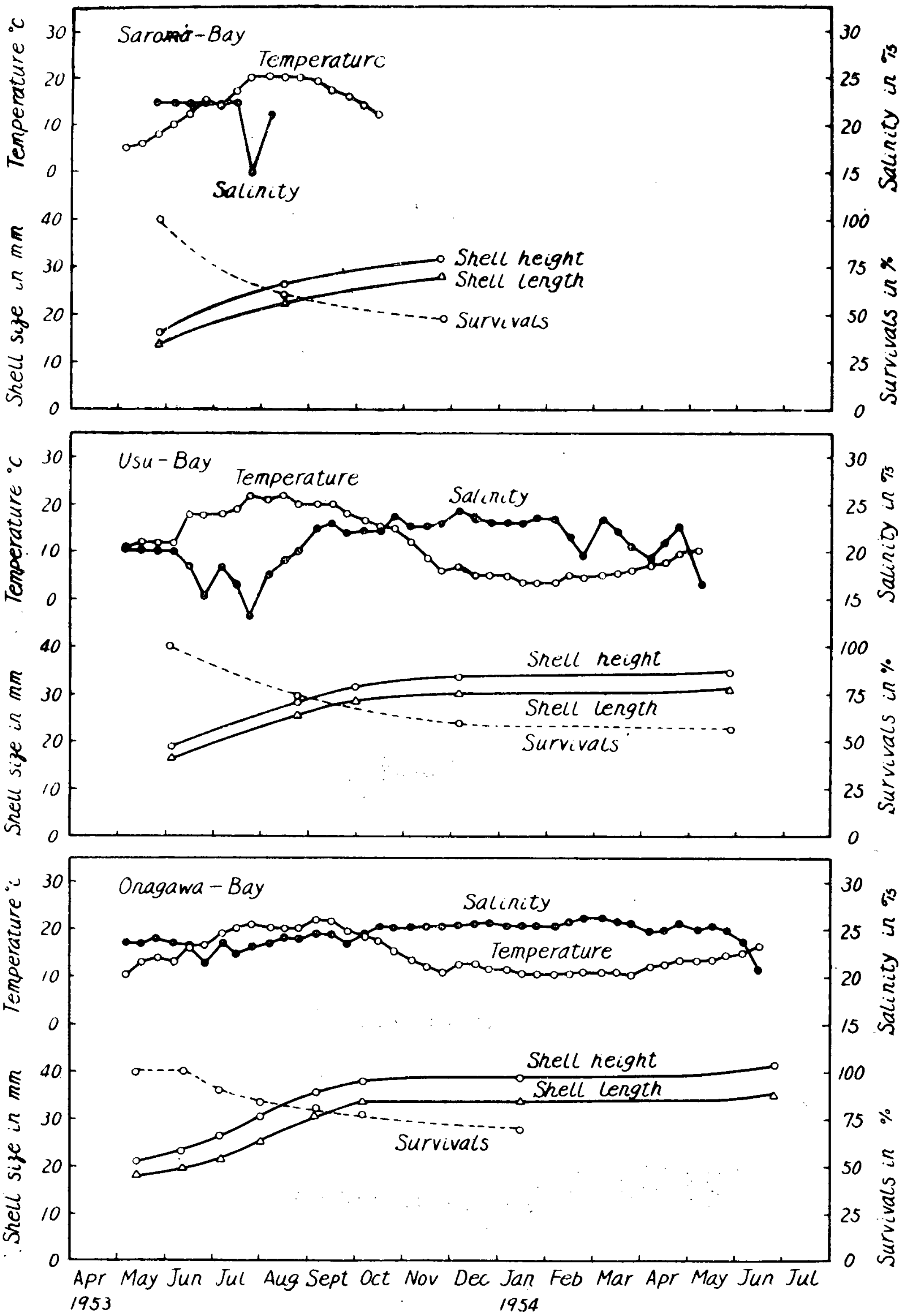


Fig. 8. Survivals and growth of Olympia oyster in three culture beds in the northern Japan.

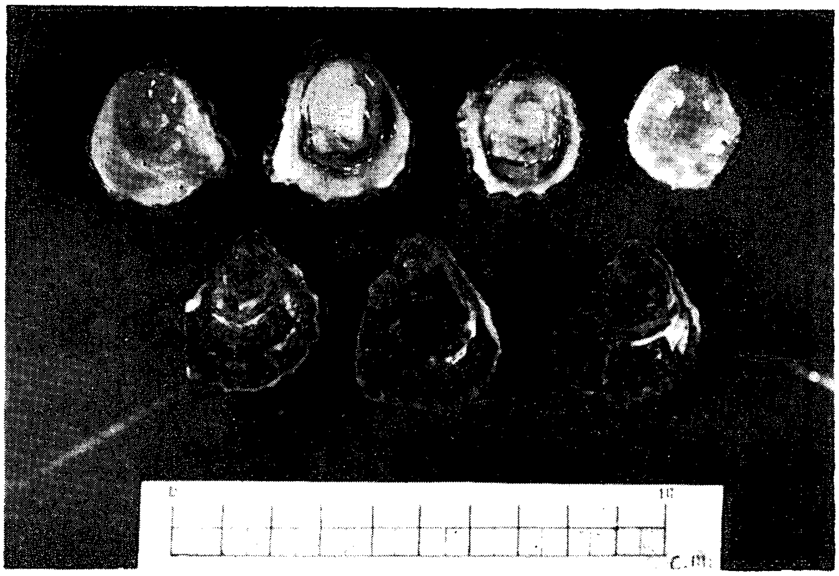


Fig. 9 Showing olympia oysters cultured for six months in Saroma Bay.

Table 7. Results of measurements of Olympia oyster at various culture grounds.

Name of bed.	Saroma Bay	Usu Bay	Onagawa Bay
Date	Nov. 24, 1953	Dec. 4, 1953	Jan. 17, 1954
Shell height, mm	33.3	34.9	33.2
Shell length, mm	28.8	29.8	30.1
Shell width, mm	11.8	11.8	12.7
Total weight, g	5.2	6.6	8.0
Wet meat weight, g	1.1	0.9	1.3
*Fattening condition	71.1	46.3	54.3

*Fattening condition is expressed by $\frac{\text{Wet meat weight in g}}{\text{Shell capacity in cc}} \times 100$

high mortality seems to be reasonable when we take the relative hardiness of two species into consideration.

At their native culture grounds it is said that Olympia oysters require four years to get marketable size, yet that they have scarcely attained greater shell length than five centimeters. Our culture record seems to indicate that in hanging culture Olympia oyster grow rapidly and will reach marketable size in two years of culture. This point will be made clear in the observations in future.

Conclusion

Olympia oysters were transplanted into Japanese water and were successfully bred in tanks by use of the non-colored naked flagellate. Then these tank-bred seeds were experimentally cultured in three bays in the northern part of Japan where the water temperature never rose so high as to induce massive spawning of the Japanese oyster, *O. gigas* and to produce the commercial set of seeds.

Thus far, Olympia oysters showed a healthy growth in hanging culture under rafts in every bed. They were expected to reach marketable size in two years. Whether they spawn and produce natural set in these beds or not, will be answered in the near future.

The Olympia oyster is a small-sized oyster and the rate of growth is very low. The culture industry of the species can exist only under the condition that the reputation of quality is extremely high as compared with other rapidly growing oysters as is on the Pacific Coast of the United States. Therefore, even when it is proved experimentally that the species can thrive in these cold waters of northern Japan, it still remains in question whether the species should be introduced into the local oyster industry. With regard to this point, the conclusion will be given after thorough examination of comparative culture experiment with several species and races of oysters now in progress.

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