STUDY OF BREEDING OF JAPANESE OYSTER, *CRASSOSTREA GIGAS*

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Introduction

Many studies have been accumulated on the various aspects of oyster biology but, so far, genetic research of oyster has never been explored in the past (1). Oysters together with other marine animals are difficult to deal with as materials for genetic study. Main reason for the difficulty has lied in the hardness in breeding the organism artificially at our disposals and keeping the isolated strains under management. Recently Loosanoff (2) has succeeded to cross-breed the related species of American clam, *Venus* in the laboratory.

Since our success in breeding the oyster (3, 4) artificially by feeding the larvae with non-colored naked flagellate as food we have carried out breeding experiments with Japanese common oysters, *Crassostrea gigas* of different localities of Japan to explore the genetics in oyster.

C. gigas distributes all over Japan and Korea. The native oysters of different localities exhibit differences in their morphological characters, growth rate, spawning conditions, adaptability to environmental conditions and also in flavor. However, as Orton et Awati (5) indicated, the characteristics of oyster is liable to change by habitat conditions. Therefore it is hard to distinguish one type from the other by mere comparison of oysters collected from different localities. As a result, there have been controversies among systematists on the identification of so called *gigas*-type oysters collected in different localities as can be seen in papers by Lischke (6), Wakiya (7, 8), Hirase (9), Kuroda (10), Senoo and Hori (11), Seki (12) and Cahn (13).

The question whether the difference in morphological and physiological characters among oysters of different localities is an inherent character or merely of phenotypic nature, can be answered by breeding oysters under identical conditions for generations.

In the series of breeding experiments we could rear artificially the larvae of gigas type oysters of various localities under confinement. The spats obtained were transplanted to several oyster beds of Japan and the United States where they were cultured under identical conditions respectively. Thus we were able to demonstrate certain differences of the genetic characters among oysters of different localities. We further carried out our breeding work through crosses among these strains and also through hybridization between these and other species of oysters.

This paper reports on the results of these breeding experiments. Through years of research, many biologists extended cooperative assistances in carrying out the culture experiments in their respective beds such as Dr. T. Kinoshita, Hokkaido Regional Fisheries Institute, Mr. S. Odera, Aomori Prefecture Fishery Experiment Station, Dr. S. Kobayashi, Fuji Pearl Co. Ltd of Mie Prefecture, Mr. F. Ohta, Fishery Experiment Station of Kumamoto Prefecture, Mr. C. Lindsey, Shellfish Laboratory of State of Washington, U.S.A. We express our hearty gratitude for their sincere assistance by which we were able to complete the experiment. We are also gratefully indebted to Professor U. Mizushima for his advice in preparing the paper.

Inbreeding of local types of *C. gigas*

1. *Material and method*

Samples of native oysters were brought to Onagawa Marine Laboratory in 1941 respectively from Saroma Bay, Hokkaido, Mangokuura Inlet, Miyagi Pref., Shimizu, Shizuoka Pref., Nagoya, Aichi Pref., Kusatsu, Hiroshima Pref., Saga, Saga Pref., Fuzan and Genzan of Korea. By mating a male and a female oyster of respective locality, the larvae were obtained and were reared in tanks separately to the spats. These spats were hanged under the floating rafts for culture in Onagawa Bay.

Comparison of the grown-up oysters revealed clearly that there was a regression in their dimensional characters and coloration by localities. Namely, shell size diminishes and shell color gets darker granually as we go from north to south. The contrast was very distinct between oysters of far north and those of far south.

Because of such contrast in characters and also of the limitation in facilities of breeding work, we decided to use Hokkaido and Miyagi oysters as representatives of northern type and Hiroshima oyster as that of southern type in the breeding followed. In 1949, Kumamoto oyster was added to the materials as a southern type.

Hirase (9) identified Hakkaido and Miyagi oysters as *Ostrea gigas* Thumberg (in Japanese, Nagagaki or Ezogaki) and Hiroshima oyster as *O.*

laperousei Schrenck (in Japanese Magaki). Amemiya (14) named Kumamoto oyster as *O. gigas var sikamea* Amemiya (in Japanese, Shikame).

We hesitate to discuss shell characters of native oysters comparatively. But, generally speaking, our samples revealed that their shell characteristics agreed with the description of Hirase (9) and Amemiya (14). Namely, Hokkaido oysters had a large and elongated shell with flat valve surface. The color was pale white. On the contrary, Hiroshima oysters had a small, round and well cupped shell with marked wave in the valve. The color was dark purple. Miyagi oyster was very close to the Hokkaido with a little smaller dimensions and darker coloration. Kumamoto oysters were much smaller than the Hiroshima but very close to it in other respects.

Mating by artificial fertilization was made with a male and a female oyster with typical appearance of respective local type which carried ripe gonads. Morphological characters of parent oysters native to each locality are summarized in Table 1. Spats collected in the tank were kept in running water of the laboratory for a while and then they were lied on hardening racks in Mangoku-ura Inlet for a period of 5 months. In April of the following year, they were transplanted to the beds of different localities of Japan for culture.

As characteristics, shell dimensions such as length, width and depth, and total weight and shell weight were measured. Relative depth of shell was expressed by the ratio of depth to the average of length and width, multiplied by 100. The ratio will be named an index of shell depth in this paper. Percentage of meat weight to the total weight is expressed as an index of meat weight whenever it was measured.

In order to express the shell coloration on numerical basis, an index number was used in accordance with the areal proportion of colored part, dark purple or brown, to the total surface of top shell, namely as follows.

Color index 1—Whole surface is gray white with no dark coloration
〃 2—A small part of shell is dark colored
〃 3—Nearly half part of shell is dark colored
〃 4—Most part of shell is dark colored
〃 5—All part is dark colored

In the culture after 1947, shell size was measured once a month to compare the growth of each strain at each bed. For growth measurement, two specified individuals on each cultch, 20 oysters in all, were used throughout the experiment. Their death rate was also recorded. In the map of Japan of Fig. 1, there are shown the localities where the oysters for the experiments were collected and also the beds where the cultures were carried out.

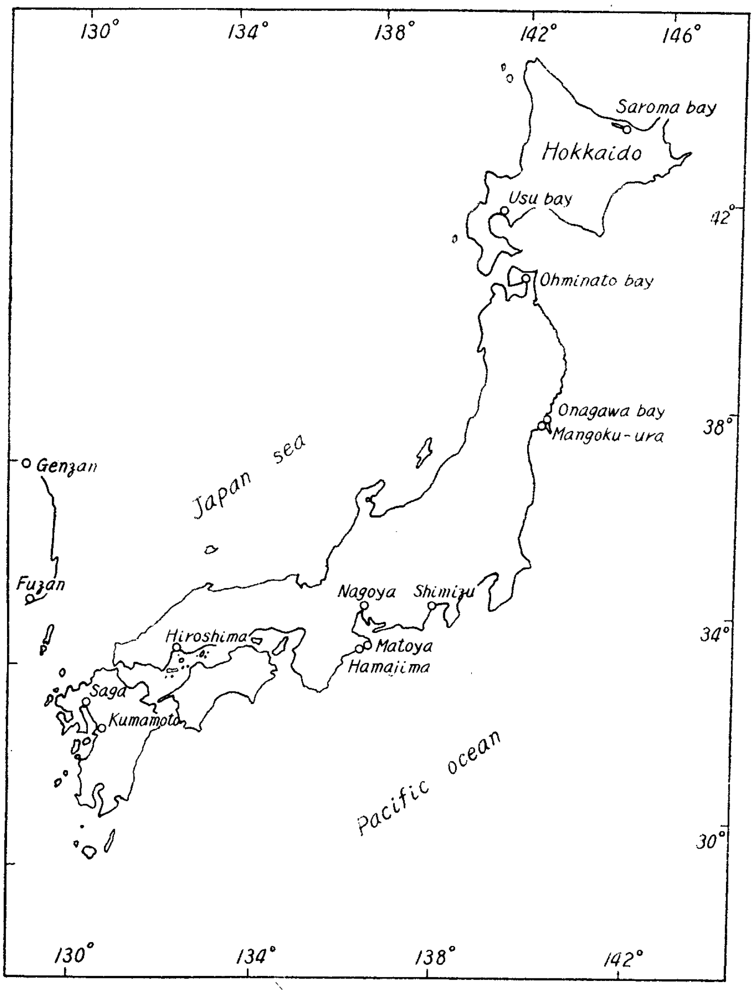


Fig. 1. Map of Japan showing the localities of origin of native oysters used for breeding and the beds where oysters were cultured.

2. *Record of breeding*

Series of inbreeding experiments are summarized in Table 1. In July,

Table 1. Shell characteristics of parent oysters (native) used for breeding.

Year of breeding	Oysters	Sex	Length (L) in mm	Width (W) in mm	Depth (D) in mm	Index of shell depth	Colour index	Flatness of valve
1941	Hokkaido	♂	210	87	59	19.9	1	flat
〃		♀	285	104	70	18.0	1	〃
〃	Miyagi	♂	128	68	30	15.3	3	slightly wavy
〃		♀	89	59	30	20.3	4	〃
〃	Hiroshima	♂	68	37	27	25.7	5	very wavy
〃		♀	66	35	20	19.8	5	〃
1950	Hokkaido	♂	102	50	20	26.3	1	flat
〃		♀	102	67	24	28.4	1	〃
〃	Hiroshima	♂	74	54	30	46.8	5	very wavy
		♀	67	50	25	42.7	5	〃
〃	Kumamoto	♂	63	26	15	33.7	3	〃
		♀	64	27	15	33.0	4	〃

1941, progenies of Hokkaido, Miyagi and Hiroshima oysters were obtained by mating respective parent oysters described in Table 2. They were cultured in Onagawa Bay for 27 months until they were sampled for measurement in July 1944. The characteristics of these strains are shown in Table 3. The strains of the 1st generation will be symbolized as G_1 in this paper.

Table 2. List of inbreeding experiments.

Localities of oysters	Generation	Year of breeding	Bed for culture	Period of culture
Hokkaido, Miyagi, Hiroshima	G_1	1941	Onagawa Bay	Apr. 1942-Jul. 1944
〃 , 〃 , 〃	G_2	1944	〃	Apr. 1945-Jul. 1947
〃 , 〃 , 〃	G_3	1947	〃	May, 1948-Jan. 1949
〃 , 〃 , 〃	〃	〃	Usu Bay	May, 1948-Feb. 1949
〃 , 〃 , 〃	〃	〃	Mangoku-ura	Apr. 1948-Dec. 1948
〃 , 〃 , 〃	〃	〃	Matoya	May, 1948-Jan. 1949
〃 , 〃 , 〃	〃	〃	Gig Harbor	May, 1948-Dec. 1948
Hokkaido, Hiroshima, Kumamoto	G_1	1949	Ohminato Bay	Mar. 1950-Dec. 1951
〃 , 〃 , 〃	〃	〃	Onagawa Bay	Apr. 1950-Dec. 1951
〃 , 〃 , 〃	〃	〃	Mangoku-ura	Mar. 1950-Dec. 1951
〃 , 〃 , 〃	〃	〃	Hamajima	Mar. 1950-Dec. 1951
〃 , 〃 , 〃	〃	〃	Kagami-machi	Mar. 1950-Dec. 1951
〃 , 〃 , 〃	〃	〃	Gig Harbor	Apr. 1950-Jan. 1952

Table 3. Characteristics of G_1 strains after 27 months of culture in Onagawa Bay.

Oysters	Hokkaido	Miyagi	Hiroshima
No. of oysters measured	8	12	16
	m σ	m σ	m σ
Length (mm)	121.6 ± 25.6	119.4 ± 25.4	91.6 ± 14.3
Width (mm)	83.1 ± 11.4	70.0 ± 8.3	58.1 ± 8.5
Depth (mm)	32.4 ± 5 5	31.0 ± 4.2	33.1 ± 4.3
Index of shell depth	31.7 ± 3.7	33.1 ± 5.3	44.6 ± 6.0
Colour index	1.4 ± 0.8	2.7 ± 1.0	4.3 ± 1.2
Flatness of valve	Flat	Slightly wavy	Very wavy

In July 1944, G_2 strains were obtained by sib-crossing two individuals in each of the G_1 strains which showed characteristics typical to the respective strains.

The characteristics of G_1 oysters used for mating are shown in Table 4. G_2 strains thus obtained were cultured in Onagawa Bay and measurements were made in July of 1946 and also in July of 1947. Characteristics of G_2 strains are summarized in Table 5 and 6.

Table 4. Characteristics of parent G_1 oysters used for inbreeding in 1944.

Oysters	Sex	Length (mm)	Width (mm)	Depth (mm)	Index of shell depth	Colour index	Flatness
Hokkaido	♂	150	95	39	31.9	2	flat
	♀	150	95	35	28.6	1	〃
Miyagi	♂	98	57	30	38.7	4	slightly wavy
	♀	116	76	36	37.5	2	〃
Hiroshima	♂	86	57	35	49.0	5	very wavy
	♀	96	64	38	47.5	4	〃

Table 5. Characteristics of G_2 strains after 17 months of culture in Onagawa Bay.

Oysters	Hokkaido	Miyagi	Hiroshima
No. of oysters	21	49	54
	m σ	m σ	m σ
Length (mm)	116.7 ± 21.4	110.6 ± 15.5	88.3 ± 14.0
Width (mm)	72.3 ± 12.6	60.6 ± 9.9	50.2 ± 7.5
Depth (mm)	22.8 ± 6.4	24.3 ± 4.6	21.7 ± 7.4
Index of shell depth	24.0 ± 5.3	28.7 ± 5.3	31.8 ± 5.5
Total weight (g)	120.9 ± 48.3	102.6 ± 29.0	57.4 ± 16.8
Colour index	1.7 ± 0.7	2.8 ± 1.0	4.6 ± 0.7
Flatness	Flat	Slightly wavy	Very wavy

Table 6. Characteristics of G_2 strains, after 29 months of culture in Onagawa Bay.

Oysters	Hokkaido	Miyagi	Hiroshima
No. of oysters	21	44	31
	m σ	m σ	m σ
Length (mm)	133.0 ± 21.2	118.1 ± 17.8	100.9 ± 12.0
Width (mm)	90.8 ± 24.3	67.4 ± 9.0	55.1 ± 9.1
Depth (mm)	39.0 ± 5.8	35.3 ± 5.2	31.7 ± 4.8
Index of shell depth	36.0 ± 5.8	38.1 ± 6.7	40.9 ± 6.3
Total weight (g)	271.9 ± 86.0	179.9 ± 58.5	105.3 ± 35.0
Colour index	1.7 ± 0.8	3.0 ± 1.3	4.7 ± 0.6
Flatness	Flat	Slightly wavy	Very wavy

In July of 1947, G_3 strains were obtained in the same way as in the case of G_2 strains. The characteristics of parent G_2 oysters are shown in Table 7. Cross-breeding among different strains was also made, using the same parent oysters, but its detail will be reported later. Besides Onagawa Bay, G_3 strains were cultured in Usu Bay, Hokkaido, Mangoku-ura, Miyagi Pref., Matoya Bay, Mie Pref., Gig Harbor, State of Washington. Characteristics of G_3 strains in various beds are summarized in Table 8. Samples of these G_1, G_2 and G_3 strains are shown in Plate I with samples of hybrid strains.

Table 7. Characteristics of parent G_2 oysters used for inbreeding in 1947.

Oysters	Sex	Length(L)	Width(W)	Depth (D)	Index of shell depth	Colour index	Flatness
Hokkaido	♂	133	90	38	34.1	1	flat
	♀	161	93	40	31.5	2	〃
Miyagi	♂	140	73	37	34.8	4	slightly wavy
	♀	148	78	40	35.4	3	〃
Hiroshima	♂	95	57	32	42.2	5	very wavy
	♀	102	64	34	41.0	5	〃

Table 8. Characteristics of G_3 strains, after 9 months of culture in various beds.

	Oysters	Hokkaido	Miyagi	Hiroshima
(1) Usu Bay	No. of oysters		24	27
			m σ	m σ
	Length (mm)	Lost by storm	82.8 ± 10.5	63.9 ± 11.7
	Width (mm)		59.3 ± 4.1	46.2 ± 6.7
	Depth (mm)		25.8 ± 4.8	24.0 ± 3.7
	Index of shell depth (%)		36.8 ± 8.4	41.3 ± 9.8
	Total weight (g)		71.8 ± 15.1	43.3 ± 19.1
	Wet meat wt. (g)		16.8 ± 3.5	10.9 ± 3.9
	Index of meat wt. (%)		23.4 ± 2.5	25.8 ± 4.2
	Color index		3.1 ± 0.9	4.6 ± 0.6
(2) Onagawa Bay	No. of oysters	30	32	16
		m σ	m σ	m σ
	Length (mm)	89.1 ± 11.1	80.9 ± 10.9	58.5 ± 8.4
	Width (mm)	66.1 ± 11.8	51.4 ± 8.4	47.3 ± 8.3
	Depth (mm)	23.7 ± 5.5	25.4 ± 5.0	19.3 ± 2.7
	Index of shell depth (%)	32.2 ± 6.7	38.8 ± 6.4	36.9 ± 6.3
	Total weight (g)	93.8 ± 27.8	63.6 ± 26.2	32.2 ± 7.7
	Wet meat wt. (g)	11.9 ± 3.5	8.4 ± 3.2	5.6 ± 2.3
	Index of meat wt. (%)	12.7 ± 1.7	13.7 ± 2.2	17.4 ± 3.3
	Color index	1.3 ± 0.7	2.7 ± 0.7	5.0 ± 0.0
(3) Mangoku-ura	No. of oysters	29	25	24
		m σ	m σ	m σ
	Length (mm)	69.9 ± 10.1	71.7 ± 10.8	51.9 ± 7.4
	Width (mm)	49.1 ± 9.4	48.9 ± 5.6	36.1 ± 4.5
	Depth (mm)	17.8 ± 3.9	24.7 ± 3.6	19.5 ± 7.6
	Index of shell depth (%)	30.4 ± 6.4	41.5 ± 5.6	43.4 ± 8.8
	Total weight (g)	34.1 ± 13.5	43.3 ± 12.6	19.6 ± 7.6
	Wet meat wt. (g)	4.8 ± 2.6	5.8 ± 1.6	3.1 ± 1.3
	Index of meat wt. (%)	13.9 ± 3.7	13.6 ± 1.4	15.6 ± 3.2
	Color index	1.7 ± 0.7	2.6 ± 0.5	3.7 ± 0.5
(4) Matoya Bay	No. of oysters	8	14	21
		m σ	m σ	m σ
	Length (mm)	78.7 ± 12.9	76.8 ± 13.3	60.5 ± 7.0
	Width (mm)	54.6 ± 9.8	50.8 ± 9.6	44.4 ± 6.6
	Depth (mm)	23.7 ± 3.2	22.8 ± 4.4	22.6 ± 3.8
	Index of shell depth (%)	35.0 ± 4.0	35.9 ± 4.6	43.2 ± 7.6
	Total weight (g)	80.1 ± 23.8	66.6 ± 21.0	40.5 ± 10.6
	Wet meat wt. (g)	13.4 ± 5.1	13.8 ± 5.0	10.3 ± 2.9
	Index of meat wt. (%)	16.4 ± 3.7	20.9 ± 2.5	27.1 ± 2.5
	Color index	1.6 ± 0.5	3.5 ± 0.9	4.5 ± 0.6
(5) Gig Harbor	No. of oysters	4	8	7
		m σ	m σ	m σ
	Length (mm)	75.8 ± 14.1	67.7 ± 13.0	69.7 ± 9.7
	Width (mm)	63.5 ± 18.0	47.0 ± 8.8	49.0 ± 5.8
	Depth (mm)	18.0 ± 2.2	18.7 ± 4.8	21.3 ± 3.3
	Index of shell depth (%)	26.4 ± 3.9	33.2 ± 4.2	38.9 ± 9.9
	Total weight (g)	64.2 ± 25.3	34.7 ± 13.7	34.8 ± 13.7

Table 9. Characteristics of G_1 strains newly introduced in 1949, after 21 months of culture in various beds.

	Oysters	Hokkaido	Hiroshima	Kumamoto
(1) Ohminato Bay	No. of oysters	30	30	30
		m ± σ	m ± σ	m ± σ
	Length (mm)	131.8 ± 18.0	89.0 ± 9.6	81.4 ± 9.6
	Width (mm)	71.8 ± 6.1	52.0 ± 5.1	49.5 ± 5.5
	Depth (mm)	31.5 ± 4.0	26.7 ± 3.1	24.5 ± 3.3
	Index of shell depth (%)	31.3 ± 4.8	38.1 ± 5.3	38.3 ± 5.8
	Total weight (g)	163.6 ± 29.3	65.9 ± 10.6	46.6 ± 9.6
	Wet meat wt. (g)	13.6 ± 3.4	8.5 ± 1.8	5.9 ± 1.8
	Index of meat wt. (%)	8.3 ± 1.1	12.9 ± 1.3	12.7 ± 2.8
	Color index	1.1 ± 0.2	4.9 ± 0.3	4.1 ± 1.0
(2) Onagawa Bay	No. of oysters	20		19
		m ± σ		m ± σ
	Length (mm)	104.4 ± 13.0	Lost by storm	61.4 ± 8.5
	Width (mm)	75.8 ± 11.8		44.6 ± 6.0
	Depth (mm)	34.6 ± 4.2		26.2 ± 4.0
	Index of shell depth (%)	39.1 ± 5.4		49.9 ± 8.3
	Total weight (g)	174.9 ± 42.0		42.2 ± 10.0
	Wet meat wt. (g)	28.2 ± 7.4		6.4 ± 2.3
	Index of meat wt. (%)	16.1 ± 2.1		15.2 ± 2.6
	Color index	1.4 ± 0.7		4.3 ± 0.7
(3) Mangoku-ura	No. of oysters	20	25	20
		m ± σ	m ± σ	m ± σ
	Length (mm)	93.6 ± 12.5	55.6 ± 6.7	55.9 ± 5.7
	Width (mm)	60.2 ± 8.6	40.3 ± 5.3	40.4 ± 4.9
	Depth (mm)	27.8 ± 3.8	25.8 ± 3.3	23.0 ± 3.4
	Index of shell depth (%)	36.4 ± 5.7	54.3 ± 7.5	48.3 ± 6.2
	Total weight (g)	82.8 ± 10.4	34.2 ± 8.9	28.2 ± 6.5
	Wet meat wt. (g)	13.3 ± 8.5	7.0 ± 1.5	5.4 ± 1.3
	Index of meat wt. (%)	16.1 ± 2.3	20.5 ± 2.5	19.1 ± 3.6
	Color index	1.6 ± 0.9	4.6 ± 0.7	4.2 ± 0.8
(4) Hamajima	No. of oysters	—	9	15
			m ± σ	m ± σ
	Length (mm)	—	65.9 ± 8.9	63.3 ± 9.5
	Width (mm)	—	46.1 ± 2.9	44.3 ± 4.4
	Depth (mm)	—	29.6 ± 3.2	28.9 ± 3.5
	Index of shell depth (%)	—	53.0 ± 3.9	54.3 ± 8.8
	Total weight (g)	—	57.7 ± 11.5	50.3 ± 9.6
	Wet meat wt. (g)	—	7.6 ± 2.9	7.6 ± 1.9
	Index of meat wt. (%)	—	13.2 ± 3.5	15.1 ± 2.2
(5) Kagami-machi	No. of oysters	3	4	24
		m ± σ	m ± σ	m ± σ
	Length (mm)	43.7 ± 8.1	41.8 ± 4.5	37.5 ± 3.8
	Width (mm)	31.0 ± 2.6	29.8 ± 4.6	26.0 ± 2.2
	Total weight (g)	14.5 ± 3.6	12.8 ± 1.7	9.0 ± 3.0
	Wet meat wt. (g)	1.9 ± 0.5	1.8 ± 0.5	1.4 ± 0.5
	Index of meat wt. (%)	13.1 ± 1.7	14.1 ± 3.5	15.5 ± 3.5
(6) Gig Harbor	No. of oysters	1	9	5
		m ± σ	m ± σ	m ± σ
	Length (mm)	3.2 ± 17.6	63.8 ± 10.0	54.0 ± 2.7
	Width (mm)	50.3 ± 7.3	40.7 ± 9.5	—
	Total weight (g)	51.5 ± 17.6	31.5 ± 9.9	22.9 ± 8.3
	Wet meat wt. (g)	6.6 ± 3.0	6.6 ± 2.1	4.5 ± 2.0
	Index of meat wt. (%)	12.8 ± 3.5	20.9 ± 2.7	19.7 ± 5.7

Another breeding experiment was started in July of 1949 with oysters newly introduced from Saroma Bay, Hokkaido, Mangoku-ura, Miyagi Pref., and Kagami-machi, Kumamoto Pref. In this case, besides line separation by inbreeding, crosses among strains of different origin were made. These breeding materials were cultured in Mutsu Bay, Aomori Pref., Onagawa Bay, Mangoku-ura, Miyagi Pref., Hamajima Bay, Mie Pref., Kagami-machi, Kumamoto Pref. and Gig Harbor, State of Washington. The characteristics of G_1 strains are shown in Table 9. Sample of G_1 strains are shown in Plate II with their hybrid strains.

3. *Result of experiment*

The results of inbreeding will be described here. The results of cross-breeding will be referred to later.

A. Mortality

a) Durability of oyster seeds of inbred strains to hardening treatment.

In hardening treatment, the seeds were laid on racks at a level which will be exposed to air even at the mean low tide. This is a treatment to harden the shell in order to make them durable for a distant transportation.

Oyster seeds of different strains were exposed to hardening treatment to compare their durability to the treatment. Mortalities of seeds during the treatments in 1947 and 1949 are summarized in Table 10. In four local strains the Kumamoto showed the lowest mortality while the Hiroshima was the highest with 44.0 per cent and 56.5 per cent of deaths. Difference among strains in both experiments were statistically significant.

Table 10. Mortality of oyster seeds during hardening treatment in Mangoku-ura.

Oysters	Year of breeding	Period of hardening treatment	Mortality %
Miyagi G_3	1947	Nov. 18, 1947-Mar. 29, 1948	38.0
Hiroshima G_3	1947	〃	44.0
Hokkaido G_1	1949	Nov. 25, 1949-Mar. 25, 1950	40.8
Hiroshima G_1	1949	〃	56.5
Kumamoto G_1	1949	〃	25.0

From these results it can be concluded that among the oysters observed the Hiroshima was the weakest against the treatment while the Kumamoto was the strongest.

b) Mortality during culture

Mortality of oysters of different strains during culture at various beds are summarized in Table 11. The results will be discribed for each bed separately.

Table 11. Mortality of oysters of inbred strains during culture in various beds.

Bed	Year of breeding	Period of culture	Mortality (%)			
			Oysters			
			Hokkaido	Miyagi	Hiroshima	Kumamoto
			G_3	G_3	G_3	
Usu Bay	1947	May 15, '48 -Feb. 19, '49	—	19.6	16.9	—
Onagawa Bay	1947	Apr. 21, '48 -Dec. 1, '48	13.9	20.0	36.7	—
Mangoku-ura	1947	May, 1, '48 -Dec. 2, '48	12.5	22.4	40.7	—
Matoya Bay	1947	Apr. 10, '48 -Dec. 21, '48	85 2	88.2	50.0	—
			G_1	G_1	G_1	G_1
Ohminato Bay	1949	Mar. 24, '50 -Dec. 24, '51	23.7	—	31.0	24.6
Onagawa Bay	1949	Apr. 8, '50 -Dec. 10, '51	54.7	—	—	38.0
Mangoku-ura	1949	Apr. 15, '50 -Dec. 21, '51	48.8	—	37.7	40.8
Hamajima	1949	Mar. 27, '50 -Dec. 10, '51	100.0	100.0 (Miyagi native)	80.5	65.2
Kagami-machi	1949	Mar. 23, '50 -Dec. 17, '51	98.0	—	96.8	71.0
Gig Harbor	1949	Apr. 15, '50 -Jan. 18, '52	38.4	—	73.9	44.8

i) Usu Bay

In this bay, G_3 Miyagi and Hiroshima strains were cultured. Possibly due to the stable environmental conditions of the bay, both oysters showed a relatively low mortality during culture as compared to other beds. The difference between the strains was not statistically significant.

ii) Ohminato Bay

G_1 strains of Hokkaido, Hiroshima and Kumamoto were cultured here. All strains showed relatively high mortality from March on, right after the transplantation, to August but almost no deaths were recorded since then. The period of high mortality corresponded to the season when the water temperature had an abrupt rise with high variation in salinity.

Here the Hiroshima showed the highest mortality but the differences between the strains were not statistically significant.

iii) Onagawa Bay

In this bay, G_3 strains of Hokkaido, Miyagi and Hiroshima and G_1 strains of the Hokkaido, Hiroshima and Kumamoto were cultured.

Among G_3 strains, the Hiroshima showed higher mortality as compared to the Hokkaido and Miyagi with significant difference. No. significance was noticed between two northern strains.

Among G_1 strains Hiroshima strains were lost in September by storm but they showed higher mortality as compared to other strains up to that date. The Kumamoto showed significantly low mortality to the Hokkaido.

iv) Mangoku-ura

Here the G_3 strains of the Hokkaido, Miyagi and Hiroshima and G_1 strains of the Hokkaido, Hiroshima and Kumamoto were cultured.

Among G_3 strains, the mortality was highest in the Hiroshima which was followed by the Miyagi and Hokkaido in order. Here the difference between the Hiroshima and two northern oysters were significant. While among G_1 strains the difference was not significant.

v) Matoya Bay

G_3 strains of the Hokkaido, Miyagi and Hiroshima were cultured. A very high mortality was recorded from September to October when the water temperature began sharp decline. Such thing never occurred in the northern beds already described. The mortality was very high particularly in Hokkaido, and Miyagi strains with 85.2 per cent of deaths respectively, while the Hiroshima showed 50.0 per cent mortality significantly lower than the others. The fact coincides with a general occurrence of higher mortality in transplanted Miyagi oysters in late summer and early fall as compared to the native oysters.

vi) Hamajima Bay

G_1 strains of Hokkaido, Hiroshima and Kumamoto were cultured here. Miyagi oysters collected naturally in Matsushima Bay were added for culture experiment in Nov. of 1950.

In this bed all oysters showed high mortality. Particularly the Hokkaido showed 81.2 per cent of deaths in the first six months and all died before the end of August of 2nd year of culture. Miyagi oysters also died out before the end of October of the second year. The Hiroshima's mortality reached 80.5 per cent but was significantly lower than the Hokkaido. Kumamoto oysters showed the lowest mortality of 65.2 per cent.

vii) Kagami-machi bed

G_1 strains of the Hokkaido, Hiroshima and Kumamoto were cultured. There were added native oysters collected naturally in Kumamoto, on Dec. 25 of 1950.

Because of high temperature and high variation in salinity, both the Hokkaido and Hiroshima sufferred high mortalities of 90 per cent and 80 per cent respectively in the first summer of culture and very few of them survived until the end of culture. The Kumamoto showed significantly lower mortality with 71.0 per cent. The native Kumamoto showed a mortality of 70.8 per cent which was very close to that of tankbred strains.

viii) Gig Harbor, Washington, U.S.A.

G_1 strains of the Hokkaido, Hiroshima and Kumamoto were shipped to the Shellfish Laboratory of State of Washington, and were cultured in Gig Harbor under raft for a period from April 15, 1950 to January 18, 1952. As is shown in Table 12, the mortality of the Hokkaido and Miyagi were 38.4 per cent and 44.8 per cent, respectively with no significant difference between them. While the Hiroshima showed high mortality of 73.0 per cent which was significantly higher than other strains.

The results of two culture experiments in eight beds above mentioned revealed that the mortality of oysters differred from bed to bed according to the environmental conditions but certain relationship in hardiness can be seen among different strains. Namely the northern type of oysters such as the Hokkaido and Miyagi were much hardy in the northern beds of low

Fig. 2 Growths of G_3 strains of Hokkaido, Miyagi and Hiroshima in Onagawa Bay.

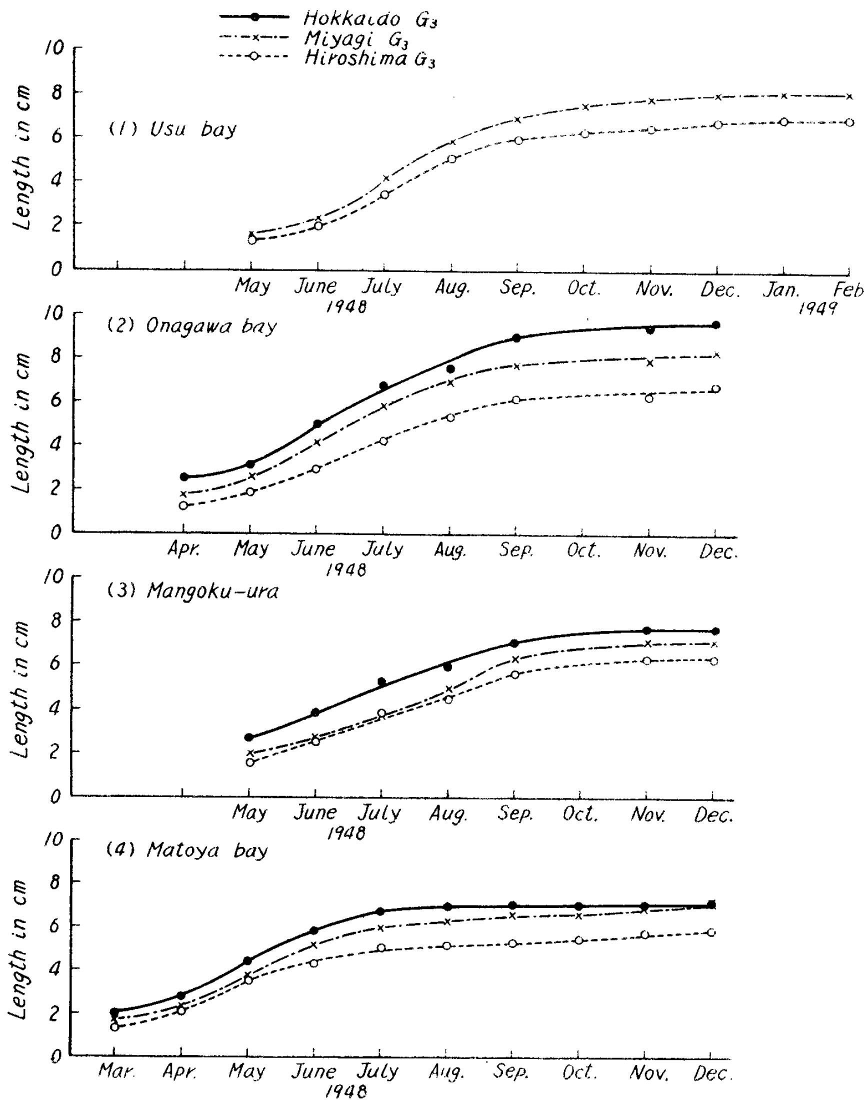
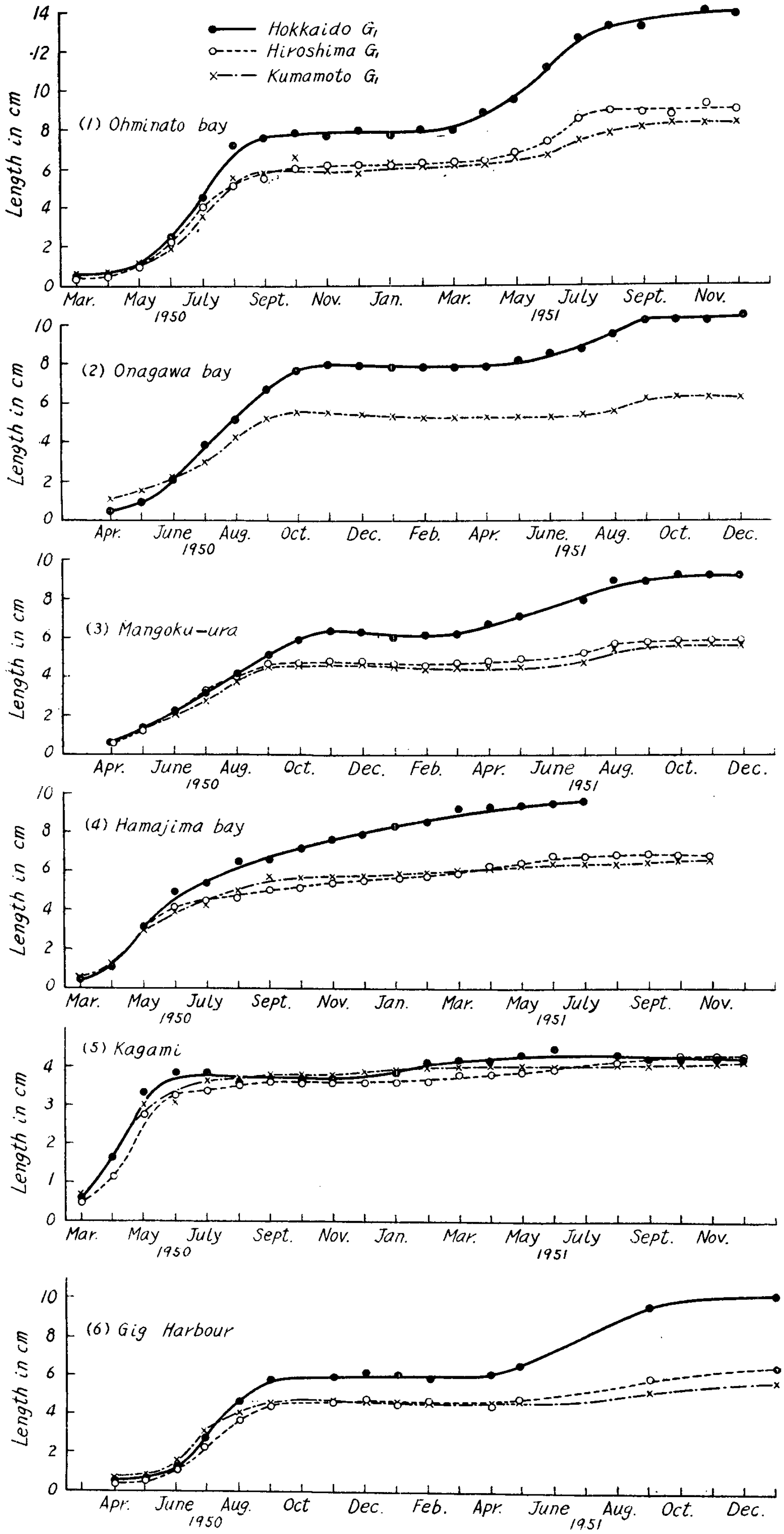


Fig. 3 Growths of the Hokkaido, Hiroshima and Kumamoto in various beds.



water temperature such as Ohminato, Onagawa, Mangoku-ura and Gig Harbor as compared to Hiroshima strains while they were weak in the southern beds such as in Mie and Kumamoto Prefecture. Seki (12) also reported a high mortality of Miyagi oysters transplanted in Ohcho bed of Hiroshima as compared to the native Hiroshima oyster.

The Kumamoto strain showed generally a low mortality in all beds as compared to three other strains indicating their superior hardiness. Their hardiness was particulary marked in the beds with high water temperature.

B. Growth

Growth of each oyster strains in various beds are shown in Fig. 2 and 3.

In northern beds of Japan such as Aomori and Miyagi, and also Gig Harbor, Washington, U.S.A., all strains showed a rapid growth from the spring through summer in the first year of culture while it was suspended during winter season when the water temperature fell below 10°C. In the second year of culture they resumed growth from the spring on, at a little slower rate than the first year. While in the southern beds such as in Mie and Kumamoto, slow growth persisted even in the winter season following the rapid growth of spring and summer. In these beds, it was noticed that the growth in the second year of culture was not so remarkable as in the northern beds as can be seen from the figure.

Growth of oysters differed considerably by beds but the consistent difference among local strains persisted through all the beds. Namely Hokkaido oysters showed the most rapid growth among them though their growths were inhibited in the southern bed such as Kagami. Kumamoto oysters showed the slowest growth. Hiroshima oysters exceeded slightly over the Kumamoto. Miyagi oysters ranked between the Hokkaido and the Hiroshima.

As can be seen from the figures the seasonal change in growths among various strains revealed that in the second year of culture, Hokkaido oysters began a rapid growth in March, or April, in Ohminato Bay, Onagawa Bay, Mangoku-ura Inlet and in Gig Harbor when the sea water temperature went up to 6° or 7°C, while in either Kumamoto or Hiroshima strains the growth was delayed almost two months until the temperature reached to 10° to 15°C. Thus the northern oyster resumed a growth at lower temperature as compared to the southern oysters. In the southern waters such as Hamajima and Kagami no interruption of grows occurred during winter season. The oyster grew slowly but steadly throughout the second year of culture.

C. Dimensional character

Among G_1 oysters, at the end of 27 months of culture, the Hokkaido strain was the largest in size and the Hiroshima strain was the smallest as is shown in Table 3. The Miyagi was a little smaller as compared to the

Hokkaido. There was a significant difference in mean and standard deviations between northern type oysters and the Hiroshima while the difference was non-significant between the Hokkaido and the Miyagi.

G_2 strains revealed, after 17 months of culture, that a similar relation as in G_1 held among them in their characteristics (Table 5), and the same was true after 27 months of culture (Table 6). The difference was significant even between the Hokkaido and the Miyagi.

G_3 strains showed the same relation in their shell size in all culture beds with an exception in Mangoku-ura Inlet where the Miyagi native showed better growth as compared to the Hokkaido. Hiroshima oysters were significantly smaller than northern oysters regardless of the culture bed.

In the breeding with newly introduced Hokkaido, Hiroshima and Kumamoto oysters Kumamoto strains showed smaller dimensions than the Hiroshima as is seen in Table 9.

The index of shell depth increased inversely with shell dimensions. Namely, the Hokkaido showed the lowest index and then followed the Miyagi and the Hiroshima. The Kumamoto strain was the highest. Such relations held throughout the generations regardless of the culture beds.

A comparison of shell form in different strains are well illustrated in diagrams (Fig. 4, 5, 6 and 7) where percentages of length, width and depth dimensions to the sum of them are plotted on triangular coordinates.

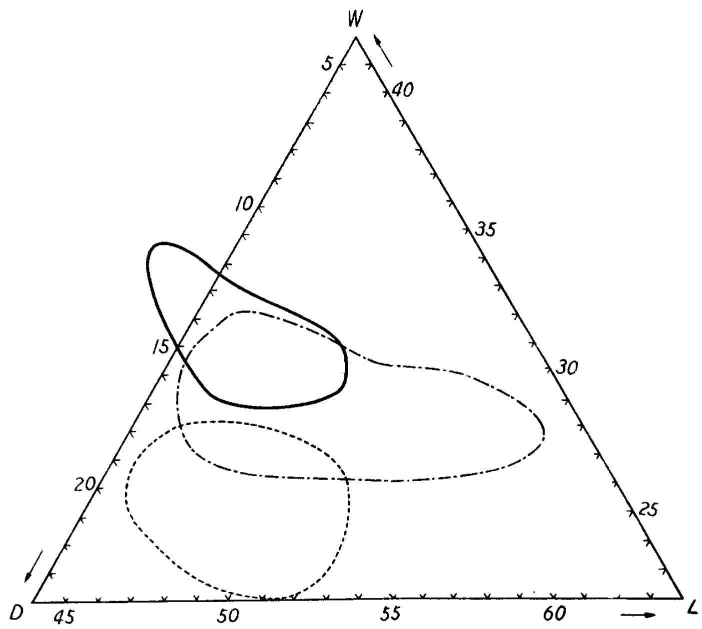


Fig. 4 Diagram showing the relation of the length (L), width (W) and depth (D) in G_1 strains of Hokkaido (———), Miyagi (— - —) and Hiroshima (-------) cultured for 27 months in Onagawa Bay.

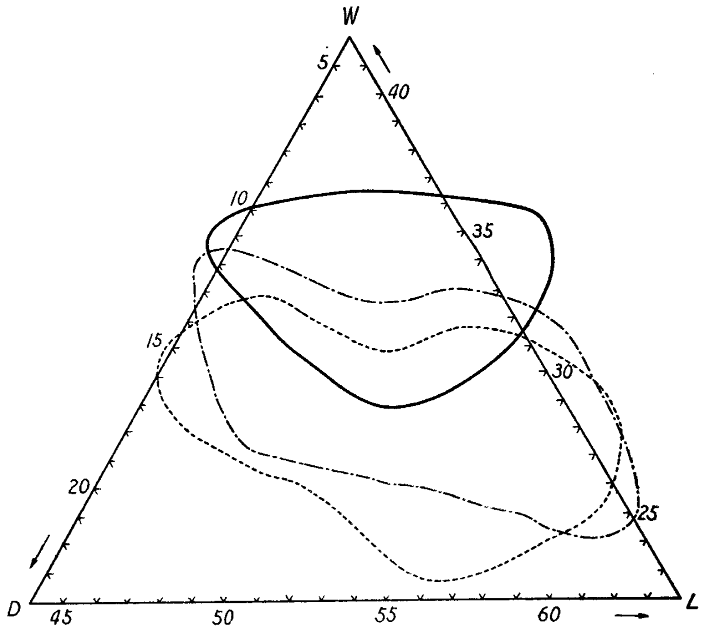


Fig. 5 Diagram showing the relation of the length (L), width (W) and depth (D) in G_2 strains of Hokkaido (———), Miyagi (— - —) and Hiroshima (-------) cultured for 27 months in Onagawa Bay.

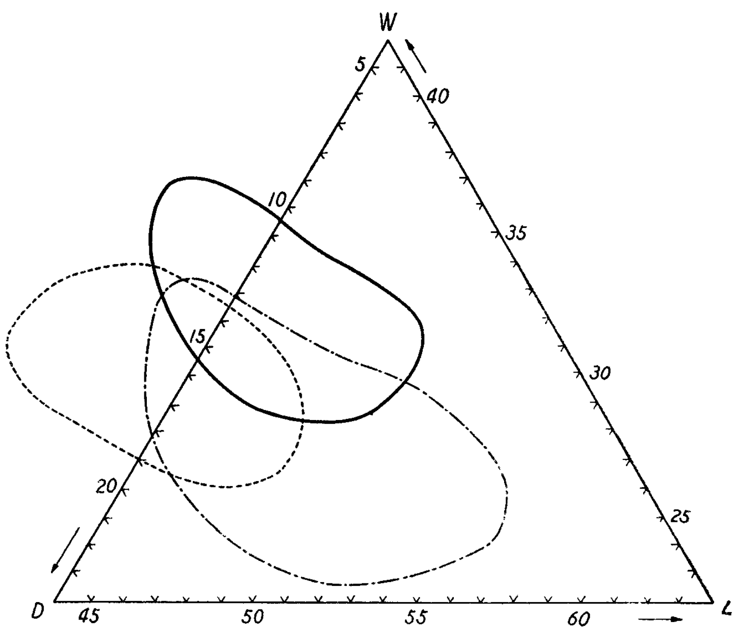


Fig. 6 Diagram showing the relation of the length (L), width (W) and depth (D) in G_3 strains of Hokkaido (———), Miyagi (— - —) and Hiroshima (-------) cultured for 21 months in Onagawa Bay.

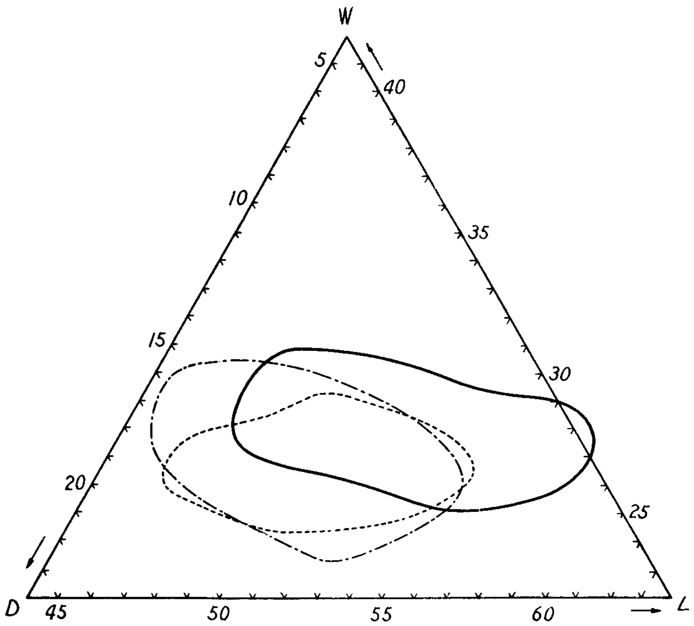


Fig. 7 Diagram showing the relation of the length (L), width (W), and depth (D) in G_1 strains of Hokkaido (———), Hiroshima (-------), and Kumamoto (— · —) cultured for 21 months in Ohminato Bay.

The index of meat weight varied in accord with the depth index. That means, the oysters with higher depth index had a relatively higher meat content. As an index of shell depth is considered an inherent character of a strains, the selection of oyster strains in respect to the relative depth of shell seems to be important from the commercial viewpoint.

Relations of total weight and meat weight among strains were the same as that of the dimensional characters regardless of the generations and culture beds. However, the index of meat weight was much higher in the southern oysters as compared to the northern oysters.

D. Flatness of shell valve

As Amemiya (14) and Hirase (9) discribed, the flatness of oyster shell valve differ by localities. Such character is well exhibited in the right valve. In Hokkaido oysters the right valve is nearly completely flat while Hiroshima and Kumamoto oysters have ridges running toward the margin showing wavy appearance. In flatness Miyagi oyster is close to the Hokkaido with only slightly wavy appearance.

E. Coloration of shell

Darkness in shell coloration, and accordingly the coloration in mantle edge, differ by strains. Results of observations on all strains in various beds are summarized in Table 12. Hokkaido oysters were gray white and devoid

Table 12. Percentage distribution of color index of various oyster strains.

Oysters	Color index				
	1	2	3	4	5
Hokkaido	54.0%	33.9%	11.6%	0.5%	0
Miyagi	6.4%	24.8%	42.2%	18.3%	8.3%
Hiroshima	0	0.8%	4.5%	21.3%	73.3%
Kumamoto	0	5.8%	14.5%	33.4%	46.4%

of dark purple or brown coloration with low color index. In their spat stage, dark spots were observed but as the oyster grew the dark part reduced gradually and was left as a trace in the grown-up oysters.

In good contrast to the Hokkaido, Hiroshima oysters have dark coloration in most part of shell surface. Their color index was 5 or 4 and a few 3.

Miyagi oyster showed an intermediate coloration in darkness between the Hokkaido and Hiroshima. Modal value of color index was 3 and a few were 4 and 2.

Kumamoto oyster is very close to the Hiroshima in coloration. Many of them had a color index of 5 or 4 and a few 3. It should be noted here that through breedings the shell coloration was found to be very similar in darkness and pattern among offsprings from a single mating in every strains.

From these observations it can be concluded that coloration is an inherent character of oysters though there is an evidence of certain modification due to metabolic activity of individual oysters.

The present breedings dealt only progenies from a single mating and no direct informations were obtained regarding the populations of each local strains. But the matings were made with oysters representatives of the population and darkness of coloration persisted for generations of breeding and furthermore from the fact that these oysters at their native beds differ in coloration in the way just shown in the experiments, it can be said with safety that the darkness of coloration is inherent to the strains of oysters.

F. Physiological and ecological characteristics

a) Vigor of the strains.

In animal inbreeding, it is often reported that the vigor of strains decline gradually as the generation proceeds. In our inbreeding of oyster for three generations we noticed no decline in the rate of fertilization at mating but there was an indication of decline in the vigor of larvae as the generations proceeded. So far as we went, we failed to obtain progeny of the 4th generation (G_4) from either one of the G_3 strains. The fact that we could obtain progenies by out-crossing G_3 strains seems to indicate that the vigor could be recovered by hybridization.

b) Spawning

Though Onagawa Bay is close to Mangoku-ura which is well known as a natural seed producing area, it is under a direct influence of oceanic water, and the water temperature seldom reach 25°C even during the hot season. Therefore, the spawning of oyster in the bay is much delayed as compared to Mangoku-ura and no natural spawning occur in years of low water temperature. Therefore, it may not be an ideal place to compare the spawning conditions of each strains but from our records of culture for a period of 10 years a few informations will be derived regarding the spawning conditions of each oyster strain.

Both Hokkaido and Miyagi strains spawn in the late August and early September when the water temperature begin declining. The Hiroshima spawn a week or two later, namely in the 1st and 2nd decades of September. Usually none of these oysters above mentioned carry the ripe gonad during winter. Kumamoto oysters show a different mode of spawning from others. In Onagawa Bay, they usually spawn naturally in late July when the temperature reach 22° or 23°C and they resume the ripening of gonad again and carry ripe gonad even in November and December. Such gonad formation at lower temperature in Kumamoto oysters was well observed in Ohminato, Mangoku-ura, Hamajima, Kagamimachi and also in the west coasts of the United States.

Gonad cells observed in Kumamoto oysters gradually decreased during a cold season but a part of them were retained until early spring. Such decline of gonad contents seemed to be not due to spwaning but to gradual degeneration of the gonad cells. This character of Kumamoto oyster is to be considered as a disadvantage from commercial point of view.

c) Glycogen content and flavor of oyster

Glycogen content of oysters was analysed with G_1 strains of Hokkaido, Miyagi, Hiroshima and Kumamoto cultured in Ohminato Bay, Onagawa Bay and Mangoku-ura and the results are shown in Table 13. In the table the glycogen contents in two hybrid strains are also shown.

Table 13. Glycogen contents of various oyster strains on dry basis.

Beds	Oysters					
	Hokkaido G_1	Miyagi G_1	Hiroshima G_1	Kumamoto G_1	F_1 Ho×K	F_1 K×Ho
Ohminato Bay	16.3%	—	20.8%	6.3%	10.7%	13.2%
Onagawa Bay	13.6%	16.7%	—	8.6%	12.5%	10.9%
Mangoku-ura	3.2%	2.9%	6.6%	2.5%	—	3.4%

Glycogen contents of oysters differ from bed to bed according to the fattening condition of beds but when we compare the strains each other it can be concluded that the content was the highest in the Hiroshima which was followed by the Miyagi and then by the Hokkaido. The Kumamoto was the lowest in glycogen content. It is well known that the glycogen contents of oyster reach a peak a few months ahead of the spawning and as the gonad formation proceed it gradually decrease and finally reach the bottom right after spawning (Okazaki and Kobayashi (18), Hatanaka (16)). Therefore, a low glycogen content in Kumamoto oysters may possibly be connected with the gonad formation during the winter season.

Comparative estimation of flavor of oyster is rather difficult because there is no standard method of analysis to determine the flavor and it differs by personal preference. Therefore, we had an assembly of 12 persons of oyster growers and biologists for sampling. Oysters presented for the test were the same strains as were used for glycogen analysis. Six hybrid strains of oysters to be referred to later were also served for the test. In the test each person sampled each of ten oyster strains in raw and gave the order according to their personal judgement of flavor. By averaging the rank number of the test the order shown in Table 14 was resulted.

Table 14. Result of panel test for determining the rank of flavor of different strains of oysters cultured in Onagawa Bay.

Oysters	Hokkaido G_1	Miyagi G_1	Hiroshima G_1	Kumamoto G_1	F_1 Ho ×K	F_1 K ×Ho	F_1 Ho ×Hi	F_1 K ×M	F_1 Hi ×M	F_1 M ×Hi
Order of flavor	8	5	1	2	10	9	4	6	3	7

Among four local strains of oysters, the Hiroshima stood at the top which was followed by the Kumamoto, Miyagi and Hokkaido in order.

The result coincides well with a general reputation that the Hiroshima oysters have relatively rich flavor as compared to the Miyagi.

It is interesting to see in the table that the ranks of hybrid strains is connected with the inbred strains crossed. This may suggest the possibility of improving the flavor of oyster by means of hybridization.

4. *Conclusion of the inbreeding of oysters of different localities*

In this part of the paper the results of inbreeding of four local oysters, belonging to *C. gigas* were reported. These four local oysters showed several genotypic characters specific to the strain. Main characteristics distinguished among them may be summarized as shown in Table 15.

From the observations on mortality during culture in several beds which covered all Japan and also Gig Harbor, Washington, it is concluded that the northern oysters adapt to the colder water region of high latitude better than Hiroshima oyster. The Kumamoto, on the other hand, is a hard oyster and can thrive even in the cold water region.

Table 15. Summary of the comparison of characteristics among oysters of different locality origin.

Characters	Oysters			
	Hokkaido	Miyagi	Hiroshima	Kumamoto
Growth	Very fast	Fast	Slow	Slowest
Size of shell	Largest	Large	Small	Smallest
Relative shell depth	Shallow	Intermediate of the Hokkaido and Hiroshima	Deep	Deep
Index of meat weight	Lowest	Low	Highest	High
Flatness of shell valve	Flat	Slightly wavy	Very wavy	Very wavy
Color of shells	Greyish white	Intermeidate of the Hokkaido and Hiroshima	Blackish purple	Blackish purple and brown
Mortality	Highest in the southern beds	Higher in the southern beds	Higher in the northern beds	Low in all beds
Season of spawning	Early	Later than the Hokkaido	Later than the Miyagi	Earliest (Carry ripe gonad cells during winter season)

From morphological characters we can easily distinguish the northern oysters such as Hokkaido and Miyagi from the southern ones, such as Hiroshima and Kumamoto.

Difference in characteristics within northern or southern oysters is not so distinct as to be statistically significant. But the Hokkaido and Miyagi can be distinguished by shell form and coloration. The Hiroshima and Kumamoto are slightly different dimensionally but rather difficult to distinguish each other. But from the difference in their spawning conditions and their range of adaptability to the environmental conditions, they can be distinguished clearly.

Cross-breeding of local strains of oyster.

I. *Hybridization of Hokkaido, Miyagi and Hiroshima oysters*

1. *Material and method*

In July of 1947, besides G_3 strains which were already referred to, following four F_1 strains were prepared by crossing the G_2 strains of Hokkaido, Miyagi and Hiroshima.

i) F_1 Ho×Hi
ii) F_1 Hi×Ho
iii) F_1 M×Hi
iv) F_1 Hi×M

The seeds were exposed to hardening treatment at Mangoku-ura for a period from Nov. 8 to March 29 and then transplanted to Usu Bay, Onagawa

Bay, Mangoku-ura, Matoya Bay, Gig Harbor, Washington for culture. Methods of culture and measurement were the same as already described in the foregeing chapters on strain breeding.

2. *Result of experiment*

A. Rate of fertilization

In all matings over 90 per cent of eggs were fertilized and no significant difference was detected between sibcross-and cross-fertilizations.

B. Mortality

Mortality record during hardening treatment revealed that F_1 strains showed generally low mortalities as compared to inbred strains.

Mortality during culture is shown in Table 16. From Table 16 and 11 following conclusion will be given.

Table 16. Mortality of hybrid strains of Hokkaido, Miyagi, Hiroshima oysters in various beds.

Culture bed	Oysters	Mortality (%)
Usu Bay (May '48-Feb. '49)	F_1 Ho×Hi	8.5
	F_1 M×Hi	6.1
	F_1 Hi×M	23.6
Onagawa Bay (Apr. -Dec. '48)	F_1 Ho×Hi	17.8
	F_1 Hi×Ho	6.6
	F_1 M×Hi	16.3
	F_1 Hi×M	50.7
Mangoku-ura (May-Dec. '48)	F_1 Ho×Hi	10.0
	F_1 Hi×Ho	21.8
	F_1 M×Hi	15.3
	F_1 Hi×M	24.1
Matoya Bay (Apr.-Dec. '48)	F_1 Ho×Hi	51.8
	F_1 Hi×Ho	46.7
	F_1 M×Hi	46.6

In Usu Bay, F_1M×Hi showed a lower mortality than G_3's of Miyagi and Hiroshima while F_1 Hi×M showed the highest mortality.

In Onagawa Bay, F_1 strains and G_3's of Hokkaido and Miyagi showed a low mortality but here again F_1 Hi×M had the highest mortality as in Usu Bay.

In Mangoku-ura, F_1 strains had a mortality from 10 to 24 per cent which were of the order of G_3's strains of Hokkaido and Miyagi but far lower than the Hiroshima.

In Matoya Bay, all of the F_1 strains had a higher mortality as compared to other beds but significantly lower than G_3's strains of Hokkaido and Miyagi.

From these observations it can be concluded that generally speaking, the cross-bred strains showed a higher hardiness as compared to the inbred strains and had a higher range of adaptability to the environmental conditions. It was rather strange that F_1 Hi×M showed a high mortality in hardening treatment and also in culture experiment. This point will be referred to again in the discussion of F_2 breeding.

C. Growth

As is seen from Fig. 8 and 9, growths of F_1 hybrids in all beds except Matoya Bay were intermediate between two strains crossed. Namely F_1 Ho ×Hi grew intermediately between G_3's of Hokkaido and Hiroshima. While in F_1M×Hi and F_1Hi×M the growth was intermediate between G_3's of Miyagi and Hiroshima. In Matoya Bay the growth of F_1M×Hi was close to G_3's of Hokkaido and Miyagi. This may be due to the poor adaptability of G_3's of Hokkaido and Miyagi to the environmental conditions as can be expected from their high mortality already mentioned.

Fig. 8 Growth of Hokkaido, Hiroshima and their hybrid strains of oyster.

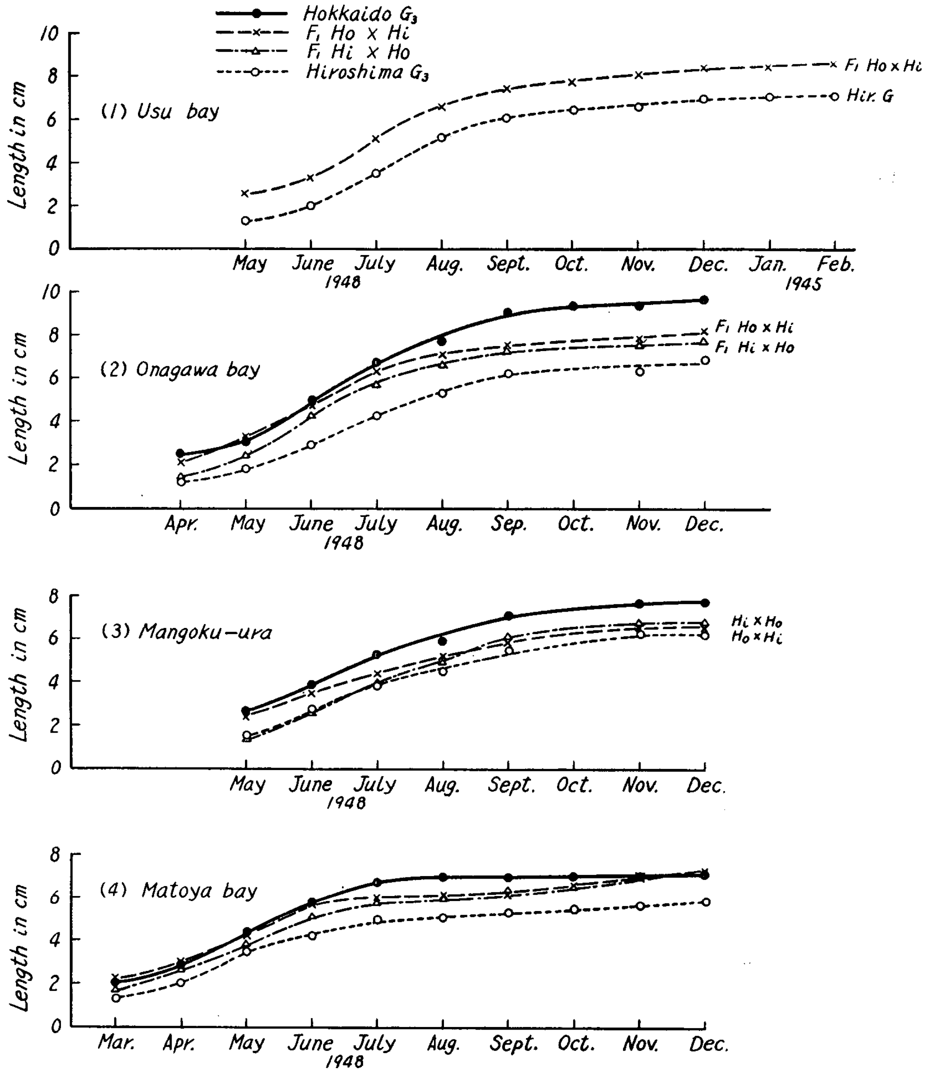
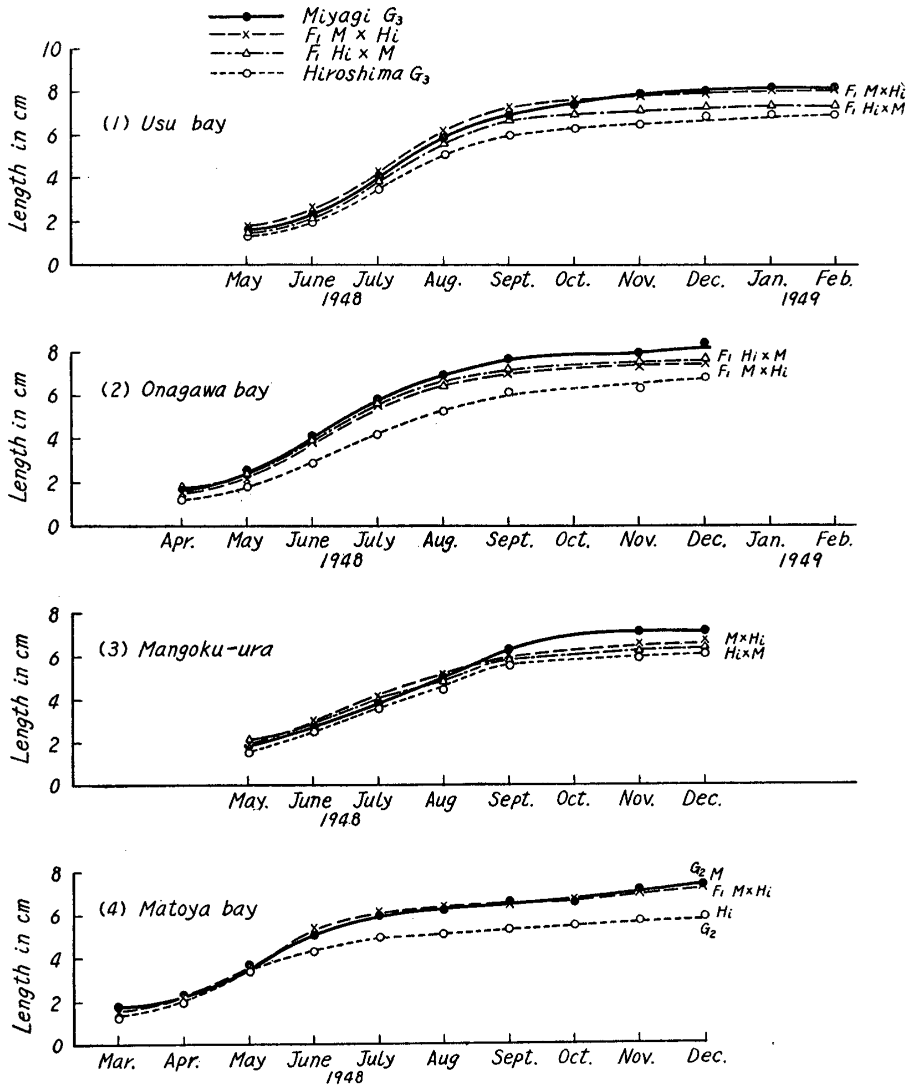


Fig. 9 Growth of Miyagi, Hiroshima and their hybrid strains of oyster.



D. Dimensional character

The result of measurements on hybrid strains are summarized in Table 17. When we compare the result in the table with that of inbreeding in Table 8, we find that in the northern beds with low water temperature such as Usu, Onagawa, Mangoku-ura and Gig Harbor, F_1 oysters showed shell dimensions intermediate between two parental strains. As an example, shell length relation between strains are shown in the histogram of Fig. 10. It was also true with total weight and meat weight. As for the total weight, if we express the ratio of the average weight of each strain to that of the Hiroshima, the Hokkaido was 2.91, the Miyagi 1.97, F_1 Ho$\times$Hi 1.90, F_1 M$\times$Hi 1.16 and F_1 Hi$\times$M 1.77. However, in the southern beds such as Matoya Bay with high water temperature, G_3's of Hokkaido and Miyagi fell behind the

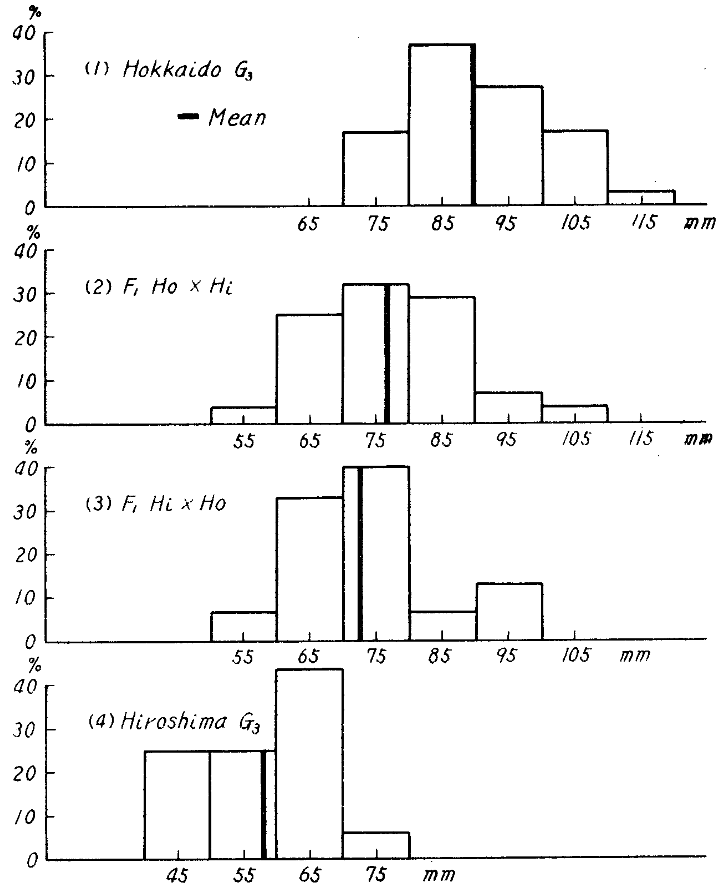
F_1 strain in their growth and fattening.

Table 17. Characteristics of F_1 hybrid strains of Hokkaido, Miyagi and Hiroshima culturded in various beds.

	Strain of oyster	F_1 Ho×Hi	F_1 Hi×Ho	F_1 M×Hi	F_1 Hi×M
(1) Usu Bay (May 10, '48–Feb. 22, '49)	No. of oysters	35		35	32
		m σ		m σ	m σ
	Length (mm)	77.1±12.1		71.6±11.1	73.1± 8.6
	Width (mm)	55.1± 6.6		50.3± 7.2	51.2± 5.0
	Depth (mm)	26.7± 3.4		25.4± 4.3	24.6± 4.6
	Index of shell depth (%)	40.6± 6.5		42.2± 7.5	39.1± 5.5
	Total weight (g)	68.0±14.8		55.3±15.1	53.8± 9.9
	Wet meat wt. (g)	16.7± 3.8		15.1± 4.5	12.7± 2.8
	Index of meat wt. (%)	24.5± 3.0		27.0± 3.8	24.0± 3.8
	Color index	2.6± 1.2		3.8± 0.7	3.7± 0.6
(2) Onagawa Bay (May 5, '48–Jan. 19, '49)	No. of oysters	28	30	9	28
		m σ	m σ	m σ	m σ
	Length (mm)	76.6±11.8	72.9±10.6	58.4± 8.5	72.3±10.2
	Width (mm)	53.6± 7.7	57.3± 5.9	43.8± 4.6	52.9± 7.1
	Depth (mm)	24.6± 4.4	23.1± 4.2	25.1± 3.5	23.8± 3.7
	Index of shell depth (%)	39.3± 7.6	36.0± 6.2	49.1± 4.4	37.5± 5.7
	Total weight (g)	69.2±20.4	61.1±12.1	37.3±10.3	57.0±12.4
	Wet meat wt. (g)	10.4± 3.5	10.3± 2.2	5.9± 1.7	8.9± 2.0
	Index of meat wt. (%)	14.8± 1.8	17.4± 1.8	16.0± 2.0	15.4± 2.0
	Color index	3.3± 1.1	2.9± 0.2	4.1± 1.0	4.1± 0.9
(3) Mangoku-ura (Apr. '48–Dec. 1, '48)	No. of oysters	30	36	34	29
		m σ	m σ	m σ	m σ
	Length (mm)	60.5±11.0	71.1± 8.1	69.9± 9.0	65.4± 9.6
	Width (mm)	42.1± 6.1	43.1± 4.4	44.0± 4.9	44.1± 5.6
	Depth (mm)	21.9± 4.2	23.2± 4.6	24.0± 3.5	24.7± 4.1
	Index of shell depth (%)	42.9± 7.0	41.3± 7.0	42.8± 8.2	45.5± 8.0
	Total weight (g)	31.5±15.2	36.3± 8.3	37.1± 9.2	36.4± 9.4
	Wet meat wt. (g)	4.5± 2.0	5.1± 1.3	4.7± 1.3	4.9± 1.5
	Index of meat wt. (%)	14.6± 2.7	14.1± 2.4	12.7± 2.0	13.6± 2.1
	Color index	2.0± 0.3	2.1± 0.3	2.2± 0.4	2.3± 0.1
(4) Matoya Bay (May, '48–Jan. 18, '49)	No. of oysters	47	42	46	42
		m σ	m σ	m σ	m σ
	Length (mm)	101.4±10.7	104.5±13.6	102.7±12.4	95.6± 9.5
	Width (mm)	64.3± 9.4	64.3± 8.2	61.7± 7.5	61.2± 6.5
	Depth (mm)	29.1± 4.0	29.8± 7.3	29.0± 5.4	28.4± 4.1
	Index of shell depth (%)	35.2± 5.6	35.7± 6.6	35.3± 7.2	36.3± 5.8
	Total weight (g)	103.0±25.8	104.8±24.9	97.6±23.1	81.3±19.0
	Wet meat wt. (g)	24.2± 8.1	24.8± 6.4	24.3± 5.7	20.9± 5.4
	Index of meat wt. (%)	23.7± 2.6	23.7± 3.1	25.2± 3.8	25.9± 4.2
	Color index	2.7± 0.6	2.8± 0.4	3.6± 1.1	3.2± 0.8
(5) Gig Harbor (May 12, '48–Dec. 12, '48)	No. of oysters	6	10	10	4
		m σ	m σ	m σ	m σ
	Length (mm)	89.6±14.4	69.6±14.4	67.7±13.6	73.7± 8.1
	Width (mm)	55.0±10.8	52.6±11.8	48.9± 7.6	52.0± 7.3
	Depth (mm)	21.0± 4.6	17.4± 5.0	19.9± 3.4	17.5± 1.3
	Index of shell depth (%)	29.6± 7.3	29.5± 7.0	34.1± 5.8	27.9± 2.8
	Total weight (g)	57.7±21.6	32.7±10.5	33.6±12.5	39.8± 5.8

In the comparison of the index of meat weight F_1 strains showed an intermediate value between the northern and southern oysters as can be seen from the tables. The same relations held also in the index of shell depth.

Fig. 10 Frequency distribution of shell length in G_3 strains of Hokkaido, Hiroshima and their hybrid strains cultured in Onagawa Bay.



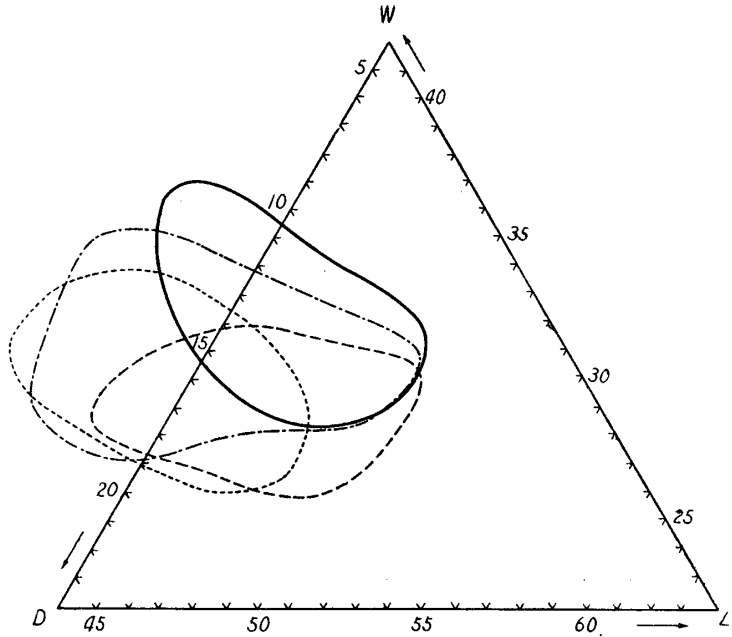
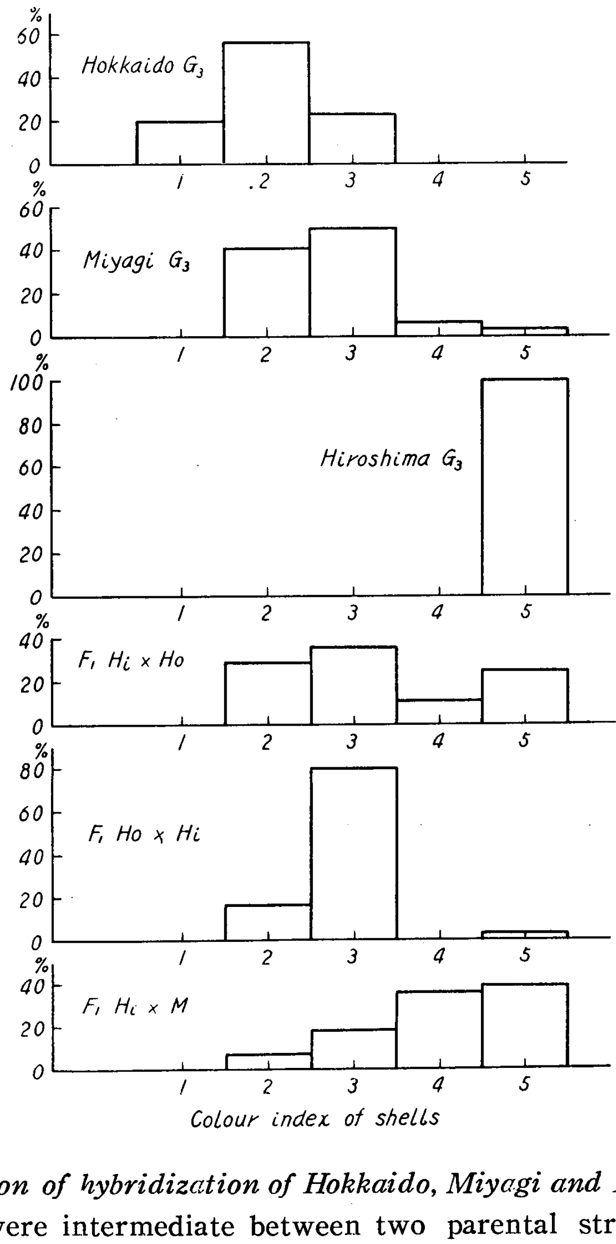


Fig. 11 Diagram showing the relation of the length (L), width (W) and depth (D) of shells of inbred and hybrid strains cultured in Onagawa Bay. G_3 Ho———: G_3 Hi-------: F_1 Ho×Hi— — —: F_1 Hi×Ho— - —.

Relations of shell length, width and depth in inbred and hybrid strains are plotted in the triangular coordinate as is shown in Fig. 11. We can see from the diagram that F_1 oysters occupy an intermediate space between two inbred strains.

Color index of F_1 strains was always intermediate between two inbred strains. Results observed in Onagawa Bay are shown in Fig. 12.

Fig. 12 Frequency distribution of the color index of inbred and hybrid strains cultured in Onagawa Bay.



3. *Conclusion of hybridization of Hokkaido, Miyagi and Hiroshima oysters.*

F_1 strains were intermediate between two parental strains not only in growth and accordingly, in the weight but also in the index of meat weight, coloration of shell and in the relation of shell length, width and depth.

These F_1 strains were hardier and had a wider range of adaptability to the environmental conditions as compared to the inbred strains.

II. *Hybridization of Hokkaido and Kumamoto oyster*

1. *Material and method*

The same individuals of Hokkaido and Kumamoto oysters as used for the inbreeding of 1949 were used for the cross. The characters of parent oysters were already shown in Table 1.

By artificial fertilization, following two hybrid strains were prepared besides two inbred strains already mentioned.

i) F_1 Ho×K

ii) F_1 K×Ho

Oyster spat were kept in the laboratory tank in running sea water for three months before they were exposed to hardening treatment in Mangoku-ura until March 25, 1950. Then they were transplanted to Ohminato Bay, Onagawa Bay, Mangoku-ura, Hamajima, Kagamimachi, and Gig Harbor, Washington. They were cultured for 21 months until December of 1951.

Method of culture and measurements were the same as already described for other culture experiments.

2. *Result of experiment*

A. Rate of fertilization

The percentage of fertilization were between 93 and 94 per cent and no difference was observed among strains.

B. Mortality

Mortality record of seeds during hardening treatment for a period from Nov. 25, 1949 to March 25, 1950 revealed that F_1 Ho×K and F_1K×Ho showed a mortality of 12.2 per cent and 22.3 per cent respectively which were lower than the Hokkaido (50.8 per cent) and the Kumamoto (25 per cent).

Table 18. Mortality of hydrid strains of Hokkaido and Kumamoto in various beds.

Culture bed	Oysters	Mortality (%) on	
		Dec. 1950	Dec. 1951
Ohminato Bay	F_1 Ho × K	15.5	19.1
	F_1 K × Ho	22.6	24.5
Onagawa Bay	F_1 Ho × K	30.5	42.0
	F_1 K × Ho	25.0	26.0
Mangoku-ura	F_1 Ho × K	20.4	
	F_1 K × Ho	20.4	31.8
Hamajima	F_1 Ho × K	65.7	95.4
	F_1 K × Ho	52.2	94.3
Kagami-machi	F_1 Ho × K	68.2	95.3
	F_1 K × Ho	64.9	98.0
Gig Harbor	F_1 Ho × K	14.8	85.2
	F_1 K × Ho	17.2	38.0

Mortality during culture is shown in Table 18. From the table and Table 12 following conclusion will be given.

In Ohminato Bay, the mortality was generally low in every one of the strains and no significant difference was observed.

In Onagawa Bay, $F_1K\times$ Ho was the lowest with 26 per cent. $F_1Ho\times K$ was a little higher with 42 per cent which was close to the Kumamoto.

In Mangoku-ura the mortality was generally high as compared to Onagawa Bay but the relations between the strains remained the same.

In Hamajima Bay, F_1 strains showed a higher mortality as compared to Kumamoto oysters but much lower than the Hokkaido. $F_1K\times Ho$ seemed to have a higher hardiness as compared to the reciprocals as was generally seen in other beds.

Relative mortality of hybrid strains to inbred strains in Kagamimachi was generally the same as in Hamajima.

From these observations, it can be said that F_1 oysters and Kumamoto oysters have a higher hardiness as compared to the Hokkaido. Particularly $F_1K\times Ho$ were very hardy and exceeded Kumamoto oyster in the beds of cold sea water. On the contrary, in the beds of low latitude with warmer water both of F_1 strains were inferior to the Kumamoto. Generally syeaking, the F_1 groups can be said to have a higher range of adaptability to the environmental conditions as compared to the inbred strains.

C. Growth

Growth of oysters in various beds are shown in Fig. 13. F_1 strains always showed an intermediate growth between two strains crossed except in Kagamimachi bed. From a high mortality in Hokkaido strains, the case in Kagamimachi can be considered as due to the fact that the growth of the Hokkaido was disturbed severely.

D. Dimensional character.

Measurement of dimensional characters was made at each bed from Dec. 1951 to Jap. 1952 after 20 to 21 months of hanging culture. The results are summarized in Table 19. From Tables 9 and 19 following conclusion will be given.

Dimensional characteristics of shells in F_1 strains were intermediate between Hokkaido and Kumamoto oysters regardless of the beds. As an example, frequency distribution of shell length in various strains of oysters cultured in Onagawa Bay is shown in Fig. 14. Total volume, total weight and meat weight also showed the similar relations. In order to see the relation of total weight among strains, if we put the average weight of Kumamoto strain as a standard, that of Hokkaido was 4.14, F_1 $Ho\times K$, 2.80, and F_1 $K\times Ho$, 2.27.

Index of shell depth showed a similar relation. Relation of shell length,

Fig. 13 Growths of inbred and hybrid strains of Hokkaido and Kumamoto in various beds.

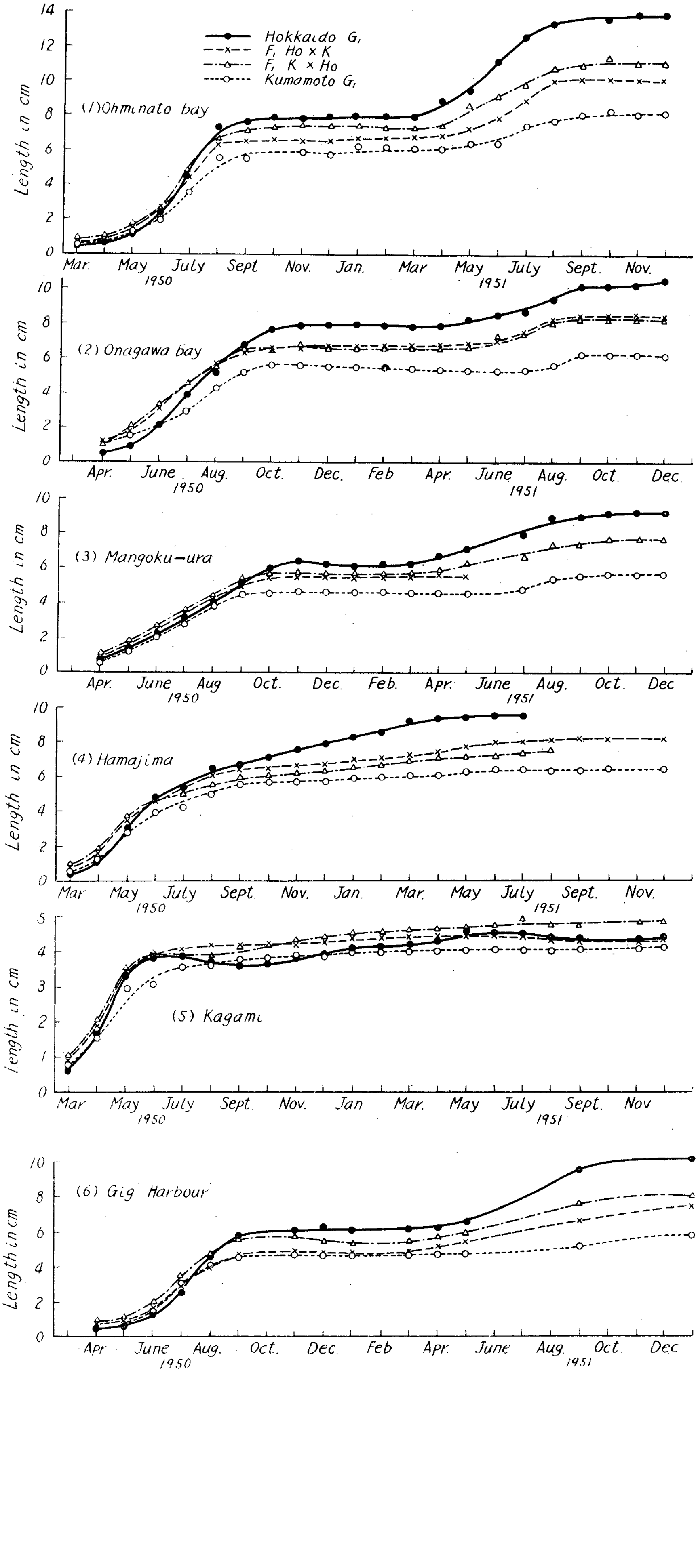
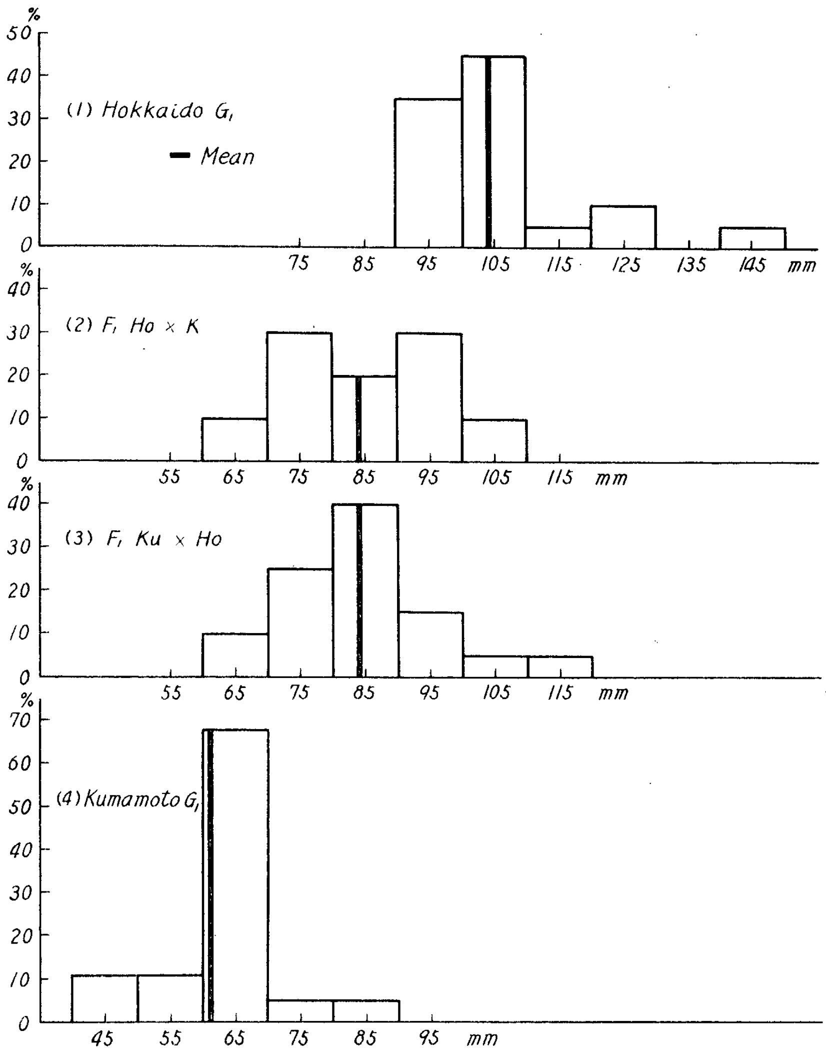


Table 19. Characteristics of F_1 hybrid strains of Hokkaido and Kumamoto cultured in various beds.

	Strain of oyster	F_1 Ho×K	F_1 K×Ho
(1) Ohminato Bay (Mar. 24, '50–Dec. 24, '51)	No. of oysters	30	30
		m σ	m σ
	Length (mm)	96.4 ± 9.6	107.9 ± 9.1
	Width (mm)	60.1 ± 11.1	61.9 ± 7.2
	Depth (mm)	28.8 ± 3.6	27.4 ± 3.2
	Index of shell depth (%)	37.1 ± 5.8	32.4 ± 4.4
	Total weight (g)	1.4 ± 19 7	7.4 ± 19.6
	Wet meat wt. (g)	11.9 ± 3.1	10.9 ± 3.0
	Index of meat wt. (%)	13.0 ± 1.6	11.2 ± 1.7
	Color index	2.8 ± 1.3	3.3 ± 0.9
(2) Onagawa Bay (Apr. '51–Dec. '51)	No. of oysters	20	20
		m σ	m σ
	Length (mm)	84.3 ± 11.0	83.8 ± 10.4
	Width (mm)	63.1 ± 8.4	60.6 ± 6.1
	Depth (mm)	31.8 ± 3.7	30.0 ± 4.6
	Index of shell depth (%)	43.8 ± 6.8	42.0 ± 7.1
	Total weight (g)	118.4 ± 30.3	6.0 ± 21.0
	Wet meat wt. (g)	17.8 ± 5.4	15.2 ± 4.6
	Index of meat wt. (%)	15.0 ± 3.0	15.8 ± 1.7
	Color index	2.8 ± 1.3	2.6 ± 0.9
(3) Mangoku-ura (Mar. '50–Dec. '51)	No. of oysters	—	20
			m σ
	Length (mm)	—	75.8 ± 9.4
	Width (mm)	—	47.8 ± 5.8
	Depth (mm)	—	24.0 ± 3.1
	Index of shell depth (%)	—	39.2 ± 4.6
	Total weight (g)	—	50.8 ± 9.9
	Wet meat wt. (g)	—	9.6 ± 2.0
	Index of meat wt. (%)	—	18.9 ± 1.8
	Color index	—	3.4 ± 0.8
(4) Hamajima Bay (Mar. '50–Dec. '51)	No. of oysters	7	—
		m σ	
	Length (mm)	82.1 ± 11.8	—
	Width (mm)	53.8 ± 6.4	—
	Depth (mm)	30.6 ± 4.0	—
	Index of shell depth (%)	44.9 ± 4.4	—
	Total weight (g)	1.8 ± 25.9	—
	Wet meat wt. (g)	11.4 ± 4.1	—
	Index of meat wt. (%)	12.4 ± 1.3	—
(5) Kagami-machi (Mar. '50–Dec. '51)	No. of oysters	6	3
		m σ	m σ
	Length (mm)	38.8 ± 4.1	42.7 ± 13.9
	Width (mm)	25.8 ± 3.1	32.3 ± 9.7
	Depth (mm)	—	—
	Index of shell depth (%)	—	—
	Total weight (g)	11.3 ± 3.3	15.5 ± 11.9
	Wet meat wt. (g)	1.4 ± 0.6	1.9 ± 1.1
	Index of meat wt. (%)	12.4 ± 2.8	12.3 ± 4.4
(6) Gig Harbor (Apr. '50–Jan. '52)	No. of oysters	3	6
		m σ	m σ
	Length (mm)	71.7 ± 1.0	75.8 ± 9.0
	Width (mm)	52.7 ± 6.4	44.2 ± 5.6
	Total weight (g)	48.1 ± 2.3	37.2 ± 8.2
	Wet meat wt. (g)	8.1 ± 2.4	7.6 ± 2.3
	Index of meat wt. (%)	16.8 ± 6.2	20.4 ± 2.7

Fig. 14 Frequency distribution of shell length of the Hokkaido, Kumamoto and their hybrid strains, cultured in Onagawa Bay.



width and depth among strains are shown in triangular coordinate in Fig. 15 which shows clearly that F_1 strains occupy an intermediate space between two inbred strains. The index of meat weight also showed a similar relation.

Color index was less than 1.6 in Hokkaido oysters and over 4 for Kumamoto while it was nearly 3 for F_1 strains. As an example, percentage distribution of color index of various strains cultured in Onagawa Bay is shown in Fig. 16.

E. Glycogen content

In Table 3 the glycogen contents of hybrid strains cultured in Ohminato Bay, Onagawa Bay and Mangoku-ura are shown with data on inbred strains.

In Ohminato Bay and Onagawa Bay, Hokkaido strains contained 14~16 per cent of glycogen and the Kumamoto 6~9 per cent while F_1 strains con-

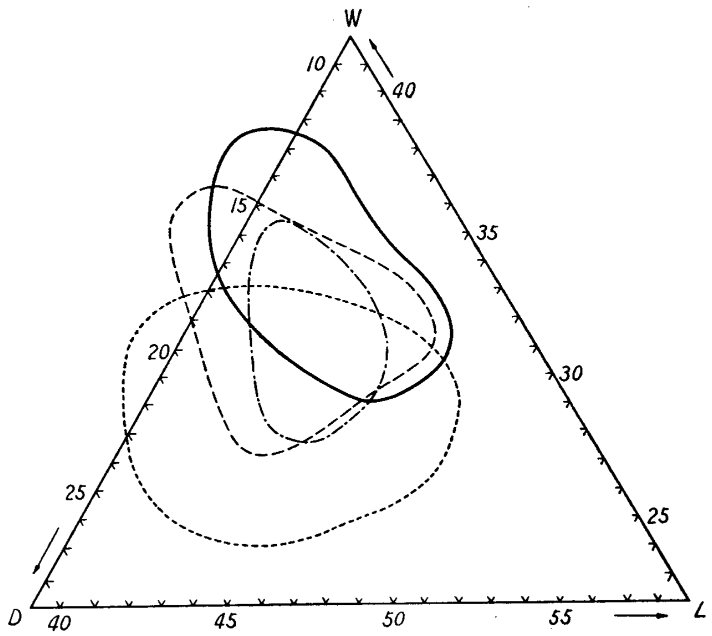


Fig. 15 Diagram showing the relation of length (L), width (W) and depth (D) of inbred and hybrid strains of Hokkaido and Kumamoto cultured in Onagawa Bay.
G_1 Hokkaido———: G_1 Kumamoto-------: F_1 Ho×K— —: F_1K×Ho— - —.

tained 11~13 per cent which was an intermediate amount of that of the two inbred strains. In Mangoku-ura, all oysters showed poor fattening and no marked difference was noticed among strains observed.

3. *Conclusion on the hybridization of Hokkaido and Kumamoto oyster*

From the results described, it can be concluded that, as was the case in the cross of Hokkaido and Hiroshima, the F_1 groups were much harder than inbred strains to the environmental conditions and they showed intermediate characters between inbred strains not only in growth, weight, index of meat weight, color index but also in the shell form. Similar relation was noticed even in their glycogen content.

Breeding of F_2 strain

1. *Material and method*

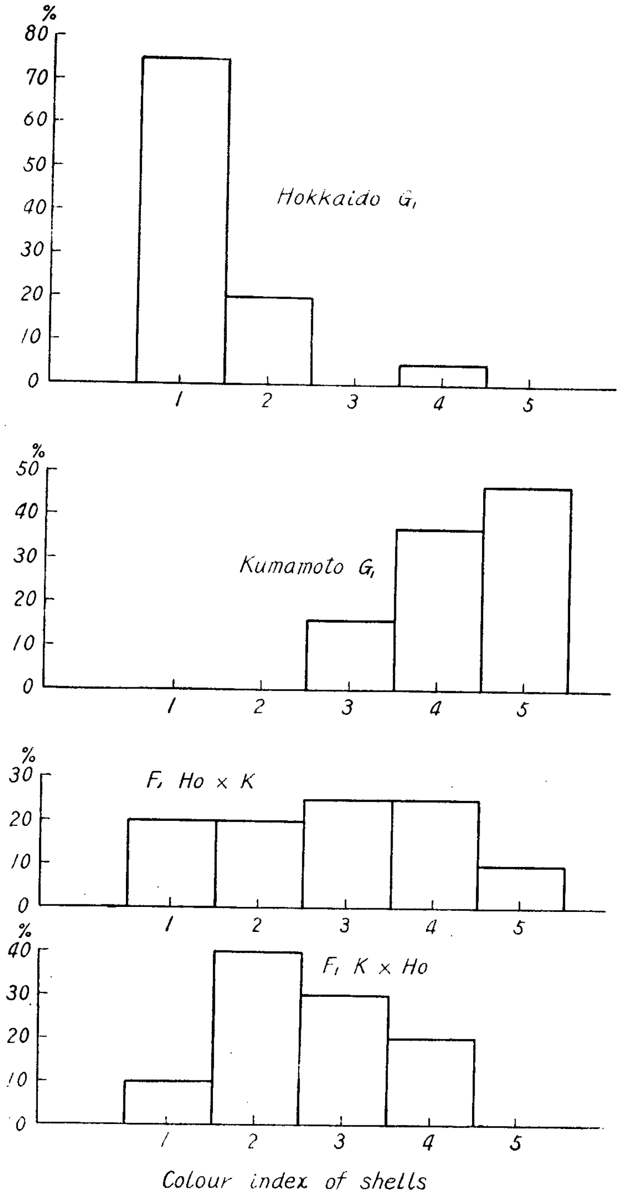
In July, 1950, F_2 strains F_2M×Hi and F_2Hi×M, were prepared by respective brother-sister mating. After exposed to hardening treatment in Mangoku-ura they were transplanted and cultured in Onagawa Bay and Ohminato Bay for 20 months until Jan., 1953.

2. *Results of experiment*

A. Rate of fertilization

The rate of fertilization was 90.7 and 92.0 per cent and no indication of declining fertility was observed in either one of the F_2 strains.

Fig. 16 Frequency distribution of the color index of the Hokkaido, Kumamoto and their hybrid strains cultured in Onagawa Bay.



B. Mortality

Mortality of oysters during culture is shown in Table 20. F_2 Hi×M

Table 20. Mortality of F_2 strains of the cross of Miyagi and Hiroshima.

Culture bed	Oysters	Mortality on		
		Dec. 1951	Nov. 1952	Jan. 1953
Onagawa Bay (June '51-Jan. '53)	F_2 M × Hi	2.7	2.7	2.7
	F_2 Hi × M	10.6	15.9	15.9
Ohminato Bay (May '51-Nov. '52)	F_2 M × Hi	6.6	6.6	—
	F_2 Hi × M	7.8	9.3	—

showed higher mortality as compared to F_2 M×Hi as was observed in their F_1 strains. Such evidences might indicate that the hybrid oyster with Hiroshima oyster as female parent tend to have a lower hardiness as compared to the reciprocal.

C. Dimensional characters

The results of measurements of oysters after 20 months of culture are shown in Table 21.

Table 21. Characteristics of F_2 strains cultured in Ohminato Bay and Onagawa Bay.

	Strain of oyster	F_2 M×Hi	F_2 Hi×M
(1) Onagawa Bay	No. of oysters	20	20
		m σ	m σ
	Length (mm)	104.1 ± 7.0	90.8 ± 13.4
	Width (mm)	65.7 ± 6.4	63.3 ± 8.1
	Depth (mm)	34.1 ± 3.3	33.1 ± 3.9
	Index of shell depth (%)	40.2 ± 3.4	43.7 ± 7.7
	Total weight (g)	140.3 ± 24.3	109.3 ± 27.1
	Wet meat wt. (g)	19.2 ± 3.5	19.0 ± 4.4
	Index of meat wt. (%)	13.7 ± 3.5	17.4 ± 2.9
	Color index	3.5 ± 0.7	3.7 ± 1.1
(2) Ohminato Bay	No. of oysters	20	20
		m σ	m σ
	Length (mm)	117.0 ± 16.1	101.5 ± 12.2
	Width (mm)	60.6 ± 6.9	59.6 ± 7.7
	Depth (mm)	29.6 ± 3.2	33.9 ± 4.1
	Index of shell depth (%)	33.6 ± 4.6	42.3 ± 5.7
	Total weight (g)	117.2 ± 31.7	101.3 ± 28.3
	Wet meat wt. (g)	15.9 ± 4.9	11.0 ± 4.0
	Index of meat wt. (%)	13.6 ± 1.8	10.8 ± 1.6

In both Bays, F_2 M×Hi showed a better growth than F_2 Hi×M. The difference was not so distinct in the first year of growth but became marked in the second year.

As a result, F_2 M×Hi fell behind F_2 Hi×M in their dimensional characters. While the index of shell depth and the index of meat weight were higher in the former approaching the character of Hiroshima strains.

Frequency distributions of several dimensional characteristics of F_2 strains, such as shell length, total weight, index of shell depth and color index revealed no wider range of distribution as compared to the inbred strains and F_1 strains. Coefficient of variation of each characteristic showed it clearly. It means that no segregation occurred so far as the dimensional characters and coloration in the F_2 generations are concerned.

3. *Conclusion of F_2 breeding*

Materials for F_2 breeding was rather meager to draw a difinite conclusion regarding genetic status of oyster, *C. gigas*. But we may emphasize a few points of interest.

First of of all, in F_2 strains no segregation occurred in dimensional and other characters studied. This seems to be interesting phenomenon worthy of further investigation.

And if it holds true in oyster hybridization it will be possible to improve the quality of oysters by means of hybridization of different strains for commercial purpose.

On the other hand, two F_2 strains of reciprocal crosses showed a certain difference indicating a stronger maternal influence over paternal one. This point seems to be worthy to be solved in the future study.

Hybridization of C. gigas with different species of oyster

1. *Cross between C. gigas and C. virginica*

Galtsoff and Smith (17) reported that eggs of either one of these oysters were fertilized readily by sperms of the other species. As we have already reported (18) our experiments revealed that fertilization and cell division proceeded normally and early veliger larvae were obtained. But further development and growths slowed down gradually and all larvae died out before they metamorphosed into umbo-stage. Davis H. C. (19) obtained the same result.

2. *Cross between C. gigas and C. angulata*

The oysters, *C. gigas*, of four localities were crossed with Protuguese oyster, *C. angulata*, transplanted from Holland. They were sent by air mail by courtesy of Dr. Korringa of Fisheries Laboratory, Bergen op Zoom, Holland, in April, 1952 and in December 1953.

In hybridization, the fertilization took place normally with a high percentage (Table 22). Larvae developed and grew normally and many spat

Table 22. Result of the cross between *C. gigas* and *C. angulata.*

Exp. No.	Date of fertilization	Mating: Female	Mating: Male	Rate of fertilization (%)
1	1952, July 10	*C. angulata*	×*C. angulata*	69.5
		C. gigas (Hokkaido)	×*C. gigas* (Hokkaido)	82.5
		C. gigas (Kumamoto)	×*C. gigas* (Kumamoto)	70.8
		C. angulata	×*C. gigas* (Hokkaido)	56.0
		C. gigas (Hokkaido)	×*C. angulata*	33.3
		C. angulata	×*C. gigas* (Kumamoto)	35.0
		C. gigas (Kumamoto)	×*C. angulata*	39.5
2	1952, July 22	*C. angulata*	×*C. angulata*	66.3
		C. gigas (Hiroshima)	×*C. gigas* (Hiroshima)	96.3
		C. angulata	×*C. gigas* (Hiroshima)	76.3
		C. gigas (Hiroshima)	×*C. angulata*	63.6
3	1953, July 16	*C. angulata*	×*C. angulata*	92.4
		C. gigas (Miyagi)	×*C. gigas* (Miyagi)	88.3
		C. angulata	×*C. gigas* (Miyagi)	78.0
		C. gigas (Miyagi)	×*C. angulata*	88.7

were obtained. And they were used for culture.

They grew normally and grown-up oysters showed specific character of each species and their crosses. Figures 10~12 in Plate II show the hybrid oysters obtained. Detail of the results of the hybridization will be reported in separate paper.

3. *Cross betwe.n C. gigas and C. echinata*

Senoo and Hori (11) reported that these two species of oyster only rarely cross-fertilize.

For crossing, we used inbred Hokkaido oyster and *C. echinata* collected at Hayama, Shizuoka Pref. The results are shown in Table 23. Gonads of

Table 23. Result of the cross between *C. gigas* and *C. echinata*.

Mating			Rate of fertilization (%)
Female		Male	
C. echinata	×	*C. echinata*	92
C. echinata	×	*C. gigas*	16
C. gigas	×	*C. echinata*	84
C. gigas	×	*C. gigas*	99

the oysters were found to be fully ripen. Intra-specific fertilization was of high rate but in the inter-specific hybridization, the rate of fertilization was very low in the cross of *C. echinata*×*C. gigas*. In this case, cell cleavage was very slow and some of them collapsed at 2 to 8 cells stage and only few of them reached early veliger stage with abnormal appearance. In the reciprocal cross, *C. gigas*×*C. echinata*, 84 per cent of the eggs were fertilized. Development took place slowly as compared to the inbred larvae and after 20 hrs most of them developed into early veliger stage. But larval shell formation was imcomplete and exhibited abnormal appearance and most of them died out in 5 hours. From the results of experiments, we can conclude that cross fertilization could occur but normal development of the larvae could not be expected in this inter-specific cross.

4. *Cross between C. gigas and C. rivularis*

Miyazaki (20) reported that almost no cross-fertilization occurred in this cross. Our results of experiment agree with his finding.

Inbred oysters of *C. gigas* of Hokkaido, Miyagi and Hiroshima strains were crossed with *C. rivularis* collected in Ariake Bay.

At the time of crossing, *C. gigas* were found to be fully ripe while *C. rivularis* were in slightly premature stage. Rate of fertilization in the cross are shown in Table 24. As is seen from the table, the rate of fertilization in the cross was very low as compared to the intra-specific cross. No normal veliger larvae have developed.

As Miyazaki (20) and Taki (21) referred to, the affinity between these

Table 24. Result of the cross betweem *C. gigas* and *C. rivularis*.

Mating			Rate of fertilization (%)
Female		Male	
C. rivularis	×	*C. rivularis*	72.3
C. gigas (Hokkaido)	×	*C. gigas* (Hokkaido)	98.2
C. gigas (Miyagi)	×	*C. gigas* (Miyagi)	98.5
C. gigas (Hiroshima)	×	*C. gigas* (Hiroshima)	88.9
C. rivularis	×	*C. gigas* (Hokkaido)	1.2
C. gigas (Hokkaido)	×	*C. rivularis*	5.8
C. rivularis	×	*C. gigas* (Miyagi)	1.8
C. gigas (Miyagi)	×	*C. rivularis*	7.2
C. rivularis	×	*C. gigas* (Hiroshima)	0.5
C. gigas (Hiroshima)	×	*C. rivularis*	2.5

two species seems to be very low and no cross can be expected between them naturally.

Summary

This paper reports on the results of breeding of Japanese oyster, *C. gigas*.

1. In inbreeding of native oysters of Hokkaido, Miyagi, Hiroshima and Kumamoto, it was proved that these local oysters differs in dimensional characters such as shell size, form and weight, and in flatness of shell valve, coloration, adaptability to environmental conditions and also in spawning condition.

   In their dimensional characters, there was a regressional change in accord with their geographical distribution. Namely, the size gets smaller, valve become wavy and the color add darkness as we go from north to south. The contrast between northern type oysters such as Hokkaido and Miyagi, and southern types such as Hiroshima and Kumamoto was very striking. Such differences in characters persisted for generations of inbreeding indicating their specificity and hereditary nature.

   Hereditary difference was also observed in their adaptability to environmental conditions. Both Hokkaido and Miyagi oysters showed a high adaptability to cold water region but they were rather weak in warm waters. Hiroshima oyster was weak in all beds cultured but they showed a higher adaptability in warmer waters as compared to northern types of oyster. Kumamoto oyster, on the other hand, was very hardy and showed high adaptability to both cold and warm waters.

2. In cross-breeding of inbred strains of Hokkaido, Miyagi, Hiroshima and Kumamoto oysters, the following results were obtained.

   The characters of hybrid oysters remained intermediate between these

of two strains crossed. It was true not only in dimensional characters but also in valve flatness and coloration.

Hybrid oysters showed a higher adaptability to environmental condition than the inbred strains. In F_2 hybrid oysters, no regregation of characters was observed.

3. In the cross between *C. gigas* and other species of the same genus it was proved that *C. angulata* crossed well with *C. gigas* and hybrid oysters could be obtained. While in the case of *C. virginica, C. echinata* and *C. rivularis*, cross-fertilization might take place but no hybrid oyster could be obtained

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Plate I

Explanation of Figures

Sample of oysters obtained in inbreeding and cross-breeding of Hokkaido, Miyagi and Hiroshima oysters. G_1...denote the generation of inbreeding.

Fig. 1. Hokkaido G_1 oyster
〃 2. Miyagi G_1 oyster
〃 3. Hiroshima G_1 oyster
〃 4. Hokkaido G_2 oyster
〃 5. Miyagi G_2 oyster
〃 6. Hiroshima G_2 oyster
〃 7. Hokkaido G_3 oyster
〃 8. Miyagi G_3 oyster

Fig. 1.

Fig. 2.

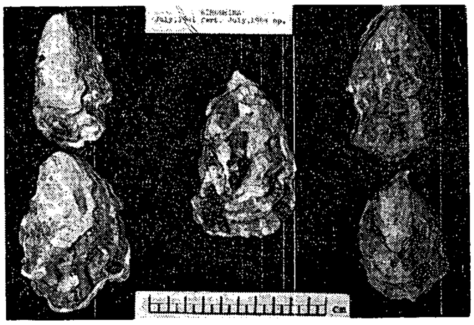

Fig. 3.

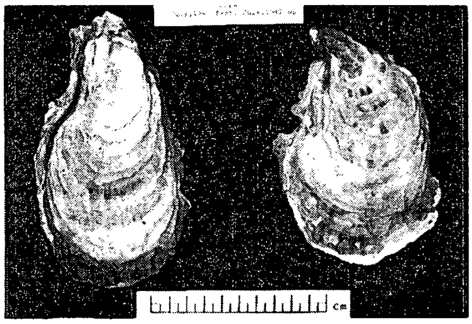

Fig. 4.

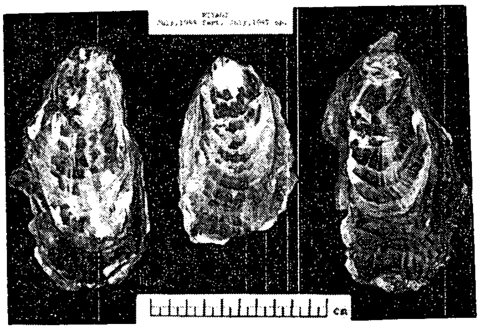

Fig. 5.

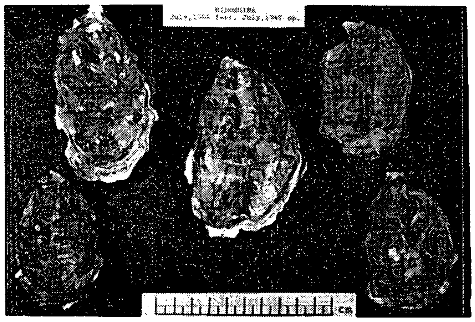

Fig. 6.

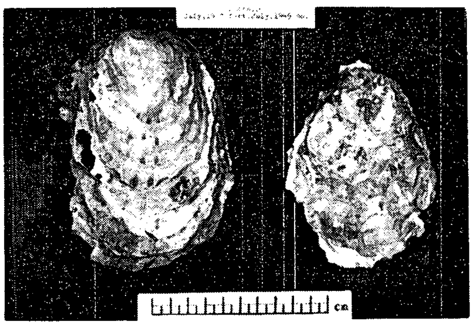

Fig. 7.

Fig. 8.

Fig. 9. Hiroshima G_3 oyster
〃 10. F_1 Ho×Hi oyster
〃 11. F_1 Hi×Ho oyster
〃 12. F_1 M×Hi oyster
〃 13. F_1 Hi×M oyster

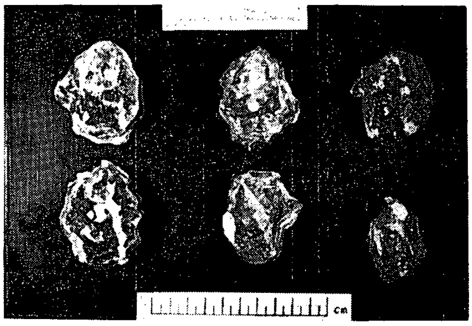

Fig. 9.

Fig. 10.

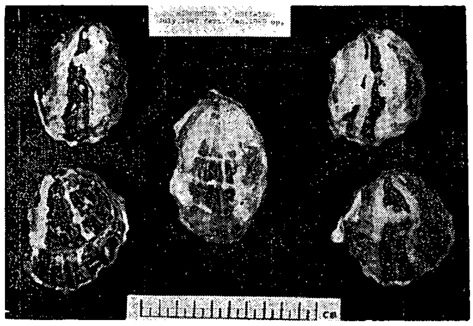

Fig. 11.

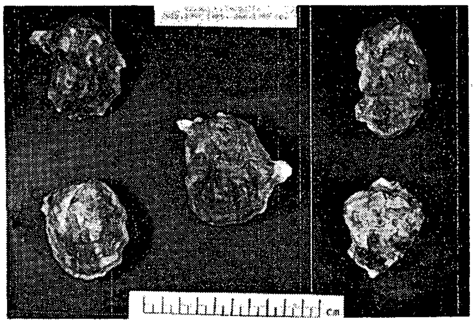

Fig. 12.

Fig. 13.

Plate II

Explanation of Figures

Sample of oysters obtained in inbreeding and cross-breeding of Hokkaido and Kumamoto oysters.

Fig. 1. Hokkaido G_1 oyster
〃 2. Kumamoto G_1 oyster
〃 3. F_1 Ho×K oyster
〃 4. F_1 K×Ho oyster

Hybrid F_2 oysters

〃 5. F_2 M×Hi oyster
〃 6. F_2 Hi×M oyster

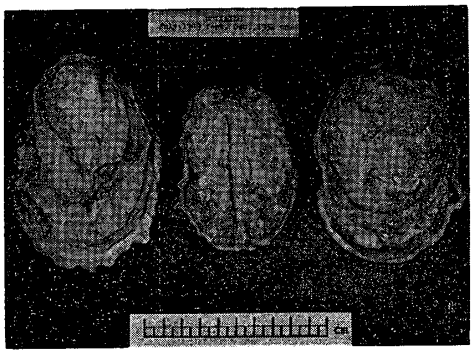

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

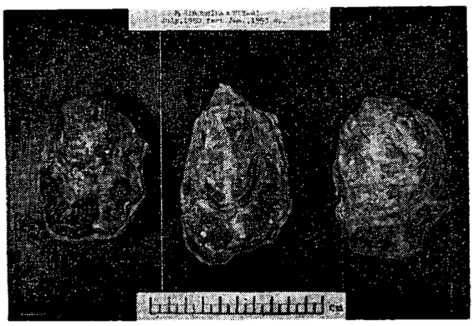

Fig. 6.

Sample of oysters obtained in cross-breeding of *C.gigas* and *C.angulata.*

Fig. 7. *C. gigas* (Hokkaido) G_1
〃 8. *C. angulata* (parent)
〃 9. *C. gigas* (Kumamoto) G_1
〃 10. F_1 *gigas* (Hokkaido) × *angulata*
〃 11. F_1 *angulata* × *gigas* (Hokkaido)
〃 12. F_1 *angulata* × *gigas* (Kumamoto)

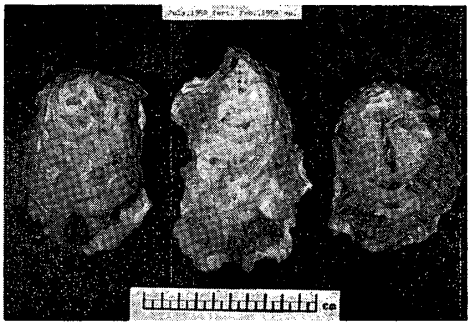

Fig. 7.

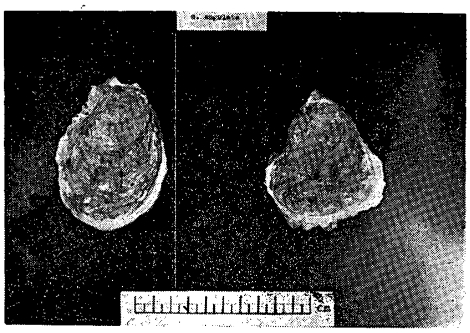

Fig. 8.

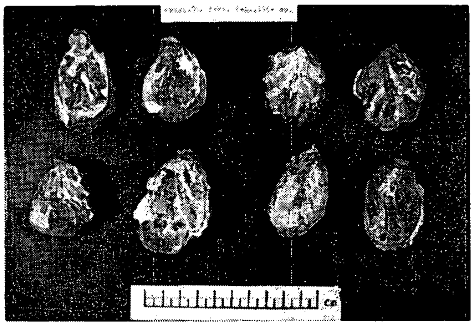

Fig. 9.

Fig. 10.

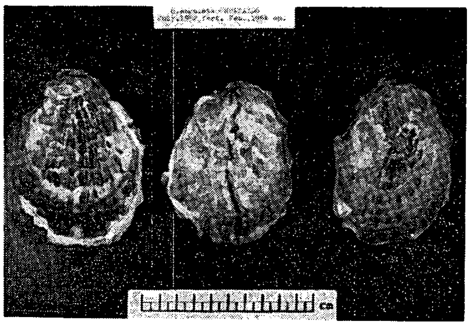

Fig. 11.

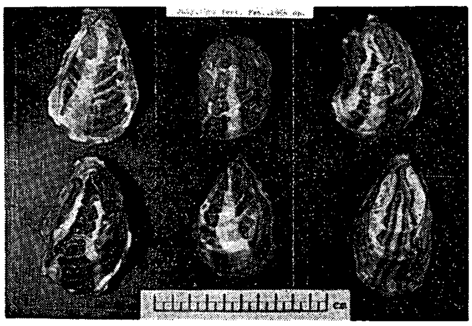

Fig. 12.