OYSTER GROWTH AND ITS ENVIRONMENT AT THE OYSTER FARMS IN HIROSHIMA BAY

by
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Foreword

In recent years, the oyster culture facilities in Hiroshima Bay and vicinity have been increased annually. It is estimated that the number of culture rafts in 1960 reached about 6,000 sets. Oyster farms stretch from the coastal area to the offshore islands. Many individual cultivators have oyster farms in all parts of the area. Thus, the environment for oyster farms is varied and the growth conditions of oysters differ. The problem of acquiring knowledge on these conditions seems to be important for the improvement of the effectiveness of culture and as data for the development of oyster farms. For this reason, during the two-year period, 1959 and 1960, we conducted an investigation on the growth of oysters at oyster farms in Hiroshima Bay and environs. In the following discussion, a resume of our research results is reported. Deep gratitude is expressed to Atsushi Furukawa, technician at the Inland Sea Area Fisheries Experiment Station, who has given valuable advice in our summarization.

Investigation Points and Investigation Method

As shown in Figure 1, 15 investigation points, in 1959, and 13 points, in 1960, were selected so that they would cover the oyster farms in Hiroshima Bay. Of these, there was some discrepancy between investigation points in 1959 and 1960 at Enami (it was at the estuary area in 1959, but moved to the offshore area in 1960), in Edauchi (it was in the central bay area in 1959, while it was moved close to the mouth of the bay in 1960), Saka (the northern side of Kanawa Channel in 1959, and moved to the central part of the channel in 1960).

Investigation of the Degree of Oyster Growth

In 1959, two year old oysters and one year old oysters were used for investigation, and only one year old oysters for 1960. Seed oysters were all collected by scallop shell attachment instruments off Kusatsu, Hiroshima City. Of two year old oysters, only those were stunted* at the tidelands at Kusatsu after seed collections were used. The suspended attachment instruments consisted of 15 sheets

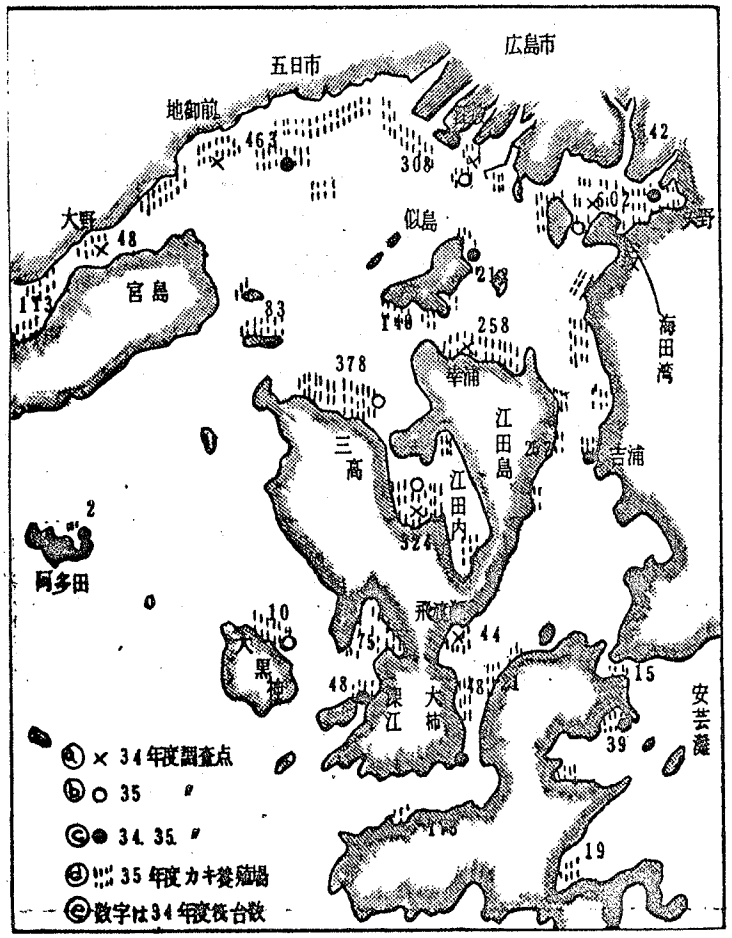


Fig. 1 Investigation Points and Oyster Farms

/Legend/: a) Investigation Point for 1959; b) Investigation point for 1960; c) Investigation point for 1959, 1960; d) Oyster farms 1960; e) Figures ..Number of rafts, 1959;

in a row at 20 cm interval and several rows were suspended from rafts. Later, they were taken up one at a time at random and the weight of the individual meat of the oysters was weighed.**

*Stunting was done by the Experimentation Station at the water level of 2.3 m and at the average shell length of 17 mm.

**Naked body was transferred to a vat and water content was removed before weighing.

Table 1

Date of Investigation of Oyster Growth

ⓐ年度	ⓑ種苗種類	ⓒ垂下年月日	ⓓ第1回調査	ⓔ第2回調査	ⓕ第3回調査	ⓖ第4回調査	ⓗ第5回調査
ⓘ34	ⓚ2年生カキ	34. 6. 26~27	8. 25~26	10. 26~27	12. 21~22	35.1.26~27	
	①1年生カキ	34. 8. 25~26	10. 26~27	12. 21~22	35.1.26~27	3. 22~23	
ⓙ35	1年生カキ	35. 9. 12~13	10. 24~25	11. 21~22	12. 21~22	36.1.24~25	2. 21~22

[Legend]: a) Year; b) Kind of seed oyster; c) Date of suspension; d) 1st investigation; e) 2nd investigation; f) 3rd investigation; g) 4th investigation; h) 5th investigation; i) 1959; j) 1960; k) 2nd year oyster; 1) 1st year oyster.

Investigation of the Environment

Items of investigations were the water temperature at water depths of 1m, 5m, and 10m, amount of chlorine, amount of oxygen existing as solution, the degree of transparency, the amount of sedimentation through the collection of the perpendicular drawn plankton at the water depth of 10 m, the dried weight of small suspension smaller than plankton net XX 13 and floating mud, and the weight reduced by heating. Small suspension was collected from 0.5 liter of water at the water depths of 1m, 5m, and 10m, and it was filtered once by the XX 13 plankton net at the laboratory, which was filtered through No 2 membrane filter before the dried weight was measured. The method of water collection in 1960 was changed to 1 liter from the 1m stratum. The collection of floating mud was made only in 1960; for this

the glass tube of 3.3 cm diameter and 20.0 cm length was suspended at the water depth of 1 m for about 1 month. This was fixed by formalin, and after more than 24 hours, was removed, and with the sedimentation constant at 100°C, its heated decreased amount was measured. The date of observations is as follows:

Table 2

Date of Investigation of the Environment

月 / 年度	8月	9月	10月	11月	12月	1月	2月	3月
34年度	25~26	22~23	26~27	25~26	21~22	25~26	22~23	22~23
35年度		12~13	24~25	21~22	21~22	24~25	21~22	

Furthermore, the investigation of small suspension was conducted from November 1959, and from October 1960.

The investigation of oxygen was not conducted in August, December, and March of 1959, September or February of 1960.

The investigation of floating mud was started in October 1960.

Results of Investigation

Degree of Growth of Oysters

The average meat weight of oysters by investigation point and season is shown in Figure 2. According to this, despite the differences in seeds, years, and seasons, the places for good growth seem to be Itsukaichi, Enami district, Ogaki, and Tobiwatase district. On the other hand, those places with poor growth are Atada-jima, the areas with offshore water in Hiroshima Bay at Fukae, such as Yano, Kaita Bay at Saka, and the second Bay area in Hiroshima Bay at Edauchi. The growth was particularly poor at the Yano district in 1959. In order to make comparisons of the growth degree of the first year oysters of 1959 and 1960 of various places, the growth degree were applied to the first degree equation, $Y = Ax + B$ (Y ... average oyster weight, x ... number of days after suspension). When A was compared, Figure 3 was obtained.

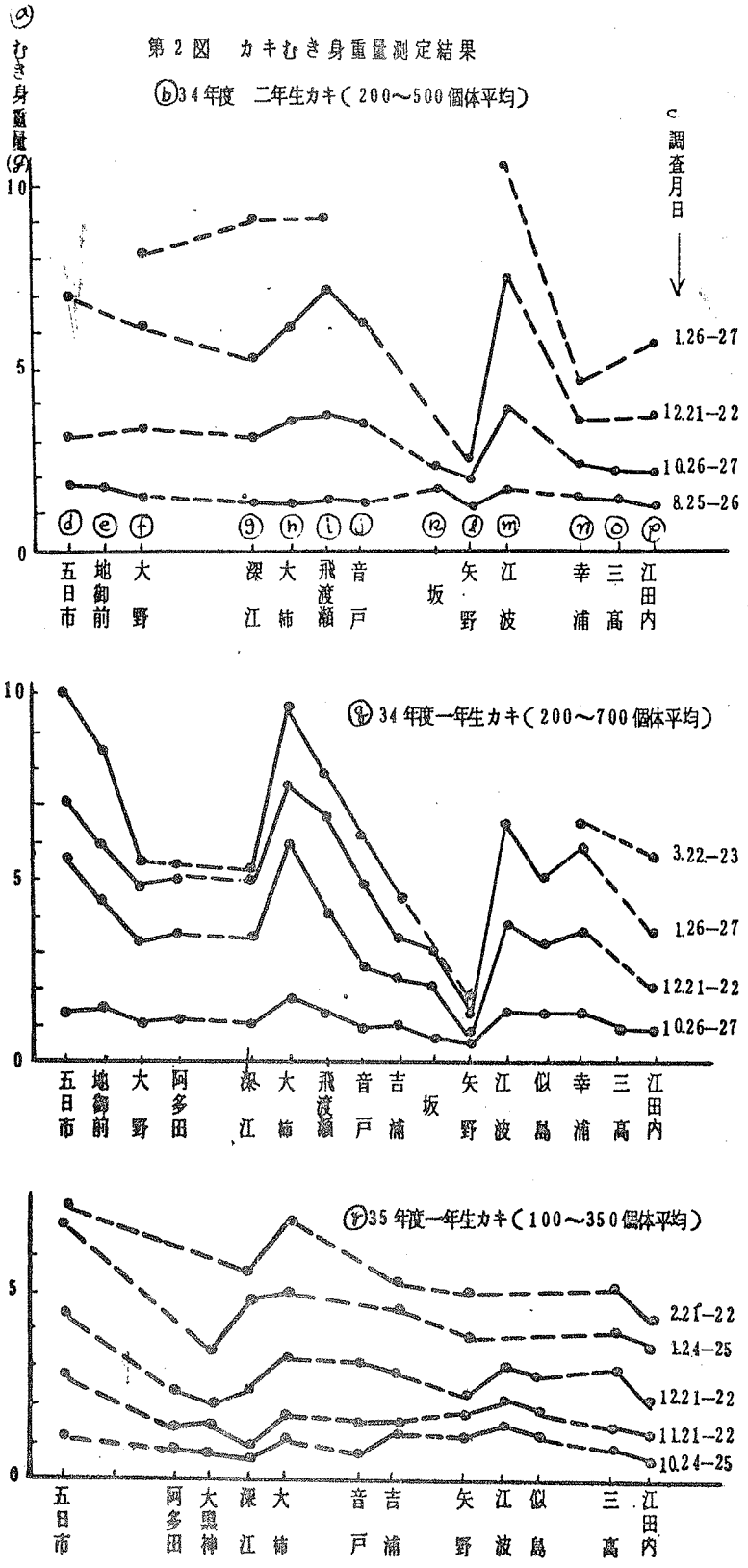


Fig. 2　Measurement of Naked Oyster Weight

/Legend/: a) Naked weight; b) 1959, 2 year old oysters (average of 200-500 pieces); c) Date of investigation; d) Hsukaichi; e) Jigomae; f) Ono; g) Fukae; h) Ogaki; i) Tobiwatase; j) Otodo; k) Saka; l) Yano; m) Enami; n) Sachiura; o) Mitaka; p) Edauchi; q) 1st year oyster (median of 200-700 pieces); r) 1st year oyster 1960 (median of 100-350 pieces).

1st Year Oysters, 1959 1st Year Oysters, 1960

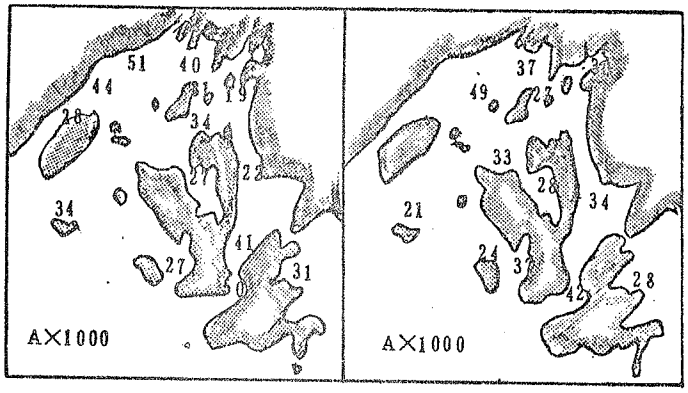


Fig. 3

The comparison of the latter between 1959 and 1960 is shown in Figure 4. In Yano, Yoshiura, and Fukae the growth was better in 1960 than in 1959; and in Atada and Ogaki, the growth was somewhat worse in 1960 than in 1959.

Investigation of the Environment

The level distribution water temperature, the amount of chlorine, the water temperature at the 5 m stratum, and of chlorine are shown in attached Figure 1. The distribution of water temperature according to this reveals that the high water temperature in summer is found in the coastal area along Hiroshima City and Edauchi. But the level inclination of water temperature is small in September, and high water temperature waters are found from October to February in offshore of Hiroshima Bay, and also in Kaita Bay. During this period there are low temperature areas in Itsukaichi, Jigomae district, and Edauchi. When water temperature of 1959 and 1960 is compared, it shows that it is

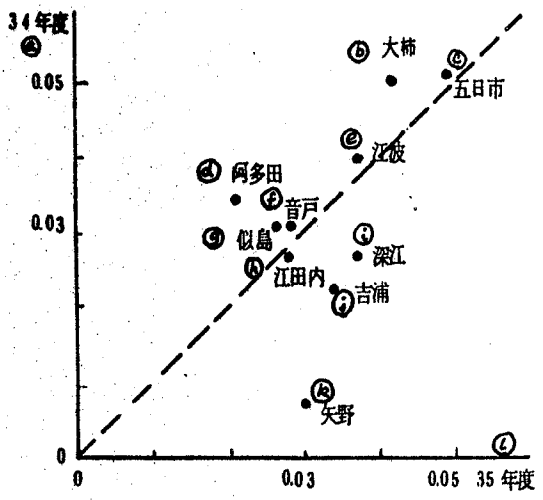


Fig. 4 Comparison of First Year Oyster Growth (A values by Year and District)

/Legend/: a) 1959; b) Ogaki; c) Itsukaichi; d) Atada; e) Enami; f) Otodo; g) Nino-shima; h) Edauchi; i) Fukae; j) Yoshiura; k) Yano; l) 1960.

high in the October-December 1960 period, and low in January and February 1960. Especially the low water temperature of Itsukaichi in January and February is remarkable and this is similar in the 1 m stratum. The cause of this seems to be the low temperature at this time. Throughout both years, a peculiar offshore water block seems to exist in the vicinity of Itsukaichi. The amount of chlorine seems to be reduced by the rivers in the vicinity of Hiroshima in summer. In winter, precipitation is small and throughout the entire area about 18% of water covers this. But in the vicinity of Itsukaichi, even in winter water of comparatively low chlorine exists. When 1959 and 1960 are compared, the amount of chlorine was low since November in 1960. This is similar in the 1 m stratum.

Figure 5 shows the monthly T. cl figure with water depth added of the 6 points, Itsukaichi, Atada, Ogaki, Yano, and Edauchi among the investigation points. According to this, the 1 m stratum in the coastal area in summer is covered with high temperature and high chlorine water, and forms a stratum distinct from the lower stratum. From fall to winter, the amount of chlorine approaches 17.5-18.5 at each point and each stratum, reducing the difference with

that of the lower stratum. As to water temperature, beginning in November the 10 m stratum shows high temperature, and the distribution of water temperature of the upper and lower strata seems to be reversed. At Ogaki, both water temperature and salinity do not form clear stratum, and reversal of water temperature and chlorine is often observed. This is probably so because the investigation point is an inlet facing Hayase Channel and the sea water is stirred by the channel water. Water temperature at Yano is generally high, but it falls on November, starting from the offshore area of Saka, and it rises again. Thus it is noteworthy that it differs from the usual coastal water which ordinarily has lower temperature than the offshore water. The horizontal and vertical distribution of water temperature and salinity show that the sea water in or about November seems to be in a very confused situation.

Oxygen in solution is small for all points in winter, and it is increased to about 6 cc/l in winter, January and February. In the offshore areas almost no difference between the upper and lower strata is observed. At Itsukaichi in 1959, oxygen in solution was great even down to the lower stratum, and the oxygen saturation in summer in the upper stratum was 120%. Contrary to this, in Yano, Enami, and Nino-shima districts, oxygen in solution was small in the lower stratum in summer. Especially at the 5 m and 10 m stratum it was less than 3 cc/l in September 1959, and saturation degree was less than 50%. Even the investigation conducted in June 1960 shows the low value of 1.8 cc/l in the 10 m stratum. Saka is similar to this, and oxygen in solution is low in the lower stratum (see attached Fig.2)

Figure 6 shows the seasonal change of the amount of plankton sedimentation. This seasonal change is similar at all places, but its amount varies greatly. In 1959 and 1960 Itsukaichi and Ogaki districts showed comparatively great amounts of sedimentation, and Yano, Saka and Ninoshima districts showed small amounts.

The amount of small suspension per 1 liter of sea water is shown in Figure 7. Its value is mainly in the 0.5 mg/l-2.5mg/l range, but change seems to be great at each time of investigation. When 1959 and 1960 are compared, it is small at Itsukaichi in 1960, and it is much at Yoshiura and Edauchi in 1960. The yearly comparison of small suspension would become problematical because the collection of sample water in 1960 was changed to the 1m stratum. The investigation of cloudiness by water depths by the water

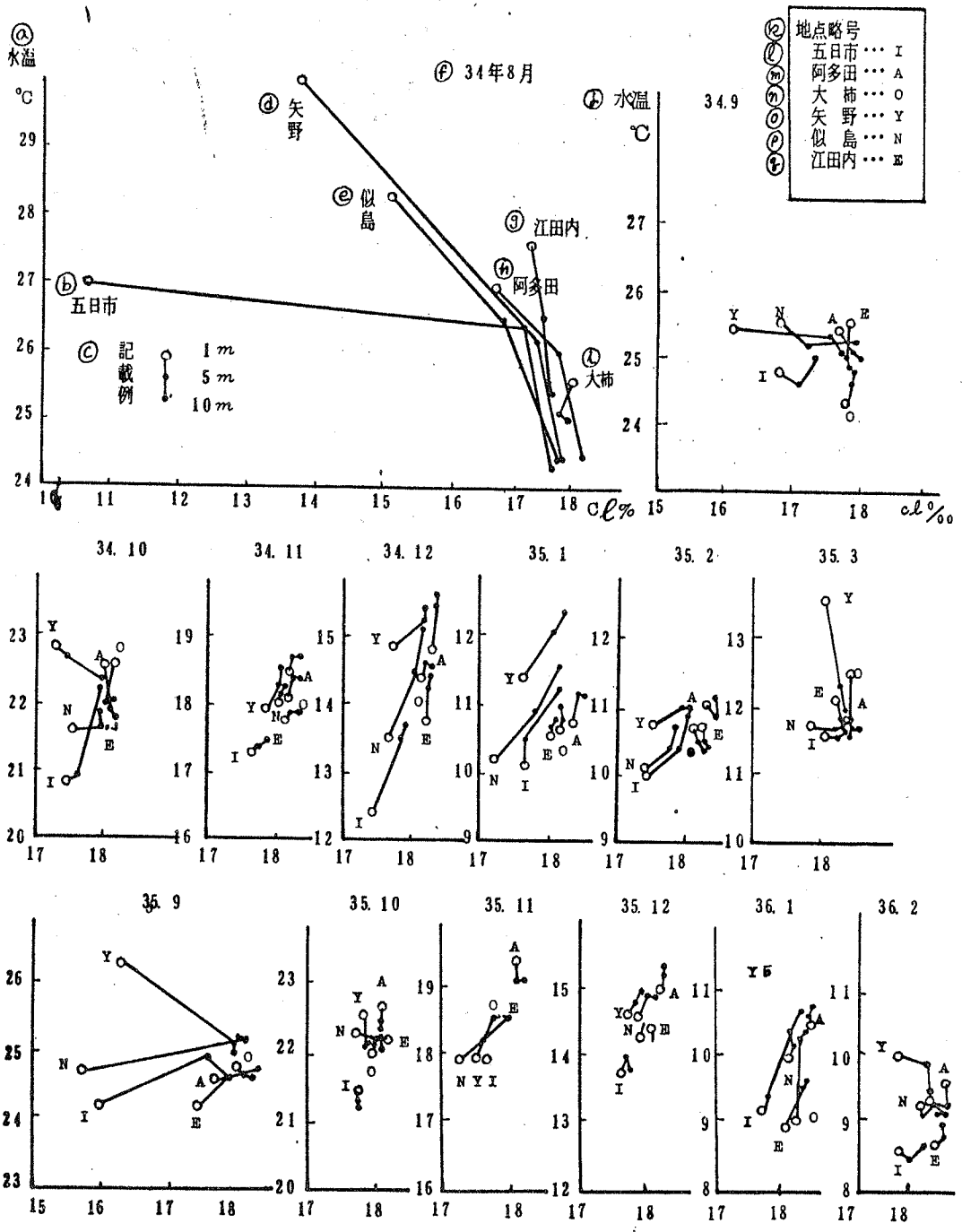


Fig. 5 Monthly T. cl Figure at Major Investigation Points

/Legend/: a) Water temperature; b) Itsukaichi; c) Samples; d) Yano; e) Nino-shima; f) August 1959; g) Edauchi; h) Atada; i) Ogaki; j) Water temperature; k) Geographical points abbreviations; l) Itsukaichi; m) Atada; n) Ogaki; o) Yano; p) Ninoshima; q) Edauchi.

cloudiness meter in January and February 1961 shows that there is sea water of much cloudiness in the lower stratum in the coastal areas of Itsukaichi and Enami. For this reason, sufficient examination must be made in collecting sample water for the investigation of small suspension. (See figure 8).

The amount of floating mud reduced by heat, and the percentage of this over dried weight at various places are shown in Table 3. The weight reduced by heat varies greatly with places and seasons. But it is always very small at Yano compared with other places. The percentage of reduced weight over dried weight is generally 20%, but it seems to be more at Yano and Saka. Also seasonal, it is low in January and February at many places.

Figure 9 shows the seasonal change of transparency. Generally it is low in summer, and it rises 1 degree in October; it falls again in November and December, and it then rises again in January-February. The cause for the low transparency in summer is the increase of the river flow due to the precipitation. And the reason it is low again in November is that it is related to the floating up of mud at the bottom of the sea due to the stirring of the sea water caused by the small horizontal and vertical inclinations of water temperature and salinity. Yano, Edauchi, and Yoshiura, and Ono in 1959, and Edauchi and Otodo in 1960 showed different processes of change than the aforementioned one of seasonal change in transparency.

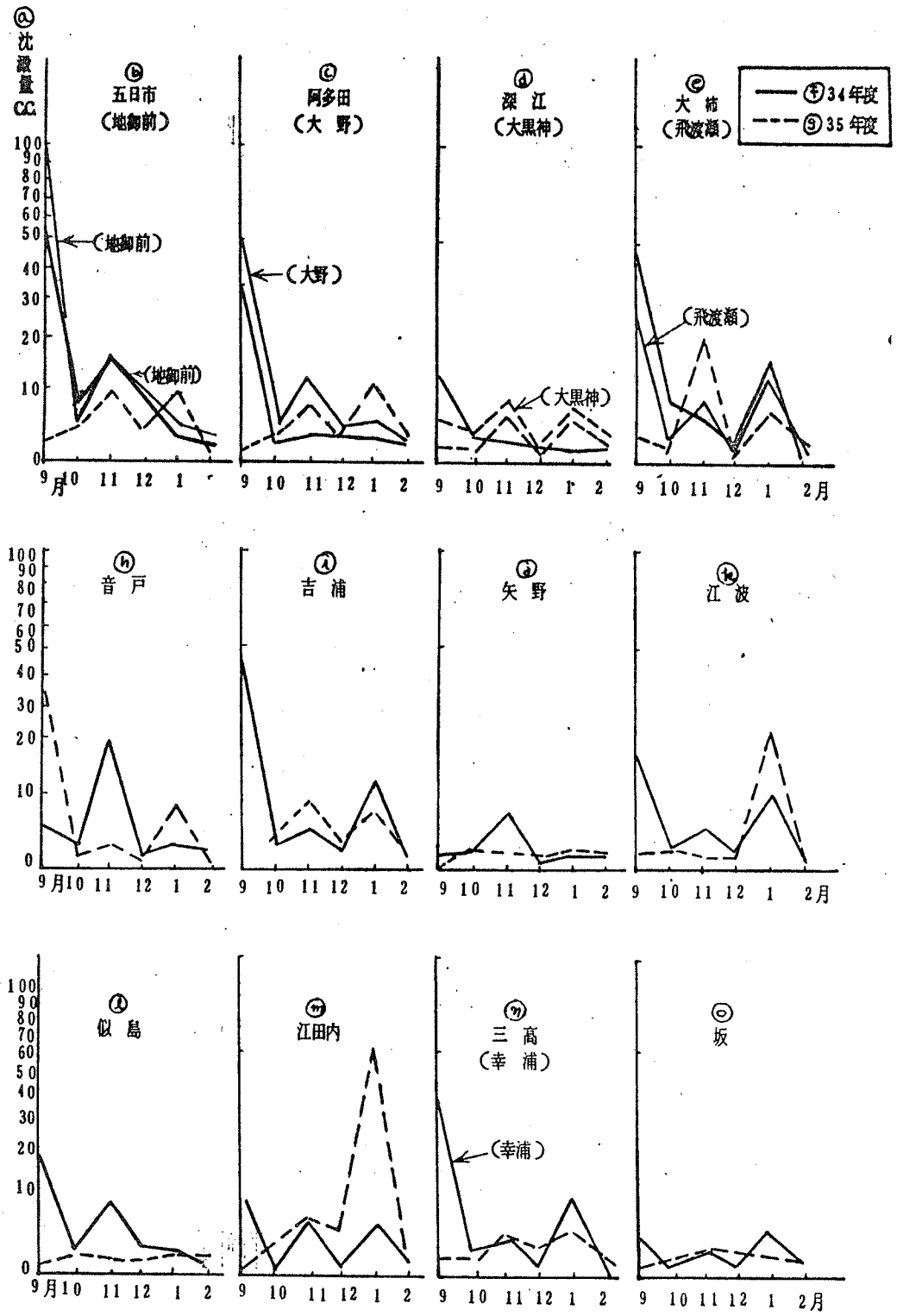


Fig. 6 Seasonal Change of Plankton Sedimentation (10 m perpendicular drawing)

/Legend/: a) Sedimentation; b) Itsukaichi (Jigomae) c) Atada (Ono); d) Fukae (Daikokushin); e) Ogaki (Tobiwatase); f) 1959; g) 1960; h) Otodo; i) Yoshiura; j) Yano; k) Enami; l) Ninoshima; m) Edauchi; n) Mitaka (Sachiura); o) Saka.

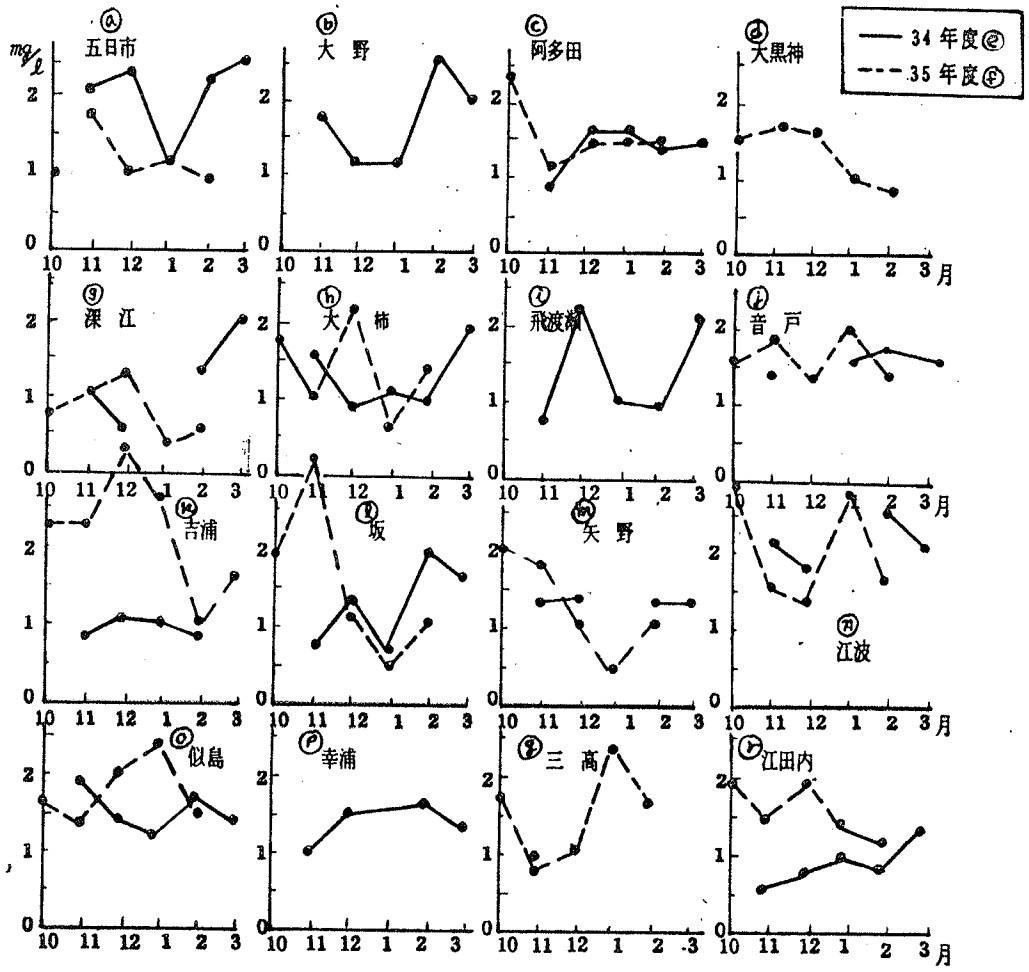


Fig. 7. Seasonal Change of Amount of Suspension

/Legend/: a) Itsukaichi; b) Ono; c) Atada; d) Daikokushin; e) 1959; f) 1960; g) Fukae; h) Ogaki; i) Tobiwatase; j) Otodo; k) Yoshiura; l) Saka; m) Yano; n) Enami; o) Ninoshima; p) Sachiura; q) Mitaka; r) Edauchi.

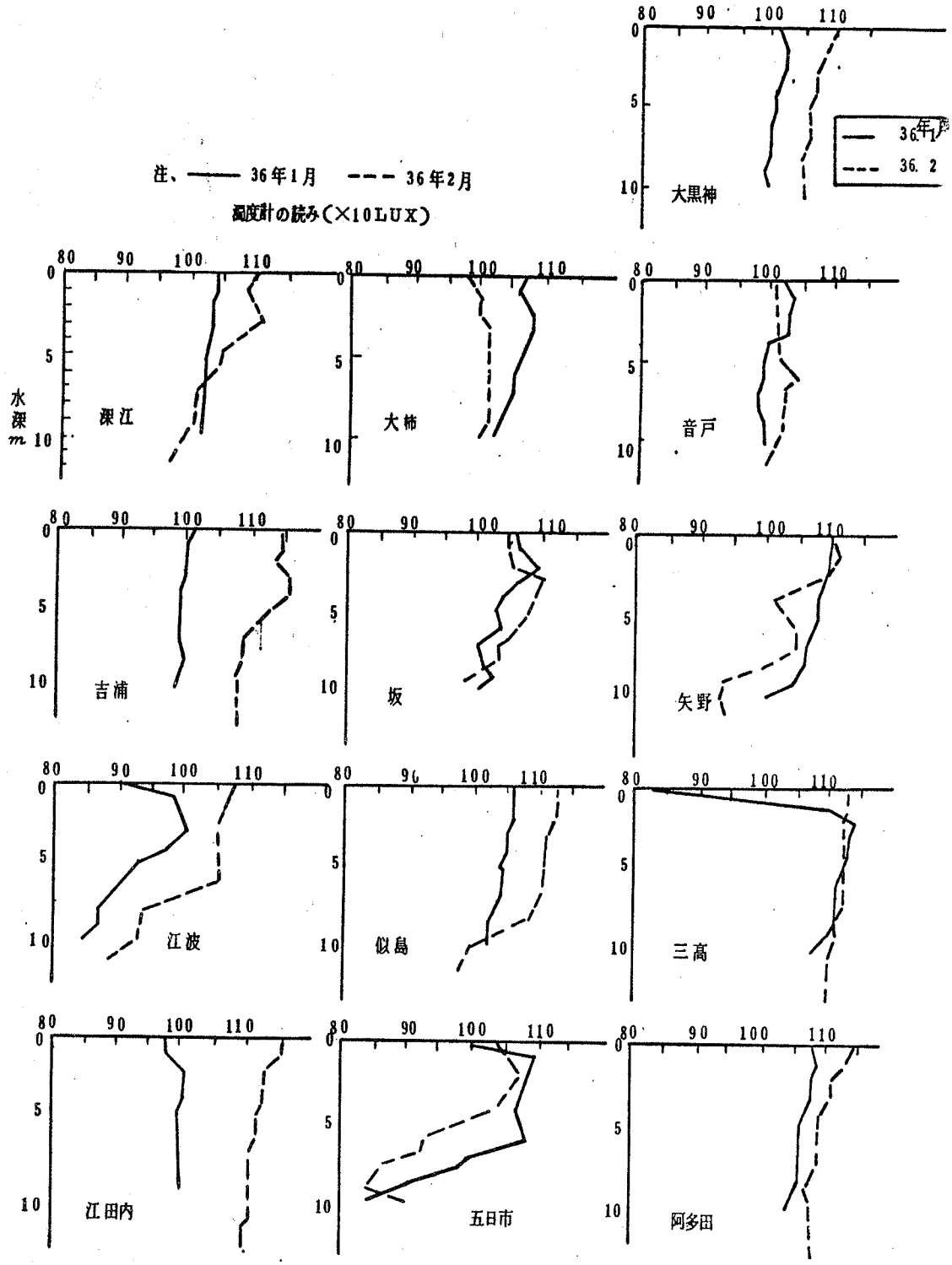


Fig. 8 Change of Cloudiness by Water Depths (By Water Cloudiness Meter, B Type, of Inland Fisheries Laborarory)

/Legend/: a) —— Jan 1961; b) --- Feb 1961; c) Reading cloudiness meter (X10LUX); d) Daikokushin; e) Jan 61; f) Feb 61; g) Water Depth; h) Fukae; i) Ogaki; j) Otodo; k) Sachiura; l) Saka; m) Yano; n) Enami; o) Nino-shima; p) Mitaka; q) Edauchi; r) Itsukaichi; s) Atada.

Table 3

Investigation of Floating Mud

ⓐ調査期間 / ⓑ調査地点	ⓒ灼熱減量 (mg)				ⓓ灼熱減量/乾重量 (%)			
	10月~11月 ⓔ	11月~12月 ⓕ	12月~1月 ⓖ	1月~2月 ⓗ	10月~11月 ⓔ	11月~12月 ⓕ	12月~1月 ⓖ	1月~2月 ⓗ
ⓘ五日市	84	90	25	80	27.5	21.4	18.6	19.2
ⓙ阿多田	92		103	62	19.7		19.2	16.7
ⓚ犬黒神	124	22	141	72	17.2	23.3	20.3	15.4
ⓛ深江	57	76	137	25	22.6	19.3	17.1	14.7
ⓜ大柿	96	79	84	58	19.9	19.4	18.3	20.4
ⓝ音戸	63	157			22.4	23.6		
ⓞ吉浦	127	107	181	86	18.1	21.3	18.4	17.3
ⓟ坂	77	105	159	146	23.5	28.3	19.7	23.5
ⓠ矢野	24	34	69	46	21.5	24.8	24.1	21.5
ⓡ江波	138	96			20.3	20.0		
ⓢ似島	86	81	116		21.7	23.2	21.6	
ⓣ三高	64	93	108	95	20.3	23.4	20.5	18.8
ⓤ江田内	103	82	98	53	19.8	24.3	17.7	19.7

/Legend/: a) Investigation period; b) Investigation points; c) Weight reduced by heating; d) Weight reduced by heating/dried weight; e) Oct-Nov; f) Nov-Dec; g) Dec-Jan; h) Jan-Feb; i) Itsukaichi; j) Atada; k) Daikokushin; l) Fukae; m) Ogaki; n) Otodo; o) Sachiura; p) Saka; q) Yano; r) Enami; s) Ninoshima; t) Mitaka; u) Edauchi.

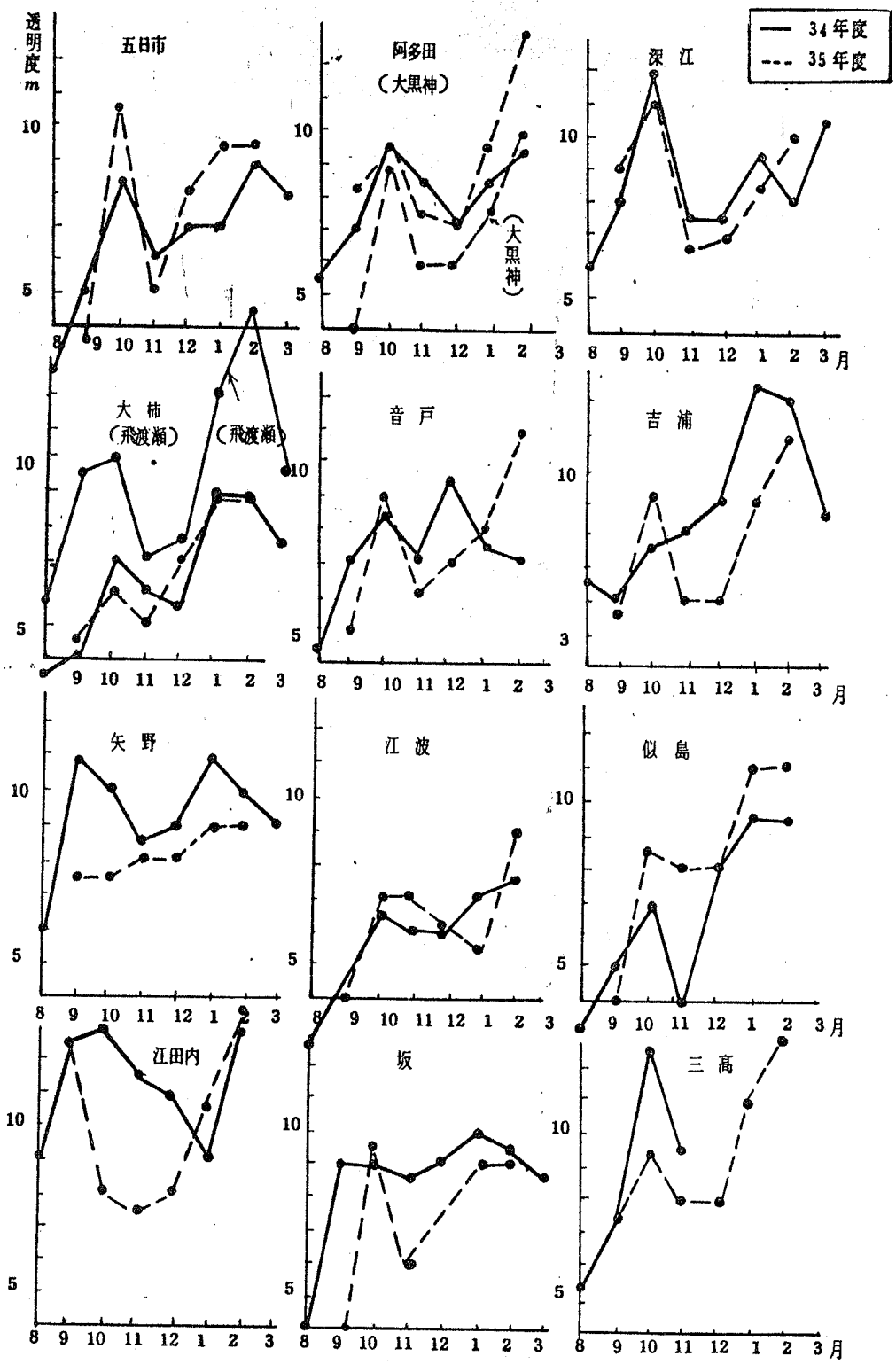
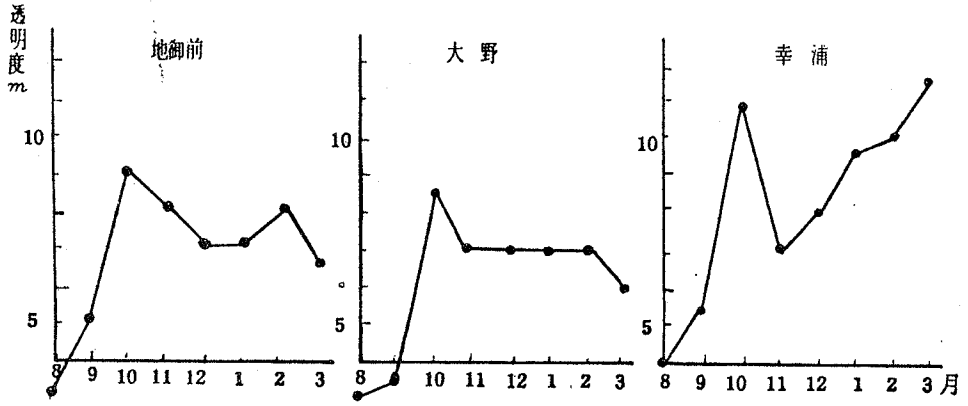


Fig. 9 Seasonal Change of Transparency

Fig. 9 (Continued)



[Legend]: a) Transparency; b) Itsukaichi; c) Atada (Daikokushin); d) Fukae; e) 1959; f) 1960; g) Ogaki (Tobiwatase); h) Otodo; i) Sachiura; j) Yano; k) Enami; l) Ninoshima; m) Edauchi; n) Saka; o) Mitaka; p) Jigomae; q) Ono; r) Sachiura.

Observation

In considering the growth of oysters, along with the fecundity of the water surface due to the natural conditions, the amount of artificial culture facilities, that is, the density effectiveness must be taken into account. In considering the oyster growth in this investigation, this has been temporarily excluded. In this case, as clear from the results of the investigation, some different conditions for the growth of oysters in Hiroshima Bay must be assumed. Recently, small suspension in the sea as the fodder of shell fish has been regarded with importance. Thus, Furukawa, et.al. give importance to small suspension other than net plankton as fodder from the quantitative viewpoint, and have been conducting research on the classification of shell fish farms by the relationship between suspension coefficient and salinity (a - cl) with the size of granules of small suspension taken into consideration, and on the measurement method of small suspension in connection with the former. We have studied the local characteristics of the growth of oysters at oyster farms in Hiroshima Bay, and of the several items on their environment. But as to the small suspension which is comparatively closely related to the

growth, we conducted investigations only of its dried weight and transparency. (On the relationship between transparency and small suspension, Yoshimura made a report concerning lakes, and Yoshikawa reports that a hyperbolic relation exists in the shallow sea. There were differences in this investigation depending on the time of investigation, but this relation could be observed.)

Accordingly, the problem of contents of small suspension, that is, the difference of the amount of organic suspension by oyster farms, must await future investigations for clarification. And also there remains the problem as to the water collection method in the investigation of small suspension by dried weight. The method of investigation which depends on the points in time, which reveals only the present amount and not the production amount, adds to the difficulty of observing in comparison directly with oyster growth. However, in the sense of concluding the investigation and proposing problems for future investigations, the results will be examined.

The contents of suspension are complicated, because some are living things, lifeless things, organic or inorganic matter. And their source of supply and production are from land, the sea itself, or from air. But Furukawa, et. al. classify suspension by origins into those originating from the sea itself, and those from land, including the sea bottom. Furthermore, for detailed classification, they regard even the plankton-originated organic suspension in the sea as sea-bottom-originated, if they sediment once to the sea bottom and float up again. The estimates of the amount of small suspension at each farm, and of the origin of the cloudiness in transparency is also related to some extent to the estimation of the qualitative contents of small suspension.

Throughout this investigation, it is found that generally Jigomae, Itsukaichi, Enami, Nino-shima, Saka, and Yano are the river flowing points of Yawata River, Ota River, and Seno River, and they also belong to offshore waters from the point of the distribution of salinity. But there is considerable difference in small suspension and in transparency at various points; in the waters west of Enami, transparency is low throughout Hiroshima Bay, and it is abundant in small suspension. (In the period before and after the rainy season of June-August, even in Kaita Bay transparency is reduced to 2-3 m due to river waters. But in the present case, we are concerned with the situation

from Fall to Winter as the period of oyster culture). The great difference in small suspension amount and transparency even in the coastal waters seems to be due not to their origin on land, but due to their origin on sea, or the predominance of the latter case. On this point, in view of the fact that small suspension is comparatively abundant even at points that have little impact from land water as determined by the distribution of salinity and the position of rivers relative to all the investigation points in Hiroshima Bay, and furthermore that the investigation period was in the season when rainfall was small in the year, it would be more appropriate to say there are other quantitative causes rather than the supply of small suspension by land water. Although the frequency of investigation is not great, the comparison of the cloudiness of sea water by water depth with the cloudiness meter reveals that at almost all points the cloudiness in the lower stratum tends to be great; especially at Itsukaichi and Enami where the depth of water is shallow, water of great cloudiness exists in the 5 m stratum. From this we can estimate that small suspension which has been object of our investigation, and the origin of cloudiness that affects transparency are at the bottom of the sea. Furthermore, the fact that the vertical and horizontal inclination of salinity in about November and the horizontal inclination of water temperature are small, and that transparency is low seasonally at the time when the reversal of the upper-lower strata of water temperature takes places might support this fact. If, in this way, small suspensions at oyster farms are composed of those originated from the sea bottom, it seems that the easiness with which the sea water at oyster farms can be stirred, suitable water depth and its width, the nature of sea bottom, and the topography of the sea bottom might have great impact on the quantity of small suspensions at oyster farms. The investigation of the water depth of Hiroshima Bay shows that at the vicinity of Itsukaichi, the area of the sea bottom with 10 m depth is considerably broad, (See the tenth time?), and it is an open area; therefore, the stirring of sea water by the tidal current and wind seems to be great. Also at Ono and Ogaki, which are situated at the channel section, the mixing of sea water by the tidal current seems to be always severe, and it is noteworthy that there is hardly any seasonal change in transparency after fall at Ono Seto. It seems that the stirring of sea water is small at the secondary bays such as Kaita Bay at Yano, and Saka, and Hiroshima Bay at Edauchi. Although this is in a different season, the fact that there is water block with extremely low oxygen saturation in the lower

stratum of Kaita Bay in summer seems to express the difficulty of sea water to be stirred. Figure 11 displays the mean transparency of various places in 1959 and 1960.

Next, let us pursue our estimation as to the contents of small suspensions. When we compare oyster growth with the amount of small suspensions and with transparency, it is not always the places where there is a great amount of small suspensions, or where transparency is low that are suitable for oyster growth. Between them, the qualitative composition of small suspensions must be posed as a problem. According to Tsujida, much of the origin of organic suspensions is plankton. The utilization of net plankton by oysters seems to be mainly after their death. When we want to determine the contents of small suspension, a problem arises when this is considered in conjunction with the fact that in much of small suspensions at oyster farms, the amount of net plankton which sediments to the bottom of the sea after death is utilized in the process of refloating by stirring as organic suspension. The sedimentation amount of the mean plankton in this respect is as in Figure 12. Generally speaking, the amount is great in Itsukaichi and Ogaki districts, and small in the Yano, Saka, and Fukae districts. It is noteworthy that the former are areas for good oyster growth, while the latter are not good for oyster growth. When the mean amount of plankton sedimentation and mean transparency are taken together, places good for oyster growth have much sedimentation of plankton and have low transparency.

The foregoing estimation, as we have stated at the beginning, contains much hazard. Especially as to the speed and frequency of the re-circulation which is composed of the sedimentation of small suspensions and their refloating, no information has been gained. Furthermore, oyster growth is subject to the impact of culture facilities. Thus, much in this respect remains for future study. Also. it is said that the reproduction of plankton accompanies the increase of microbes; therefore, in the future, it is desired that the production structure of small suspensions at oyster farms, including the last item, will be pursued.

Summary

1. At the oyster farms in Hiroshima Bay, the degree of oyster growth and the environment of oyster farms, through the weight of oyster meat at oyster farms in 1959 and 1960,

were investigated.

2. As waters suitable for oyster growth, the waters west of Hiroshima City from Enami, through Itsukaichi to Jigomae, and Seto at Hayase of Ogaki are mentioned. And as areas where oyster growth is not good, such secondary bay areas as Kaita Bay at Yano and Saka, Hiroshima Bay at Uda-uchi, and such offshore waters of Hiroshima Bay as Atada, and Fukada are mentioned.

3. From precipitation, distribution of salinity, the positions of rivers, and the vertical distribution of the cloudiness of sea water, it has been estimated that more small suspensions during the culture period are produced by the sea itself (especially by the process of the sedimentation of plant plankton to the bottom of the sea and its refloating), than by the movement from land.

4. The amount of small suspensions seems to be affected by the easiness of the influence from the sea bottom, that is, the mixing of sea water, the depth of sea bottom, and the nature of sea bottom. But small organic suspensions that are important as oyster fodder are influenced by the amount of plant plankton produced. Thus, for the decision of oyster farms the two must be considered in combination. The result of investigation seemed to indicate that places for good oyster growth satisfied these points.

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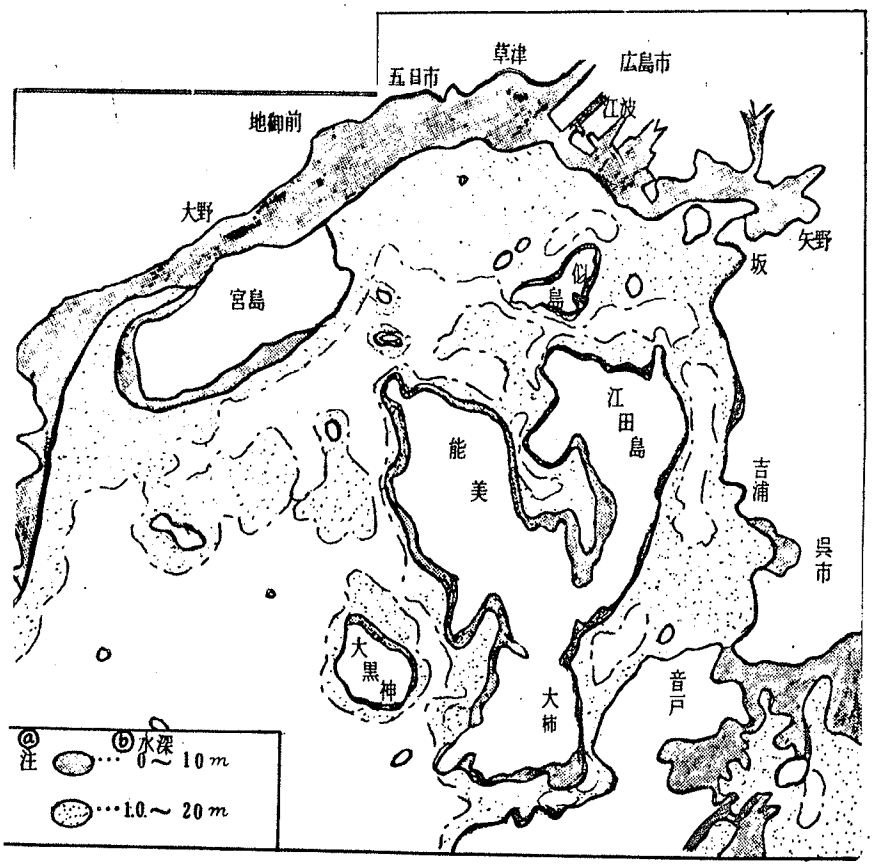


Fig. 10 Distribution of Water Depth of Hiroshima Bay

[Legend]: a) Note; b) Depth of water.

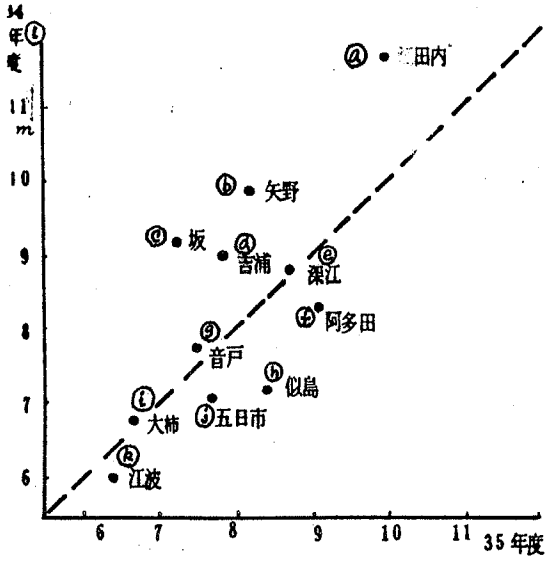


Fig. 11 Mean Transparency (Sept-Feb)

/Legend/: a) Edauchi; b) Yano; c) Saka; d) Yoshiura; e) Fukae; f) Atada; g) Otodo; h) Ninoshima; i) Ogaki; j) Itsukaichi; k) Enami; 1) 1959; m) 1960.

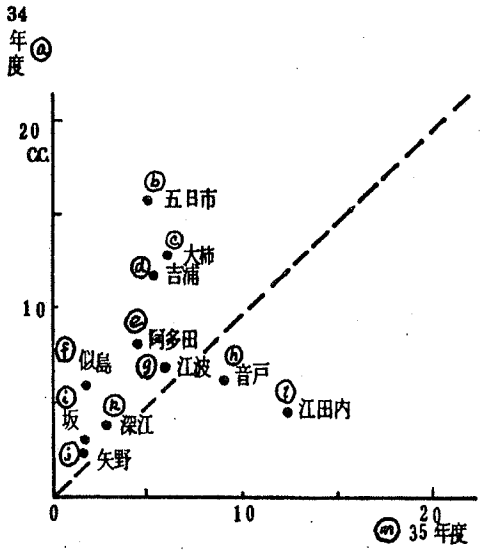
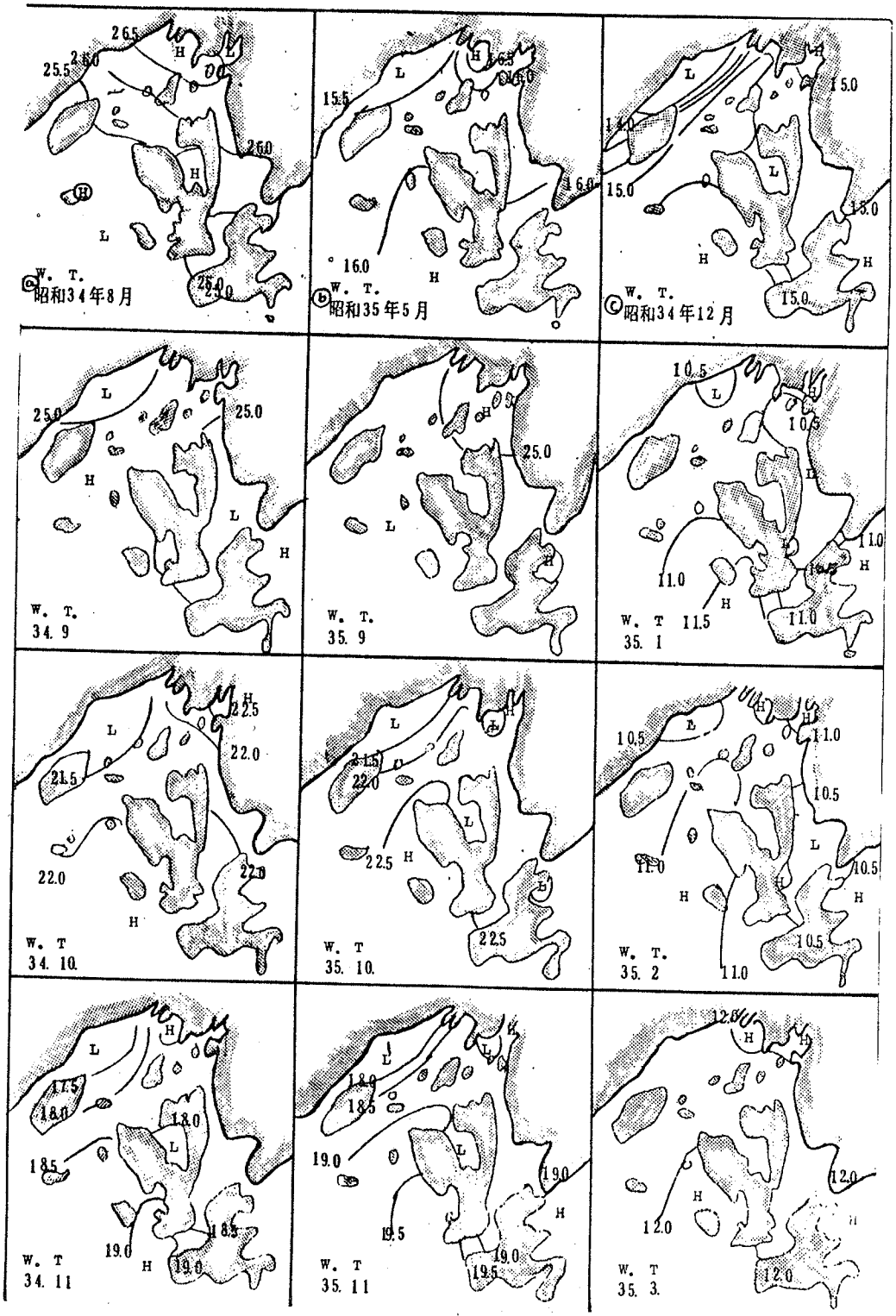


Fig. 12 Mean Plankton Sedimentation (Sept-Feb)

/Legend/: a) 1959; b) Itsukaichi; c) Ogaki; d) Yoshiura; e) Atada; f) Nino-shima; g) Enami; h) Otodo; i) Saka; j) Yano; k) Fukae; 1) Edauchi; m) 1960.

Appendix 1. Distribution of Water Temperature in the 5 m Stratum



Appendix 1 (Continued)