STUDY ON HERRING IN THE NORTH-WESTERN PACIFIC OCEAN
II. DISTRIBUTION AND CATCH OF KORFO-KARAGINSK HERRING IN 1967 AND 1968

Gunzo KAWAMURA*

Introduction

In the Korfo-Karaginsk area, in 1967, there was no catch of feeding herring from June 18 till July 7, though before and after that period there were huge catches. So the length of this "non-catch" period affected the results of fishery. This predicament was presumed to be due to the change of distribution and behaviour of herring. All catchers searched for herring shoals in a wide area by an echo-sounder or a gang of drift net, but herring shoals could not be found or be caught. The work reported here was undertaken to characterize biologically and physically the distribution and the behaviour of Korfo-Karaginsk herring in this non-catch period. To clear the mechanism of fish behaviour, a certain implicated factor should be solved. Realizing this point, the author commenced a study of this subject in coopelation with specialists of correlated fields.

The author had the opportunity to go on board the herring mother ship "Banshu Maru No. 5" during the fishing seasons of 1967 and 1968, and observed the herring fishing and the oceanic fishing ground conditions. But no immediate cause of this non-catch was cleared by the analysis of the temperature, the salinity and transparency of the water where herring was cautht. The change of behaviour was thus presumed: in this non-catch period herrig were either in the coastal water or dispersed in the wide area horizontally and vertically.

Moreover the changes in liver wiehgt, adipose deposit and activity of protease that might indicate the physiological change of this herring were observed.

Material and Method

The author had the opportunity to go on board the herring mother ship "Banshu Maru No. 5" of Taiyo Gyogyo Co. Ltd. during the fishing season from April till August in 1967 and 1968, and was able to observe the herring fishing, the oceaninc fishing ground conditions, liver weight, adipose deposit, stomach contents and activity of protease in the digestive organs, and sampled plankton.

The temperature was observed by a BT in 1967 and by a reversing thermometer in 1968. The water was sampled from various layers by Nansen Bottle in

* *Laboratory of Fisheries Ecology, Faculty of Fisheries, Hokkaido University*
北海道大学水産学部漁場学講座

1968 and salinity was measured in laboratory. The plankton was sampled at each observed point and fixed in 10% formalin, and the food plankton for herring, Euphausia, *Calanus* and zoea were picked up from each sample and their wet weights were measured in laboratory in 1967.

The liver weight of fresh herring was measured in 1967 and 1968. The liver weight decrease according to the time elapsed after the catch, so it was measured quickly when fish was in a condition of rigor mortis. And the adipose deposit of frozen herring samples was measured in 1967. This was measured by H. Kondo of Hokkaido University. In 1968, to estimate the feeding activity, activity of protease of the stomach, pyloric caeca and intestines of frozon herring samples were observed by Dr. T. Saito of Hokkaido University. The stomach contents were observed in 1967 and feeding index was graded into five stages according to the amount of stomach contents and the condition of the stomach.

Results and Discussion

In 1967, the bottom gill net fishing of "Banshu Maru No. 5" fleet was carried out from April 23 to May 30. In the bigining, the net was set at a depth of 100 to 150 m, and the catch contained fish with un-matured ovary. According

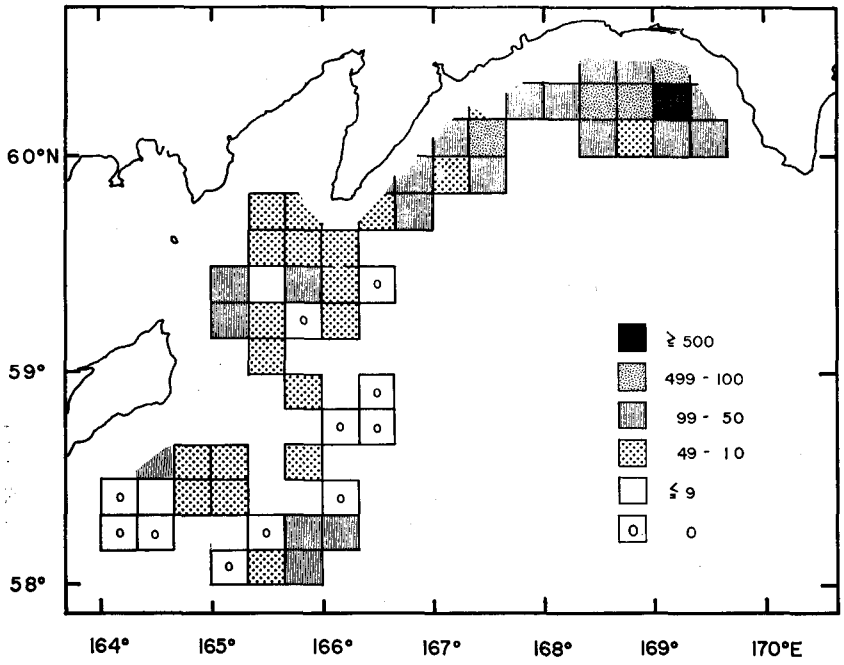

Fig. 1. Total catch of "Banshu Maru No. 5" in 1967 as measured in term of catch per statistical rectangle

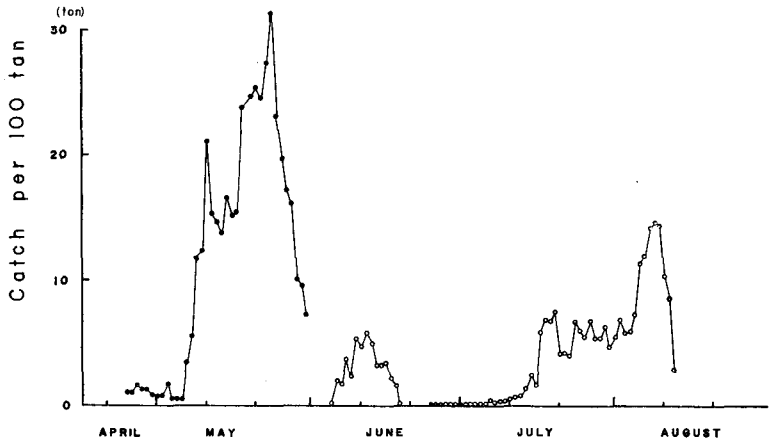

Fig. 2. Daily changes of catch per 100 tan in 1967, averaged in five days
Closed circle: Pre-spawning herring caught by bottom gill net
Open circle: Feedng herring caught by drift net

to comming to maturity, the setting positions were moved northward to shallower inner parts, at a depth of 70 to 80 m, in the Korfa Gulf. After spawning, spent fish fed in the surface layer, so the type of fishing method was changed to the drift net from the bottom gill net as of June. Spent fish retured in direction of the south-westward current. This agrees with J. Harden's note concerning the movement of spent fish.[1] This spent fish offered us some catch every day, but the trial of the shoals were lost on June 18, and there was only a little catch though all drifters and mother ships searched for herring by an echo-sounder or an experimental gang of drift net in a wide area in the Korfo-Karaginsk region until July 7 when huge shoals were found out in the Olyutorskii Gulf. This searched area was fully covered because it was presumed to teem with herring according to literature data.[2][3] After that finding out, the fishing area was resumed in the Olyutorskii Gulf, and again huge catch could be obtained untill the end of fishing operations on August 13 (Fig. 1 and Fig. 2). Though all drifters could find out no herring shoals, it is quite probable that the herring might have been dispersed or distributed widely horizontally and vertically even near the bottom during that period, because a gang of experimental drift net had a little catch in every statistical rectangle in this 1967 period and many large herring were caught on a gang of anchored gill net with a 85 mm mesh size fore pollack that was used for bait for zuwai crab in 1968. Herring might have been in inner coastal waters within the 12-mile line off the coast where Japanese boats could not enter.

The water temperature of the bottom layer varied from 1.0 to -1.3 degrees near the entrance to the Korfa Gulf in May 1967 and 1968, and huge catch of pre-spawning

herring, under the coastal movement for spawning, were caught even in water below the freezing point. So the pre-spawning herring would pass through this cold water to spawning bed in Korfa Gulf, and this cold water might not prevent the movement of mature herring.

The oceanic conditions in the Olyutorskii Gulf were variable. Oceanic water inflows into this gulf from the east and fresh water from the rivers stretches out, and these waters show a complicated feature. In the observed area, the inner water was colder and less saline. The horizontal distribution of temperature and salinity was not so variable below the 50 m layer and above the 25 m layer it was much variable; the inner part of the gulf was cold and less saline (Fig. 3 and Fig.

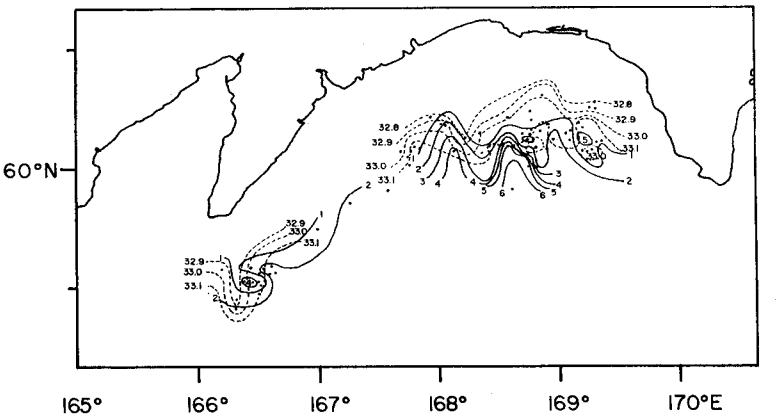

Fig. 3. Horizontal distribution of temperature and salinity at the depth of 25 m from June till August 1968

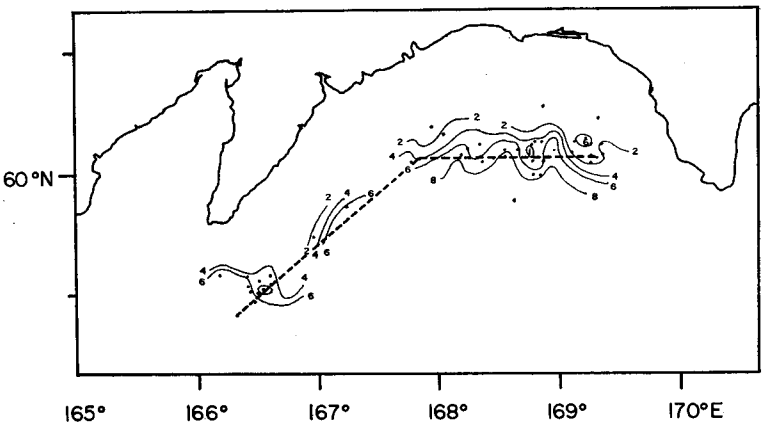

Fig. 4. Horizontal distribution of temperature at the depthe of 15 m in 1968: Broken line shows the line which of the vertical distribution of temperature and salinity

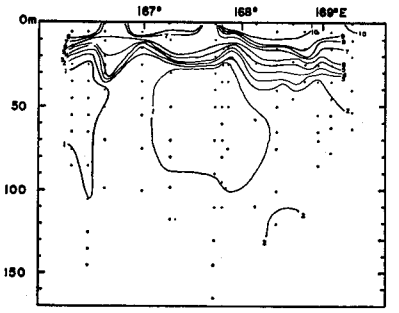

Fig. 5. Vertical distribution of temperature in the fishing ground in the Olyutorskii Gulf from June to August 1968

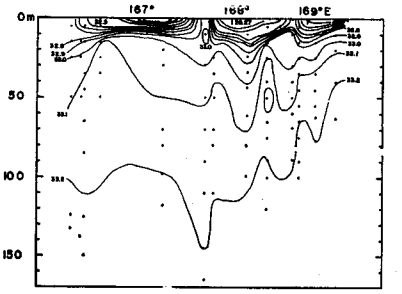

Fig. 6. Vertical distribution of salinity in the fishing ground in the Olyutorskii Gulf from June to August 1968

4). The surface temperature was not so variable in May and June, but in July and August it varied ±2°C according to the weather and sea conditions. In this gulf, both in 1967 and 1968, there were many visible current rips, and two of them were in the 59°35'N. 166°30'E. and 60°10'N. 169°00'E. area, the direction of the former was NE-SW and that of the latter was NW-SE.

Fig. 5 and Fig. 6 show the vertical distribution of temperature and salinity on the line that links the three points at 59°29'N. 166°18'E., 60°05'N. 167° 46'E. and 60°06'N. 169°08'E. along the coast in June, July and August in 1968 (Fig. 4). Between 167°E. and 168°20'E., colder water lay in the 30 m to 100 m depth. There was no extreme variance of temperature below the 30 m layer, but above this layer the temperature gradient was bigger. The pattern of the vertical distribution of salinity was a complicated one. Salinity varies from 33.25‰ to 29.27‰ vertically. The surface distribution of salinity above the 20-m layer was discontinuous at

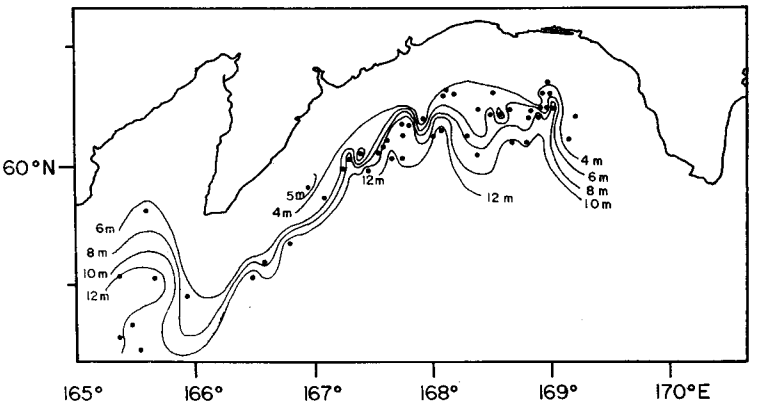

Fig. 7. Distribution of transparency in fishing ground in 1967

166°20'E., 167°55'E. and 168°55'E.. Among these discontinuous points, diluted water of 31.20, 29.27 or 32.10‰ lay, and this feature could show the visilble effect of the spreading of slush water from the coast.

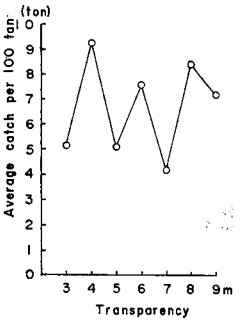

Fig. 8. Relationship between transparency and catch in August 1967

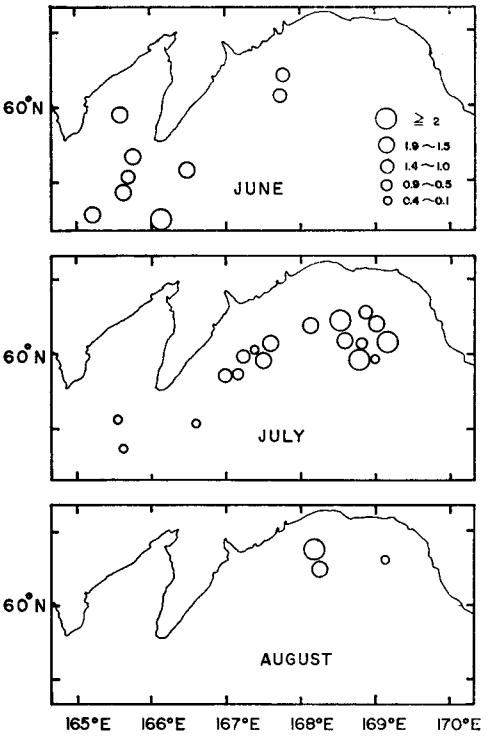

Fig. 9. Monthly distribution of food plankton in 1967

Feeding herrng was caught in these very various waters. The echo patches that were believed to be due to herring shoals were found in the 40m to 100m depth, and herring were caught at the drift net in the surface layer. If the catch of herring had been the same as the echo patch, it would be reasonably assumed that spent fish migrated vertically from 100m depth to the surface, and in this region the temperature varied from 1°C to more than 10°C and the salinity varied from 33.2‰ to less than 29.3‰, so herring might migrate vertically in these gradients of temperature and salinity and could adapt to these environmental changes.

The distribution of transparency in fishing grounds observed in 1967 is shown in Fig. 7. It shows a similar pattern to that of distribution of water temperature and salinity in 1968. In summer, the author quite often found the lower transparent water stretching out from the inner parts of the gulf. And the stretch was stronger in the east.

B. M. Mednikov reported that the most abundant catch was obtained at the transparency of 7 to 8 m, and his figure showed a decline of catch below 5 m. In 1967, in the lower trasparent water below 4 m, there were huge echo trances that were believed to be due to herring shoals and there was a catch of 15 ton per 100 tan. In the non-catch period, there was a little catch in every statistical rectangle, and a

first huge herring shoal was found in a lower transparent water in 1967. This agree with the results of experimental fishing for feeding herring in the Okhotsk Sea in 1957.[6] This might suggest a common type of schooling behaviour of herring. And in the 9m transparency water there was a catch of 23 ton per 100 tan, and diatoms adhered thickly on the net from 10m to 20m layers. And so it is not always thought that diatoms prevent the distribution of herring.[5][6][7]

The transparency at fishing positions was compared with herring catch in August when the catch was comparatively better, and there was no clear correlation between them (Fig. 8).

The distribution of food plankton in 1967 is shown in Fig. 9. The amount of food plankton was lesser in July than in June in the water after the fishing for pre-spawning herring was operated, and in the Olyutorskii Gulf there was no significant difference in quantity from June to August. This could explain the change of distribution from the offshore water of Karaginskii Island to the Olyutorskii Gulf during those months, but could not explain the absence of herring sholas in the non-catch period. Though the food condition was approximately constant in the Olyutorskii Gulf in summer, in the non-catch period there was a little catch everywhere, but before and after that period herring formed huge shoals, which might suggest the behaviour changes independent from food.

The stomach of pre-spawning herring contained a few Euphausia but most of their stomach was empty. And many Euphausia were sampled from the bottom layer in the fishing ground of pre-spawning herring, so these herring could

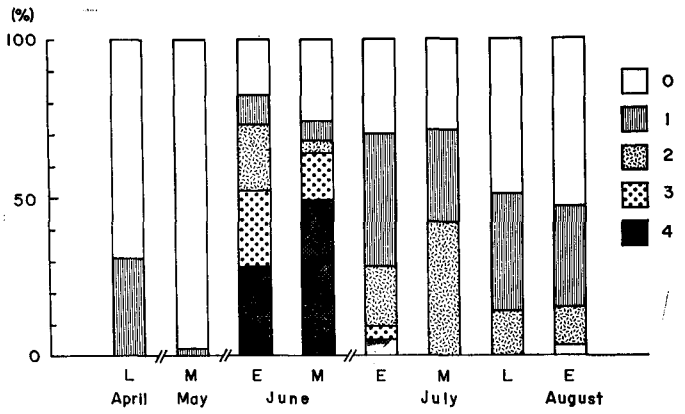

Fig. 10. Change of feeding index
0: An empty stomach
1: A stomach which contained food but without being filled
2: A stomach which was filled with food
3: A grown and softened stomach which was not filled
4: A grown and softened stomach which was filled with food

take food but would not need it. Most of stomach of spent herring contained some herring eggs, some of them contained about 180 eggs. After spawning spent herring feed heavily. The stomach of Korfo-Karaginsk herring contained Euphausia, *Calanus* and zoea in 1967 and 1968. In June the feeding index varied from 0 to 4 and the amount of contents was most abundant in this period. In July the feeding index declined consecutively; percentage of 0 and 1 increased, there was no stomach of 3 and 4 stages in early and late July and there was only a few of them in mid-July. In August a half had empty stomach, 3-stage stomach were few and there was no 4-stage stomach (Fig. 10).

The changes in the activity of protease of digestive herring organs showed a similar tendency to the changes concerning the amount of stomach contents; it was a lower level before spawning and suddenly increased in feeding period (Fig. 11). This might suggest the changes of feeding requirement before and after spawning.

Before spawning liver weight and adipose deposit were at a lower level and

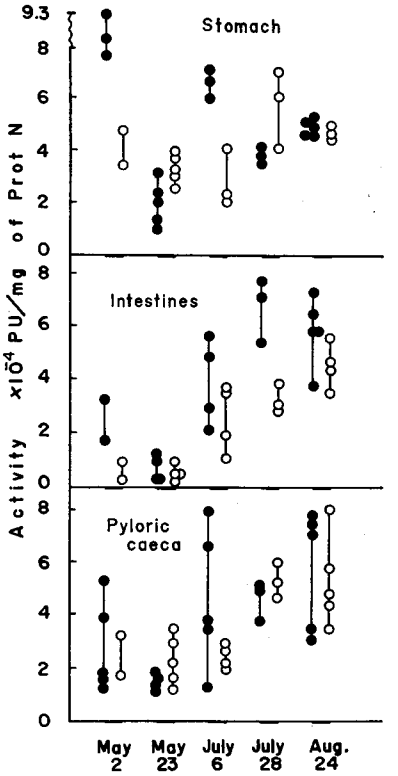

Fig. 11. Changes in the activity of protease of digestive herring organs
Open circle: Male Closed circle: Female

in feeding period these increased suddenly in June, in July they declined and in August increased again (Fig. 12 and Fig. 13). That sudden increase might be due to heavy feeding in June and this might suggest that consumed nutrition might be redeposited rapidly in a short term.

Tne change in liver weight and adipose deposit of feeding herring showed a similar tendency to that of catch per effort for feeding herring; after a rapid rise they fall once and rise again. This agreement might suggest some correlation between them.

These discussion and assumption mentioned above were based on the hypothesis that Korfo-Karaginsk herring consist of one stock, but there is no evidence for this hypothesis, furthermore the author noted the probability of two local stocks in Korfo-Karaginsk herring stock.[8]. So these features of rising or falling in feeding period might be due to two stocks of different levels or phase differences of changes in the nutriment deposit.

These biochemical study concerning the fish behaviour introduced preliminarily here offer us worth something, these must be further studied in cooperlation with specialists of correlated fields.

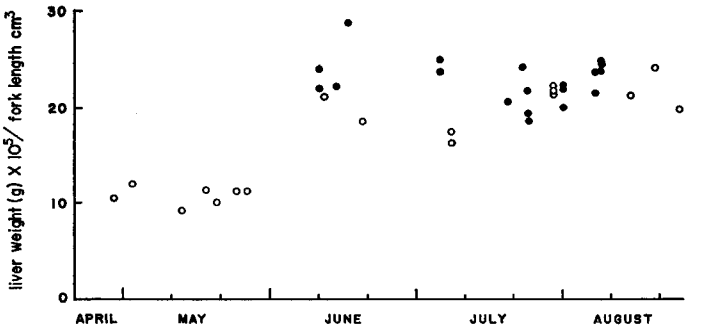

Fig. 12. Changes of the liver weight
Open circle: Measured in 1968 Closed circle: Measured in 1967

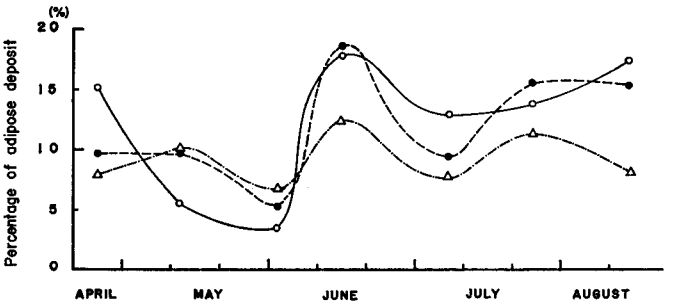

Fig. 13. Changes of the adipose deposit
Open circle: Internal organs Closed circle: Body Triangle: Head

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Summary

In 1967 and 1968 the author boarded a herring mother ship "Banshu Maru No. 5" of Taiyo Gyogyo Co. Ltd. and observed herring fishing, the temperature and salinity of the water, the transparency of the fishing ground, liver weight, adipose deposit, stomach contents and activity of protease, and sampled plankton. And the results are summarized as follows:

(1) The spawning herring passed through the cold water below the freeezing point in the entrance to the Korfa Gulf, and the temperature varied from 1°C to more than 10°C and salinity varied from 33.2‰ to less than 29.3‰ vertically in fishing ground, and herring was distributed or might have been distributed vertically in these gradients.

(2) There was no clear correlation between transparency and catch.

(3) In 1967 there was a non-catch period in the feeding herring fishing period, and in this non-catch period dispersed herring might have been distributed in the wide water vertically and horizontally.

(4) The changes of herring distribution and behaviour could not be explained by environmental conditions.

(5) Liver weight, adipose deposit, feeding index and activity of protease were at a lower level before spawning, and after spawning they reached to a higher level rapidly and maintained that level, this might suggest that the consumed nutrition might redeposit rapidly in a short term.

(6) The changes in liver weight and adipose deposit of feeding herring showed a similar tendency to that of catch per effort for feeding herring.

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