Population Studies on Round Herring—I^{*1} On Round Herring Fished off the Western Coast of San'in District

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One of the good fishing grounds for the round herring is off the western coast of the San'in district. Other main fishing grounds along the coast of San'in district lie around Oki islands and off the coast of Kyushu. A comparison of the relative abundances at two stages, the juvenile and the spawner, was made in order to understand the population dynamics of the round herring that dwells off the western coast of Shimane Pref. The results indicate that the relationship between the Parent and the Progeny well fits to a density dependent reproduction curve. It was, also, found that this species spawns from May to June off Hamada and consists of several subpopulations that are found off the coast of San'in district. The increase in mean fork length over the fishing season, based on measurements, give a growth curve of the round herring. Round herrings off the western coast of San'in district grow up 17 cm in mean fork length at the end of the year of birth.

Round herring, *Etrumeus teres* (DeKay) is still one of the commercially important fishes caught off the western coast of San'in district, although the catch of sardine, *Sardinops melanosticta* is on the increase recently. There are two types of purse seine fisheries to catch pelagic fishes along the western coast of Shimane Prefecture. The larger one is Japanese purse seine (WASEN-KINCHAKU AMI) at Hamada City, and the smaller one is operated by smaller boat less than 10 G.T. at Ohama, Masuda City. About 90% of round herring catch from the western coast of Shimane Pref. is caught by these two purse seines. In this paper, therefore, the round herring fished by these purse seines are discussed.

Materials and Methods

Data used in this paper is commercial catch statistics of round herring by purse seine at Hamada in 1962-1973 and at Ohama in 1969-1973. Daily commercial catch and effort statistics of these have been systematically recorded by the Ohama branch of Masuda Fishermen's Union and the Hamada Fishermen's Union. Samplings were made at Ohama and Hamada fish markets from 1972 to 1974. The specimens were measured on fork length, gonad weight, number of vertebrae including urostyle and so on. In this paper mean fork length are used. Gonad weight index, $(G.W./F.L.^3) \times 10^4$ is used to estimate a spawning season, where G.W. means a gonad weight in gram and F.L. means a fork

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length in cm. Two different developmental stages, juvenile and spawner were treated for the analysis. The catches in weight are used as indices of abundance of both stages, since fishing operations have continuously been done during the whole fishing season unless sea conditions did not permit the operation.

Results and Discussion

Fluctuation in Catches

The annual catch of larger purse seine at Hamada ranged from 404 to 2,694 tons over the period of 1962 to 1973 and that of smaller one at Ohama did from 136 to 357 tons over the period of 1969 to 1973.

Fig. 1. Fishing grounds of two purse seine fisheries.

Figure 1 shows the fishing grounds of these two seines. This figure shows that the larger purse seine operated comparatively more offshore than smaller one. Other main fishing grounds along the western coast of San'in district lie around Oki islands, about 200 km northeast of this fishing ground and the coast of Kyushu, about 200 km southwest. The catch of round herring from other localities than these three fishing ground is very small on the coast of San'in district. Fig. 2 presents CPUE, the daily catch per unit effort, as one of the examples in 1962–1973. It is seen from this figure that the fishing season of larger purse seine at Hamada is from May to November, and CPUE in this larger purse seine declines in August and then increases again. On the other hand, fishing season of smaller purse seine is from August to November. CPUE in smaller purse seine declines also in the fishing season. When the catches of two fisheries decrease, the CPUE for them decrease linearly. The reason of this linear decrease of $\log(\text{CPUE})$ may be ascri-

Fig. 2. Daily round herring fluctuation in log (CPUE) in 1970. $\times$ shows the day there is no operation.

bable chiefly to the effect of the exploitation. The trend shown in Fig. 2 are not particular for 1970 but almost similar every year.

Growth

Figure 3 shows the increase in mean fork length over the fishing season, since the length compositions of round herring seem to normal distributions. The group of 5–17 cm

Fig. 3. The growth in mean fork length of round herring.

in mean fork length is mainly taken by smaller purse seine in Ohama. Part of them came from the catch of the larger purse seine in Hamada. The group of about 20 cm in mean fork length is mainly taken by larger purse seine in Hamada. This figure shows the growth of round herring.

Figure 4 shows the mean number of vertebrae of round herring sampled at Ohama. These 674 specimens correspond to the group of 5–17 cm in mean fork length. The number of vertebrae range from 53 to 55 and the mode is 54. In this Fig. 4 there dose not appear the variation of mean number of vertebrae, except unusual high value (which is shown as a point in a parenthesis in Fig. 4). It can be seen that this group belongs to the same population. Then, the curve in Fig. 3 represents a growth curve in juvenile. We have, $L_t = 37.9 (1 - e^{-0.0039 (t-76.9)})$, the daily growth curve obtained in curve-fitting by least squares method*, where L_t is fork length in cm and t is number of days from 1st, April. YOKOTA and ASAMI¹⁾ gave the growth curve of round herring off the Pacific coast of Japan and the fact that round herring grows up 13.2 cm at the end of 0-year and 17.7 cm at the end of I-year. Round herring off the western coast of San'in district grows up 17 cm in mean fork length at the year of birth. MURAKAMI and SHINDO²⁾ gave the similar trend of the increase in body length of round herring off the coast of Kyushu district. The growth of round herring off the western coast of San'in district does not show the similar growth curve of round herring off the Pacific coast of Japan.

Fig. 4. Seasonal fluctuation of mean vertebrae.

Fig. 5. Seasonal fluctuation of mean G.W. Index.

Spawning season

Round herring fished by smaller purse seine are so-called juvenile less than 17 cm in mean fork length. Measurements of gonad weight are done for larger fish in the catches of larger purse seine at Hamada. Fig. 5 shows mean G.W. Index. The G.W. Index has the peak on May, except for a low value which is in parenthesis in Fig. 5 and then decrease

* FAO Fish. Tech. Paper No. 101 (1971).

gradually. It reaches to near 0 in the middle of July. These specimens were taken from the east part of fishing ground of larger purse seine. According to the spawning survey* of Shimane Pref. from 1951 to 1957, there are two different spawning grounds off the coast of San'in district. One is the sea off Hamada and the other is the sea around Oki islands. Two main fishing grounds (except the coast of Kyushu) lie off the coast of San'in district as a mentioned above. Then, round herring population off the coast of San'in district are divided two groups. Thus the round herring living off the western coast of Shimane Pref. may spawn in May to June in the sea off Hamada. Spawning season of round herring in the Tsushima Strait is from April to June^{3,4)}. It takes about two months to attain 5 cm in total length after hatchout⁴⁾. Fry of round herring have frequently been observed in the beginning of July. The fact that round herring in 7 cm in mean fork length are caught at Ohama in the beginning of August may also corroborate that this species spawn there from May to July. Thus, it is concluded that the round herring off the western coast of Shimane Pref. spawns from May to June off Hamada.

A Relations of Parent to Progeny

The round herring fished by larger purse seine from April to July are spawners. They spawn in May to June off Hamada. The catch record of larger purse seine from April to July is used as an index of yearly level of the spawner biomass, or Parent in this paper. The number of eggs is not used as an index of Parent here, although ITO⁵⁾ gave the linear relation of the number of ova-body weight of round herring and the fact that more than 17.0 cm in standard length may spawn. On the other hand, round herring fished by smaller purse seine and those fished by larger purse seine in August to November are juveniles. The catch records of larger purse seine and smaller one from August to November are used as indices of yearly level of the juvenile biomass, or Progeny in this paper.

As is seen in Fig. 2, log (CPUE) decreases linearly with time. This tendency for 1970 is also common to those for other years. This decline may be attributable to the constant exploitation rate, as the fishing effort per day is constant over the fishing season. This phenomenon shows no migration has been taken place,

Fig. 6. Relation between indices of spawner and juvenile based on larger purse seine. The line give the curve fitted to the Ricker's method.

* Bull. of the Fish. Exp. Stat. of Shimane-ken in 1951-1957.

or a stationary immigration, or a stationary emmigration, or a mixture of last two exist there. As such stationary conditions may not be expected in these fishing grounds, it is more reasonable to take that this species, especially in juvenile, may stay in a range of fishing ground. These population belong to the same subpopulation off the western coast of Shimane Pref., because of the phenomena mentioned above and the fact that other fishing grounds of juvenile and spawner are very far from there. The indices of the spawner biomass and of the juvenile biomass are plotted in Fig. 6. The curve obtained here tends to increasing to a peak and then decrease gradually. Relation between indices of spawner and juvenile based on smaller purse seine is not shown but the trend is similar to Fig. 6. If the plot in Fig. 6 is represented by Ricker's reproduction curve⁶⁾, $N_0 = 15.49 S \exp(-0.0046 S)$, where N_0 means index of juvenile and S does index of spawner. According to Fig. 2 of NAKAHARA and OGAWA⁷⁾ there is no linear relationship between Parent and Progeny of round herring. The present result indicates that the curve more or less fits to density dependent reproduction curve. Some deviation may suggest the influences of abio- and bioenvironmental conditions.

Among pelagic fishes, the fluctuation of round herring abundance is very small. The result, density dependent reproduction curve have an interesting bearing on the nature of pelagic fishes. It may suggest that small fluctuation of round herring abundance is mainly caused by density dependent reproduction and round herring population consists of several subpopulations off the western coast of San'in district. The investigation of these possibilities must be a subject of future research.

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