On Management of Branquillos Population in the Sweeping Trammel Net Fishery

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(Received July 12, 1975)

This paper presents a method for managing the branquillos population taken by the sweeping trammel net fishery in Wakasa Bay. The study was made on the basis of informations obtained up to the present time from the view point that the fishery seemed to be controlled chiefly by the population size rather than by the regulations of fishing period and number of boats.

An analysis was made with the data on the commercial fishery of branquillos taken by long line in western Wakasa Bay to examine the migration of the species. The analysis showed that branquillos might make little migration, at least for a relatively short period. Under the assumption that the species migrates very little and recruits into the exploited phase from the egg stage in the fishing area, a mathematical model was considered in order to establish a method whereby the fish population management was possible, namely in satisfying two conditions, sustaining an adequate recruit and exploiting year classes efficiently.

The application of the above method to the data of 1970 showed that the sweeping trammel net fishery is greatly dependent on the rather small sized branquillos in Wakasa Bay. It was also recognized that it is also necessary to manage the branquillos population corresponding to its yearly condition, as there appeared a considerable variation in the size of year classes.

The sweeping trammel net fishery in Wakasa Bay has licensed chiefly for the duration of about a month in August every year and in a restricted area (687 km²), as shown in Fig. 1, since 1961, the year of commencement of the license system. There are the regulations for this gear as follows: the length and height of net are less than 300 m and 3.1 m, respectively, and the stretched mesh size is more than 6 cm. The species caught in the gear are branquillos, *Branchiostegus japonicus japonicus*, and other species such as *Dentex tumifrons* and *Mustelus manazo* etc. and about 90% of total catch has been occupied only by branquillos every year. Therefore, this paper deals with almost branquillos population.

Branquillos catch per boat-day in the fishery of Wakasa Bay is plotted against the population size from 1961 to 1970 in Fig. 2. It is seen from this figure that the rate of increase in catch per boat-day decreases gradually with the population size at least in the range of less than 160 tons. The plot of fishing effort on the population size shows that the effort increases with the size (Fig. 3). These facts seem to show the fishery has been controlled chiefly by the population size rather than by the regulations

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Fig. 1. Fishing area permitted for the sweeping trammel net fishery in Wakasa Bay. The triangle shows the fishing area permitted.

of fishing period and the number of the licensed boats at least for the size below about 150 tons.

To manage the branquillos population in the sweeping trammel net fishery substantially, it is necessary to develop a method for the management. This paper deals with a method for managing the branquillos population in the fishery on the basis of the informations obtained up to the present time.

Materials

The present paper used the data on the commercial fishery of branquillos with sweeping trammel net in Wakasa Bay in summer, 1961–1970. Fukui Pref. has systema-

Fig. 2. CPUE plotted against population size in the branquillos fishery with sweeping trammel net in Wakasa Bay, 1961–1970.

Fig. 3. Annual fishing effort plotted against population size in the branquillos fishery with sweeping trammel net in Wakasa Bay, 1961–1970.

tically recorded the commercial statistics of this fishery, which contain the daily catch by every boat, since 1961. The population size are those which were obtained in the previous paper¹⁾ for 1961–1965 and those for 1966–1970 were estimated by the same method.

This paper used the length composition of the commercial catch with the gear in the bay in 1970. The mesh selectivity curve and the population number index used here are ones obtained in the previous papers^{2,3)}.

To examine the migration of branquillos, the data were used on the commercial fishery of branquillos with long line in the western Wakasa Bay, which is called Tango-kai, 1965–1966. Kyoto Pref. Fish. Exp. Stat. collected the data about the operation location and catch of every species with long line by 18 of 75 boats belonging to Ine Fishermen's Union, Kyoto, over a year period from Sept. of 1965. The fishing area was divided into seven sub-areas such as A, B, C, D, E, E', and F as shown in Fig. 4.

Fig. 4. The fishing area of the long line fishery in the western Wakasa Bay, A, B, C, D, E, E' and F showing sub-areas.

General Theory

The previous paper³⁾ showed that the annual catch of branquillos with sweeping trammel net varied considerably over the range of 18 to 100 tons in Wakasa Bay from 1961 to 1970 and that yearly variation of it might be ascribable to that of the population size. An analysis of yearly variation in the population size gave a density dependent reproduction curve of branquillos in Wakasa Bay. Further, the license system of sweeping trammel net made the survival rate small, and so the branquillos population size was dependent greatly on those of age classes of 1 and 2 years old.

The above findings require the management method that produces relatively constant and higher yield within man's power to control. For this purpose, an attempt is made to consider a method for managing fish populations, corresponding to their yearly conditions. And the above mentions show that, in the management of the

branquillos population, the followings must be taken into account: first, the size of spawning population is optimum for sustaining a great recruit and, secondly, better yield is obtained from every year class.

Let us consider a mathematical model to establish a method for fish population management satisfying two conditions mentioned above. It may be permitted to assume that branquillos migrates little and recruits into the exploited phase from the egg stage in the fishing area as shown later. Suppose that the fish is fished only with sweeping trammel net and that this fishery is carried out in summer every year. As the fish spawn chiefly in autumn,⁴⁾ the fish which has not been fished in this fishery contributes to the reproduction if natural mortality is neglected over the period between fishing and spawning seasons. Under these conditions, denoting gonad weight index, body weight and the population number index at length l_i by G_i , W_i and N'_i , respectively, an index E of egg number spawned can be given as follows:

$$E = \sum G_i W_i N'_i (1 - f_i) \times 10^{-1}, \quad (1)$$

in which f_i is exploitation rate for fish of length l_i . On the other hand, the permissible catch Y in summer is presented by

$$Y = \sum W_i N_i f_i, \quad (2)$$

where N_i refers to the population number at l_i . Here the exploitation rate f is expressed by functions of fishing effort, mesh size and length of fish. Denoting the exploitation rate for the peak of mesh selectivity curve by f_o , f_i can be approximated by

$$f_i = f_o S_i, \quad (3)$$

where S_i refers to relative efficiency of a given mesh size for fish of length l_i . In the case of using the sweeping trammel net with mesh size m , if the size and length composition of the exploited fish population are obtained by some methods, E and Y for various values of f_o can be calculated by Eqs. (1), (2) and (3) using gonad weight index G , body weight W and mesh selectivity curve.

Next, let us consider the yield obtained from a year class throughout its life span. Suppose fishing intensity and natural mortality to be constant year by year. It is assumed that fish recruits into the exploited phase at age t_r and let the fish population size at age t_r be R . Denoting body weights at ages t_r and $t_r + k$ by W_o and W_{r+k} , respectively, the yield Y obtained from a year class throughout its life span is given as follows:

$$\begin{aligned} Y/RW_o = & f_r + f_{r+1}(1-f_r)(1-D)(W_{r+1}/W_o) \\ & + f_{r+2}(1-f_r)((1-f_{r+1})(1-D)^2(W_{r+2}/W_o) \\ & + \dots \\ & + f_{r+x}(1-f_r) \dots (1-f_{r+x-1})(1-D)^x(W_{r+x}/W_o), \end{aligned} \quad (4)$$

where f_{r+k} refers to exploitation rate for fish of age $t_r + k$, $t_r + x$ to the age t_d when all surviving fish die and D to natural mortality rate. Since f_{r+k} is obtained from Eq. (3)

using relative efficiency for mean length of fish of age t_r+k , Eq. (4) gives Y/RW_0 for the combination of mesh size and exploitation rate f_0 for the peak of mesh selectivity curve and indicates that Y/RW_0 represents relative yield produced from a year class throughout its life span.

Suppose that length composition and the exploited fish size are obtained before the fishing season by some methods, for example, fishing experiment or the data on commercial catch of the previous years etc. Then, Eqs. (1) and (4) give the index E of egg number and relative yield Y/RW_0 for the combination of mesh size and exploitation rate, respectively, if gonad weight index and body weight for every length, growth curve and natural mortality rate are obtained. The above result gives m and f_0 which are optimum both for egg number and for better yield produced from a year class. Accordingly the allowable catch can be determined for the given values of m and f_0 by Eq. (2).

Results and Discussion

Let us illustrate an example on the data of 1970 by the above method. Before going further, an examination is made on the migration of branquillos with the data on the commercial fishery of branquillos with long line in the western Wakasa Bay as the mathematical model mentioned above can not be applied to the management if the fish migrates markedly. Table 1 gives fishing effort (in boat-day) and catch (in kg) of branquillos by the sampled boats in the commercial long line fishery for each sub-area of the western Wakasa Bay in every month over a year period from Sept. of 1965.

Table 1. Fishing effort X (in boat-day) and catch C (in kg) of branquillos fished by the sampled boats in the commercial long line fishery for each sub-area of the western Wakasa Bay over a year period from Sept. of 1965

Month	Sub-area											
	A		B		C		D		E		E'	
	X	C	X	C	X	C	X	C	X	C	X	C
Sept.	65	249.5	19	86.0	21	117.4	14	61.5	35	362.6	11	90.0
Oct.	36	254.7	45	322.3	66	273.2	45	226.1	39	356.2	19	161.3
Nov.	56	299.1	25	194.0	31	176.4	8	39.6	18	175.1	3	27.7
Dec.	45	381.1	29	335.5	67	655.0	45	485.4	19	271.8	2	28.4
Jan.	3	1.3	10	189.1	8	54.6	4	27.7	0	0	0	0
Feb.	27	123.6	13	73.4	15	26.7	10	62.0	3	13.3	2	8.0
Mar.	18	34.1	15	14.8	30	13.1	28	16.3	0	0	0	0
Apr.	40	2.8	65	7.8	56	7.4	26	1.3	6	0	3	1.3
May	21	2.3	58	5.9	45	9.2	10	0	16	2.3	116	4.5
Jan.	109	37.4	13	5.2	39	7.8	8	6.7	2	8.3	57	0.7
Jul.	56	47.5	6	30.8	36	100.3	12	67.2	4	9.4	0	0
Aug.	21	26.5	0	0	0	0	0	0	3	12.1	0	0
Sept.	54	198.7	17	67.7	3	22.9	0	0	0	0	3	0.4

Fig. 5. Monthly variations in CPUE of branquillos in the long line fishery for every sub-area of the western Wakasa Bay over a year period from Sept., 1965, dotted lines showing no data.

Catch per unit effort (CPUE) was calculated for sub-areas in every month with the data in Table 1 and is plotted against month in Fig. 5, in which the dotted lines present no data. In general, as shown in Fig. 5, CPUE increases gradually from Sept. and reaches a peak chiefly in Dec. or Jan., and then decreases gradually, being nearly zero in summer. According to fishermen, yellowtail, *Seriola quinqueradiata*, red porgy, *Pagrus major*, and *Paralichthys olivaceus* are chiefly with long line from spring to summer every year. The baits used in the long line fishery change with the aimed species, for example, a shrimp (*Metapenaeopsis barbata*) for branquillos, anchovy, *Engraulis japonica*, for *Paralichthys olivaceus*, and squid for yellowtail and red porgy. In spring and summer, therefore, a decline in CPUE may be supposed to be ascribable to the change in the objective fishes from branquillos to others. In practice, the experimental fishing caught considerable amount of branquillos with sweeping trammel net in sub-areas B and E.⁴⁾

A comparison of the monthly variation of CPUE in Fig. 5 was made among sub-areas. The comparison seems not to show a remarkable difference in the trends of the monthly variation in CPUE among sub-areas as seen in Fig. 5. The above mention indicates that branquillos make little migration at least for a few months though there

remain some problems on the mode for dividing the area into the sub-areas.

FUNADA⁴⁾ reported that, in the experimental fishing of sweeping trammel net in sub-areas B (main area of the long line fishery) and E (area of the sweeping trammel net fishery), the catch of branquillos in the former was dependent greatly on fish of 20–25 cm in length and fish below 20 cm in length were relatively abundant in that of the latter as compared with the former. He discussed also that the small proportion of bigger fish in sub-area E may be considered to be due to the intensive fishing of sweeping trammel net and that branquillos make little migration between sub-areas. OKIYAMA⁵⁾ investigated the early history of this species and discussed that it might make little migration after the change of the habitat from pelagic to benthic.

The above mentions seem to support the assumptions used in the last section though there remain some problems on the early life history of branquillos. Accordingly, let us apply the method mentioned above to the data on branquillos population in the sweeping trammel net fishery of 1970 in Wakasa Bay. As fish more than a year old have been caught in the sweeping trammel net fishery of Wakasa Bay, it is assumed that all branquillos recruit into the exploited phase at a year old and all surviving fish die at 8 years old. Natural mortality rate is given $D=0.26$ by TANAKA's method⁶⁾ derived under the assumption that natural mortality coefficient is inversely proportional to life span. This value seems not to show a large contradiction to one obtained by a relation between survival rate and fishing effort in the previous paper³⁾.

Using the estimates of the parameters mentioned above, the mean length and weight of each age, and mesh selectivity curve, relative yield Y/RW_0 is calculated for the combination of mesh size and f_0 by means of Eq. (4). The calculated result is given as functions of f_0 and mesh size m in Fig. 6, which is called yield-isopleth diagram. In 1970, as the values of f_0 and m were 69% and 6 cm, respectively,⁷⁾ Fig. 6 gives Y/RW_0 about 2.5. As seen in Fig. 6, therefore, there is a possibility that a larger mesh size gives a better yield produced from every year class under the same fishing intensity.

Next, consider the size of spawning population to sustain great recruit. The index

Fig. 6. Isopleth diagram of branquillos catch with sweeping trammel net and egg number index E of branquillos calculated from the data of 1970. The solid and dotted lines show isopleth diagram and egg number index, respectively.

E of egg number was calculated for the combination of f_o and m by Eq. (1), using the relations of body weight and gonad weight index to length⁵⁾, the population number index and the length composition of 1970.³⁾ The values of E thus calculated are represented as functions of m and f_o by dotted lines in Fig. 6. As the previous paper³⁾ gave a better range of E , 20–35 to sustain a great recruit, Fig. 6 gives $m=8$ cm and $f_o=70\%$ as a better combination of them.

A combination of Y/RW_o and E in Fig. 6 gives $m=8$ cm and $f_o=70\%$ for a better management of the branquillos population with sweeping trammel net in Wakasa Bay in 1970. The above management allows to catch branquillos of about 18 tons that corresponds to whole exploitation rate of about 20%. This tells that, as the fishery is dependent greatly on rather small fish, the allowable catch reduces markedly if mesh size increases. After some years from the commence of the above management, however, the allowable catch may be supposed to increase in a considerable degree because of sustaining a great recruit and exploiting year classes efficiently.

The present method requires the data on the size and size composition of fish population before the commercial fishery starts. These data may be obtained before fishing season by the following methods: first, experimental fishing prior to the fishing season and, secondly, prediction from the data of the previous years. Experimental fishing prior to the season gives catch per unit effort and size composition. In the branquillos fishery with sweeping trammel net, as the gear efficiency is known, the fish population size can be obtained from the catch per unit effort. Next, an attempt is made to examine the possibility of their prediction from the data of the previous years. As sweeping trammel net has the mesh selectivity to branquillos, the correction of length composition of catch with its curve gives one of the population which is not exploited chiefly. In this fishery, therefore, there is a possibility that the corrected length composition of a given year serves some informations on the size composition and size of the fish population for the following year. In future, however, this method must be studied further.

Finally, the author wishes to express his sincere thank to Dr. Tasae KAWAKAMI for his continual guidance throughout this work. The author is also deeply grateful to Mr. Kaoru ŌE, Fish. Division of Fukui Pref., and Mr. Seiji KIYONO, Kyoto Pref. Fish. Exp. Stat., for placing the original data concerning the catch statistics of the branquillos fisheries.

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