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journal or publication title	Tohoku journal of agricultural research
volume	2
number	1
page range	83-104
year	1951-12-20
URL	http://hdl.handle.net/10097/29048

STUDIES ON THE POPULATIONS OF THE FLATFISHES IN SENDAI BAY
I. *LIMANDA angustirostris KITAHARA*

By

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(*Received June 10, 1951*)

Since the flatfishes have a narrow range of migration, the population of fishing grounds is apt to decline rapidly under intense fishing and modern efficient methods. For the sake of conservation of the resources of such fishing grounds a population study of flatfishes is considered to be of fundamental importance. This is particularly true in Japan where even though flatfishes comprise the main part of the catch of coastal trawling fisheries (Sokobiki-Gyogyô), the factors affecting the population have never been thoroughly studied.

In the study of fish populations, especially that of the trawl-caught fishes, it is necessary to treat the bottom fish community as a whole, and not as individual species or race. As a means to approach the problem we must make an analysis of the population of each species to begin with and then study the community as a whole, taking into consideration the inter-relation of the various species.

Magarei, *LIMANDA angustirostris KITAHARA*. known as the slender halibut, ranks highest among the trawl-caught fishes in Sendai Bay, being caught during all seasons of the year, it was therefore selected as the first species to be studied during the research on flatfish population in Sendai Bay.

The samples used for study were collected once, twice, or three times a month throughout the year. Statistical analysis of these samples were made in order to find the state of migration, the age of fishes, the age-composition of catches, the amount of available stock, the survival rate and other characteristics of the fish population. Though many points remain unsolved, the results obtained to date are presented.

Acknowledgments

We should like to express our hearty thanks to the members of Fish Market of Yuriage Fisheries Cooperative Association, for their kind cooperation in obtaining samples and also for statistical records of landings. We are especially indebted to Prof. Dr. T. Imai for reading the manuscript and to Mr. S. Kurita and Mr. R. Okamoto for their valuable advice and to Mr. T. Shôji for assistance given during the investigations. We express our hearty thanks to all.

Materials

Samples were collected at the Yuriage Fish Market or on board once, twice, or three times a month from April, 1949 to January, 1950. A sample of twenty to thirty specimens was drawn at random from the catch, and their body lengths and weights, scale and otolith rings, vertebral numbers, gonad development and stomach contents were examined.

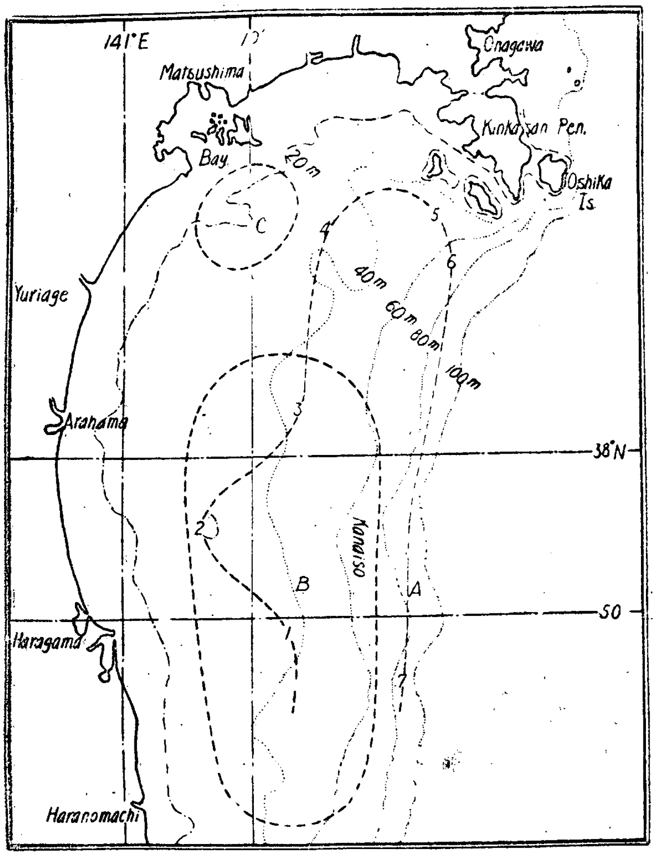


Fig. 1 The map of Sendai Bay.

For age-determination of fishes, we used the patterns of scale and otolith. The centrum of vertebra, which is used for age-determination in other fishes, was found to be impractical in this case.

Age-dertermination

1°. *Observations on the formation of scale rings.*

A resting zone marked on the scale was counted as a ring, because the narrowest interval between two circuli could not always be distinguished. The growing zone and the resting zone on the scale and otolith were examined for the purpose of determining the time of formation, and the number formed in a year.

Transition from the resting zone to growing zone in the scale occured during the period from March to May, while transition from the growing zone to the resting zone occured during the period from September to October. All fishes caught during the months from June to August showed growing zones in the margins of their scales, while those caught from November to January showed resting zones in the scale margins (cf. 2 and 3).

Analysis of the specimens collected on Aug. 2, when the formation of resting zone was complete, showed three modes in the length frequency of the samples which indicate the fish groups have one, two and three rings in the scale (cf. Fig. 11). It is clear from these observations that the resting zone is formed once per annum. Therefore, a resting zone can be regarded as a year ring.

The alternation of growing and resting zones in the scale was found to be closely connected with gonad development and spawning. The spawning season in Sendai Bay, as a rule, lasts from March to May. Fishes with fully compact gonads, always showed a resting stage in their scales, while the spawned fishes without exception showed a growing zone. Thus, it was not until the spawning was completed that the scale margin began to add the growing zone.

An examination of gonad development during spawning season revealed that spawning rarely if ever occurrs in the "II"-age group and younger fishes, even though in the case of these younger fishes a gonad development similar to that of the adult was observed.

2°. *Detailed observations on the change of scale patterns.*

As the changes in scale margins were found to be closely related to the reproductive cycle as stated above, the transition phase of the scale from resting to growing zones or vice versa and its relation to the gonad development by age and sexes were examined in considerable detail.

The transition phase from resting zone to growing zone was examined in the spawning group, because it was connected with the spawning of fishes (cf. Section of Migration). The results were shown in Table 1 and Fig. 2. In April, nearly all fishes over two years of age in the spawning group showed the resting zone on their scale margins. However, percentage of spawned individuals in the group remained fairly constant and very low throughout the whole spawning season. This fact seems to indicate that the older fishes (older than two years of age) dispersed, immediately after spawning, leaving the fishing ground (cf. Section of Migration).

It seems to be reasonable to suppose that active spawning of the older fishes occurred on or before Apr. 19, and that only few of them spawned after this period. In case of "II"-group it is clearly seen that the transition from resting to growing zone began about the middle of April and ended about the middle of May.

Table I. The number of fish, scales of which were in growth stage or rest stage, respectively, among the post-spawning group and the pre-spawning group.

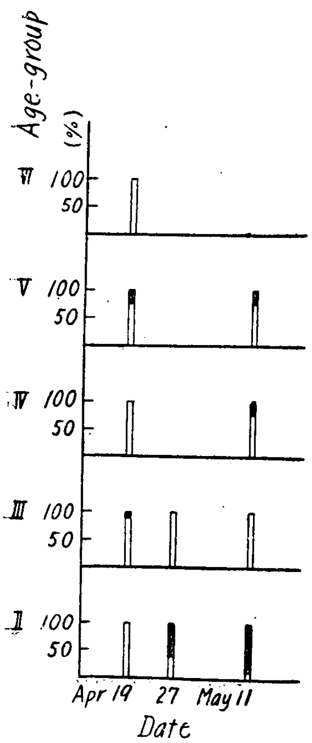
Fish-group	Date	Condition of scale margin	Age-groop				
			II	III	IV	V	VI
post-spawning group	Apr. 19.	growth stage	0	1	0	1	0
		rest 〃	0	0	0	0	0
	〃 27.	growth 〃	8	0	0	0	0
		rest 〃	0	0	0	0	0
	May 11.	growth	5	0	1	1	0
		rest 〃	0	0	0	0	0
pre-spawning group	Apr. 19.	growth 〃	0	0	0	0	0
		rest 〃	6	6	3	3	1
	〃 27.	growth 〃	0	0	0	0	0
		rest 〃	4	1	0	0	0
	May 11.	growth 〃	0	0	0	0	0
		rest 〃	1	7	3	3	0

The transition phase of "II"-group then was examined, with the results were shown in Fig. 3. In most of the females, the transition from resting to growing zone occurred during the short period between Apr. 19 and 27, while in the male it lasts longer, occurring from Apr. 19 to May 11 or even later.

The transition phase from growing zone to resting zone, as related to the gonad development of the recruitment group of younger fishes was then investigated (cf. Section of Migration). It was found there is a tendency that the older the fish becomes, the later the transition phase occurrs (Fig. 4).

In "III"-group and "II"-group the resting zone generally appeared after Sept. 16, though some specimens still showed growing zones on Oct. 16. Some of the specimens of "I"-group showed a resting phase on Sept. 16, but the majority of them had finished the transition by Oct. 5.

Analysis of the transition period was then made with respect to sex (Fig. 5).



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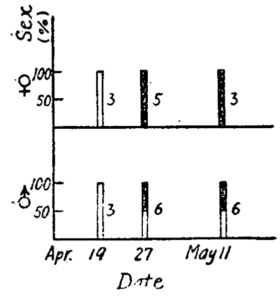

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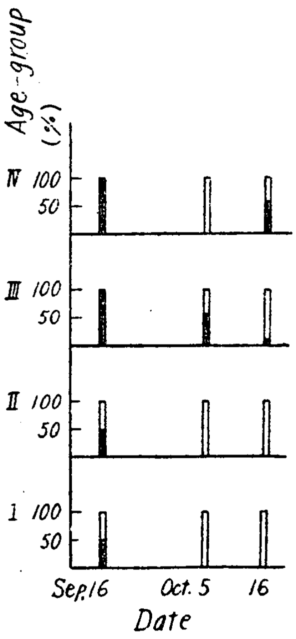

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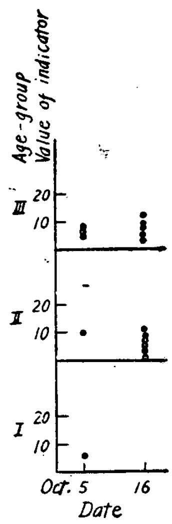

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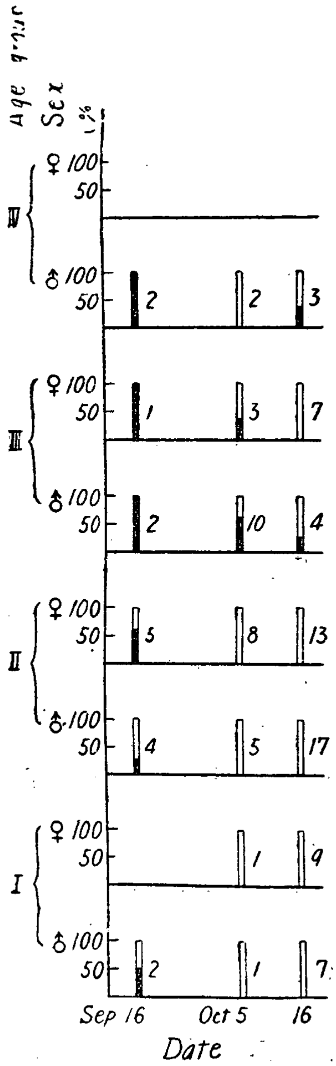

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Fig. 2 The percentage of fish in growth phase (black portion) and rest phase (white portion) in the Area "A", showing the transition from rest phase to growth phase.

Fig. 3 The percentage of the "II"-Group fish in growth phase (black portion) and rest phase (white portion) in the Area "A", showing the difference by sexes in the transition from rest phase to growth phase. Figures show the number of specimens.

Fig. 4 The percentage of fish in growth phase (black portion) and rest phase (white portion) in the Area "B", showing the transition from growth phase to rest phase.

Fig. 5 The percentage of each age group fish in growth phase (black portion) and rest phase (white portion) in the Area "B", showing the differenece by sexes in the transition from growth phase to rest phase. Figures show the number of specimens.

Fig. 6 The distribution of the index;

$$\left(\frac{\text{gonad weight}}{\text{body weight}}\times 1000\right)$$

of each age group in the Area "B", showing the degree of maturation.

It was found that in "II"-group the male entered the resting phase earlier than the female, and that the scale development was closely related to the gonad development in both sexes. In order to express the degree of maturity, ratio of 1000×gonad weight to body weight was used as an index. The distribution of the indices during the period of maturity is shown in Fig. 6. The index was found to be higher in "III"-group than in "II"-group. In "II"-group the value obtained showed a tendency to increase in relation to the change of phase in scale margin. However the sample of "II"-group was considered too small to discuss in detail.

Migration

The seasonal migration of each age group was studied for each fishing ground by means of comparing the change in age-composition and also the modes in length frequencies of the catches.

The principal area of fish distribution can be divided into two area, "A" and "B" (Fig. 1). Between the isolines of 60 meters and 80 meters in depth there is an area named "Kanaiso" (or iron reef), where net hauling is impossible due to the rough bottom (Fig. 1). Area A, as shown in Fig. 1, is a ring-like area around Kanaiso and indicates the migratory route of the relatively larger fishes of the spawning group. The region encircled by the Kanaiso line, the 25 meters isoline and the line of 37° 40' N is Area B, where the relatively smaller fishes predominated throughout the year.

Area C in Fig. 1 is supposed to be a passage for halibut juveniles from the nursery ground to the open sea.

No fish of "O"-group was collected from Areas A, B and C during the period of this study (Figs. 7~11). The gear selection was not considered, because selection by mesh is checked by sea-urchins (which comprise the majority of the catch), immediately after the beginning of operation. This fact presumably indicates that "O"-group is distributed in very shallow waters. The spawning of this halibut occurs in the area about 10 miles off the coast during March, April and May. The hatched larvae, then migrate towards shallow nursery grounds, such as Matsushima Bay, where they probably stay until next year, because in the early spring the fishes which became one year old were collected nearby the waters of nursery ground.

1°. *The migration in Area B.*

A. "I"-group. "I"-group which has passed the first winter in the nursery ground migrates gradually into Area B during the spring as the water temperature increases. From June to November, it is supposed they migrate into Kanaiso and pass the second winter there.

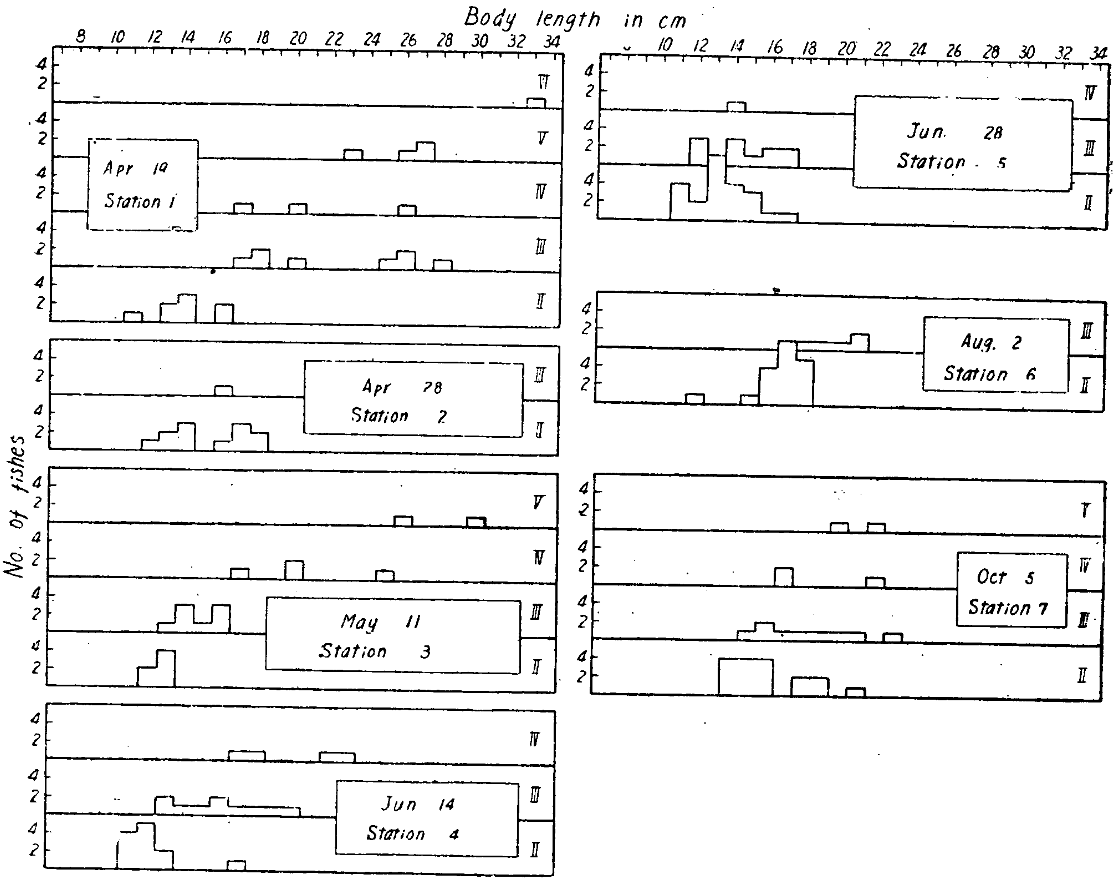

Fig. 7 Length frequencies of each age-group in the Area "B" at the different time of the year.

The age-compositions of samples from Area B are shown in Figs. 7 and 8. Fig. 7 shows those from the inshore region in Area B designated Area B_1 and Fig. 8 those from the offshore region near Kanaiso designated Area B_2. In Area B the number of individuals belonging to "I"-group was always smaller than "II"-group therefore it is supposed that the majority should be in the other, probably more inshore region than Area B.

The ratio of the number of "I"-group to "II"-group (I/II) was calculated for each sample, to find out how "I"-group migrated from the nursery ground

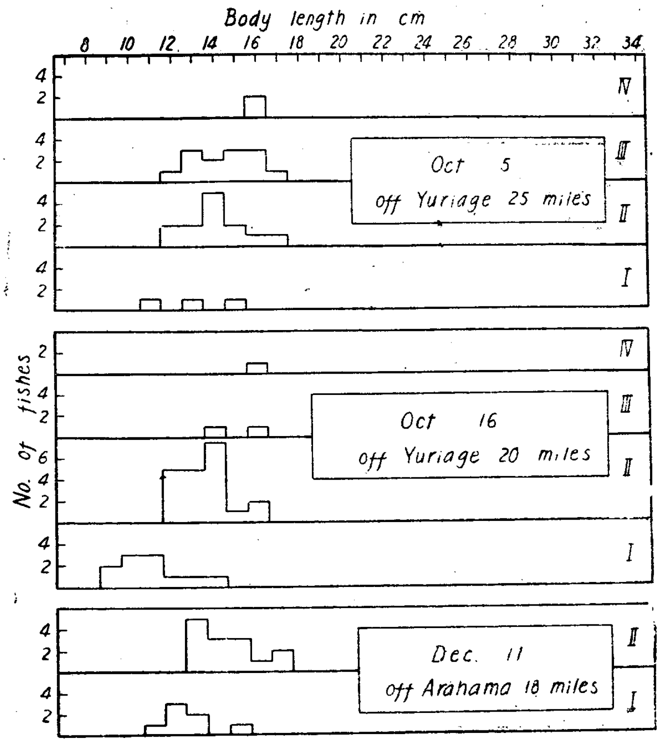

Fig. 8 Length frequencies of each age-group in the Area "B" at the different times of the year. The notations are the same as in Fig. 7.

towards Area B (Table 2). The ratio in Area B_1 showed the highest in May, declined gradually, increased again in October, then dropped to zero in November. In the nursery ground, located at the mouth of Matsushima Bay, the ratio increased from July to September (Fig. 9 and Table 2).

Table II. The change of the ratio of "I"-Group to "II"-Group in Areas B_1, B_2 and C.

Date \ Area	B_1	B_2	C
May 19	3/9		
May 27	4/12		
Jul. 18			6/38
Aug. 2	7/25		
Sept. 6	5/30		
Sept. 16			35/18
Oct. 5		3/13	
Oct. 16		10/21	
Nov. 8	0		
Dec. 11		7/13	

The increase or decrease in the ratio of I/II naturally resulted from either the increase or decrease in the number of "I"-group and the decrease or increase of "II"-group, or both. From the two facts, namely that the ratio I/II was the highest in May and that from that time on this value gradually decreased, it may be assumed that "I"-group, migrated into Area B_1 from the nursery ground in May, and then gradually moved to Kanaiso until September. The increase of the ratio in October indicates a fall immigration of "I"-group from the nursery ground towards Area B_1. This assumption is made from the fact that from May to August, the ratio I/II in Area B gradually decreased, while in Area C the ratio increased in the same period. The modal values in length frequencies of "I"-group in Area B_1 increased from September to October, while the ratio of I/II itself showed a minimum in September. Accordingly,

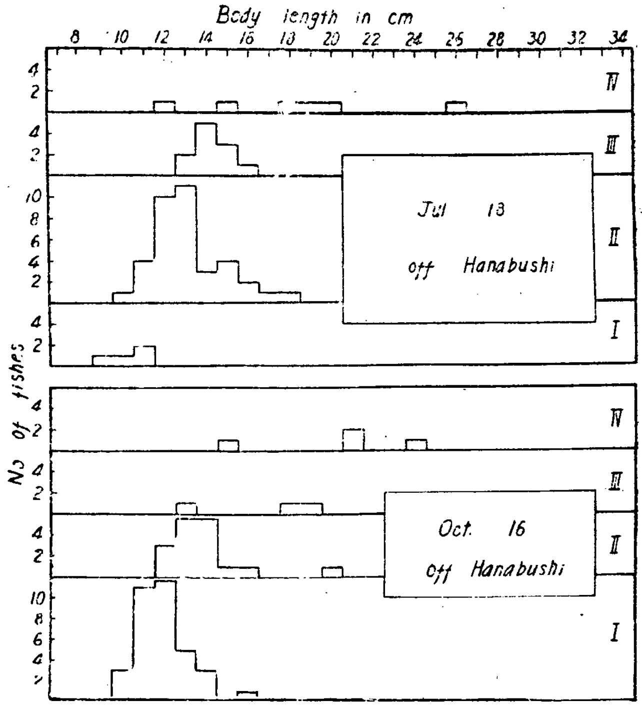

Fig. 9 Length frequencies of each age-group in the Area "C" at the different times of the year. The notations are the same as in Fig. 7.

the ratio of I/II in Area B_1 reached the minimum during the period Aug. 2 to Sept. 6. If "I"-group in Area C is assumed to migrate to Area B_1, the ratio of I/II in Area C should be the maximum at the end of August, when this ratio in Area B_1 is the minimum. As soon as autumn migration of "I"-group from Area C to Area B began in October, the ratio I/II in Area C decreased. This is shown clearly in the age-composition of the sample caught on Sept. 16 in Area C.

In general, fast-growing individuals in "I"-group from Area C, migrated at first to the open sea in spring, while the slow-growing individuals remained until the end of summer and in fall move towards Area B. The existence of two modes in the length-frequencies of the same age-group as shown in Fig. 7, can only explained by two migrations which occur in the same year.

B. "II"-group

"II"-group which passed the second winter in Area B_2 began to move into Area B_1 from spring to fall. During this period a part of them joined in the spawning group of Area A, while the remainder returned to Area B_2 beginning in October.

The modes in the length frequencies of "II"-group in Area B, showed seasonal changes indicating a rather complicated migration of "II"-group. Two modal values are observed in the length frequencies of "II"-group as shown in Fig. 7, they increased gradually from May to September, though it was found that the relative number of fishes with lower modal value increased. After October both of the modal values decreased and the relative number of "II"-group decreased. Two modes were also observed in Area B_2 as in Area B_1. But in this case, the relative number of "II"-group increased during the same period.

The migration of "II"-group can be explained from the seasonal variations in the modal value in length frequencies and relative abundance in Areas B_1 and B_2. At first the larger fishes of "II"-group migrated from B_2 to B_1, gradually followed by the smaller fishes until the beginning of September. As a result of increase in numbers of "II"-group the ratio I/II in Area B_1 decreased gradually (Table 2). Small parts of "II"-group were believed to join the spawning group at Area A in the early spring. After October the ratio I/II in Area B_1 which had been declining as a result of the autumn migration of "I"-group from Area C, and the migration of the large part of "II"-group from B_1 to B_2 in which the larger one moved early than the smaller ones (Fig. 7) changed and began to increase. Thus the migration of "II"-group in this area can be explained by the analysis of the length frequency and the age-composition of fishes in Areas B_1 and B_2.

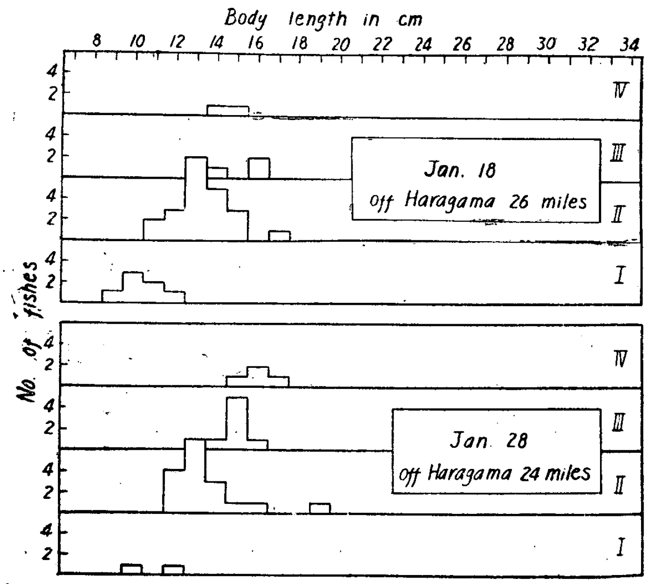

Fig. 10 Length frequencies of each age-group off the Area "B" at the different times of the year. The notations are the same as in Fig. 7.

C. "III"-group.

The main part of "III"-group, which passed the third winter at Kanaiso, returned to inshore region to join with the spawning group. The smaller sized fishes of "III"-group, though few in number, seem never to have spawned before. These smaller sized fishes began to migrate into Area B_2 from about October until the end of November, and in the next spring nearly all of them join with the spawning group.

In fact, in Area B_2 "III"-group disappeared before December leaving only "I"-group and "II"-group, while in Area B_1 "III"-group increased rapidly in number, showing the maximum at the end of November.

In a word, a separation and exchange of age-groups took place between two areas B_1 and B_2.

The smaller sized fishes of "I"-group and "II"-group which were found far east off Kanaiso in January (Fig. 10), presumably came from Area B.

2°. *The migration of the spawning group in Area A.*

The body length frequencies in each age-group in Area A are shown in

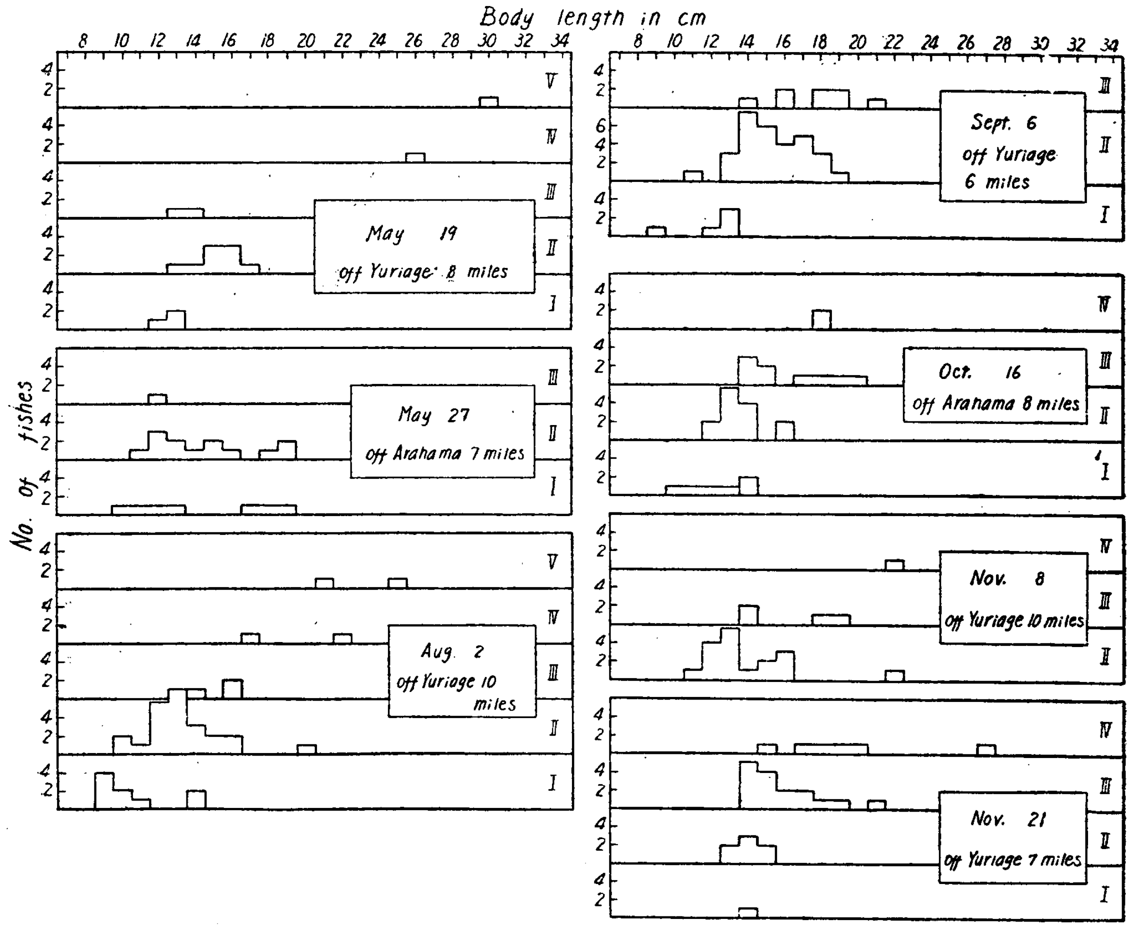

Fig. 11 Length frequencies of each age-group in the Area "A" at the different times of the year. The position of each station in this figure is shown in Fig. 1. The notations are the same as in Fig. 7.

Fig. 11. The larger sized fishes were not obtained on Apr. 28 due to failure of equipment. The main grpup in Area A, which appeared off Haragama at 40 meters depth in April (cf. Fig. 1), migrated northward along the 40 meters isoline during May and June turning eastward along the southern side of Oshika Peninsula, then southward to appear at a depth of 100 meters off Yuriage (cf. Fig. 1), and reaching a location off Haranomachi (Fig. 1) at the end of November. The number of frequencies and also the modal values of body lengths of the older fishes decreased from April to June, after that the number of each age-group remained rather constant but its modal value increased gradually.

Such facts indicate that the older fishes which had finished spawning were gradually dispersing out of the fish'ng ground during this period (cf. 1). The sampling stations are shown in Fig. 1.

Population Studies

1°. *Racial difference.*

Because the racial differences of Magarei in Sendai Bay can not be discussed from the migration, the vertebral number was examined in order to distinguish between them.

Two samples from Areas A and B were collected each at a considerably long intervals and were taken as representative of both areas (Sept. 26 and Oct. 5 in A, May 19 and Dec. 21 in B).

The significance of difference between two average numbers of vertebrae among these samples were shown in Table 3, 4, 5. Singnificant differences could not be seen between the two samples from Area A or Area B and also between both Areas. Therefore, the samples of Magarei in Sendai Bay may be considered to be taken from the same race.

Table III. Distribution of the vertebral number, showing the comparison between the two samples a_1 and a_2 in the Area A. $\Pr\{F>F_0\} >0.20$.

Vertebral number	Number of fishes		
	a_1	a_2	Total
37	9	7	16
38	11	21	32
39	0	3	3
Total	20	31	51

2°. *Amount of available stock.*

The writers applied Shibata's Method[8] for the calculation of the amount of halibut stock. The record of landings at the Yuriage Fish Market in 1949

Table IV. Distribution of the vertebral number, showing the comparison between the two samples, b_1 and b_2 in Area B. $Pr\{F>F_0\}>0.20$

Vertebral number	Number of fishes		
	b_1	b_2	Total
36	1	2	3
37	4	0	4
38	12	26	38
39	3	1	4
40	0	1	1
Total	20	30	50

Table V. Distribution of the vertebral number, showing the comparison between the two samples, A(a_{12}) and B(b_{12}). $Pr\{F>F_0\}\gg 0.05$.

Vertebral number	Number of fishes		
	a_{12}	b_{12}	Total
36	0	3	3
37	16	4	20
38	32	38	70
39	3	4	7
40	0	1	1
Total	51	50	101

fiscal year were used as the data of abundance measures.

The amout of the catches of *LIMANDA angustirostris* has been recorded separately from other flatfishes. The catch per voyage for each vessel had also been recorded.

Of the trawl boats operating in Sendai Bay, more than 90% are based at Yuriage. Since the landings to the market might be more or less directly proportional to the total catch, there would be no trouble in applying Shibata's Method, though not all the fishes caught were landed at the market.

Vessels of Yuriage Port principally operate in Area A from April to March and in Area B from October to December respectively. The average number of hauling is eight per voyage (for twenty four hours) from April to October and sixteen (for forty eight hours) in November and December. The fishing efficiency of boats was taken being very nearly the same for all vessels concerned. So, the writers regarded the fishing effort for twenty four hours as a unit.

The catch and the number of units of fishing effort for each 10 days during the fishing season were calculated, and then the average catch per unit of fishing effort from the begining of the fishing season to the end of each

10 days period was calculated.

The correlation obtained between these values and the number of fishing efforts is shown in Fig. 12.

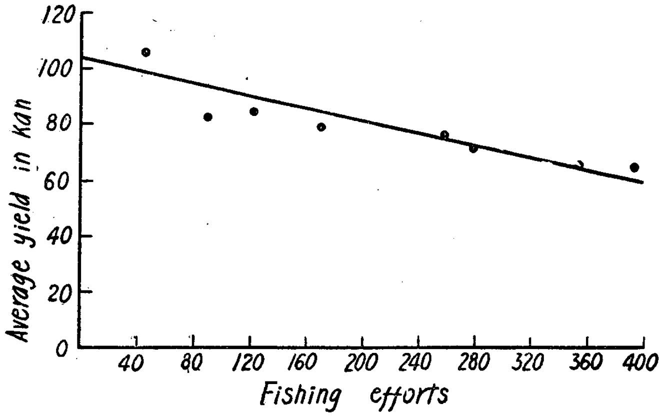

Fig. 12 The correlation line between the average catch and fishing efforts in the Area "A".

In Area A the equation of regression was $y = 104 - 0.114x$, namely $F/n = 104 - 0.114n$ and this corresponded to $F/n = Sk(1 + k/2) - Sk^2/n$ where F: total catch, n: number of fishing efforts, S: amount of available stock, k: fishing intensity*. And from this $k = 0.219 \times 10^{-2}$ and $S = 47{,}439$ kan ** were obtained (Fig. 12 and Table 6). S stands on the assumption that the total catch was landed at Yuriage Market.

Table VI. The total catch and the total number of fishing efforts from the beginning of the fishing season to the end of every decade, and also the average catch per one fishing effort at the end of every decade.

Area	Period	Total catch in kan.	Total number of fishing efforts in kan.	Average catch in kan.
Area-A	Apr. 11–Apr. 20	5,230.00	45	116.00
	〃 – 〃 30	7,465.60	90	83.00
	〃 –May 10	10.484.40	123	85.00
	〃 – 〃 20	13,448.90	171	79.00
	〃 – 〃 30	19,350.80	258	75.00
	〃 –Jun, 10	19,392.50	280	71.00
	〃 – 〃 20	22,712.80	353	64.00
	〃 – 〃 30	25,050.50	393	64.00
Area-B	Sept. 11–Sep. 20	11,498.90	101	114.00
	〃 – 〃 30	15,751.90	145	109.00
	〃 –Oct. 10	20,388.90	263	77.00
	〃 – 〃 20	22,206.10	367	61.00
	〃 – 〃 30	22,398.10	387	58.00
	〃 –Nov. 10	22,884.60	423	54.00
	〃 – 〃 20	23,331.30	481	49.00
	〃 – 〃 30	23,731.80	521	46.00
	〃 –Dec. 10	23,868.00	543	44.00
	〃 – 〃 20	24,900.00	623	40.00
	〃 – 〃 30	26,836.00	717	37.00

* k is the rate of catch-per-unit-of-effort to amount of available stock.
** 1 kan equals to 3.75 kilo grams.

In Area B, through the same procedure as above, the equation becomes as follows: $y=117-0.132x$, so that $S=51,852$ kan and $k=0.3356\times10^{-2}$ (Table 6 and Fig. 13).

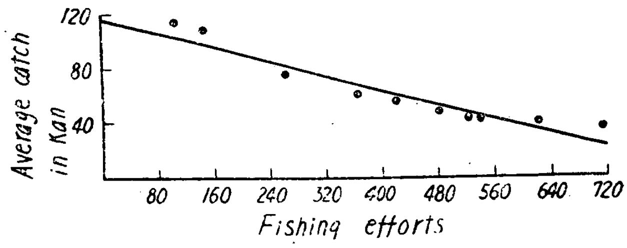

Fig. 13 The correlation line between the average catch and the fishing efforts in the Area "B".

3°. *Age-composition.*

Since the migration of this halibut is complicated (as already stated) the population and its compositions in each fishing ground fluctuates by the fishing season and also by the ground.

In consequence, a representative age-composition of Area A and that of Area B were combined, considering the relative amounts of both areas, so as to calculate the whole age-composition of this halibut in Sendai Bay.

The age-composition of fish group in Area A should be represented by the sample obtained during the most active period of spawning before the dispersion of older fishes from this area occurred. Therefore the age-composition of the sample obtained on April 19 were taken as representative of Area A. In the case of B, because of the inconsistency in the age-composition of two areas, B_1 and B_2, and of the difficulty in finding a quantitative ratio between the two areas, two samples obtained at the same time in B_1 and B_2, of which the amounts of catch are known, were taken for the calculation as being representative of the composition of Area B. Two samples of Oct. 16 satisfied the above conditions in Area B, because the exchange between "II"-group and "III"-group were taking place most intensively at this time, and these groups were of similar age-composition. Thus the distribution in Area B may be considered homogeneous. "I"-group was omitted from the representative age-composition, and did not contribute to the avilable stock.

From these considerations the following age-compositions were obtained: namely, II : III : IV : V : VI = 8 : 7 : 3 : 4 : 1 in Area A and I : II : III : IV = 16 : 34 : 11 : 3 in Area B. In the case of the latter, Group B_1 (34 specimens) and Group B_2 (30 specimens) were mixed and taken as the age-composition of Area B as stated above. The representative age-composition in Sendai Bay can be expressed as follows: II : III : IV : V : VI = 128 : 53 : 18 : 10 : 3, calculated from the ratio in amounts (47439/51852) and the average body weights (Area A-163 grams and Area B-52 grams).

4°. *Survival rate.*

The survival rate was calculated according to Doi's Method[2] using the regression analysis, and the result was 0.40 (estimated). If the distribution of the age-composition were in good conformity with that of ρ^{x}; x (age) and y (the logarithm of the number of fishes) would show a linear relationship.

As a result of examination on the linearity by the regression analysis, F_0 was 481.82, and as F is 167.5 with 1% risk, therefore the linearity of this case could be admitted on less than 1%-risk. As to the fiducial limit, $\rho_1=0.46$ as the upper limit and $\rho_2=0.35$ as the lower limit were obtained with 5%-risk.

5°. *Fishing rate.*

The fishing rates were calculated from the amounts of available stock and it was 0.53 in A and 0.52 in Area B.

6°. *The theoretically maximum yield.*

Using the data quoted in 3°, the regression equation between total catch and fishing efforts, $F=104n-0.114n^2$ in A and $F=117n-0.132n^2$ in B were obtained

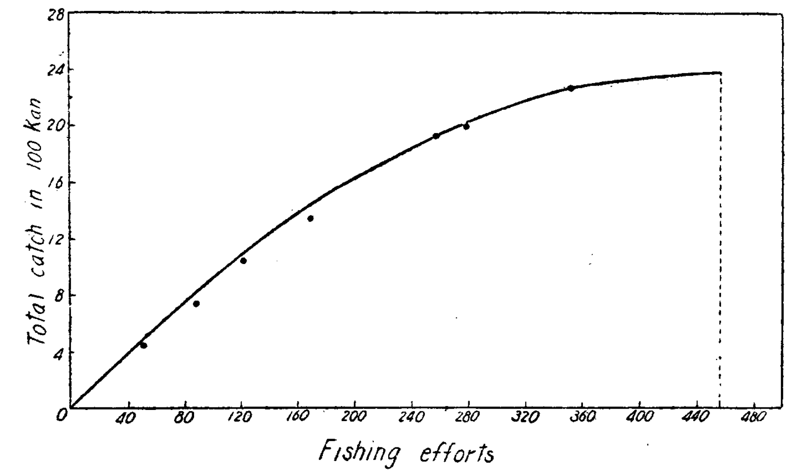

Fig. 14 The correlation curve between the total catch and fishing efforts in the Area A.

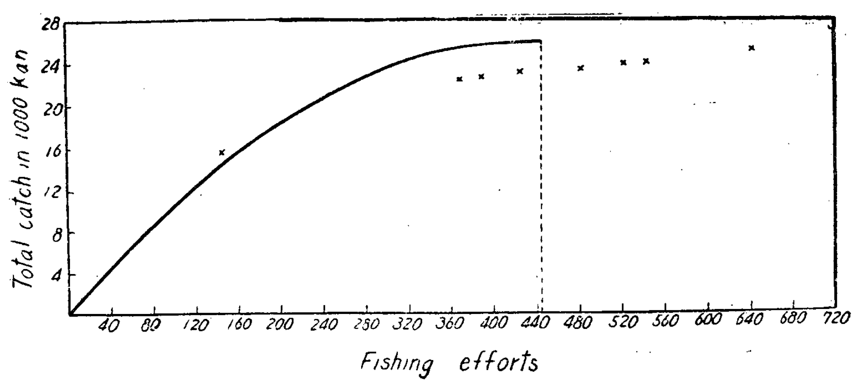

Fig. 15 The correlation curve between the total catch and fishing efforts in the Area B.

(Figs. 14, 15 and Table 6). From the calculation of n when dF/dn was zero, 457 in A and 444 in B were obtained as the maximum values of n. When these values were put into the above equation the maximum catches, $F=23{,}719$ kan in A and 25,926 kan in B were obtained.

Judging from Figs. 14, 15 and Table 6, the fishery of this halibut was very inefficient compared to the fishing effort in both areas. Moreover in Area B the present number of fishing efforts revealed the so-called "over-effort"-phenomenon (Huntsman, 1948).[3]

7°. *Natural mortality.*

Since the average fishing rate of both areas was 0.52, and the survival rate was 0.40, the natural mortality would be 0.17 ($\rho=(1-m)(1-f)$).

8°. *Relative number of "I"-group in the age-composition of the whole ground.*

The relative number of "I"-group in the age-composition of the whole ground becomes 51, because in Area B it was 16 (from 3°), and the fishing rate in Area B was 0.52, then 26 in relative number should be caught during the time they grow from "I"-group into "II"-group. On the other hand, as the relative number of "II"-group was 128 and the natural mortality was 0.17, $128\times1/0.83+26=180$ was obtained as the relative number of "I"-group and from this about 5/18 of "I"-group are considered to migrate from the nursery ground into Area B.

Biological Notes

Food investigation.

The kinds of ingested food were examined with the samples for each month and for each area (Table 7 and 8). The body length was taken as a standard, for it seems that the capture and preference for food is limited by body length rather than the age of fish. From the tables we can roughly determine the feeding habits of the halibut.

Quality indicator.

The quality indicator $1000\times W/L^3$ was calculated with each age-group in Areas A and B.

(1) Area A (Fig. 16).

Though the quality indicator of each age-group in Area A showed an almost constant value throughout the time of sampling, there seemed to be a small increase within each age-group from April to October; in other words, there was a tendency to increase body length in the spring and body weight in fall. The general constancy in the quality indicator conceivably indicates the fact that this group was a migratory group. This is interesting when compared with the fish group in Area B.

Table VII. The kind of foods injested, in the Area-A.

Range of body length in cm.	Kind of food	Number of fish examined.				
		1949				1950
		Apr.	May	Jun.	Oct.	Jan.
25–	Sand eel	1	2			
	Ohter fishes	1				
	Urochordata	1				
	Decapoda (Crustacea)					1
	Bivalves	1				
20–25	Sand eel			2		
	Bivalves	1				
15–20	Sand eel			1		
	Other fishes	5	1	1		
	Decapoda (Crustacea)	5		2		
	Amphipoda	6				
	Gasropoda	2		1		
	Polychaeta	4				
–15	Sand eel			6		
	Decapodt (Crustacea)	1	1			2
	Amphipoda	2	4			1
	Gastropoda		1			1
	Bivalves	1				
	Polycaaeta	2		1	1	1
	Echinoderma	1				

Table VIII. The kind of foods injested, in the Area-B.

Range of body length in cm.	Kind of food	Number of fish examined.					
		1949					1950
		May	Aug.	Oct.	Nov.	Dec.	Jan.
25–	Sand eel		1				
20–25	Sand eel	1					
	Other fishes	1					
15–20	Sand eel	2		1			
	Other fishes						1
	Eggs of fishes				1		1
	Decapoda	2					1
	Amphipoda			2	1		
	Polychaete	1	1		2		
	Echinoderma		2	1	1		
–15	Sand eel	1	1				
	Other fishes		2	1			
	Decapoda	1	2			1	
	Amphipoda		6	10	1	1	
	Bivllves			2		2	3
	Gastropoda						1
	Polychaeta		5	13	3	2	6

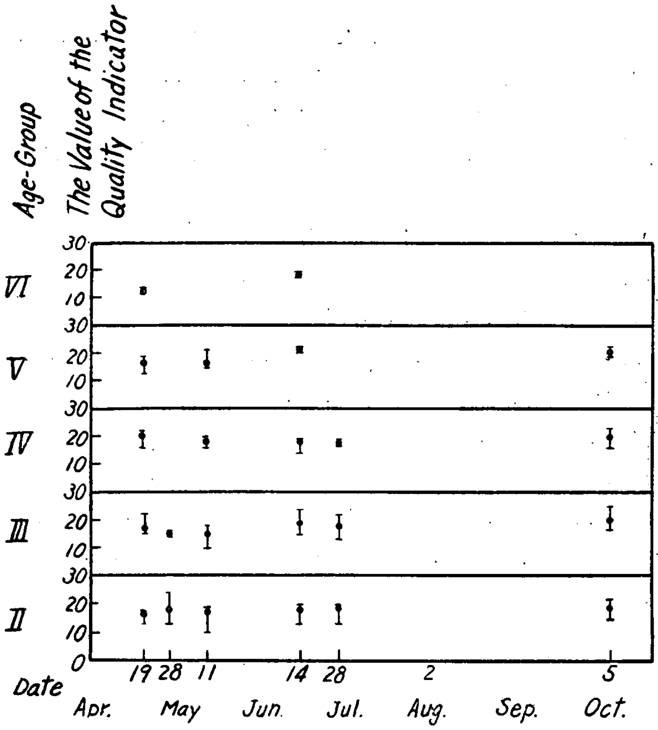

Fig. 16 The quality indicator of each age group in the Area A at the different time of the year. ⊢⊣ shows the range and ●, the mode of the quality indicator.

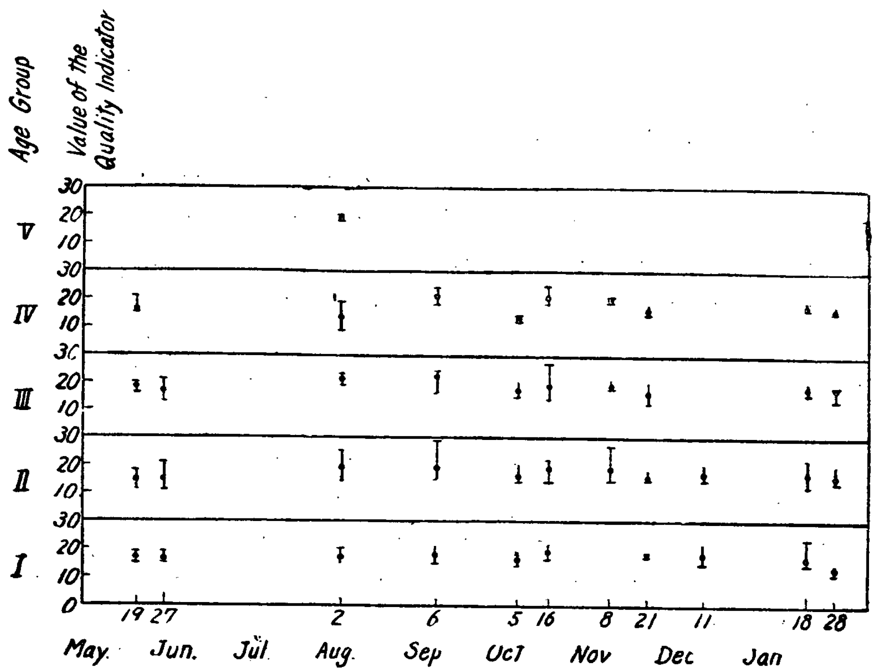

Fig. 17 The quality indicator of each age group in the Area B at the different times of the year. ⊢⊣ shows the range and ●, themode of the quality indicator.

(2) Area B (Fig. 17).

In the population of Area B, there was a conspicuous fluctuation in the quality indicator: namely, the indicator showed the maximum at the beginning of September, then decreased temporarily at the beginning of October, increased again in the middle of October and showed a marked decrease after that time. Generally speaking, there appeared a similar but more intensive tendency for the quality indicator to increase from spring to fall when compared to Area A, the temporary reduction at the beginning of October coincides with the change to the resting zone from the growing zone in the scale pattern. The intensive fluctuation occurred in the quality indicator is probably due to the habitat of this group, which does not migrate according to the changes of their environment.

In order to express numerically the difference of the quality indicator between A and B, the mean of the most prominent mode in every sample and the standard deviation of this mean was calculated for each age-group (Table 9).

Table IX. Means and Standard Deviations of Quality Indicators

Age \ Area	A	Number of Fish	B	Number of Fish
I			17.1±1.45	28
II	17.7±0.75	76	17.1±1.57	160
III	17.3±1.89	46	18.7±1.78	53
VI	18.5±1.18	14	17.5±3.15	19

No significant differences were found when comparing the means of the quality indicators of both areas. Concerning the fishes two and four years of age, the values of standard deviations were larger in B than in A. This fact clearly shows the difference of the ecological conditions of the two groups.

Estimation of body length by means of scale.

The body lengths and the scale lengths-(length along the longer axis from the core to the margin of the covered portion)-of two hundred and twelve specimens were measured in order to calculate the coefficient of E. Lea's formula.

Provided that we express the body length L in centimeters and the scale length as T in milimeters, the formula of L and T is $L=8.3T-2.4$; and when the length from the core to the n-th year ring-(the outer boundary of resting zone)-is r_n, body length when the n-th ring was formed is L_n, the formula $L_n=r_nL/T-8.3(L-r_n/T)$ was obtained.

Sex ratio.

The sex ratio, obtained by examing one hundred and forty one specimens including both groups, A and B, was 1:0.999. Therefore no prominence of either sex was observed.

Summary

1. The research on *LIMANDA angustirostris KITAHARA* has been carried out from April, 1949 to March, 1950 in Sendai Bay. Samples were taken once, twice or three times per month from catches of commercial boats or on board the research boat throughout the year.

2. From the state of migration, the population of this halibut was divided into the spawning group (A) and the recruitment group (B).

3. It was realised that the ring of scale or otolith is formed once per annum.

4. The changes with time in the pattern on scale or otolith was coincided perfectly with the state of gonad development, viz., that the margin of both scale and otolith of the fish before spawning showed rest phase while that of the fish after spawning showed growth phase.

5. The transition period from rest phase to growth phase was from April to May in the spawning group and that from growth phase to rest phase was from September to October in the recruitment group.

6. The migration of each age group in Sendai Bay was discussed in detail from the points of the age-composition and length frequencies of the samples.

7. No racial differences of statistical significance were found between A and B groups, when using the vertebral number as a criterion.

8. The amount of available stock in 1949 was 47,439 kan in Area A and 51,856 kan in Area B. The fishing intensity was 0.32×10^{-2} in Area A and 0.23×10^{-2} in B.

9. The age-composition for total samples was II : III : IV : V : VI = 128 : 53 : 18 : 10 : 3.

10. Survival rate was 0.40 and fishing rate was 0.53 in A and 0.52 in B.

11. Food was examined and shown according to body length and sampling time.

12. The fluctuation of the quality indicator was smaller in the migratory group than in the recruitment group.

13. The relation between body lengths and lengths of scales was expressed by a formula according to E. Lea's method.

14. Sex ratio was 1 : 0.999.

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