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Title	ECOLOGICAL ANALYSIS OF THE CATCH IN A SET-NET FISHING GROUND NEAR HAKODATE, HOKKAIDO
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Citation	北海道大學水産學部研究彙報, 9(1), 1-13
Issue Date	1958-05
Doc URL	https://hdl.handle.net/2115/23021
Type	departmental bulletin paper
File Information	9(1)_P1-13.pdf

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ECOLOGICAL ANALYSIS OF THE CATCH IN A SET-NET FISHING GROUND NEAR HAKODATE, HOKKAIDO*

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Many studies have been reported in relation to the pattern of a shoal of fish in the set-net fishing ground. For instance, on the correlation between the haul and the oceanographic and climatologic conditions, it has been reported from the coast of Japan in the Pacific Ocean that a large take of yellow-tail occurs in a day or two after the low pressure has passed the fishing ground[1)2)] There have been many reports on the effect of the oceanographic and meteorological factors not only on the fishery of yellow-tail, but also on those of mackerel, sardine and saury[3)4)5)] In reference to the front, direction and speed of wind, air temperature and rainfall, Kojima[6)7)] has studied the haul of squid in the several set-net fishing ground near Shimane Prefecture. Only one investigation has been reported on the correlation between the migrating salmon and meteorological elements in the coast of Kamchatka[8)]

The topics discussed in previous works may be classified into the following two categories, namely, (1) correlation between oceanographic and fishing conditions and (2) annual fluctuation in the haul of a single species selected from the various kinds of fishes which were landed from a fishing ground. Further, in most cases, the haul has been given as a summing up of the quantities of a given species of fish which were landed from a few or several set-nets settled either in a large bay or along a broad coast. Ecologically speaking, however, the minute oceanographic and climatologic conditions around every set-net fishing ground are doubtless different from one another even in the same bay. Besides, as the set-net fishing ground is considered to be subject to an enormous natural environment, the shoal of fish in the ground is always affected by various changes of both major and minor environments.

To clarify the mechanism of catch in the set-net fishing ground from the ecolgical point of view, it seems to be important to analyse the correlation between the total amount of each species in every haul and the environmental elements in a single ground. Further, it is necessary to study some successional fluctuations occurring among all the fishes which migrate into the fishing ground throughout the fishery period. Nowadays, however, very little information is avilable on the successional fluctuation of the catch as studied under microclimatological considerations.

Having such problems in mind, the author wrote the present paper to deal with the

* The expense of this study was defrayed from a Grant in Aid for Fundamental Scientific Research by the Ministry of Education, donated to the laboratory of Professor Shinjirô Kobayashi.

results of a preliminary study made on the analysis of the catch in a set-net fishing ground. Generally saying, however, it is very difficult to obtain precise data for each haul. So, the author examined the quantity of every catch as carefully as possible, presenting himself at every time of hauling, and endeavoured also to hear references to the fishing conditions of the ground from the fishermen who had worked there.

Before proceeding further, the author wishes to thank Prof. Shinjirô Kobayashi of the Faculty of Fisheries, Hokkaido University, for his valuable advice rendered during the course of the present study and for his kindness in reading the original manuscript. Thanks are also due to Mr. Yataro Iwasawa for offering his own fishing ground used in the present study and his kindness in offering valuable old data on both the catch and the ground. The author is indebted to the staff members of the Hakodate Marine Meteorological Observatory for supplying the data on the atmospheric pressure and its tendency. The author wishes to express his thanks to Profs. I. Saito, G. Kawasaki and Assist. Prof. M. Ishida of Hokkaido University for use of their instruments and for giving many helpful suggestions. Thanks are likewise offered to Prof. S. I. Sato and Mr. K. Kobayashi of Hokkaido University for kindly identifying the species of the fishes studied.

SITUATION AND CONSTRUCTION OF THE SET-NET AND METHOD

The set-nets by which the present study was performed are situated at the head of Hakodate Bay facing Tsugaru Strait on the south-west (Fig. 1). Mt. Hakodate 334 meters high overlooks the bay in steep relief on the east side (Fig. 2). The two set-nets are settled there. One is situated about 700 meters off and the other about 2000 meters distant from the former so as to be in the inner part of Hakodate Bay. Usually, the fishermen call the former "off set-net" and the latter "shore set-net". For convenience' sake, the author named the former "O-net" and the latter "S-net" in this study. The fishermen often said that a current rip is found in the area between O-net and S-net. In every year, the fishing of both nets starts approximately in early April and lasts to the middle of July. The present study was conducted during this period in the two years

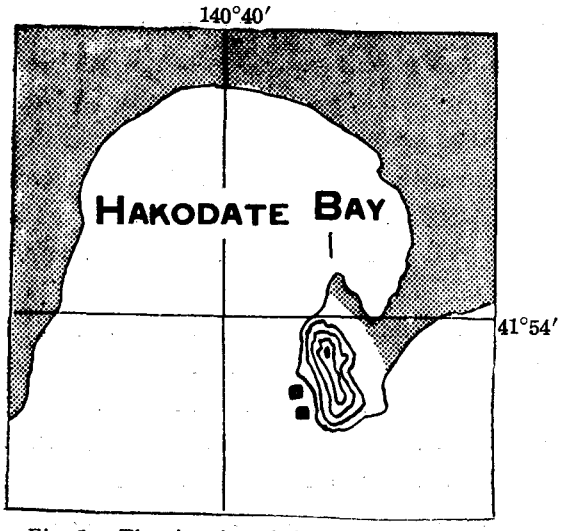

Fig. 1. The situation of the set-net fishing ground off Mt. Hakodate ■ Site of a set-net

of 1956 and '57, referring also to some data of 1954 and '55.

The scheme of the set-net is illustrated in Fig. 3. 'Leading net' (A) extends rectangularly from shore to offing so as to intercept the sea vertically. The fish which knock against 'leading net' are introduced into 'main net' (B). The fish are taken by hauling 'pulling net' (D) to which they were confined passing through 'acclivity net' (C) from 'main net'.

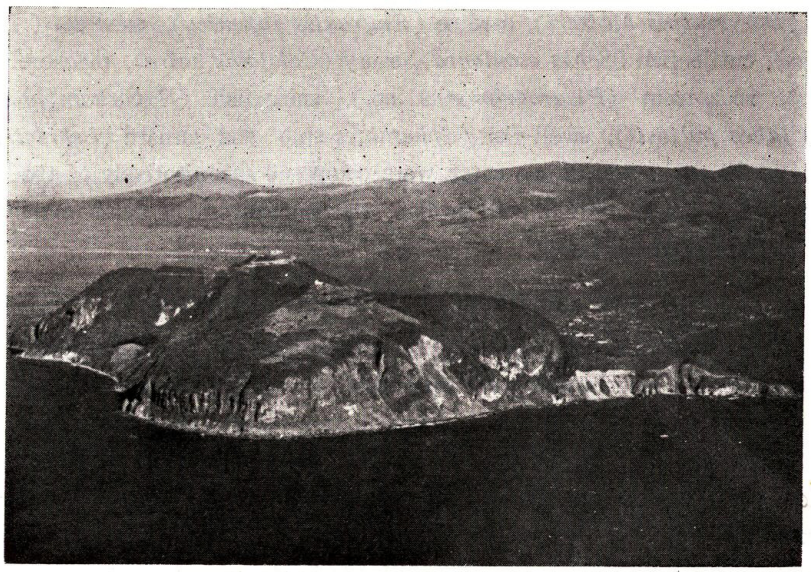

Fig. 2. Aerial view of Mt. Hakodate (Mr. A. Yonekura photo.)

Except on stormy days, the haulings are made twice a day at about 4 in the morning and at about 16 in the evening.

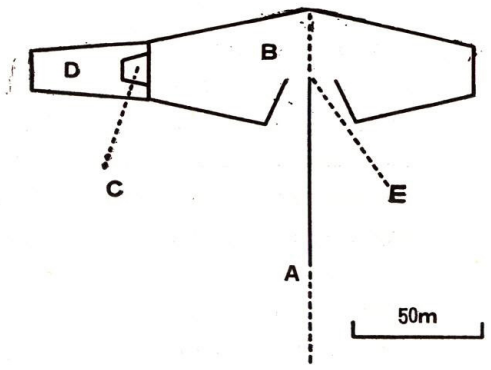

Fig. 3. The scheme of a set-net
A : Leading net B : Main net
C : Acclivity net D : Pulling net
E : Entrance of the main net

As the environmental factors, the water temperature, the specific gravity, the transparency, direction and speed of the wind, the atmospheric pressure and its tendency were measured. Of these factors, the atmospheric pressure and its tendency are those which were measured at the Hakodate Marine Observatory which is situated about 10 kilometers distant from the fishing ground. The direction and speed of the wind alone were measured with the eye. To record the continuous changes of the water

temperature, a self-registering thermometer was set in the sea at the depth of 15 meters in a corner of the main net. The direction and velocity of the tidal current were recorded by making use of a current-meter.

RESULTS AND DISCUSSION

The fish which were caught in the present study are composed of the following 13 species: trout (*Oncorhynchus masou*), squid (*Ommastrephes sloani pacificus*), calamary (*Doryteuthis bleekeri*), sardine (*Engraulis japonica*), sand-eel (*Ammodytes personatus*), cuttle-fish (*Sepia esculenta*), saury (*Cololabis saira*), mackerel (*Scomber japonicus*), rock-trout (*Pleurogrammus* sp.), snipe-fish (*Hyporhamphus sajori*), herring (*Clupea pallasii*), swell-fish (*Spheroides* sp.) and gurnard (*Lepidotrigla* sp.). However, as the main part of the catch were composed quantitatively of the first four species, trout, calamary, squid and sardine, the present study deals mainly with the behaviour pattern of these fishes.

Annual and monthly fluctuations of the catch

Fig. 4 shows the annual and monthly fluctuations of the quantities in the four species cited above ; calculations were made from the catches of both O-and S-nets, in the years of 1954 to '57. As clearly shown in this figure, the trout catch of the O-net is considerably larger than that of the S-net excepting in 1957. When the monthly total catch of this fish is considered, the peak was commonly found to occur in May in the years of 1955 to '57, excepting in April of '54. No marked difference was recognized between the morning and evening hauls in the trout.

In the squid catch, the morning and evening hauls showed a striking contrast. That is, as the figure illustrated, almost all of the quantities of this fish were taken by the morning haul. To clarify such a characteristic haul, a preliminary study made on the diurnal migrating behaviour of this fish will be described in the following section. No marked difference was found between the hauls of this fish in the O-and S-nets. Regarding the squid fishery, it is noticeable that the annual fluctuation of the haul is considerably large; for instance, only a small quantity of the fish was landed in 1956.

In the calamary fishery, the quantity of the morning haul is generally much more abundant than that of the evening, being somewhat similar to the squid catch. Such a similar tendency of the haul in the squid and calamary may be ascribed to a behaviour pattern common to these fishes.

In most cases, the sardine was taken in both morning and evening hauls. However, considering from the time and relative quantity in both hauls, the diurnal migratory periodicity of this fish appears to be not so distinct as in the trout. A sudden and good take as occurred in the O-net of 1956 may be considered as a characteristic of the sardine fishery. Generally saying, except the sardine, the fishing season of each fish is

found to occur constantly every year.

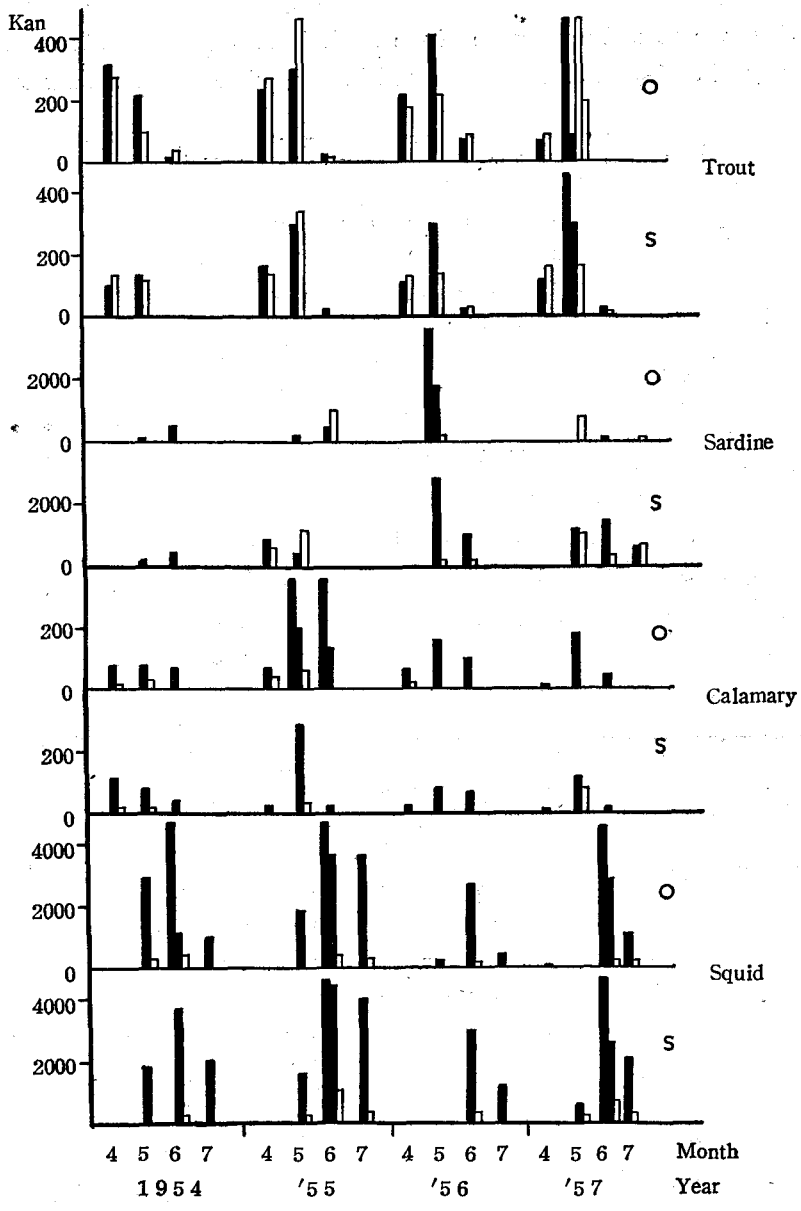

Fig. 4. Annual and monthly fluctuations of the quantities of the catches in each set-net (Kan : 4Kan=15Kg)

■ : Morning haul □ : Evening haul O : Off set-net S : Shore set-net

Catch process and water temperature

Catch process

To show the general appearance of the catch process during the term of this study, the quantity of each species was calculated in every five-day period for each net; the

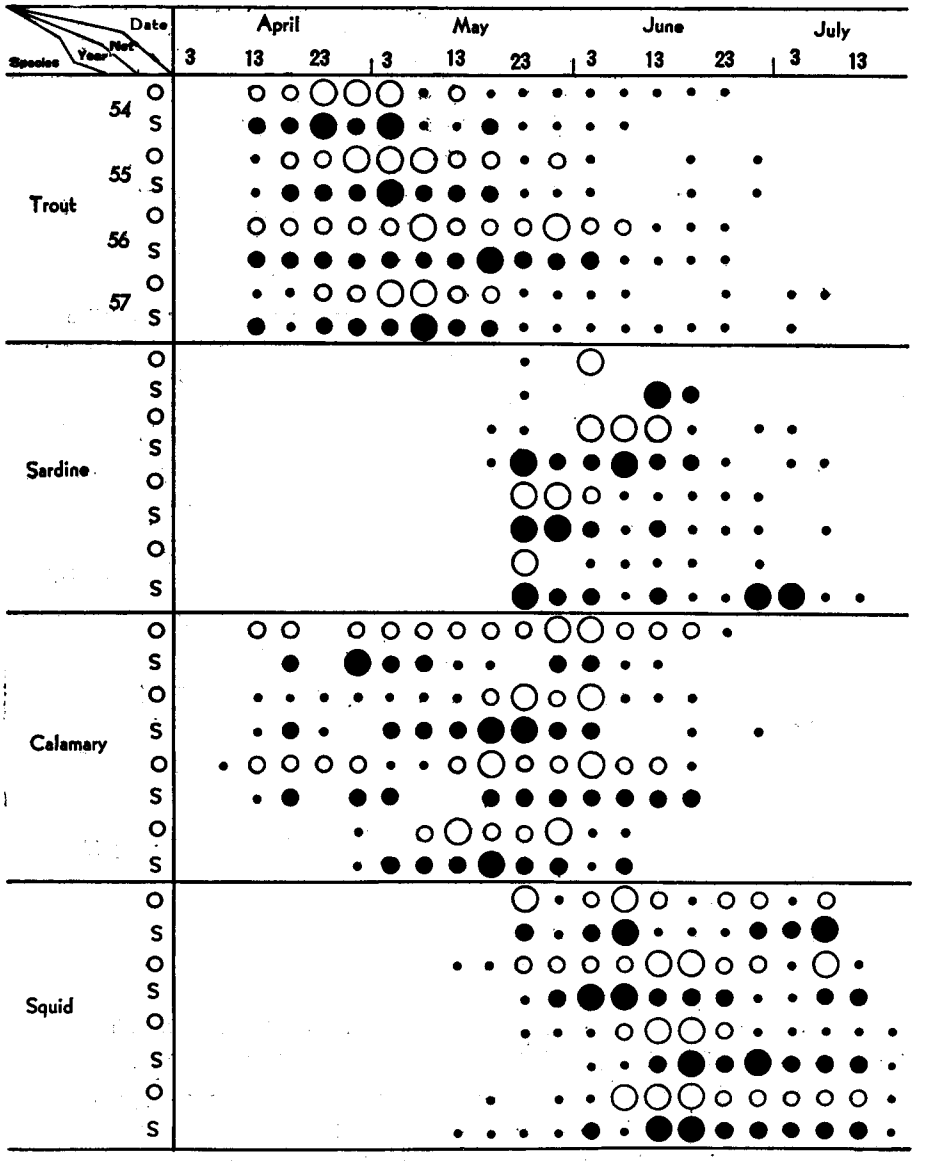

Fig. 5. The fluctuation in the quantities of the fish in every 5-day period

● : Good take • : Moderate take · : Poor take No mark means that the catch is zero. O : Off set-net S : Shore set-net

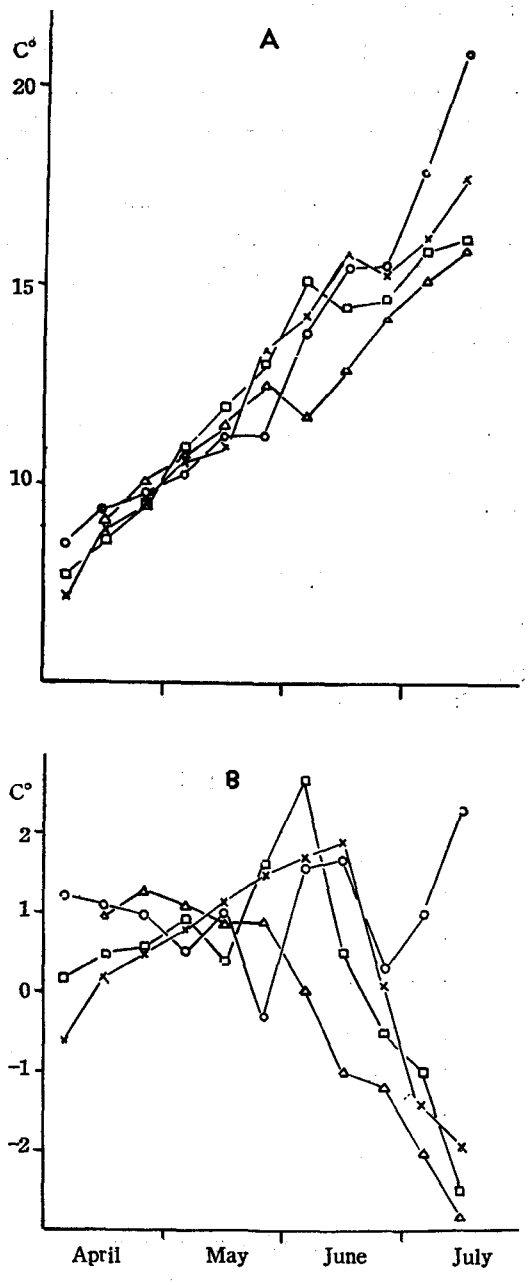

Fig. 6. A) Annual fluctuation of the water temperature off the fishing ground B) Deviation from the mean value in each period calculated from the data of the past twelve years
△ : 1954 □ : '55 ○ : '56 × : '57

magnitude of the catch thus obtained was classified into the following three grades: good, moderate and poor. From the results illustrated in Fig. 5, the following conclusions may be reached. That is, in the trout fishery, the first coming date of the period of increased catch varies a little with the year. In the haul of this fish, it seems to be characteristic that the period of increased catch of the O-net arrives almost commonly earlier than that of the S-net. Similarly to the trout fishery, the increasing periods of both squid and calamary appear to come variably with the year. Further, it seems to be a common phenomenon that regarding the fisheries of these trout, squid and calamary, the poor and then the moderate catch-periods come on before good hauls of them are realized. Being different from the catch processes of these species, the period of increasing catch of the sardine appears to come suddenly, and that, very rarely.

Although the years studied are small in number, summarizing the successive fluctuation in the catches of the four species, it is presumable that the increasing period of each fish is as follows: in the trout, from the end of April to the beginning of May; in the calamary, from the middle of May to the end of the same month; in the squid, from the beginning of June to the middle of the same month; and in the sardine, from the end of May to the middle of June.

Correlation between the catch process and water temperature

Fig. 6, A shows the annual fluctuation of the water temperature of every ten-day period measured at the fishing ground which is, as already described, distant from shore about 2000 meters; B shows the deviation from the mean value in each period calculated from the data of the past twelve years. In the sardine fishery of 1955, the water temperature in both the first and increasing periods was just the same, 11.4° C. As already stated in the former section, the sudden and good hauls of this fish were found to occur on the same day, May 23, for the consecutive three years of 1955 to '57. The water temperature of this day was 11.4°C in 1955, 13.2°C in '56 and 13.4°C in '57, respectively. It is curious that characteristic haul of the sardine was realized on the same day of the three separate years under the different temperature environment. In addition to this case, similar examples of such coincidences can be cited further. For instance, the water temperature in the last period of the sardine catch in 1956 and that of the increasing period in '57 was equally 16.2°C.

Table 1 indicates the ranges of the water temperature in each period in which the four species of the fish were taken in the years 1954 to '57. The trout alone appears to respond to a relatively constant range of temperature. Even assuming the ranges of

Table 1. Range of the water temperature in each fishing period
O : Off set-net S : Shore set-net

Species \ Period / Net		First period	Increasing period	Last period
		C°	C°	C°
Trout	O	8.7 — 9.2	9.8 — 13.1	14.3 — 15.3
	S	8.7 — 9.2	10.1 — 12.0	11.8 — 15.3
Calamary	O	7.3 — 9.5	11.0 — 15.1	14.3 — 15.4
	S	8.7 — 9.5	10.1 — 13.4	14.3 — 15.5
Sardine	O	11.4 — 12.5	13.1 — 15.5	11.8 — 18.0
	S	11.4 — 12.5	11.4 — 16.3	15.4 — 17.8
Squid	O	10.2 — 13.2	11.8 — 18.0	15.3 — 21.0
	S	10.7 — 15.1	14.2 — 15.3	15.3 — 21.0

the water temperature in each period of the other three species to be not so large, however, it is recognized that the maximum degree of the temperature in the first period and the minimum of the increasing period are found to be overlapped with each other. A similar overlap of temperature is also seen between the maximum degree of the increasing period and the minimum of the last period in the fisheries of the calamary, sardine and squid.

From these facts, it seems reasonable to conclude that the seasonal changes in the catch of these four species depend not only on the water temperature, but also on other environmental factors. Also it may be said that the catch of the trout has a relatively close relation with the water temperature when compared with the catches of the other fishes concerned.

Correlation between the quantity of the catch and the low pressure

When considered from the results of the meteorological studies in Northern Japan[9] the general courses of the low pressure which come upon the present set-net fishing ground are to be classified into the following main three types as shown in Fig. 7 : the first one is that which comes up north along the coast of the Japan Sea (J-type), the second comes up north along the coast of the Pacific Ocean (P-type), and the third comes to the Pacific Ocean from the Japan Sea across the northern part of Japan proper (C-type).

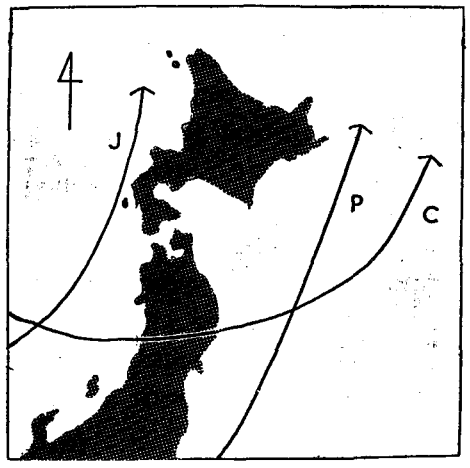

Fig. 7. General courses of the low pressure which approach the set-net fishing grond
(J) : Comes up north along the coast of the Japan Sea. (P) : Comes up north along the coast of the Pacific Ocean.
(C) : Comes to the Pacific Ocean northerly from the Japan Sea across the northern part of Japan proper.

Table 2. The correlation between the increase or decrease of the catch and the approach of the atmospheric depression in every course

Tendency / Species / Course	⌒	＼	／	⌣	—
			Trout		
J	6	8	7	6	7
P	0	1	5	2	4
C	2	5	4	2	1
Total	8	14	16*	10	12
			Calamary		
J	0	2	2	0	3
P	1	0	3	0	1
C	0	1	0	1	1
Total	1	3	5*	1	5*
			Squid		
J	3	13	6	1	3
P	3	1	6	1	3
C	3	2	6	0	1
Total	9	16*	18*	2	7

J. Comes up north along the coast of the Japan Sea P. Comes up north along the coast of the Pacific Ocean C. Comes to the Pacific Ocean from the Japan Sea across the northern part of Japan proper
⌒ : The catch increases for a few or several days after the atmospheric depression hits the set-net fishing ground.
＼ : The catch decreases gradually during several days.
／ : The catch increases gradually during several days.
⌣ : The catch increases for a few days before and after the atmospheric depression hits the set-net area.
— : The catch does not change for several days during which the low pressure approached the set-net.
* : See the text.

According to the respective types of these courses, a test was made to ascertain the degree of correlation between the fluctuation in catch of each fish and the atmospheric tendency. The results are given in Table 2. When examined for their possible correlation regarding only each type of the course of the low pressure, no significant difference of the catch was found among the five cases of the atmospheric tendency. For instance, it is clear without examination that in the trout fishery no difference of the catch is found among the tendencies at the time of the J-type. However, in the squid fishery, a high frequency of good hauls is found to be realized in the J-type at the time of the decreasing tendency. With respect to the summed up total frequencies of those of the three courses, the correlation between the haul and the atmospheric tendency was considered to be in the confidence interval of 60 per cent reliability when examined by the method of occurrence probability.[10] It is natural that low pressure does not so frequently approach the fishing ground during a fishery season, every year. The low significancy obtained above may partly be reduced to the small number of the frequencies in the approach of the low pressure which occurred in the four years studied. So, further studies are essential to clarify the present problem. However, it may be presumable from these results that a good haul of the trout occurs for a few or several days after the atmospheric depression has passed from the fishing ground, and a good take of the squid can be expected for a few days before and after such a low approached.

Daily fluctuation of the catch

To analyse the fluctuation of the catch, it is necessary to study the movement of fish as correlated with various environmental factors, under consideration of the microclimatology. Fig. 8 shows the increase or decrease of the trout catch at the beginning of May, 1957, as influenced by the various changes of the environmental factors. A good take was recorded during the days from the 7th to the 9th. A low pressure hit the fishing ground on the 5th, though the weather soon recovered. Thereafter, only a slight fluctuation of the atmospheric pressure was seen. The surface water temperature of these days varied in the range of 9.0° to 10.2°C. Considering from the data measured in the neighbouring days, it is presumable that the water temperature of this period shows an ascending tendency. The specific gravity showed a progressive elevation in the days from the 7th to the morning of the 9th, though thereafter it decreased slowly to the usual level. The degree of transparency changed every day, the minimum showing 10 meters on the morning of the 9th. A prevailing south-east wind blew continuously in this period. From the observations described above, it is conceivable that a good haul of the trout was realized under the conditions which caused a strong and continuous inflow of the ocean current into the bay accompanying with the wind from a suitable direction by which both confusion of the wave and depression of the transparency were

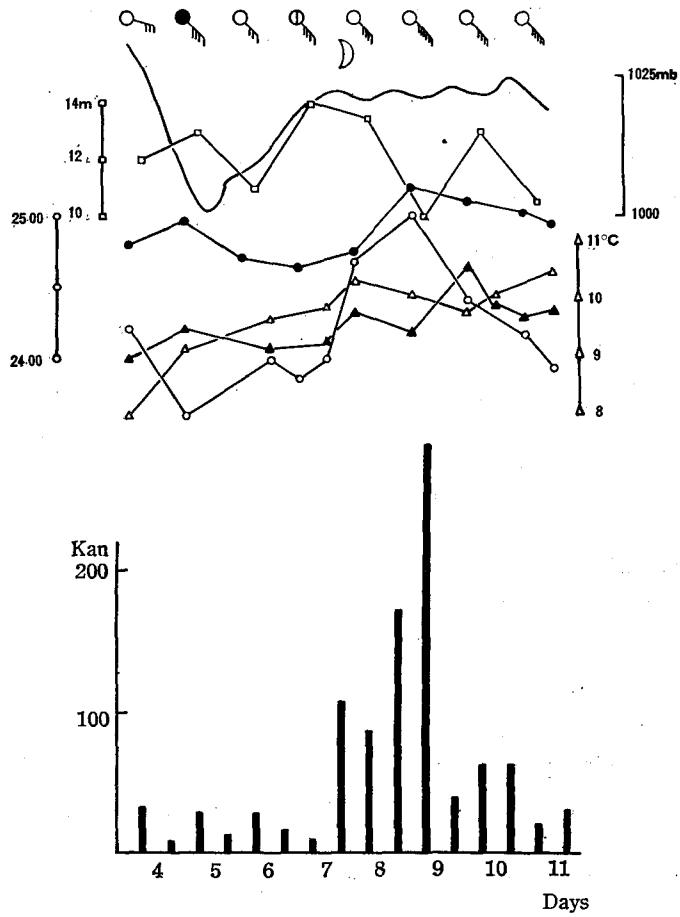

Fig. 8. Correlation between some environmental factors and the daily catch of the trout at the shore set-net fishing ground, early in May 1957
(Amount of the catch is given by "Kan" ; 4 Kan=15 kg)
□ : Degree of transparency ——— : Atmospheric pressure
○ : Specific gravity of the upper layer ● : Specific gravity at the depth of 15 meters △ : Water temperature of the upper layer ▲ : Water temperature at the depth of 15 meters

induced around the fishing ground. Although such a supposition may be made concerning the trout fishery, it must be reconsidered that fish behaviour does not depend on a single environmental factor, but, rather, on a coaction which results from many factors.

Except the study on the yellow-tail fishery by making use of the sounder,[11] no experiment has yet been done on the problem at what time fish enter into the set-net. Using a fish-detector, the time-relative abundance of the squid was examined at the entrance of the set-net (cf. Fig. 3, E) as a preliminary study. Although the absolute number could not be counted, a relative tendency of the passing squid population was estimated approximately. The observations were made three times in July, 1957, the detector running continuously from evening to early morning. The time-relative abundance calculated from the marks which were recorded at every ten-minute interval is illustrated in Fig. 9. The results show that the passing squids are much more abundant during the hours from about 20 to 24 than at any other intervals. In addition to such a diurnal behaviour pattern, it was clearly observed that the squids move upwards in the sea in the period of the active migration.

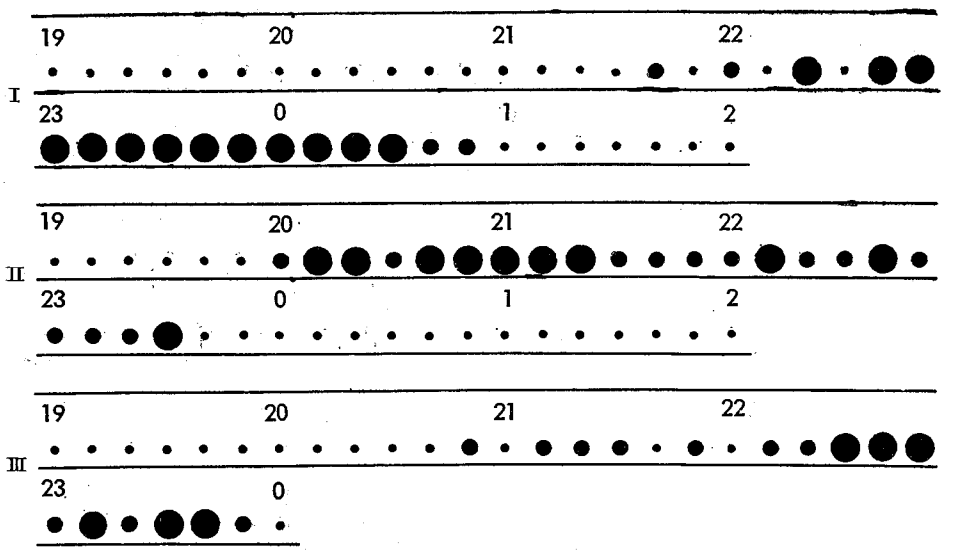

Fig. 9. Time-relative abundance of the passing squids at every ten minutes
● : Abundant • : Moderate · : Poor

SUMMARY

1. The correlation between the meteorological factors and the quantity of the haul was examined from a successional view point, on the basis of the catches of species of fish, trout, calamary, squid and sardine, which were caught at a set-net fishing ground near Hakodate, Hokkaido.

2. The trout haul tends to increase for a few days after the low pressure passed the set-net fishing ground. The changes of some physical factors around the ground in such a good-haul time are briefly discussed.

3. The haul of squid increases for a few days before and after the atmospheric depression hit the fishing ground.

4. The period of the first take as well as the increasing period of the catch in each species was commonly found to come earlier at the off-net than at the shore-net.

5. Almost all of the quantities of both calamary and squid were landed in the morning haul.

6. Using a fish-detector, it was clarified that most of the squids migrate into the net during the hours from about 20 to 24.

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