ON THE JAPANESE BLACK TUNA (Thunnus orientalis)

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Explanatory Note

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Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

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ON THE JAPANESE BLACK TUNA (THUNNUS ORIENTALIS)

Translated from the Japanese language by

W. G. Van Campen
Pacific Oceanic Fishery Investigations

CONTENTS

1/ From the Bulletin of the Japanese Society of Scientific Fisheries, Volume 4, Number 1. May 1935.

2/ (Hokkaidō Fisheries Experiment Station. Fukui Prefecture Fisheries Experiment Station) From Bull. Jap. Soc. Sci. Fish., Vol. 6, No. 2, pp. 73-74. July 1937.

3/ From Bulletin of the Japanese Society for Scientific Fisheries, Vol. 8, No. 6, pp. 292-294. March, 1940.

On the Estimation of Favorable Temperature for Long-Line Fishing of Tunny

[English synopsis] Owing to the lack of observations both of the accurate depth d and of temperature θ of the layer in which tunnies off the Pacific coasts of Japan are angled with long-lines, the catch has customarily been discussed, reference being made only to the surface temperature θ_0.

From July to Dec. 1930, off the North-eastern Japan, and from Dec. 1930 to March 1931, off south to Bosyû, several fishery research boats carried out the said observations for the tunny, including Thunnus thunnus L., Thunnus alalunga (Gmelin), Parathunnus sibi (T. & S.), and Germo macropterus (T. & S.). Their reports enabled the writer to examine the difference between the distributions of total catch N as well as of the frequency of catch f, referred to the temperature θ and those referred to θ_0.

Off the North-eastern Japan, both N and f show the mode at 19-20°C of θ_0, while at 18-19°C of θ (Fig.1). Evidently the difference is due to the remarkable stratification of the water during summer time. No definite explanation can be given to the appearance of a secondary mode at 13-15° of θ. Off south to Bosyû, both the mode of f at 19-20°C and of n (= N/f) at 17-19°C are not changed in θ and θ_0, showing that the stratification in temperature is but slight during winter (Fig.2).

Estimation, if not very accurate, of θ without direct observation can yet be made by calculating preliminarily the value of $\theta_0 - \theta$ from other serial observations of temperature for each region and for each month, provided d is known. From the records of θ_0, submitted by a fishing company "Tôkai-Enyô Kabushiki Kaisha," for Thunnus alalunga (Gmelin) off south to Bosyû in 1930, θ was calculated in such a way as just stated, with the result that the mode of N lies at about 18°C, d having been taken as 50-100m or 100m (Fig.3 a). Remarkably enough, the variation of N in θ is much smaller than that in θ_0. A mode at the same temperature is seen in the frequency distribution of θ, at which the catch was maximum in every month (Fig. 3 b). Some other records were also treated similarly and again the mode of N at 18°C was obtained. [end of English synopsis]

In discussing favorable temperatures for the capture of fishes such as the tuna and mackerel, which swim in the middle layers, we should seek to find out the temperature of the water at the depths where the fish swim[1]. Hitherto, however, it has not been clear in many cases at what depth the fish were swimming and few observations have been made of anything but surface water temperatures so all that could be said was that tuna are taken most frequently and in the greatest numbers where the surface

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1) Aikawa, Hiroaki: Situation in the Fisheries for Tuna, Skipjack, and Saury on the Pacific Coast, Suisan Gakkai Ho, Vol.5, No.4, pp.364-365, draws attention to this.

water temperature is around 21°C [2),3)]. During the winter season in January, February, and March the different depths (at least down to 50m) have nearly the same temperature and the difference between the temperature at the level where the fish are taken and that at the surface is slight, but through the spring and summer in May, June, and July the water temperatures in the upper layer rise rapidly from month to month and their difference from the temperatures of the lower levels increases. As stratification becomes distinct, the water temperatures at the depth where the fish are caught and at the surface must become markedly different. The difference in temperatures is still fairly great in November, but in December it decreases rapidly and the two levels become almost homothermal. The object of the author in this paper has been to show the degree of error in the estimation of favorable temperatures for fishing based on such surface observations, the favorable fishing temperatures corresponding to the depths actually fished, and a method of estimating at will the approximate temperature of the middle layer when only surface observations have been taken.

Depths at which tuna longlines catch fish. A scanning of Table 1, based on data [5)] from the Chiba Prefecture Fisheries Experiment Station, reveals that the estimated positions of the hooks lie within a range of 30m at the shallowest to 170m at the deepest, with most of them within the range of 50-100m. In northern waters some hooks fish at the comparatively shallow depths of 50-70m (as a matter of fact, in the coastal waters of Hokkaidō and the southern Kuriles many tuna leap on the surface and drift nets and trolling lines are much used [6)], while the farther south one goes the deeper are the levels at which fish are taken. Off Kōchi and Miyazaki prefectures they are at the comparatively deep levels of 80-170m [7)].)

It appears also that the depth at which fish are taken varies from month to month within the same sea area. For example, the season of the

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2) Takayama, Itarō and Seiji Andō: An Observation on the Tuna Fishing Situation in 1930. Fisheries Experiment Station Report No.5(38) 1934.
3) Shizuoka Prefecture Fisheries Experiment Station: "On the Albacore" (Study of 1931 on the data of the three years 1929, 1930, and 1931.) also states that fish are caught most frequently at 21°C, thus differing greatly from the figure of 18°C published by the late Dr. Kishinouye 4).
4) Kishinouye, K.: Contributions to the comparative study of the so-called scombroid fishes. Jour. Coll. Agricul. Imp. Univ. Tokyo, 8(3), 293-475.
5) Chiba Prefecture Fisheries Experiment Station Report (photostat) "Longlines Used by the Most Successful Fishing Vessels in Each Prefecture in 1932."
6) Kawana, Takeshi: The Tuna Fishing Situation and Oceanographical Conditions in Hokkaidō. Hokkaidō Fisheries Experiment Station, Fisheries Survey Reports. Vol. 31, 1934.
7) Marukawa, Hisatoshi: "Developing the Sea" p. 165 says that this is because the thermocline is deeper than it is in the south.

fishery for black tuna [*Thunnus orientalis*] in the coastal waters of Hyūga begins in the middle of December. At first longlines are used (fishing depth 76-150m) and the fish are taken where the surface temperature is 22°C, but in the middle of January a change is made to trolling gear and the surface temperatures are 18°-19°C. Early in March the fish go deep, the trolling lines no longer catch fish, and longlines come into use again with the surface temperature at 21.5°C. In the middle of April the fishing comes to an end [8]. There has not been as yet, however, any thorough study of the depths at which the fish are taken, and many items have not been clarified.

Favorable temperatures for catching tuna (a) Northern part of the Northeastern Sea Area. I shall attempt to treat the data from the Sakigake Maru, of Aomori Prefecture, the Daitō Maru, of Miyagi Prefecture, the Akita Maru, of Akita Prefecture, and the Chōkai Maru, of Yamagata Prefecture, all of which vessels took temperatures at the upper and lower levels during the cooperative tuna fishing experiments of 1930. These observations were made from June to December, 1930, a season when the difference between the temperatures at the upper and lower levels is great, and covered an area centering off Erimosaki and extending between 141° - 144°E, 37°- 42°N. First of all, Fig.1 a), b) are graphs of the distribution of catches and numbers of fish caught (total of black tuna, albacore, big-eyed tuna, and yellowfin) plotted against surface water temperatures and against the temperature of the level at which the fish were taken according to the above-mentioned fishing logs (30m for the Daitō Maru, 18-36m for the Akita Maru, 46-53m for the Chōkai Maru, records lacking for the Sakigake Maru but assumed from Table 1 to be 50m). From these graphs it can be seen that in these waters the most fish were taken where the surface temperature was 19°-20°C but at the 25-50m levels, where the fish were caught, there are two modes at 13°-15°C and 18°-19°C. It is still difficult to tell for sure whether the former is an apparently favorable temperature based on schools especially concentrated by an upwelling of cold water from the lower level of the Oyashio Current system or whether it is the temperature at which black tuna of a certain age-class swim. However, the fact that in the coastal waters of Izu and Sagami the large set nets take the most black tuna at temperatures of 14°-15°C presents useful data for the future consideration of this question.

b) Favorable temperatures on the winter grounds in Zunan waters. Fig. 2 a), b) shows the relationship between the number of tuna taken and the number of catches made and the water temperatures at the surface and at 100m (according to Table 1 100m is approximately the level at which the fish were caught, except that the Kiyō Maru fished at 70m), the data being drawn from the records of the Kiyō Maru, Kaikō Maru, Fuji Maru, and Kōhō Maru's operations during the winter months of December, January, February, and March, when the temperatures at the upper and lower levels are considered to be comparatively uniform, in the cooperative tuna fishing

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8) Summary of the Activities of the Miyazaki Prefecture Fisheries Experiment Station for 1931. 1933. pp. 10-18.

experiments of 1930. It was found from these graphs that during the winter season the most fish are taken when the temperatures at both the surface and at 100m are 18°-19°C, the greatest number of catches is made at 19°-20°C, and the largest average catch per time fished is obtained at 17°-19°C. A point to be noted here, however, is that in the Zunan area the yearly average temperature at the 100m level is about 20°C and the yearly average variation is about 9°C, these values being smaller than the yearly average of 22°C and the yearly variation of 13°C in the surface temperatures. These temperatures are higher than those found in the waters north of Kinkazan (yearly average below 10°, yearly variation 10°-12° C) and the yearly variation is less[9]. Accordingly, the belief that the level of favorable temperatures is limited to a narrow range is not an error resulting from concentration on the 100m level as can be seen from the fact that there are rather large seasonal variations in the water temperatures at 100m.

An experiment in correcting the surface water temperature to the temperature favorable for catching fish. The data are drawn from charts submitted to the Fisheries Experiment Station by the Tōkai Enyō Co. showing the fishing grounds, number of fish taken, and surface temperatures for the albacore catches for each month. Seeking to find the distribution of the catch in relation to the surface temperature a mode was obtained at about 20°C, however, it is thought that there will be a marked variation during the season when the temperatures become stratified, as described above.[10] These data cover only surface temperatures, and observations for the middle and lower levels are lacking. According to Table 1 the depth at which fish are taken in the Zunan area may be thought to be 50-100m or 100m. In converting the surface temperature to the temperature at the fishing level the most reasonable method is probably to correct it by using the results of vertical observations on the fishing ground in question for the month under consideration, but this is difficult under present conditions. While it is a method greatly lacking in precision, what has been done has been to adopt the average temperatures[9] for each month at a point 100 miles southeast of Nojimasaki in Chiba Prefecture as representative of the vicinity of the center of this fishing ground. From these values I have subtracted 0.5°C in January, 0°C in February, 0.5°C in March, 1°C in April, 2°C in May, 3°C in June, 5°C in July, and 1°C in December, and have taken this as the temperature at the 100m level.[11] The correlation between this temperature at 100m and the

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9) Uda, Michitaka: Monthly Oceanographic Situation of the Kuroshio and Oyashio Currents in Average Years. Fisheries Experiment Station Report No. 3. 1933. pp.100-102.

10) Uda, Michitaka: An Observation on the Albacore Fishing Situation and the Oceanographic Conditions in the Zunan Area. Report of the Symposium on Fisheries Physics, No. 27. July 1931.

11) In doing this the differences from year to year and from place to place in the curve of vertical distribution of water temperatures from 0-100m within a particular sea area for a given month were ignored and the declination in the temperatures at the surface and at the 100m level were assumed to be always equal.

distribution of the tuna catch is shown by the solid line in Fig. 3a. When this is compared with Fig. 2a, the temperatures for the time when the largest catches were made in each month are distributed around centers of remarkably uniform value, with the mode at a little over 18°C. Then taking 50-100m as the fishing level the surface temperatures were corrected to the temperatures at these depths by subtracting 0.5°C in January, 0°C in February, 0.5°C in March, 1.5°C in April, 1.5°C in May 2.5°C in June, 3.5°C in July, and 1°C in December. The distribution of the catch in relation to the temperatures obtained in this manner for the 50-100m level is shown by the broken line in Fig. 3a. Exactly as seen at 100m, the most favorable temperature is slightly over 18°C. Next, changing the point of view, I plotted the best catch for each month against the water temperatures during 11 months covered by two fishing seasons from March 1929 to May 1930 as shown in Fig. 3b, obtaining exactly the same results as in Fig. 3a. Using the same method I converted the surface temperatures for the catches in the three-year survey carried out by the Shizuoka Prefecture Fisheries Experiment Station in 1929, 1930, and 1931[3] and plotted them against the catch; the mode remained almost fixed at a little over 18°C throughout the season.

If we look at the monthly tuna fishing situation as given in Takayama and Ando[2] we see that catches at 18°-19°C have been most numerous in January, February, March, April, the first half of May, the latter half of November, and in December, but in May, June, and July, months when a good deal of fish is taken, (the main fishing grounds being the central and southern portions of the Northeastern Sea Area) it is understood that because of the rise in temperature of the surface waters the favorable fishing temperatures seen at the surface are apparent rather than real.

Conclusion. Suitable temperatures for catching tuna, which in the past have been thought to cover a remarkably broad range judging only by the surface temperatures, are restricted to an unexpectedly narrow range when the depth at which the fish are caught is taken into account or when a correction is made for seasonal rises in the surface temperature. The studies described above indicate that it is probably correct to consider that in the southern part of the Northeastern Area and in the Zunan Area the favorable temperature for tuna fishing is generally 18°-19°C.[12] There are, however, not a few examples of catches being made at rather remarkably low temperatures in the Oyashio current area and sometimes at remarkably high temperatures in the Satsunan and Ogasawara areas so these areas are excluded from consideration here. This paper, in brief, is intended to point out that in discussing the favorable temperature in any sea area one should first of all take into account the temperatures at the depths at which fish are actually being taken. This means that in scouting for tuna fishing grounds in general it is not sufficient to take only surface observations (although this is fairly satisfactory in the winter) and observations of the middle layers are necessary. In case only surface observations can be made it is best to calculate an approximation by making

12) An attempt using similar methods to ascertain the favorable temperatures for mackerel catches in the Japan Sea revealed that they were centered around approximately 14°-16°C.

Table 1 Tuna longlines used by the most successful fishing boats in each prefecture in 1932 (Chiba Prefecture Fisheries Experiment Station)

Prefecture	Vessel	Fishing Area	Fishing Period	Branch Line + Sekiyama + Wire
Hokkaidō	Taihei Maru	off Etorofu - off Iwate	August-December	16 ken* (5 shaku)**
Aomori	Fukuei Maru	off Aomori-Hokkaidō	July-December	18
	Genei Maru	off Aomori and Hokkaidō	August-December	17
Miyagi	Kanan Maru	east of Kinkazan - off the Zunan Shotō	November-March	18
Chiba	Fusa Maru	off the Bōsō area	November-March	10
Kanagawa	Kanshirō Maru	300-400 miles east of Chōshi	October-April	11
Shizuoka	Tōyō Maru	off Chōshi and Sanriku	October-March	17
Mie	Juju Maru	off Chiba Prefecture	November-March	12
Wakayama	Hōrai Maru	off the Bōsō area	September-May	14.5
Ehime	Jingū Maru	off Kagoshima-Aomori	October-March	49
Miyazaki	No.2 Taishō Maru	200-250 miles south of Aburatsu	December-March	40
Kōchi	Daikoku Maru	31°40' 132°10' - 134°20'	March-May	32
Ogasawara	Iwō Maru	Ogasawara waters	November-late January	11

* 1 ken = 1.82 metres

** 1 shaku = 30.3 cm

Table 1 (Cont'd)

Float Line	Distance Between Floats (Maximum sag)	Hook Depth (depth at which fish are caught)
17 <u>ken</u>	150 <u>ken</u> (13)	50-70m
15	300 (13)	50-70m
15	300 (21)	48-80m
25	220 (70)	65-171m
12	180 (28)	33-76m
22	200 (63)	50-150m
13	158 (24)	45-82m
24	330 (50)	55-130m
20-25	200 (63)	53-148m
19	240 (38)	77-135m
15-20	300 (42)	97-170m
23	200 (31)	95-143m
9	242 (19)	30-59m

a correction by methods like those described above Of course in doing this one must have in advance a general idea of the depth at which the fish are caught (the level at which the fish swim). Some studies have already been made of the environmental factors which affect the density, concentration, and biting qualities of the tuna schools within the zones of suitable temperature, but there are still many points left for future study. 13)14)15).

In conclusion I express my deep thanks to Dr. Nobuyoshi Ogura, Dr. Morisaburō Tauchi, Mr. Mitsuyo Okada, Mr. Itarō Takayama, Mr. Kinosuke Kimura, and Mr. Morisaburō Sakai, who gave me valuable instruction and comments on this study.

(December 9, 1934)

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13) Shimoda, Mokuichi: A Survey of the Skipjack and Tuna Fisheries in the waters of British Borneo and the Netherlands East Indies. Suisei, April 1930.

14) Ikeda, Nobuya: On Oceanographic Conditions on the Tuna Longlining Grounds and the Level at Which the Tuna Swim in the Outer South Seas. Gyorōkai Shi, No. 1. 1932.

15) Sūzuki, Shin: Tsuri Hyakutai, Chapter 4. February 1931.

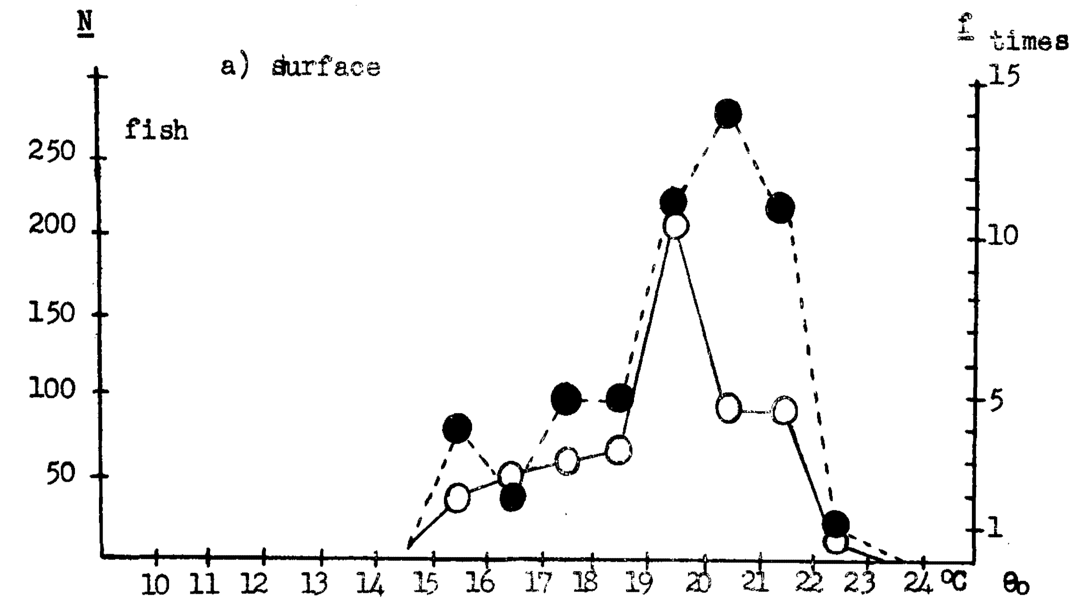

Fig.1a Distribution of number of catches (f) and number of fish caught (N) in relation to surface temperatures (θ_0) on the tuna fishing grounds of the Northeastern Area from June to December, 1930.

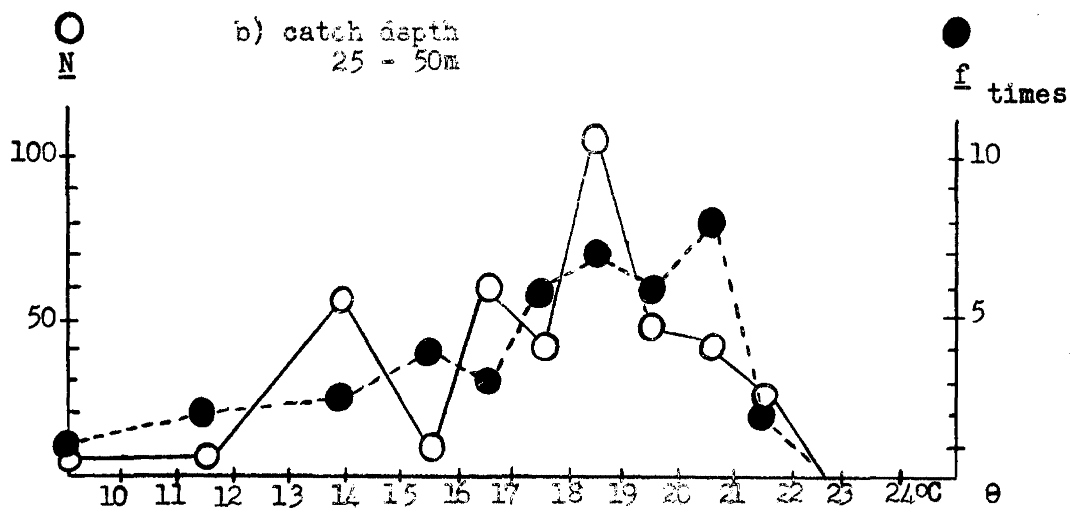

Fig.1b Distribution of number of catches (f) and number of tuna caught (N) in relation to temperatures (θ) at the depths at which fish were taken (25-50m) on the tuna fishing grounds of the Northeastern Area from June to December, 1930.

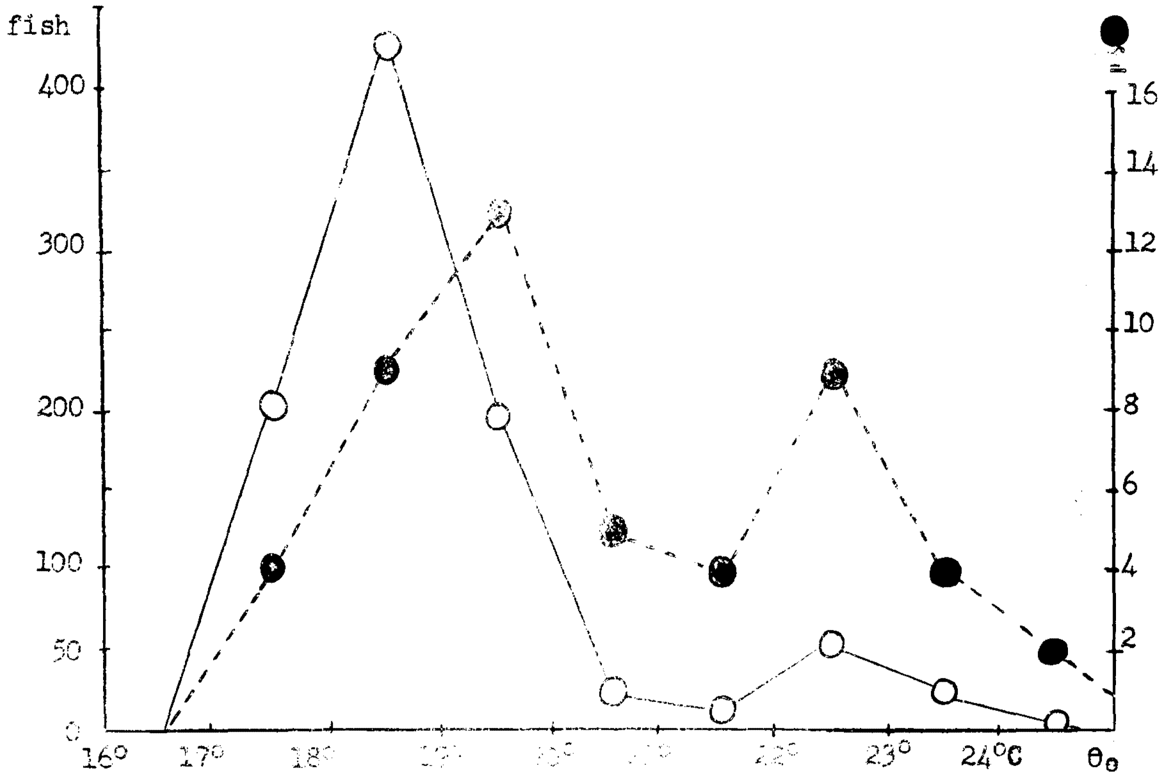

Fig.2a Distribution of the average number of fish per catch (n) and the number of catches of tuna (f) in relation to the surface temperature (θ_o) on the tuna grounds south of Boshu in December, 1930, and January, February, and March, 1931.

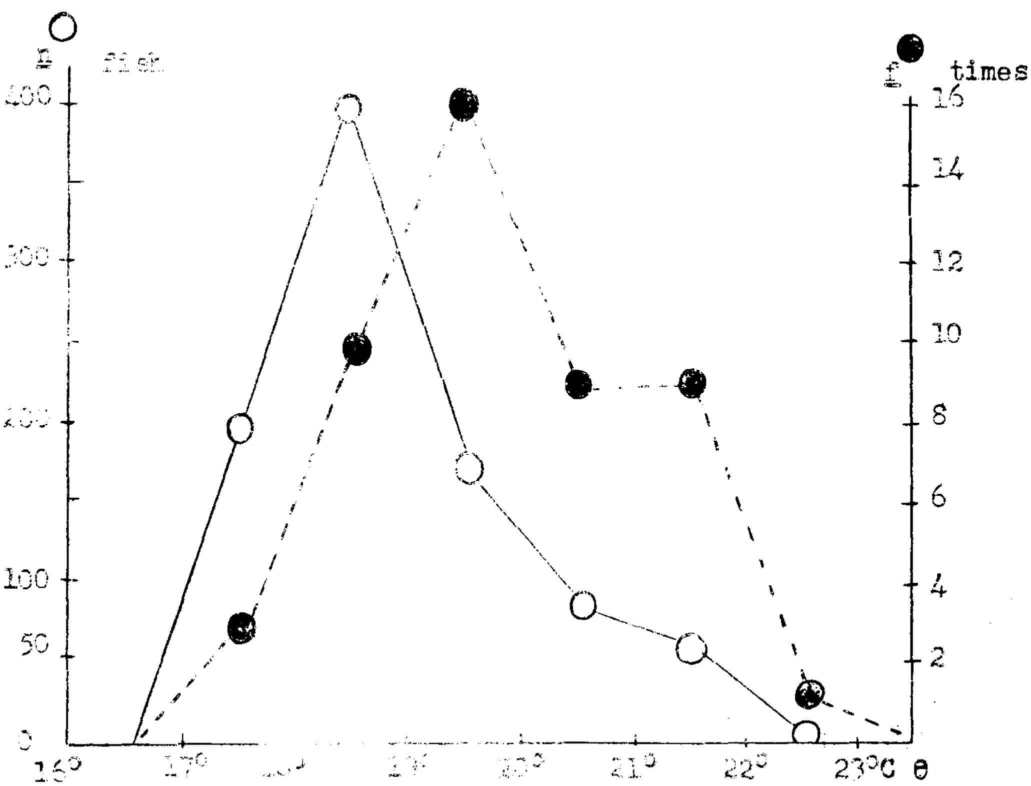

Fig.2b Distribution of the average number of fish per catch (n) and the number of catches of tuna (f) in relation to the temperatures at the 100m level (θ) on the tuna grounds south of Boshu in December, 1930, and January, February, and March, 1931.

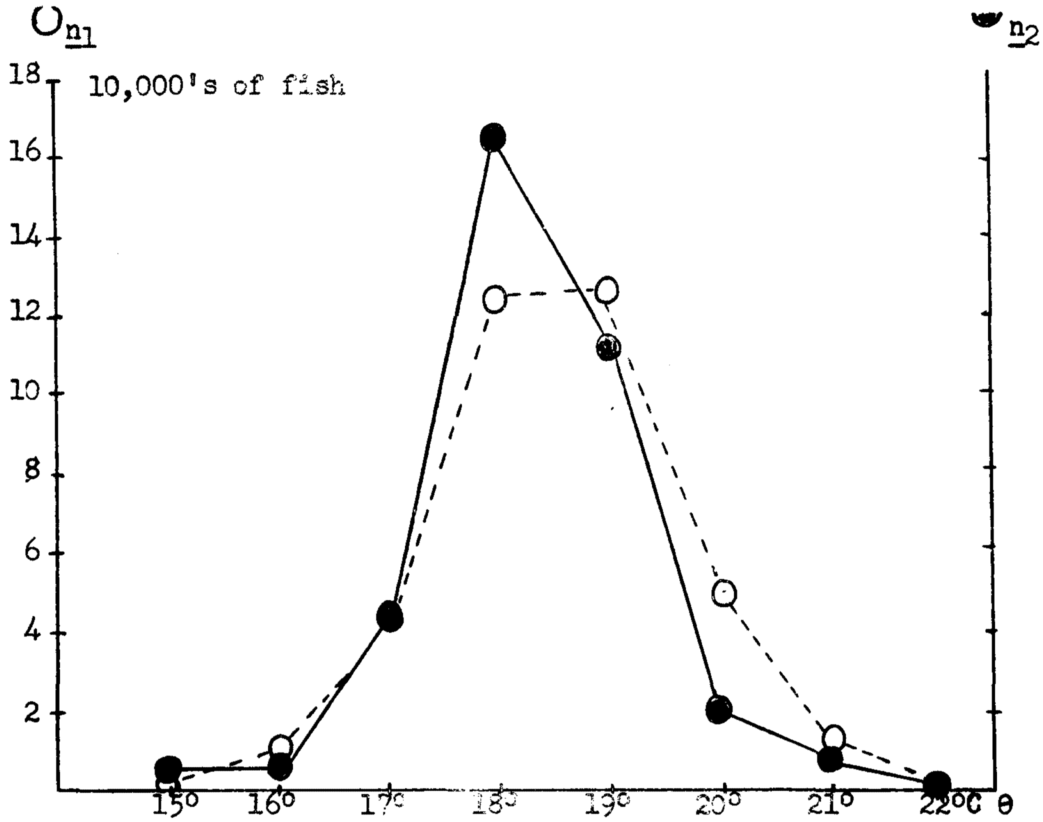

Fig.3a Favorable temperatures for catching albacore in the Zunan Area in 1930. θ = water temperature n1 = number of fish caught in relation to temperature at 50-100m n2 = number of fish caught in relation to temperature at 100m

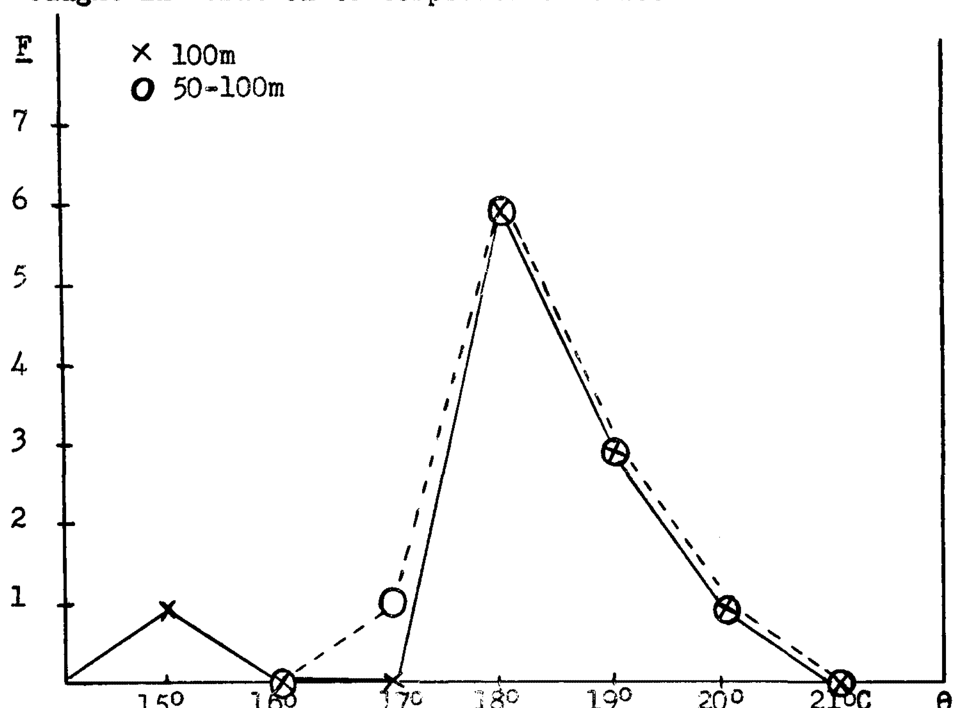

Fig.3b Frequency (F) distribution of surface temperatures at the time of the largest albacore catch of each month of 1929 and 1930 in the Zunan Area. θ = water temperature x = F in relation to temperature at 100m O = F in relation to the temperature at 50-100m

The Catch of Tunny, Thunnus Orientalis (T. & S.), off Kushiro, Hokkaidō, in Relation to the Vertical Difference in Water Temperature

Synopsis (in English)

From the thirteen years catch statistics from 1924 to '36 and the records of regular oceanographic observations, there is found a negative correlation between the catch per boat of large tunny, weighing above 20 kwan (75 kg), and the difference in temperature at the surface and at 50 m depth.

[end of English synopsis]

The author has previously[1] investigated the relationship between oceanographic conditions and the fishing for tuna [2] off Kushiro in Hokkaidō, and has found that there is a negative correlation between the weight of fish caught per boat per cruise and the vertical difference in water temperature [3]. Since that time four years' more data have been added (Table 1), and it has been decided to make a reexamination of the problem here.

Now when we consider the correlation between the number of large, medium,[4] and small fish, which were not treated in the previous report, and the vertical difference in water temperature (Figure 1), there is a close correlation for the large fish, but for the medium and small fish there is hardly any.[5] According to Table 1 the large (and medium also) clearly tend to decrease. This should be considered a diminution in the

(1) Kawana, Takeshi: On the Correlation Between Tuna Fishing and Oceanographic Conditions, Hokkaidō Fisheries Experiment Station, Reports of Fisheries Investigations (31) 1934, pp.80.

(2) black tuna, kuroshibi, Thunnus orientalis (Temminck & Schlegel).

(3) The difference between the surface temperature and the temperature at 50 meters. Average for 10 - 50 miles off Kushiro. August.

(4) Large fish are over 20 kan [1 kan = 8.27 pounds], medium between 10 and 20 kan, and small under 10 kan.

(5) The coefficient of the correlation between the number of large fish and the difference in water temperatures is $r = 0.41 \pm 0.18$. The coefficient for the total of weight in kan of large, medium, and small fish taken per cruise and the difference in water temperature is $r = 0.582 \pm 0.123$, so if instead of the number of large fish we take the number of kan or take only the especially large fish among the large group, it is thought that we can obtain a far higher coefficient of correlation. However, we do not know the number of kan weight for each of the groups of large, small, and medium fish.

stock of large tuna, and in addition to this trend [6] one should probably discuss the elimination of this long-term change by the year-to-year variations due to oceanographic conditions and so forth.

This tendency can be shown approximately by the linear correlation $y = ax + b$ between the number of fish taken per boat per cruise y and the year x. By the method of least squares we get $a = 0.313$ and $b = 6.365$ and can draw the solid line shown in Figure 2.

The coefficient of correlation between the vertical difference in water temperatures and the deviation from this regression line is $r = -0.738 \pm 0.085$, and fairly reliable values can be obtained.

Furthermore, the catch of small fish per cruise is correlated with the surface water temperature in August, 15.0 - 16.5°C appearing to be the favorable temperatures (Figure 3). [7]

In preparing this paper I received much kind advice from Professor Okada of the Fisheries Experiment Station, and Assistant Technician Nakajima of the Hokkaido Fisheries Experiment Station and Mr. Hisashi Saga of the Kushiro Fish Market supplied me with materials. I wish to express here my deep thanks to these persons.

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(6) This trend also appears to be related to the broadened scope of the fishing grounds through the increase in vessels fishing, but there are no data on which to determine this point.

(7) According to the study by Mr. Takeo Kida of the total number of fish (large, medium, and small) taken per cruise on the grounds off Kushiro in August 1935, there is a favorable surface temperature at 17°C. Kida, Takeo: On the Surface Water Temperatures and the Summer Season Tuna Grounds Off Kushiro and Urakawa. Bull. Jap. Soc. Sci. Fish. 5 (2), 1936, 85-90.

Table 1 Number of Fish Taken and Average Water Temperature 10-50 Miles South of Kushiro in August

Year	Number of Trips	Number of Fish Caught			Number of Fish Taken Per Trip			Water Temperature		Temperature Difference
		Large	Medium	Small	Large	Medium	Small	Surface	50 m	
1924	1,474	5,777	—	2,018	3.9	—	1.4	17.6°C	5.2°C	12.4°C
1925	1,882	11,339	4,057	9,015	6.0	2.2	4.8	17.1	6.2	10.9
1926	2,722	27,119	7,123	603	10.0	2.6	0.2	12.2	5.4	6.8
1927	5,361	23,852	17,995	16,922	4.5	3.4	3.1	18.0	2.6	15.4
1928	6,369	15,420	26,146	46,299	2.4	4.1	7.3	15.6	3.4	12.2
1929	10,804	73,474	27,576	63,158	7.0	2.6	5.9	14.6	6.8	7.8
1930	10,028	33,900	26,564	80,648	3.4	2.7	8.1	16.4	6.4	10.0
1931	11,404	29,692	34,625	117,782	2.6	3.0	10.3	15.7	5.4	10.3
1932	8,725	19,786	10,396	39,501	2.3	1.2	4.5	15.1	3.8	11.3
1933	7,167	23,305	4,664	50,801	3.3	0.7	7.0	13.7	3.5	10.2
1934	5,001	15,110	2,798	27,329	3.0	0.6	5.5	15.4	5.1	10.3
1935	5,724	15,193	10,080	13,781	2.7	1.7	2.4	13.1	3.1	10.0
1936	4,104	13,052	3,123	5,472	3.2	0.8	1.3	13.4	3.0	10.4

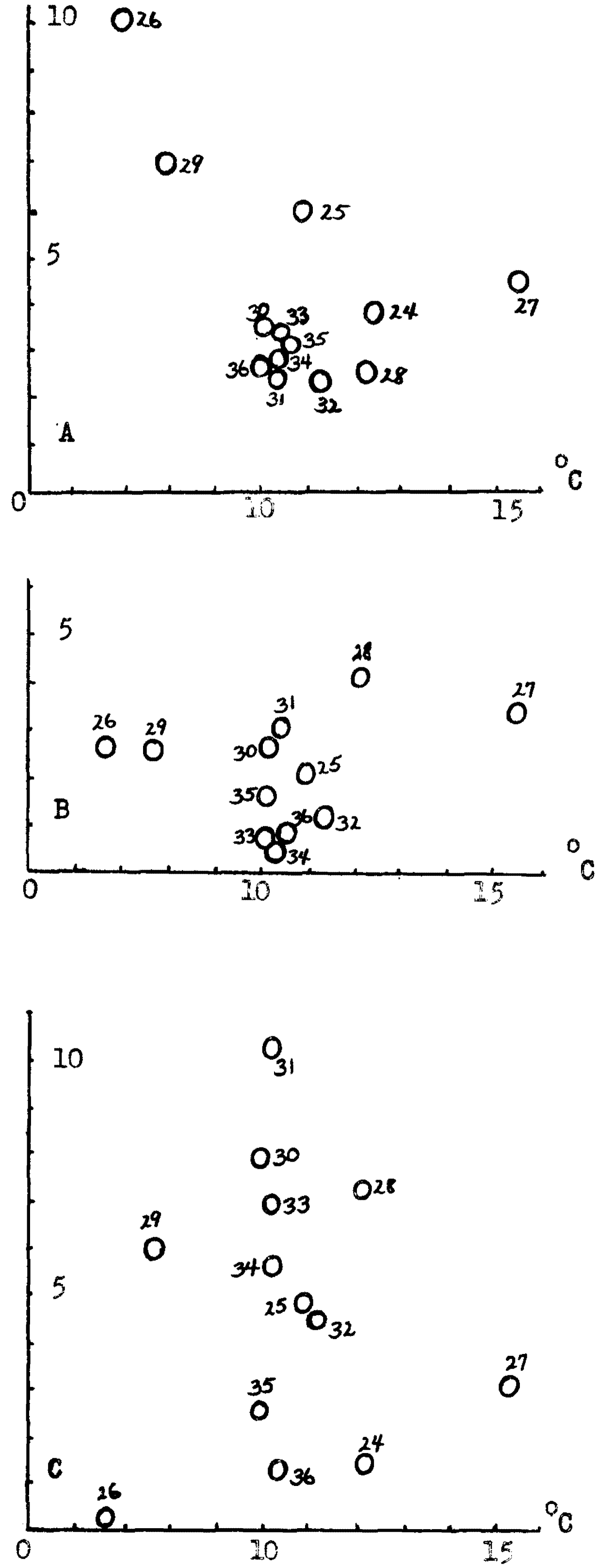


Figure 1 Correlation between the difference between the water temperatures at the surface and at 50 meters (horizontal scale) and the number of large, small, and medium-sized fish taken per cruise.

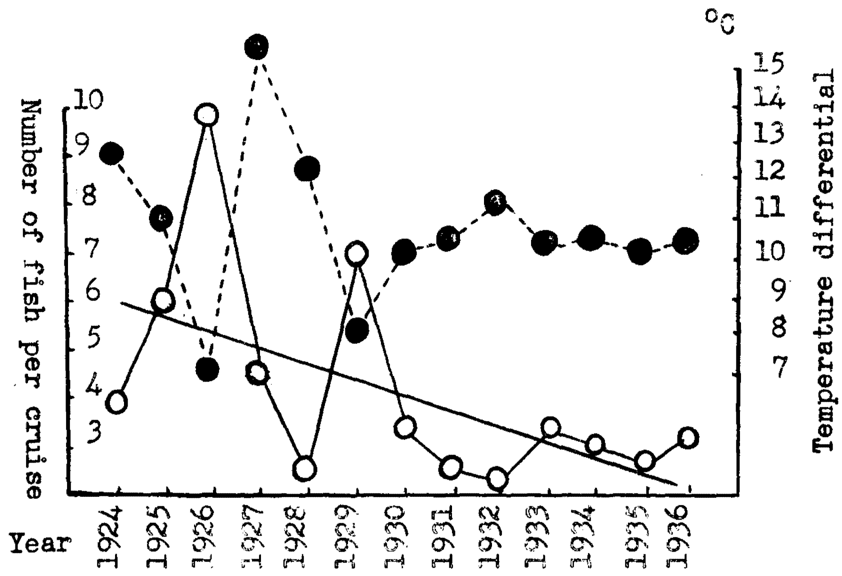


Figure 2 Vertical temperature differential and number of large tuna taken per cruise (whole season)

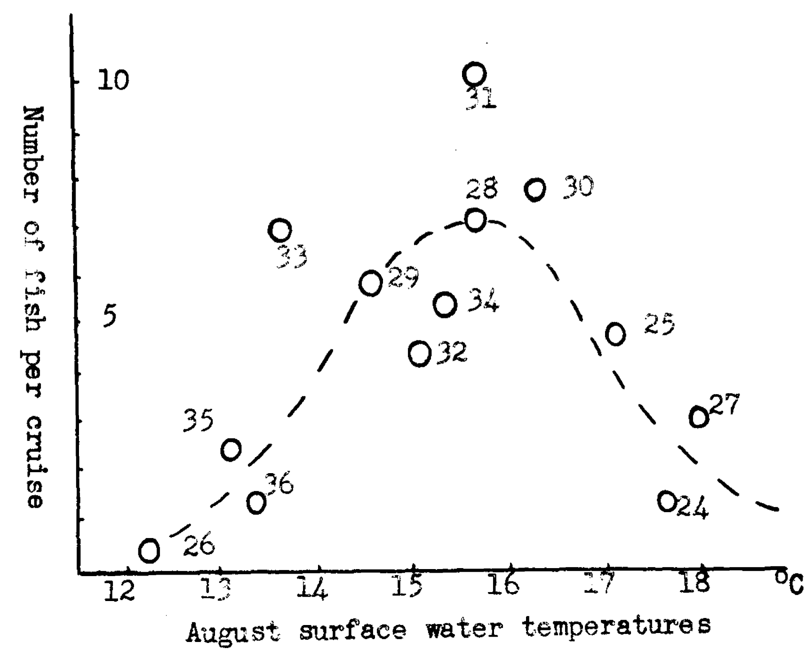


Figure 3 Number of small tuna taken per cruise (whole season) and surface water temperatures in August

[English title and synopsis]

Appearances of the Groups of Thunnus orientalis (T. & S.) in the Seas South of Kyûshû

SYNOPSIS

Average catch per boat per voyage as well as the average body-weight of Thunnus orientalis (T. & S.) fished during every decade of the months in the seas south of Kyushu was investigated with the daily records of the landings from long-line fishing-boats for tunny at the two ports Aburatu and Nangô from Dec. 1934 to June 1939, as basis.

Generally speaking, larger fishes appearing early in the fishing season gradually give place to the smaller-sized. Minor fluctuations in the average body-weight, however, can be recognized as follows: --

Season:	From mid-Dec. to early Jan.,	Early and mid-Feb.,	Mid to late March,	Late April,	Towards mid-June
Aver.weight:	ca.55 Kwan (206 kg),	ca. 45 " (169 kg),	ca. 52 " (195 kg),	ca. 40 " (150 kg)	ca.47 " (176 kg)
Hauls:	At the beginning of hauls,	With earlier good hauls,	With later good hauls,	Towards, and	At the end of hauls.

[End of English synopsis]

Hiroaki Aikawa and Masuo Katō (1) have used the vertebrae of the honmaguro, Thunnus orientalis (Temminck & Schlegel) to determine its age, have found the ranges of length and weight, the growth rate, and the condition factor for each age, and from the records of the landings at Aburatsu in 1937 they have shown that the tuna landed at Aburatsu consist mainly of three groups of eighth-year, ninth-year, and tenth-year fish. Of these eighth-year fish form 31%, ninth-year fish 49%, and tenth-year fish 20% of the whole catch. The percentage of eighth-year fish does not change markedly throughout the whole fishing season, but the ninth-year fish are most numerous in the peak season, and the tenth-year fish are rather numerous only at the beginning of the season.

The present authors have made a study of the general trends and changes throughout the fishing season in the tuna schools which migrate into the Satsunan sea area, basing the work on the records of the number of vessels returning from fishing, the number of fish landed, and the weight (in kan [8.27 pounds]) of fish landed as given in the daily reports of the tuna long-line fishing situation (a very few troll-caught fish are included) at the two ports of Aburatsu and Nangō (Sakaematsu) from December, 1934, to June, 1939.

(1) Aikawa, Hiroaki and Masuo Katō; Bull. Jap. Soc. Sci. Fish. 7(2), 1938.

The number of boats entering port, the number of fish landed, and the weight of landings, averaged by ten-day periods, (Figure 1) show that the peak season is from the middle ten days of January to the first ten days of April, and that during this period the fishing falls off somewhat from the last ten days of February to the first ten days of March. The fact that in general the fishing situation parallels the abundance or scarcity of schools on the fishing grounds can be seen from the average number of fish landed per boat per trip as plotted for each ten-day period (Figure 2, above). This means that the peak season is when the schools are plentiful, and that during the period from the last ten days of February to the first ten days of March the schools temporarily decrease in numbers. Because the number of boats fishing is very small, it is not certain, but it appears that from the middle ten days of May on the schools increase. However, if we look at the average body-weight plotted by ten-day periods (Figure 2, lower), the period from the last ten days of February to the first ten days of March represents a shift in the average body-weight from about 45 *kan* to about 52 *kan*, and the period from the last ten days of April to the middle ten days of May shows a shift of the average body-weight from about 40 to about 47 *kan*. This can still be said even though we try to split the changes in average body-weight into long-time changes throughout the season (trends) and short-term changes (deviations) (Table 1, Figure 2). Then if y is taken as the average body-weight for the ten-day period (in *kan*), and x is the ordinate of the period, with the period in which the first catch was made as the base point, the trend for Aburatsu, with the middle ten days of December as the first period, is $y = 54.29 - 0.87x$, and for Nangō, with the third ten days of December as the first period, it can be shown as $y = 49.50 - 0.32x$.

To summarize, in the black tuna which migrate into the Satsunan sea area from the middle ten days of December to the first ten days of June of the following year, the general trend is from schools of larger fish to schools of smaller fish. If, however, we examine this in further detail, we find in the early part of the season from the middle ten days of December to the first ten days of January a migration of a group of larger fish with an average weight of around 55 *kan*. In the first half of the peak season, which is centered around the first and second ten-day periods of February, there is a large group of smaller fish with an average weight of around 45 *kan*, and in the second half of the peak season, which is centered around the middle and last ten-day periods of March, there is a large group of larger fish with an average weight of around 52 *kan*. In the last ten days of April for a time there is a group of smaller fish under 40 *kan*, and after that as the end of the season approaches a group of smaller fish of about 47 *kan* again appears.

In conclusion we wish to express our heartfelt thanks to Dr. Morisaburō Tauchi, Professor in the Fisheries Institute, for taking the trouble to read the manuscript, and to the Fisheries Associations of Aburatsu and Nangō, which spared no labor in compiling the daily reports on the fishing situation.

Table 1 Average Number of Fish and Average Weight (kan) of Fish Landed Per Boat Per Trip in Each Ten-day Period

Month and Ten-day Period	Number of Fish Landed		Aburatsu			Nangō		
	Aburatsu	Nangō	Av.Weight	Trend	Deviation	Av.Weight	Trend	Deviation
Dec. II	4.52	——	56.42	54.29	2.13	——	——	——
III	3.07	3.04	54.12	53.42	0.70	53.24	49.50	3.74
Jan. I	5.23	5.27	52.14	52.55	-0.41	50.66	49.18	1.48
II	6.59	6.22	50.66	51.68	-1.02	50.08	48.86	1.22
III	9.20	10.66	49.10	50.81	-1.71	49.32	48.54	0.78
Feb. I	9.58	14.36	45.44	49.94	-4.50	45.60	48.22	-2.62
II	7.10	11.88	44.80	49.07	-4.27	44.22	47.90	-3.68
III	5.71	7.90	47.26	48.20	-0.94	46.50	47.58	-1.08
Mar. I	5.37	7.41	48.64	47.33	1.31	49.80	47.26	2.54
II	11.41	13.90	50.04	46.46	3.58	52.32	46.94	5.38
III	13.54	17.63	51.54	45.59	5.95	50.42	46.62	3.30
April I	7.93	9.41	47.42	44.72	2.70	45.86	46.30	-0.44
II	8.31	7.35	43.54	43.85	-0.31	41.34	45.95	-4.64
III	3.31	4.71	39.54	42.98	-3.44	38.62	45.66	-7.04
May I	4.02	5.05	42.46	42.11	0.35	46.96	45.34	-8.38
II	7.04	14.09	46.42	41.24	5.18	46.93	45.02	1.98
III	12.73	29.99	45.68	40.37	5.31	49.70	44.70	4.50
June I	5.61	42.00	35.03	39.50	-4.47	49.70	44.38	5.32
II	1.00	——	32.50	38.63	-6.13	——	——	——

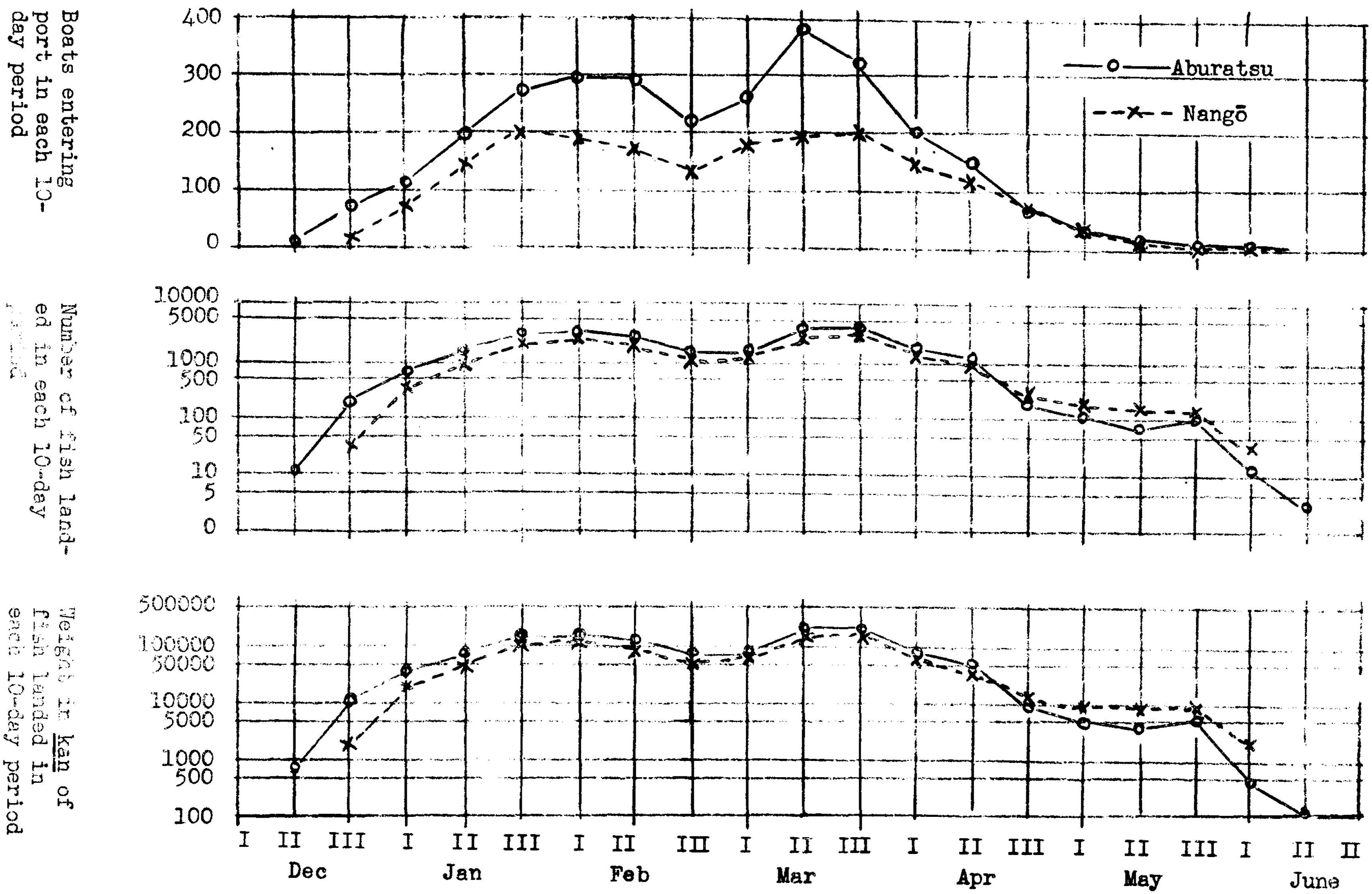


Figure 1 Five-year averages of vessels entering port (four years for Aburatsu only), numbers of fish landed, and weights of fish landed in each ten-day period.

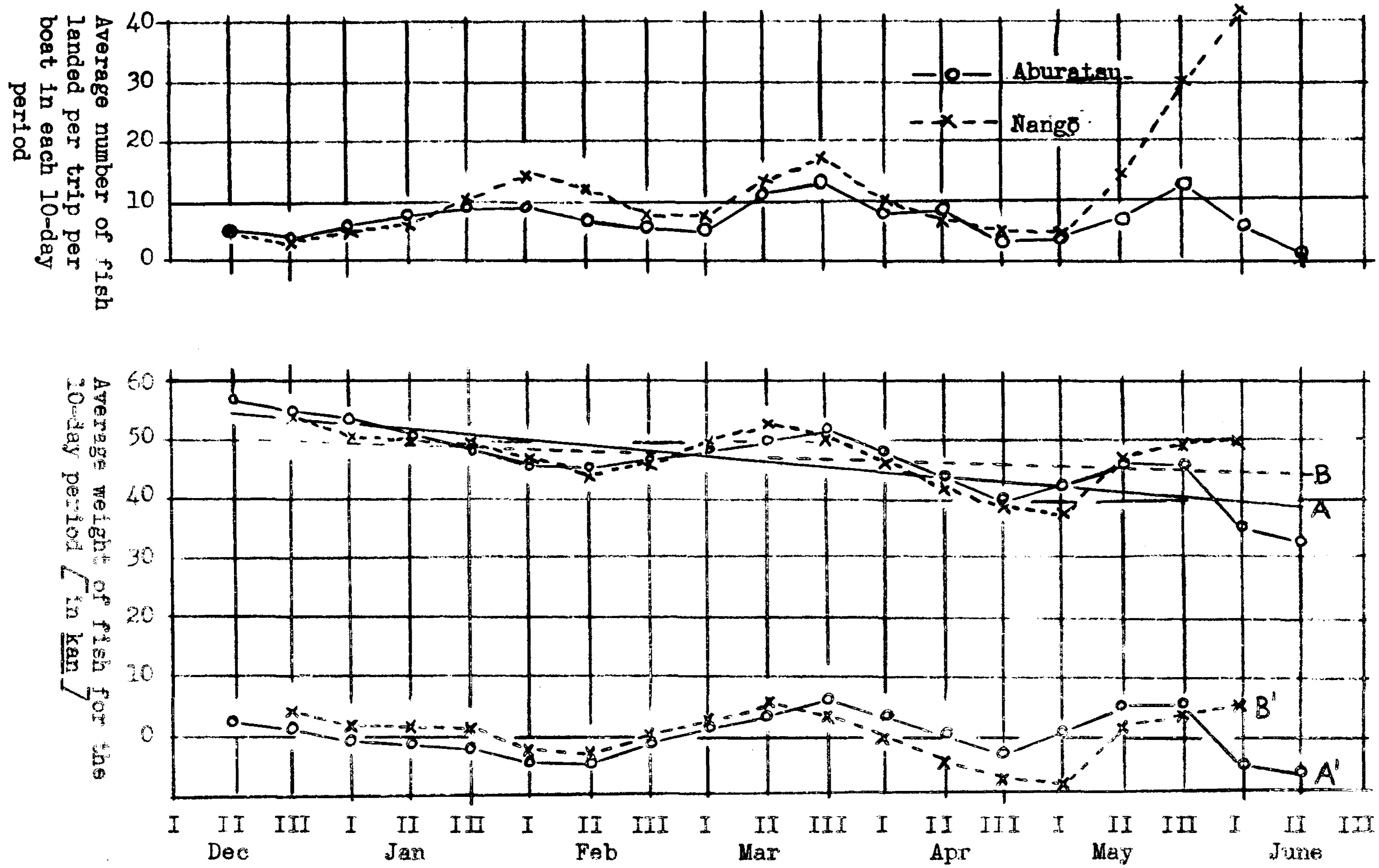
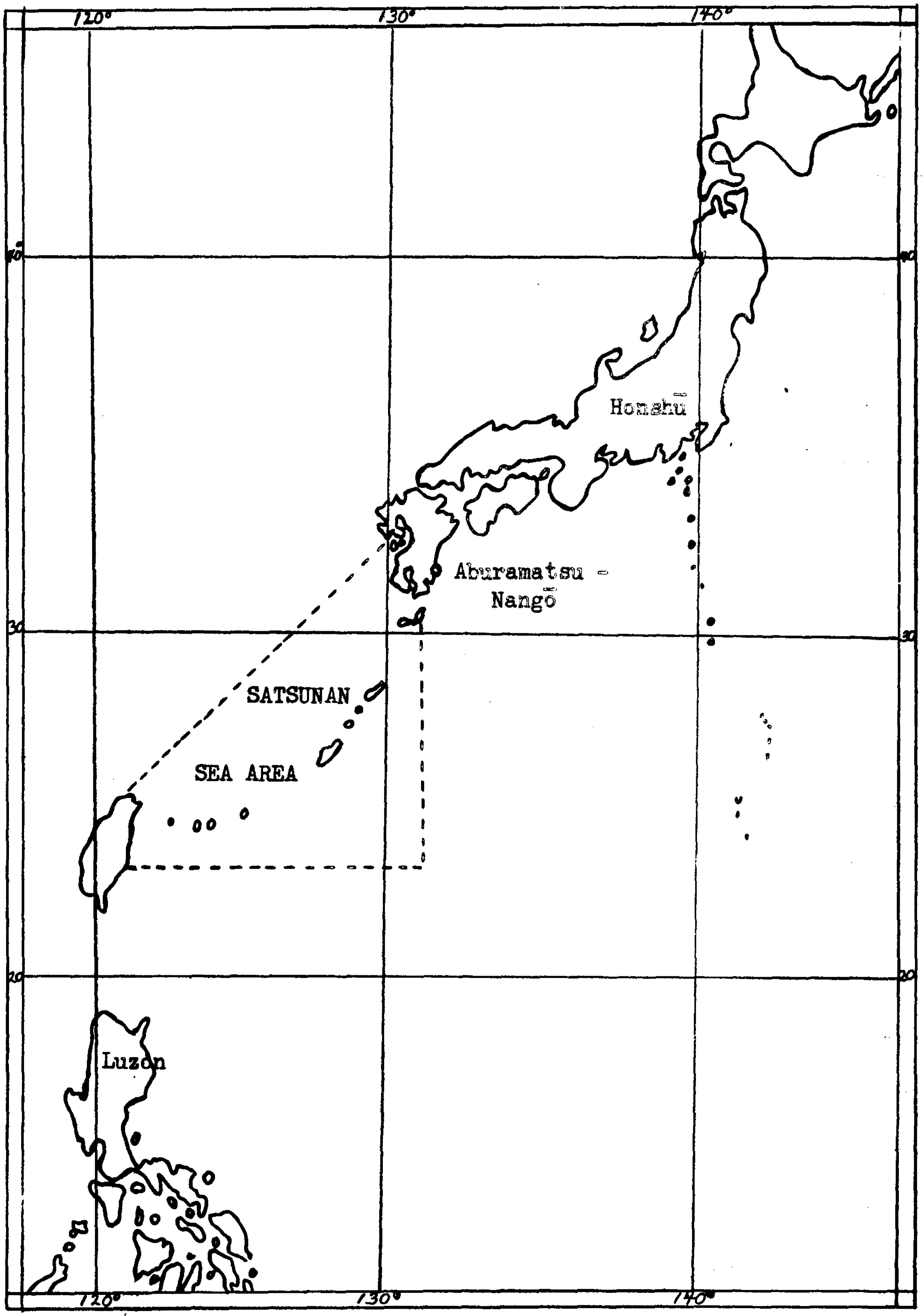


Figure 2 Five-year averages (four years for Aburatsu only) of number of fish landed per boat per trip for each ten-day period and average body weights for each period. A - B is the line of trend, A' - B' is the line of deviation. If the average body weight for the 10-day period is y and the ordinate of the 10-day period, based on the period in which the first catch was made, is x,

A: $y = 54.29 - 0.87x$ B: $y = 49.50 - 0.32x$



120°
130°
140°
40
30
20
Honshū
Aburamatsu - Nangō
SATSUNAN
SEA AREA
Luzon