THREE PAPERS ON THE STOCKS OF TUNA IN JAPANESE WATERS

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THREE PAPERS ON THE STOCKS OF TUNAS IN JAPANESE WATERS

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Pacific Oceanic Fishery Investigations

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1/ From the Bulletin of the Japanese Society of Scientific Fisheries [Nippon Suisan Gakkai Shi], Vol. 9, No. 4.

On the Stock of <u>Thunnus orientalis</u> (Temminck & Schlegel)

Synopsis in English

A study on the stock of <u>Thunnus orientalis</u> (Temminck & Schlegel), in which the catch records for each body-weight class were utilized as bases, showed that survival rate is .30 for young fish, <u>meji</u>, but .75 for the adults, while fishing rate is .55 for the youngs but .10 for the adults. [end of English synopsis]

According to Kimura(1) on the fishing grounds of Shigedera in the northeastern corner of Suruga Bay juvenile black tuna are first taken in the large set nets around July and August. At the end of that year and the beginning of the next year they are 2 - 4 kg in weight, and during the peak season in April, May, and June they weigh about 5 kg. In the spring of their third year they attain a weight of about 10 kg, and around March and April they leave the fishing grounds. Consequently fish in their third year and older may be regarded as engaged in the great migrations of the species.

Aikawa and Katō(2) have determined the ages of the black tuna from the vertebrae and have established the ages for each length-weight class. As they have pointed out, their results disagree to some extent with those obtained by Kimura(1). One point which is difficult to explain is their finding that sixth-year fish were not taken on the Shigedera grounds during the five years from 1924 to 1928. Nevertheless, in the present paper the discussion of the stock of the black tuna will be based tentatively on the findings of Aikawa and Katō.

The number of fish of each year class taken on the Shigedera grounds during the nine years from 1924 to 1932 has been calculated according to the findings of Kimura and Ishii(3). (Table 1). If we seek the survival rate from these figures, we get .74.*If, on the basis of Kawana's(4) data (Table 2), we calculate the survival rate for the periods 1922-1925 and 1926-1932, we get .70 and .66 respectively.**

According to Aikawa and Katō(2), in the landings at Numazu large fish predominate in the spring while fish of the year and second-year fish predominate in the autumn. Fish of the year, which are taken during roughly half of the year, comprise 49% of the catch, and second-year fish, which are taken the year round, make up 47%. The third-year fish, which appear for only a short time in the spring, form only 4% of the catch. If we calculate the survival rates for young fish from these data,† we get .23 for fish of the year and .34 for second-year fish. A similar calculation made by substituting age groups for length-weight groups in Aikawa and Katō's data on the landings of black tuna at Aburatsu in the spring of 1937 (Table 3) gives a survival rate of .57.

The Fisheries Experiment Station(5) reports by weight classes the number of black tuna taken by yellowtail nets and tuna nets along the coast and by pole fishing, long lines, trolling, drift nets, and harpooning in the offshore waters. A study of this data for the three years 1937, 1938, and 1939 (Table 4) gives the survival rates†† of .90 for small and medium tuna and .78 for medium and large tuna. If we assume further that the natural mortality rate is the same for all fish of the second year and older, we deduce from the ratio of adult to young fish that the fishing rate for the young is .57 and that for the adults is .060. This leaves us with a natural mortality rate of .20. Of 50 small black tuna released on the Japan Sea side of Hokkaidō in August and September, 1932, only 6 were recaptured giving a fishing rate of $\frac{6}{50}$ or .12. However, .06 is the proportion of the tuna belonging to the stock which is taken in one year while .12 is the proportion of the tuna which come in to the Japan Sea side which is taken in one year, and therefore it is hard to make any close comparison, but it is thought that both of these values are not too far off.

Because with species like the black tuna, which have a wide range of migration, the course and time of migration probably differ with age, it may happen that older fish are comparatively plentiful or scarce over a rather long period of time, and it may be difficult to learn the composition of the stock by studying the catch from a limited area. Furthermore a short-term study of the catch from a rather broad area can hardly escape being affected by year-to-year variations in oceanographical conditions. Nevertheless, since there is difference between the survival rates obtained from data from various sources, it is probably permissible to make general deductions concerning the stock on the basis of these data. It is therefore probably not too far wrong to consider that the rates of survival are on the order of .30 for young fish and .75 for adult fish, and that the catch rate is on the order of .55 for young fish and .10 for adult fish.

[notes]

(1) Kimura, Kinosuke : Growth Rates of Black Tuna and Yellowfin Tuna as Revealed in the Catch from the Shigedera Fishing Grounds. Bull. Jap. Soc. Sci. Fish., 1 (1). May 1932.

(2) Aikawa, Hiroaki and Masuo Katō : Age Determination of Fishes (Preliminary Report No.1). Bull. Jap. Soc. Sci. Fish., 7 (2). July 1938.

(3) Kimura, Kinosuke and Kazumi Ishii : Fishing Conditions in the Northeastern Part of Suruga Bay (Part 1), On the Black Tuna and its Young. Bull. Jap. Soc. Sci. Fish., 1 (5). January 1933.

(4) Kawana, Takeshi : On the Relationship Between the Tuna Fishery and Oceanographical Conditions. Report of Fisheries Investigations (31), March 1934.

(5) Fisheries Experiment Station : Appendix to Oceanographic Charts, Fixed Fisheries; Pelagic Fisheries.

*According to Aikawa and Katō's data, fish in the 40-100 kg group include $\frac{41.0 - 40.0}{41.0 - 21.6} = .05$ of the fourth-year class, all of the fifth-year class, and $\frac{100 - 73}{110 - 73} = .73$ of the sixth-year class. The fish weighing over 100 kg include $1 - .73 = .27$ of the sixth-year class and all fish of the seventh-year and older classes. Therefore if p is the rate of survival, the ratio between large and medium fish is $\frac{.27p^2 + \frac{p^3}{1-p}}{.05+p+.73p^2}$ This gives $\frac{310}{340} = .91$ and therefore $p = .655$. If we assume that there are no third-year young tuna included among the small adult tuna weighing less than 40 kg, since these fish include $1 - .05 = .95$ of

Table 1

Landings of Young and Adult Black Tuna from the Shigedera Grounds in Shizuoka Prefecture

		Total For Seven Years 1924-32
young	fish of the year	14,000 fish
	first-year fish	150,000
	second-year fish	2,600
adults	small (under 40 kg)	235
	medium (40-100 kg)	340
	large (over 100 kg)	310

Table 2

Black Tuna Catch at Kushiro in Hokkaidō

Average 1922-25	
small (under 10 kan)	4.29 thousand fish
medium (10-15 kan)	1.72
large (over 15 kan)	6.72
Average 1926-32	
small (under 10 kan)	52.80 thousand fish
medium (10-20 kan)	21.49
large (over 20 kan)	31.89

[TN: 1 kan = 8.27 lbs.]

Table 3

Tuna Landed at Aburatsu Between the Latter Part of January and the End of May, 1937

Year Class	Weight	Number of Fish
Fifth	11.0 - 19 5 kan	2½
Sixth	19.5 - 29.3	367½
Seventh	29.3 - 38.6	2,061
Eighth	38.6 - 49.4	2,380
Ninth	49.4 - 61.3	2,129
Tenth	61.3 - 80.0	948
Eleventh	80.0 -	2

$$\text{survival rate} = \frac{2{,}129 + 948 + 2}{2{,}380 + 2{,}129 + 948}$$

$$= \frac{3{,}079}{5{,}457}$$

$$= .565$$

Table 4

Catch of Black Tuna in Japanese Coastal and Offshore Waters

(Average of 1937, 1938, 1939)

Japan Sea (including Yellow Sea)			Pacific Coastal	Pacific Offshore
young	(under 3 kan)	373,163 fish	586,259 fish	885,978 fish
adults	small (3-10 kan)	5,470	1,714	89,188
	medium (10-40 kan)	10,749	737	
	large (over 40 kan)	5,781	4,232	

the fourth-year class, the ratio between small and medium fish is $\frac{.05+p+.73p^2}{.95}$. This gives $\frac{340}{235} = 1.45$ so p = .83. Averaging these figures p = .74.

**In the same way the ratio between large (over 15 kan) and medium (15-10 kan) fish is $\frac{.53p+\frac{p^2}{1-p}}{.19+.47p}$. This gives 3.9 which means that p = .70. The ratio between large (over 20 kan) and medium (20-10 kan) fish is $\frac{.95p^2+\frac{p^3}{1-p}}{.19+p+.05p^2}$ or 1.48 which gives the value p = .655.

† Fish taken in their first year are represented by f_0, those which become second-year fish by p_0, those taken in their second year by f_1, those which survive into the third year by p_1, and those taken in their third year by f_2. If the proportion of each of these year classes which is captured is related to the length of time during which the fish are present on the fishing grounds, we get $f_0:f_1:f_2 = \frac{1}{2}:1:\frac{1}{4}$. Therefore the proportions of fish of the year, second-year fish, and third-year fish which are taken are $\frac{1}{2}:p_0:\frac{1}{4}p_0p_1$. This gives 49:47:4 so $p_0 = \frac{47}{49} \times \frac{1}{2} = .48$ and $p_1 = \frac{4}{47} \times 4 = .34$. Therefore the percentage which live an additional year, that is the survival rate, is $(.48)^2 = .23$ for fish of the year and .34 for second-year fish.

††Since small adult tuna weigh 3-10 kan they include $\frac{5.75-3.0}{5.75-2.2} = .78$ of the third-year fish, and $\frac{10.0-5.75}{11.0-5.75} = .81$ of the fourth-year fish. Medium fish weigh 10-40 kan and include 1-.81 =.19 of the fourth-year class, all of the fifth-, sixth-, and seventh-year classes, and $\frac{40.0-38.6}{49.4-38.6} = .13$ of the eighth-year class. Large fish weigh over 40 kan and include 1 - .13 = .87 of the eighth-year class and all fish of the ninth-year class and older. Accordingly if p represents the survival rate then small:medium:large = $.78+.81p : .19p+p^2+p^3+p^4+.13p^5 : .87p^5+\frac{p^6}{1-p}$. In both the Japan Sea and the Pacific the ratio between medium and small fish is 1.61 so p = .90, and the ratio of large and medium is .87 so p = .78.

If the catch rate for young tuna is represented by f′ and the catch rate of adult tuna by f, and the young tuna include fish of the year, all of the second-year class, and $1 - .78 = .22$ of the third-year class while the adult tuna group includes .78 of the third-year class and all of the older year classes, then the ratio between adult tuna and young tuna is

$$\frac{f}{f'} \times \frac{.78 \times .48 \times .34 + .48 \times .34 \times \frac{.75}{1-.75}}{\frac{1}{2} + .48 + .22 \times .48 \times .34} = \frac{.62}{1.02}\frac{f}{f'} = .61\frac{f}{f'}$$

Since this gives .064 for the whole area, $\frac{f'}{f} = 9.5$. If we use δ to represent an identical natural mortality rate for all fish above the second-year class, then $(1-\delta)(1-f') = .34$, $(1-\delta)(1-f) = .75$. Accordingly $f = .060$, $f' = .57$, and $\delta = .20$.

On the Stock of the Yellowfin Tuna Neothunnus macropterus (Temminck & Schlegel)

Synopsis [in English]

Based on the catch records given for each body-length and body-weight classes, the stock of Neothunnus macropterus (Temminck et Schlegel) was studied. If the natural mortality rate is assumed to be .20, the survival rate is known to be .75 for young fish but .57 for the adults while the fishing rate to be .06 for the youngs but .29 for the adults. [end of English synopsis]

The ages deduced by Kimura[1] from the length distribution in the catch and those determined by Aikawa and Katō[2] on the basis of the circuli appearing on the vertebrae are not in agreement. In this paper I have followed the conclusions of the latter, and have studied the stock by deducing the ages of the fish from their length and weight.

According to Kimura and Ishii[3] among approximately 2,980 small yellowfin tuna and about 630 large yellowfin tuna taken on the Shigedera fishing grounds during the nine-year period from 1924 to 1932 fourth-year fish predominated among those weighing 12 kg or more followed by seventh and eighth-year fish in that order. (Table 1, calculated from Kimura's[1] graph of weight distribution). According to Aikawa and Katō's[2] table of the weights of yellowfin landed at the Numazu market in 1937, which includes 1,214 fish under 12 kg and 1,292 fish over 12 kg, fourth-year fish predominated among those weighing more than 12 kg (Table 2). However, among fish taken east of Formosa[4] on longlines sixth-year fish were most numerous followed by seventh-year fish (Table 3). Near the South Sea islands quite a few small yellowfin are taken mixed in with skipjack [5][6][7], but among those taken farther off shore sixth-year fish predominate (Table 4). In both cases the number of young yellowfin taken is small.

Collating these facts it appears that third-year fish leave the islands and bays and take up a migratory life, that fourth-year fish are comparatively

Table 1

Yellowfin Tuna Taken on the Shigedera Grounds (Juveniles Omitted)

Age	Weight	Number of Fish
3	8.6 - 14.0 kg	6.0
4	14.0 - 21.4	68.7
5	21.4 - 30.0	17.3
6	30.0 - 44.0	14.0
7	44.0 - 57.5	23.0
8	57.5 - 75.0	20.5
9	75.0 -	1.5
		total 151.0

Table 2

Yellowfin Tuna Landed at the Numazu Market in 1937

Age	Weight	Number of Fish	
0	- .40 <u>kan</u>	124.5	
1	.40 - 1.15	825.5	
2	1.15 - 2.30	163.0	
3	2.30 - 3.70	231.0	Note: 130 of the third-year fish were over 12 kg.
4	3.7 - 5.7	981.0	
5	5.7 - 8.0	70.5	
6	8.0 -11.7	43.5	
7	11.7 -15.3	50.0	
8	15.3 -20.5	17.0	
	total	2,506.0	

Table 3

Yellowfin Tuna Taken East of Taiwan

Age	Length	Number of Fish	Weight	Number of Fish
0	- 38 cm	—	- 1.5 kg	—
1	38 - 54	—	1.5 - 4.3	1
2	54 - 70	1	4.3 - 8.6	1
3	70 - 85	1	8.6 -14.0	—
4	85 - 100	1	14.0 -21.4	1
5	100 - 115	3	21.4 -30.0	3
6	115 - 130	39.5	30.0 -44.0	40.5
7	130 - 145	26	44.0 -57.5	24
8	145 - 160	1.5	57.5 -75.0	2.5
		total 73.0		total 73.0

coastal in character, that sixth-year fish are comparatively pelagic, and that in their seventh and eighth years the fish again migrate into the coastal waters. Consequently a good deal of caution is necessary in deducing the composition of the stock from the data gathered at various fishing grounds.

Since it is thought that fish in their first and second years remain close to islands and in bays, the ratio of first-year to second-year fish will probably give the survival rate for each locality. For the waters adjacent to Numazu this is $\frac{163.0}{825.5} = .198$. After they enter their third year the fish enter upon a migratory existence and there is probably no great age differential in the subsequent survival rates. However, there are differences between the ages of the fish which occur in coastal waters and those found in pelagic waters and this gives rise to differences in the age composition of the catch. The survival rate for sixth-, seventh-, and eighth-year fish is $\frac{50.0+17.0}{43.5+50.0} = .716$ for the waters adjacent to Numazu, and $\frac{(26+1.5)+(24+2.5)}{(39.5+26)+(40.5+24)} = .416$ for the waters east of Taiwan. The former is a coastal fishing ground while the latter is a pelagic ground so the average .566 for the two can be said to be the survival rate for sixth-year to eighth-year fish. On the Shigedera fishing grounds the survival rate for fish of the fourth year and older is $\frac{17.3+14.0+23.0+20.5+1.5+0}{68.7+17.3+14.0+23.0+20.5+1.5} = .529$, which indicates that the excessively small number of fifth-year fish in the waters adjacent to Numazu probably represented a condition restricted to the year 1937. Consequently it will probably be satisfactory to consider the survival rate of the fish after they have entered upon a migratory life as .57.

On the Pacific coast of the American continent and from Southern California to the Equator a considerable quantity of yellowfin is taken along with skipjack. On the northern grounds migratory schools are fished during a three-month season in August, September, and October, but on the southern grounds the fishing continues throughout the year. It is thought that the schools fished are mainly migratory schools of young fish. These yellowfin of the Eastern Pacific, like those of our Western Pacific waters, are probably related to the small yellowfin which reside permanently around the various islands which are scattered over a wide area north and south of the Equator, but since we do not have enough data to pursue these questions any further at present it is recommended that we proceed on the assumption that the yellowfin tuna of the eastern and western Pacific should be treated as separate stocks.

As was mentioned above, in the South Seas young yellowfin occur mixed with skipjack, but we have no exact knowledge of their numbers. In the course of his investigations Kimura found that in the Ogasawaras a fairly large quantity of small yellowfin is taken along with the larger fish, however, detailed knowledge is lacking regarding the numbers of small and large yellowfin taken at other places so a thorough treatment of this question will have to be left until a later date. What we wish to postulate here is that among the stock of fish which come into the waters adjacent to Numazu the proportion of small and large yellowfin is about equal and that there is no great difference in the rate of catch for the two size groups. Assuming this to be the case, it appears from the amount landed at the Numazu market that the survival rate of young yellowfin in the stock as a whole is .75. If we assume that the natural mortality rate for yellowfin is the same as for the black tuna [Thunnus orientalis], we get a fishing rate of .06 for the young fish and .29 for the mature fish.*

Table 4

Yellowfin Tuna Taken in the Waters of the South Sea Islands

Age	Number of Fish
3	.5
4	1.0
5	14.5
6	137.0
7	9.0
8	——
	total 162.0

[footnotes]

(1) Kimura, Kinosuke : Growth Rates of Black Tuna and Yellowfin Tuna as Revealed in the Catch from the Shigedera Fishing Grounds. Bull. Jap. Soc. Sci. Fish., 1 (1). May 1932.

(2) Aikawa, Hiroaki and Masuo Katō : Age Determination of Fishes (Preliminary Report No.1). Bull. Jap. Soc. Sci. Fish., 7 (2). July 1938.

(3) Kimura, Kinosuke and Kazumi Ishii : Fishing Conditions in the Northeastern Part of Suruga Bay (Part 2), On Yellowfin Tuna, Spearfish, Yellowtail, Amberjack, and Mackerel Scad. Bull. Jap. Soc. Sci. Fish., 2 (2). July 1933.

(4) Kanamura, Masami and Kakuji Imaizumi : Experimental Tuna Longline Fishing East of Taiwan. Report of Experimental Fishing by the Shōnan Maru in 1936.

(5) Ikebe, Kenzō : On the Age of Yellowfin Tuna from Palau Waters. South Sea Fishery News, 3 (10). December 1939.

(6) Ikebe, Kenzō : Weights and Ages of Tuna from Palau Waters. South Sea Fishery News, 4 (1). February 1940.

(7) Ikebe, Kenzō : Measurements of Yellowfin Tuna from South of the Marshall Islands. South Sea Fishery News, 4 (2). March 1940.

*Of the total number of fish of the year S_0, those which come into the waters adjacent to Numazu are represented by r_0. The rate of catch in those waters is f_0' and the rate of survival is p_0', but for the stock as a whole the rate of catch is f_0 and the rate of survival is p_0. Of the fish in their third year and older which have entered upon a migratory life, the part which comes into Numazu waters is represented by r and their rate of catch in those waters by f', but for the stock as a whole the rate catch is f. As shown above, we get the values $p_0' = .20$, $p = .57$, $f_0' r_0 S_0 \left(.5 + p_0' + p_0'^2 + \frac{101}{231} p'^3\right) = 1,200$; (the rate of catch of $\frac{1}{2}f_0'$ is given here for fish of the year because, although second-year and third-year fish are both taken from May to December, fish of the year are taken only after August); $\gamma r S_0 p_0^3 (1-\frac{101}{231}+\frac{p}{1-p}) = 1,300$. Accordingly $\frac{f'r}{f_0' r_0} p_0^3 = \frac{1,300}{1,200} \times \frac{.5+.2+(.2)^2+.44x(.2)^3}{1-.44+\frac{.57}{1-.57}} = .43$.

The young yellowfin in the waters adjacent to Numazu come up through the Ogasawaras together with the mature fish and are carried from the south by the same ocean currents which bring the migratory schools, and for these reasons it is probably approximately correct to consider that $r_0 \doteq r$. Since the catch in Numazu waters is made with fixed nets, it is probably also safe to assume that $f_0' \doteq f'$. Consequently if $\frac{f'r}{f_0' r_0} = 1$ then $p_0 = .75$. The natural mortality rates for both young and adult yellowfin do not differ greatly and are thought to be of the same order as those for the black tuna. Therefore if $s = .20$, the rate of catch for the young fish is $f_0 = 1 - \frac{.75}{.80} = .062$ and that for adult fish is $f = 1 - \frac{.57}{.80} = .287$.

On the Stock of the Albacore, Germo germo (Lacépède)

Synopsis [in English]

Stock of Germo germo (Lacépède) was studied on the basis of catch records classified according to the body-length and body-weight. Survival rate was estimated to be about .66, while fishing rate as about .18. [end of English synopsis]

The California albacore, which had been showing a tendency to decrease in abundance since 1916, had by 1926 fallen into a condition in which it might be said that there was almost no catch at all, and that condition has persisted to the present day.(1) In the past the albacore catch on the coasts of Japan has been very small, but under the stimulus of the demand from California positive efforts have been made to increase the catch and the fishing grounds have been extended farther and farther out to sea in the search for the schools. Along with these developments, however, certain ill omens have appeared in the fishing situation. The comparatively large albacore which migrate in close to the coasts in the summer have gradually diminished in numbers and the fishery has barely been able to keep going by increasing the catch of the medium-sized albacore which migrate into the offshore waters in the winter.(2) This may perhaps be due to a change in the course of migration of the albacore, which are the most truly pelagic of all the tunas, but in case this decline may possibly be due to overfishing, it is a problem which requires a great deal of attention. The present study was undertaken because of my desire to gain some knowledge concerning these points.

Uno[3] investigated the composition of the tuna catch taken by pole fishing in the waters east of Cape Nojima and found that in May and June of 1935 the catch was 6% fourth-year fish, 86% fifth-year fish, and 8% sixth-year fish while in June of 1936 it was 16% fourth-year fish, 70% fifth-year fish, and 14% sixth-year fish. When the weight groups of the albacore taken east of Cape Nojima from January to May, 1936, and the length groups of those taken on the same grounds in the same period of 1937 by the Fumi Maru[4] are converted into age groups by the method of Aikawa and Katō [4], fifth-year fish are most numerous followed by fourth-year, third-year, and sixth-year fish in that order (Table 1). A consideration of that part of the reports of investigations of the Fisheries Experiment Station[5] in which the catch is indicated by sizes of fish shows that the proportion of large fish is greater in the Northeastern Area than on the distant offshore grounds (Table 2). The proportion of small fish was greater on both grounds in 1937 than it was in 1936, however, it is thought that there still appears to be room for the development of fishing grounds for large fish in the distant offshore areas.

Where two or more of the size categories of small, medium, and large are combined in the table of albacore catch by sizes compiled by the Japanese Tuna Canners Association,[6] they have been broken down and distributed proportionally by numbers of fish into small, medium, and large size groups (Table 3). If we compute the survival rate* from these data, we get .54 for 1934, .84 for 1935, .56 for 1936, and .64 for 1937, an average for the four years of .66. The considerable variation in the survival rate value from year to year is probably due to the fact that the age composition of the fish which migrate into the present limited fishing grounds cannot be regarded as the age composition of the stock. This indicates that the above-mentioned irregularities which have recently appeared in the fishing situation cannot be said to be necessarily due exclusively to overfishing. This is all the more apparent when we consider that the survival rate is proportionately large and that accordingly the fishing rate is proportionately small.**

[notes]

(1) Bureau of Commercial Fisheries: The commercial fish catch of California for the year 1935, Fish Bulletin (49), 1937.

(2) Hasegawa, K.: On the Report of the Summer Albacore Investigation. Collected Lectures on the Canning of Tunas in Oil. February 1938.

(3) Uno, Michio: The Composition of the Catch of Tuna Taken by Pole Fishing in the Waters East of Cape Nojima. (Preliminary Report No.I). Bull. Jap. Soc. Sci. Fish. Vol.4, No.5. January 1936; (Preliminary Report No.II), Vol.5, No.4. November 1936.

(4) Aikawa, Hiroaki and Masuo Katō: Age Determination of Fishes (Preliminary Report No.1). Bull. Jap. Soc. Sci. Fish. Vol.7, No.2. July 1938.

(5) Part published in Reports of Oceanographical Investigations (58)-(61), (63).

(6) Japan Tuna Canners Association: Report of Activities for 1937 (Sixth Yearly Report). 1938.

Table 1

Albacore Catches by the Fuji Maru on Grounds East of Cape Nojima

January to May, 1936

Age	Weight	Number of Fish (Estimated)	Per Cent
0	- .27 kan	—	—
1	.27- .61	7.5	2.0
2	.61-1.07	6.5	1.7
3	1.07-1.68	48.0	12.6
4	1.68-2.45	114.0	30.0
5	2.45-3.52	176.0	46.1
6	3.52-4.82	29.0	7.6
7	4.82-6.4	—	—
8	6.4 -	—	—
Total		381.0	100.0

January to May, 1937

Age	Length	Number of Fish (Estimated)	Per Cent
0	- 35 cm	43	8.0
1	35- 46	11	2.1
2	46- 55	19	3.6
3	55- 64	96	18.0
4	64- 73	136	25.4
5	73- 82	161	30.2
6	82- 91	54	10.1
7	91-100	14	2.6
8	100-	—	—
Total		534	100.0

Table 2

Tuna Long Line Catches of Cooperating Vessels

Fishing Period	Grounds	Number of Fish Taken			Cooperating Vessels
		Large	Medium	Small	
November and December, 1936	Senri [1,000 miles]	106	2,543	13,951	No.1 Kihō Maru and No.2 Kihō Maru from Wakayama Prefecture, Shinsei Maru and No.5 Hinode Maru from Shizuoka Prefecture
November and December, 1936; January, 1937	Northeastern	5,199	4,760	7,977	No.5 Kompira Maru and No.3 Fukukichi Maru from Miyagi Prefecture
November and December, 1937	Senri	——	3,171	1,603	No.5 Tōyō Maru from Shizuoka Prefecture
"	Northeastern	63	2,301	5,336	No.2 Sasayama Maru from Mie Prefecture; Shinsei Maru and Hango Maru from Shizuoka Prefecture

Tuna Ground Investigations by Research Vessels

Fishing Period	Grounds	Number of Fish Taken			Vessels
		Large	Medium	Small	
From January, 1936, to December, 1937	adjacent waters	136 6	265 1,661	1,605	Kiyō Maru of Wakayama Prefecture, Mogami Maru of Yamagata Prefecture, Musashi Maru from Tokyo District, and Sagami Maru from Kanagawa Prefecture
		(also 7 fish of various sizes and 46 of unknown size)			
From November, 1936, to December, 1938	pelagic waters	1,129	2,324 7	1,921	Akita Maru from Akita Prefecture, Kōhō Maru from Kōchi Prefecture, Fuji Maru from Shizuoka Prefecture, Sagami Maru from Kanagawa Prefecture, and Iwate Maru from Iwate Prefecture
		(also 36 fish of various sizes)			

Table 3

Albacore Catch Classified by Sizes (in units of thousands of fish)

Year	Large	Medium	Small	Total
1934	462.4	804.5	280.2	1,547.1
1935	847.6	238.1	133.8	1,219.5
1936	305.6	481.0	790.6	1,577.2
1937	129.7	133.5	503.1	766.3
Total	1,745.3	1,657.1	1,707.7	5,110.1

*The "large" category comprises fish of 5 kan weight and over [1 kan = 8.27 pounds] so according to Aikawa and Katō (4) it includes $\frac{6.4 - 5.0}{6.4 - 4.82} = .89$ of the seventh-year fish and all of those of the eighth year and older. The medium fish are from 3 to 5 kan in weight and include 1 - .89 = .11 of the seventh-year fish, all of the sixth-year fish, and $\frac{3.52 - 3.00}{3.52 - 2.45} = .49$ of the fifth-year fish. Small fish comprise 1 - .49 = .51 of the fifth-year fish and all fish in their fourth year or younger. If the survival rate is represented by p, the ratio between large and medium fish is $\frac{.89p^2 + \frac{p^3}{1-p}}{.49+p+.11p^2}$. This formula gives a figure of .57 for 1934, 3.55 for 1935, .64 for 1936, and .97 for 1937 or an average of 1.05 for the four years. The corresponding survival rates are .54, .84, .56, .64, and .656 respectively.

**Among other tunas the natural mortality rate for the black tuna has been calculated at .20 (see preceding article in this journal). The albacore probably does not differ widely in this respect, so if we assume a natural mortality rate of .20, we get a catch rate of $1 - \frac{.66}{1-.20} = .18$. The catch rate for the black tuna is .10, but the catch rate for the young fish shows the high figure of .55. For the yellowfin tuna the catch rate for the young fish is .06 while that for the mature fish is .29. (See the two preceding articles in this journal.)