Albacore Migration and Growth in the North Pacific Ocean as Estimated from Tag Recoveries

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THE ALBACORE, *Germo alalunga* (Bonnaterre), is considered a choice tuna by Americans because of its excellent canning quality. It is fished by Americans along the Pacific coast of the United States and by the Japanese in North Pacific waters extending from the coast of Japan to about the 180th meridian. In recent years the Japanese have extended their albacore fishing grounds to tropical and subtropical waters of the Pacific and Indian oceans (Mimura, 1957; Van Campen[2]), and more recently, to Atlantic waters.

A tagging program was instituted by the Pacific Oceanic Fishery Investigations (POFI) [in 1959 it became the Bureau of Commercial Fisheries, Hawaii Area] as a part of an albacore research project being conducted under Public Laws 329 (80th Congress) and 466 (Saltonstall–Kennedy Act, 83rd Congress). Employing the California type-G "spaghetti" tag (Wilson, 1953) (Fig. 1), and to a limited extent, the POFI- developed dart tag (Yamashita and Waldron, 1958), tagging was conducted on albacore taken by POFI vessels on exploratory cruises to the North Pacific. Intensive albacore tagging has been conducted on the West Coast by the California Department of Fish and Game and data on some of their recoveries have been published (Blunt, 1954; Ganssle and Clemens, 1953). This report summarizes the tagging results obtained by POFI, and includes a preliminary analysis of albacore migration and growth.

ACKNOWLEDGMENTS

The success of a tagging program depends largely on the cooperation of the fishermen making the recoveries, their interest in the program, and the care with which they record and transmit data pertinent to each recovery. We extend our gratitude to the numerous commercial fishermen and research agencies, both in the United States and in Japan, who have rendered excellent cooperation in this respect.

The writer is indebted to Dr. Robert H. Riffenburgh of the University of Hawaii for guidance in the growth analysis.

ALBACORE TAG RELEASES

Between January, 1954, and August, 1957, a total of 1,201 albacore was tagged and released in the temperate North Pacific (Fig. 2). Included in the total are 270 albacore tagged in the Japanese live-bait fishing grounds in the spring of 1956 (Van Campen and Murphy, 1957). The remaining tag releases were made in the central and eastern North Pacific, and consisted of 855 fish taken by surface trolling and 76 taken by long-lining.

The size-frequency distribution of the tagged albacore is given in Figure 3. The 270 fish tagged off Japan are not included since they were not measured. Measurements were made, however, on samples of fish from each school in which tagging was conducted, and these indicated a relatively narrow size range of 60.4 cm. to 83.4 cm. in length. In addition to these, 94 troll-caught fish tagged off the California coast are not included since no measurements were recorded. The long-line gear accounted for a wide size range of fish (50 to 120 cm.) while surface trolling took fish up to 87 cm. in length (Fig. 3).

ALBACORE TAG RECOVERIES

As of September, 1958, 15 (1.2 per cent) of POFI's tag releases had been recovered (Table 1). Seven of the recoveries (Nos. 1, 2, 3, 8, 9,

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[2] Van Campen, W. G. MS. The Japanese summer albacore fishery. Submitted for publication as a research report.

TABLE 1
POFI ALBACORE TAG RECOVERIES

NO.	DATE TAGGED	POSITION OF RELEASE		DATE RECAP-TURED	POSITION OF RECAPTURE		NET DISTANCE TRAVELLED (miles)	DAYS OUT
		Latitude	Longitude		Latitude	Longitude		
1	10/4/54	46° 30′ N.	159° 18′ W.	11/28/55	35° 45′ N.	157° 39′ E.	2.055	420
2	10/5/54	43° 31′ N.	161° 16′ W.	1/19/56	35° 23′ N.	141° 20′ E.	2.670	471
3	10/9/55	42° 16′ N.	147° 16′ W.	6/24/56	31° 54′ N.	158° 37′ E.	2,660	259
4	10/17/55	44° 55′ N.	144° 48′ W.	8/1/56	31° 21′ N.	117° 17′ W.	1,515	288
5	7/31/56	44° 31′ N.	174° 55′ W.	7/23/57	30° 08′ N.	119° 03′ W.	2,775	357
6	8/1/57	34° 49′ N.	121° 57′ W.	9/17/57	34° 49′ N.	121° 26′ W.	26	47
7	7/22/57	35° 43′ N.	122° 58′ W.	10/7/57	36° 24′ N.	123° 07′ W.	41	77
8	10/16/55	43° 40′ N.	144° 40′ W.	11/23/57	33° 22′ N.	174° 07′ E.	2,025	769
9	11/17/56	36° 44′ N.	127° 37′ W.	11/17/57	38° 08′ N.	174° 53′ E.	2,800	365
10	7/23/57	42° 20′ N.	127° 33′ W.	5/26/58	32° 15′ N.	144° 15′ E.	4,230	287
11*	7/22/57	47° 00′ N.	126° 18′ W.	6/10/58	33° 40′ N.	144° 00′ E.	4,300	323
12	7/16/57	44° 47′ N.	130° 04′ W.	7/11/58	30° 00′ N.†	118° 45′ W.†	1,035	360
13	7/16/57	44° 47′ N.	130° 04′ W.	8/22/58	32° 00′ N.†	122° 00′ W.†	860	402
14	11/14/56	38° 00′ N.	128° 25′ W.	8/23/58	32° 15′ N.	122° 30′ W.	455	647
15	11/21/56	35° 21′ N.	123° 57′ W.	7/21/58	34° 00′ N.	122° 10′ W.	130	607

* Fish No. 11 was marked with a POFI dart tag; all others with California "spaghetti" tags.
† Approximate position of recapture.

10, 11) were made by the Japanese in their summer live-bait and winter long-line fisheries, while the remaining 8 were made by Americans in the West Coast fishery.

With the exception of two American recoveries (Nos. 6 and 7) which were made within 47 and 77 days, respectively, of the date of release, the remaining 13 represented relatively long periods between release and recovery, ranging from 259 to 769 days. While all of these long-term recoveries provided valuable

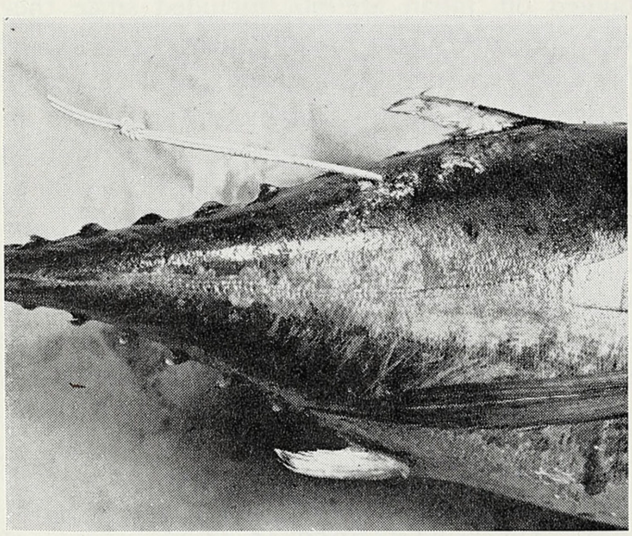

FIG. 1. An albacore (recovery No. 4) with a California type-G tag attached. This fish was at liberty for approximately 10 months before recapture (Table 1).

information on the movements of albacore in the North Pacific, complete data on growth were not obtained since information on several of the recoveries did not include length or weight measurements.

MOVEMENTS SHOWN BY TAGGED ALBACORE

The net movements of the tagged fish are depicted in Figure 4. Perhaps most significant is the migration of fish between the major fisheries. A fish tagged in the American fishery off California (No. 9) moved across into the Japanese mid-ocean winter long-line grounds to be retaken there. Two others tagged in the West Coast fishery off the Pacific northwest (Nos. 10, 11) made a complete trans-Pacific migration and were recaptured in the Japanese live-bait fishery. Albacore tagged in mid-ocean north of Hawaii migrated into the West Coast fishery (Nos. 4, 5) as well as into the Japanese long-line (Nos. 1, 2, 8) and live-bait (No. 3) fisheries. Tag recoveries reported by the California Department of Fish and Game also showed movements of albacore from waters off California to the coast of Japan (Ganssle and Clemens, 1953). Movement in the opposite direction, from the Japanese fishery into the American fishery, has yet to be demonstrated.

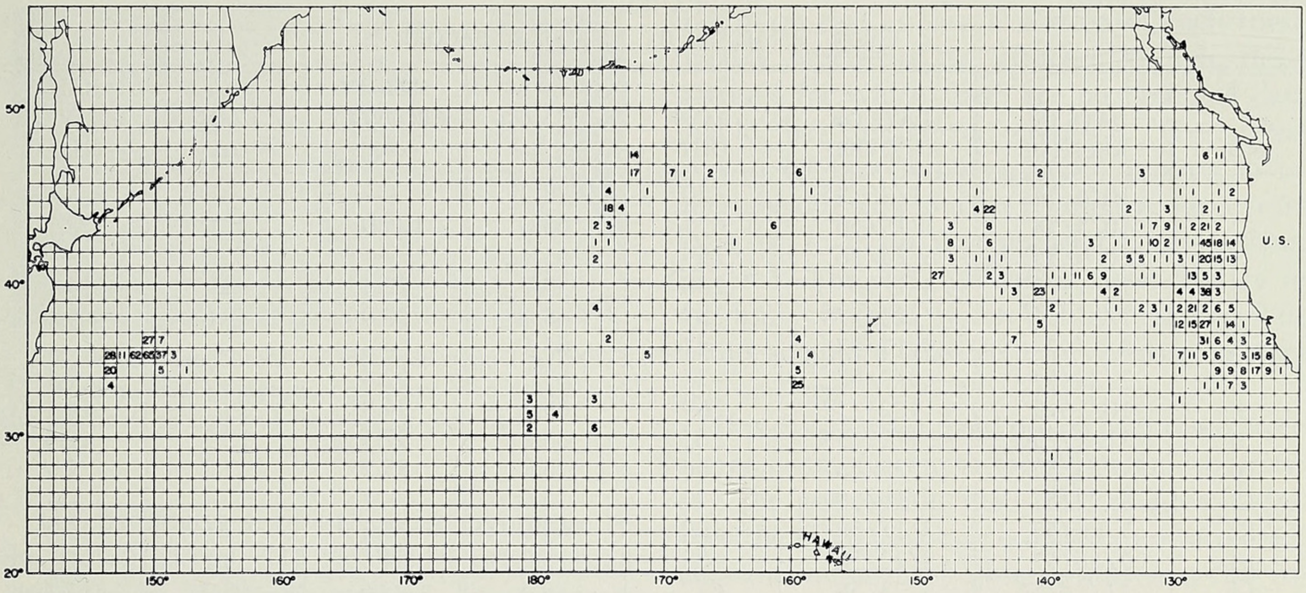

FIG. 2. Numbers and locations of POFI tag releases, January, 1954–August, 1957. (California type-G tag was used on 1,090, and the POFI dart tag on 111 albacore.)

GROWTH SHOWN BY THE TAGGED ALBACORE

Of 15 recoveries to date, 11 were accompanied by size data at the time of recovery (Table 2). The estimated annual growth of these fish was extremely variable, ranging from 3.8 to 28.7 cm. per year.

Although it is realized that the available data are inadequate for any conclusive growth study, a preliminary analysis was made in order to present some approximation of the albacore growth rate. Following the method of growth curve transformation described by Walford (1946), the length of fish at the time of release (age N) was plotted against the length after one year (age $N + 1$), the latter representing the length at release plus the estimated value of one year's growth (Fig. 5). There is a suggestion of linearity in the plots, with the exception of one (No. 2, Table 2). The growth reported for this fish is obviously out of proportion to the others. When the Japanese transmit data pertinent to a tag recovery they usually specify the method of measurement used. This was not done in this particular instance; for this reason and because the reported length seems excessive, this fish is dropped from further consideration. The remaining 12 points (including two from published California data) fall about the regression line $Y = 26.29 + .77867X$ obtained by the least squares method, where Y is the length at $N + 1$, and X the length at N.

Also shown in Figure 5 is the line of no growth ($L_N = L_{N+1}$) drawn in with a 45° slope through the origin. The point of intersection between the regression line and the line of no growth is described by Walford as the upper asymptote of the growth curve, which in this case falls at approximately 118 cm. The 118-cm. asymptote of maximum growth for the sample data of this paper is slightly less than that which would be expected for albacore populations in general; measurements of commercial landings indicate the population asymptote to be about 124 cm. (Suda, 1954; Otsu and Uchida, 1959*a*).

The growth curve (Fig. 6) was derived from Figure 5. This method does not enable us to obtain that portion of the growth curve falling below the point of inflection, and since the smallest fish for which there are data is a 60-cm. fish, the extrapolation toward the smaller sizes is dubious.

In an attempt to describe the complete growth curve, particularly that portion falling below the point of inflection, for which Walford's method does not apply, the data were fitted to a Gompertz equation, $y = ab^{c^{-x+d}}$, where y is the length in centimeters and x the age in years. A

TABLE 2
GROWTH SHOWN BY TAGGED ALBACORE

NO.	DATE OF RELEASE	DATE OF RECOVERY	DAYS OUT	SIZE AT RELEASE (cm.)	SIZE AT RECOVERY (cm.)	NET GAIN (cm.)	GAIN PER YEAR (cm.)
1	10/4/54	11/28/55	420	78.2	—	—	—
2	10/5/54	1/19/56	471	68.0	105.0	37.0	28.7
3	10/9/55	6/24/56	259	63.4	—	—	—
4	10/17/55	8/1/56	288	59.9	72.3	12.4	15.7
5	7/31/56	7/23/57	357	68.4	78.0	9.6	9.8
6	8/1/57	9/17/57	47	66.5	—	—	—
7	7/22/57	10/7/57	77	65.5	67.0	1.5	7.1
8	10/16/55	11/23/57	769	65.1	94.8	29.7	14.1
9	11/17/56	11/17/57	365	85.2	97.5	12.3	12.3
10	7/23/57	5/26/58	287	78.0	85.2	7.2	9.2
11	7/22/57	6/10/58	323	75.0	—	—	—
12	7/16/57	7/11/58	360	65.0	77.3	12.3	12.5
13	7/16/57	8/22/58	402	75.0	84.5	9.5	8.6
14	11/14/56	8/23/58	647	79.4	92.6	13.2	7.4
15	11/21/56	7/21/58	607	68.6	86.4	17.8	10.7
A*	8/11/53	2/2/54	176	84.0	88.0	4.0	8.3
B*	8/16/53	2/23/54	192	91.0	93.0	2.0	3.8

* Fish tagged by the California Department of Fish and Game and reported by Blunt (1954).

rapid approximation method by Riffenburgh[3] for estimating the parameters of the Gompertz curve was used. The same paper contains a lengthier and more precise method in which the estimates converge stochastically to the parameters, but it was felt that the number of data available was inadequate to assure convergence. Thus, the approximation technique was utilized.

The method uses three sets of data points: $(i,\ y_i)$, $(i+j,\ y_{i+j})$, and $(i+k,\ y_{i+k})$. The numerical calculation involved is markedly simplified if $k = 2j$. In this case, the triplet of points having x-values of $N + 3$, $N + 5$, and $N + 7$ (Fig. 6) was selected from among the set of triplets possessing the property $k = 2j$; these points fall approximately within the portion of the curve for which there are observed data. The corresponding y-values, obtained from Walford's curve, were $y_3 = 62.7$ cm., $y_5 = 84.8$ cm., and $y_7 = 98.2$ cm. The estimate of the parameter $c = 1.43$ was obtained by the equation:

$$c^{-j} = \frac{\log \dfrac{y_{i+k}}{y_{i+j}}}{\log \dfrac{y_{i+j}}{y_i}}$$

and the estimate of the parameter $b = 0.177$ by the equation:

$$\log b = \frac{\log \dfrac{y_{i+k}}{y_{i+j}}}{c^{-i}\, c^{-j}\, (c^{-j-1})}.$$

[3] Riffenburgh, R. H. MS. A new method for estimating parameters of the Gompertz growth curve. University of Hawaii and Pacific Oceanic Fishery Investigation, U. S. Fish and Wildlife Service, Honolulu.

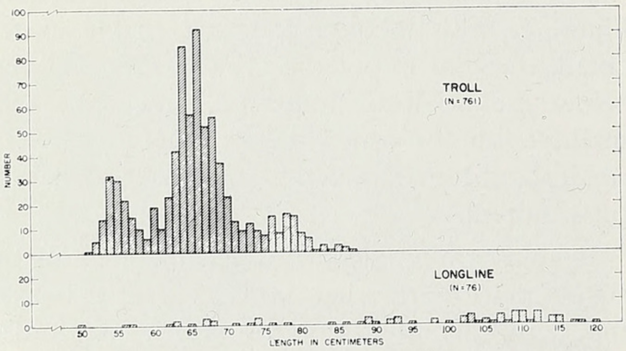

FIG. 3. Size-frequency distribution of albacore tagged by POFI in the North Pacific, January, 1954–August, 1957.

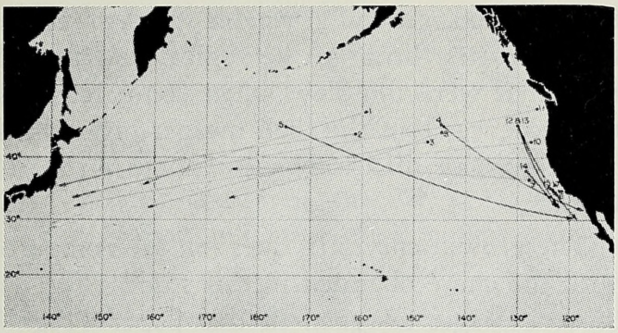

FIG. 4. Net movements of albacore tagged by POFI. (The lines have no significance other than connecting the points of release and recovery of each fish.)

The parameter *a,* or the upper asymptote of the growth curve (118 cm.), had already been estimated by Walford's method. These parameters were fitted into the Gompertz equation as follows:

$$y = (118)\ (0.177)^{(1.43)^{-x+d}}$$

which resulted in the asymmetric sigmoid curve shown in Figure 7. Inspection showed that if this curve is shifted 0.23 year to the right, it will present an adequate fit for the data; thus, an estimate of *d* is 0.23.

The curve derived by the Walford method (Fig. 6) is superimposed on the Gompertz curve. There is fair agreement between the two in the portions representing lengths between 40 and 85 cm., and the observed data do not deviate much from either curve. If albacore growth follows a typical Gompertz curve, then this represents a possible entire growth curve of the albacore, including that portion not possible to determine by the Walford method. It should now be possible to assign specific ages.

It can be seen by inspection that the curve approaches the abscissa reasonably closely at $N - 2$ years, suggesting that hatching is in this time vicinity. While the size indicated at hatching deviates from the expected size to the order of 2 cm., this error is not large considering the assumedly random deviations of the observed data from the estimated growth curve and the small sample size. With $N - 2$ as the arbitrary origin, the adjusted ages are given below the original designations. The resulting length for each year beginning with this origin is presented in Table 3 along with values obtained by the Walford method. While there is every indication that at least a portion of each curve reliably represents the albacore growth, those portions for which there are no observed data should be considered tentative. The initial growth by the Gompertz curve appears to be unreasonably slow since it requires about 3 years for a fish to attain a weight of 1 pound (about 30 cm.). The early growth is slow, relative to the result obtained by the Walford method. The results suggest a possible error in assigned ages of 1 or 2 years.

This disagreement and others may result from one or a combination of the following debilities: (a) the assumption that albacore growth follows the Gompertz curve may be unwarranted; (b) the number of observations may be inadequate; (c) there is the possibility that there is differential growth between the sexes after the onset of sexual maturity, causing an unbalanced sex ratio in favor of males among the larger albacore (Otsu and Uchida, 1959*b*). If this is true, then the growth curves are subject to inaccuracies in the upper portions representing fish larger than 90 cm., the approximate size at which the albacore is believed to attain sexual maturity. A differential growth rate may have been responsible for the slightly

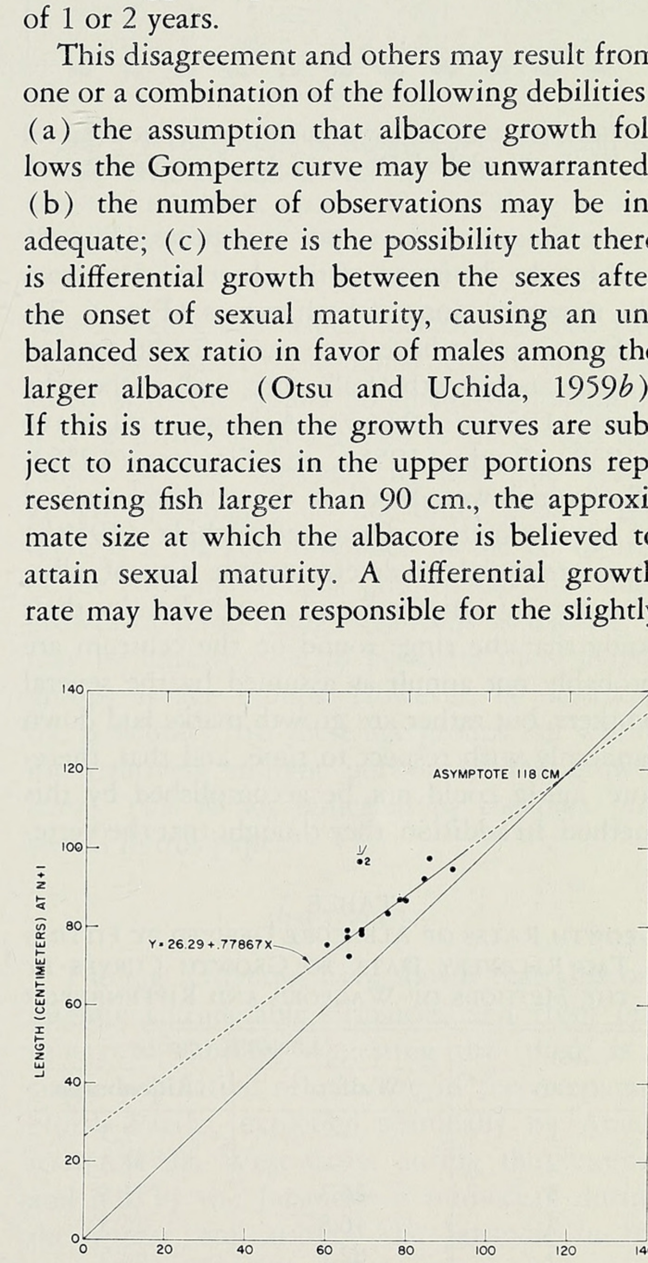

FIG. 5. Growth shown by tagged fish plotted by Walford's (1946) method and fitted with a straight line. The intersection of this line and the line $L_n = L_{n+1}$ indicates the upper asymptote of the albacore's length. Fish No. 2 was excluded from calculation of the regression line.

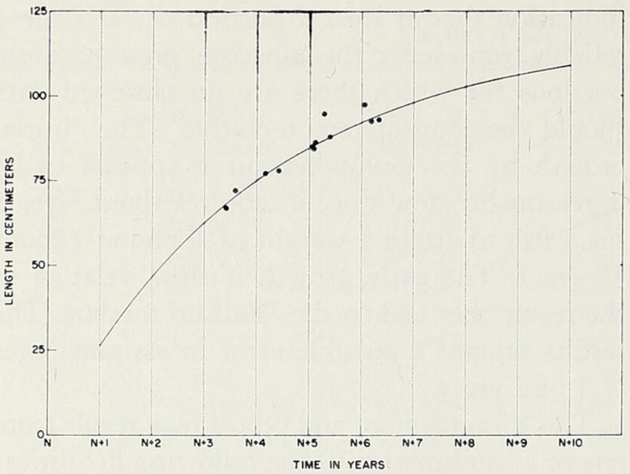

FIG. 6. Portion of growth curve of albacore obtained by Walford's method. Observed data are superimposed.

low estimate of the upper asymptote (Fig. 5) and for the deviation of the observed data from the upper portions of both curves (Figs. 6, 7).

Some studies have been made in the past on the age and growth of albacore, such as those by Uno (1936*a*; 1936*b*), Aikawa and Kato (1938), Partlo (1955), and Figueras (1955), all of which were based on the vertebral method of age estimation. Otsu and Uchida (1959*b*) also attempted to determine the age of albacore by this method and concluded in their study that the rings found on the centrum are probably not annuli as assumed by the several workers, but rather are growth marks laid down randomly with respect to time, and that, therefore, aging could not be accomplished by this method. In addition, they thought that the vertebral method generally yielded growth curves that were too linear to be typical and growth rates that were too slow when compared with the evidence from the then meager tag returns. The results of this study substantiate their criticisms.

The growth curves in question are compared with the curve obtained in this study (Fig. 8). Since the ages assigned in this paper (Fig. 7, Table 3) were arbitrarily defined, and since there are obvious discrepancies in the ages assigned by various workers, the mean lengths are plotted at yearly intervals without regard to the specific ages given. In other words, the curves in Figure 8 may be shifted freely in either direction along the abscissa. It is noted that the several growth rates do not differ markedly in magnitude.

It is clearly seen, however, that the presently derived curve, at least a portion of which is believed to be a fair representation of the actual albacore growth curve, is curvilinear, while the others, with the possible exception of Uno's (1936*b*) results, are almost perfectly linear. This difference in curvature supports the contention that the age of albacore could not be determined by the vertebral method. The linearity suggests that the rings found on the vertebrae are associated with growth rather than with age, and that ring formation is a linear function of fish growth.

Aside from growth studies by the vertebral

TABLE 3

GROWTH RATES OF ALBACORE DERIVED BY FITTING TAG RECOVERY DATA TO GROWTH CURVES BY THE METHODS OF WALFORD AND RIFFENBURGH

AGE* (years)	LENGTH (cm.)	
	Walford	Riffenburgh
1	—	7.5
2	—	17.3
3	26.3	31.5
4	46.8	46.5
5	62.7	62.5
6	75.1	75.0
7	84.8	86.0
8	92.3	94.5
9	98.2	101.0
10	102.7	106.0

* The ages given are based on an arbitrarily selected origin (Fig. 7) and are therefore tentative.

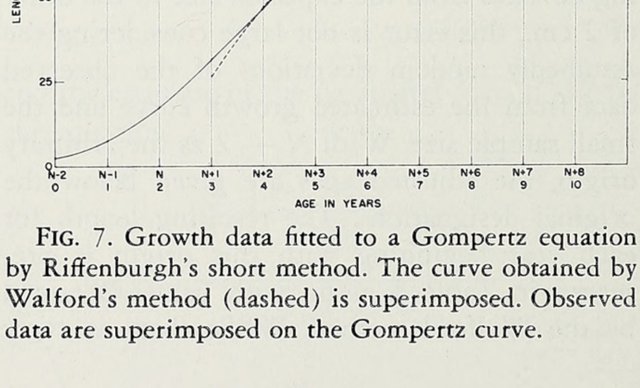

FIG. 7. Growth data fitted to a Gompertz equation by Riffenburgh's short method. The curve obtained by Walford's method (dashed) is superimposed. Observed data are superimposed on the Gompertz curve.

method, several workers have analyzed albacore size frequencies. Brock (1943) found two regularly occurring modal groups in the California length frequencies for the years 1924 to 1928 inclusive. The consistency in the appearance of these groups indicated that they were year classes. A more uniform relation was seen in the "lagged difference," or the difference in the modal size of group A in 1 year with that of group B in the following year, rather than between the two modal groups of the same year. The modal lengths (lagged) of both California and Oregon albacore are reproduced in Table 4.

The lagged modal values for the California albacore fall in nearly perfect agreement with the growth shown by the tagged fish, indicating that the distinctly bimodal distribution represents two age groups, one a year older than the other, as postulated by Brock. The growth of the Oregon albacore, on the other hand, was somewhat less than that estimated for the California albacore, and consequently lower than the growth shown by the tagged fish.

Suda (1954) has examined the size distribution of albacore taken in the Japanese winter long-line season and has traced six different size groups which appear yearly. The modes of these groups were: 57 cm., 67 cm., 78 cm., 89 cm., 100 cm., and 111 cm. The spacing of the intervals is uniformly 10 or 11 cm., thus representing a straight-line growth if these length groups are assumed to be age classes. The author concluded that these length groups may be considered as age groups if they are handled as five groups consisting of ages I to IV and an advanced age group which includes the last two modal groups. If these modal lengths are compared with the results obtained from tagging, it is seen that as in the case of the results obtained by the vertebral method, the yearly growth increments do not differ greatly, but there is a marked difference in the curvatures of the two curves. Suda pointed out that since growth of most living organisms is logistic, it may be unreasonable to postulate these length groups as age groups. However, he advanced the possibility that these age groups fall within the relatively straight portion of the growth curve. This is not indicated by the data presented in this paper.

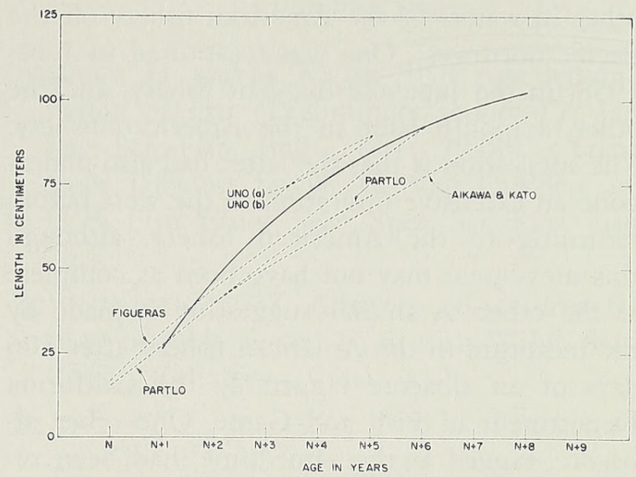

FIG. 8. A comparison of the growth curves obtained by the vertebral method with the Walford curve obtained in this study. Specific ages are disregarded in the plotting of these curves.

TABLE 4
MODAL LENGTHS OF CALIFORNIA AND OREGON ALBACORE, IN CENTIMETERS
(Reproduced from Table 7, Brock, 1943)

GROUP A	GROUP B	DIFFERENCE
CALIFORNIA ALBACORE (1924 to 1928)		
1924, 64.89	1925, 77.18	12.29
1925, 64.87	1926, 77.16	13.29
1926, 68.84	1927, 81.04	12.20
1927, 65.80	1928, 78.27	12.47
OREGON ALBACORE (1938 to 1940)		
1938, 66.18*	1939, 74.19	8.01
1939, 64.02	1940, 74.26	10.24

* Only a single small sample was taken in 1938 after the season was underway.

DISCUSSION

The tag recoveries have shown that albacore migrate considerable distances, and from one fishery to another, suggesting that there is a single population of albacore in the temperate North Pacific, exploited seasonally by Americans off the West Coast during the summer and fall, by the Japanese in mid-ocean during the winter, and also by the Japanese in the western Pacific during the spring and summer.

While no recoveries of albacore tagged off Japan have yet been reported in the American fishery, there are suggestions of movements in that direction. For example, recoveries 11 and 12 were of fish tagged within a week of each other in waters of the American fishery off the Pacific northwest. One was recaptured in June, 1958, in the Japanese live-bait fishery, and the other, a month later in the American fishery. The suggestion is that the latter had also undergone an extensive migration to the west before returning to the American fishery, although this movement may not have been as complete as the other. A similar suggestion is made by the recapture in the American fishery after 306 days of an albacore tagged by the California Department of Fish and Game. One other albacore, tagged at the same time, had been recaptured a month earlier 145 miles east of Tokyo, Japan (Anonymous, 1957). An appreciable tagging program by the Japanese may show definitely whether or not there is a movement of fish from the Japanese live-bait fishery into the American fishery.

However, judging by the sizes of fish generally taken in the different fisheries, it is possible that even extensive tagging by the Japanese would not confirm such a movement towards the east. The chances for American recovery of Japanese-tagged fish are not good unless the Japanese tag unusually small fish or unless unusually large fish move into the American fishery in large numbers. The sizes of fish commonly taken in the respective fisheries are

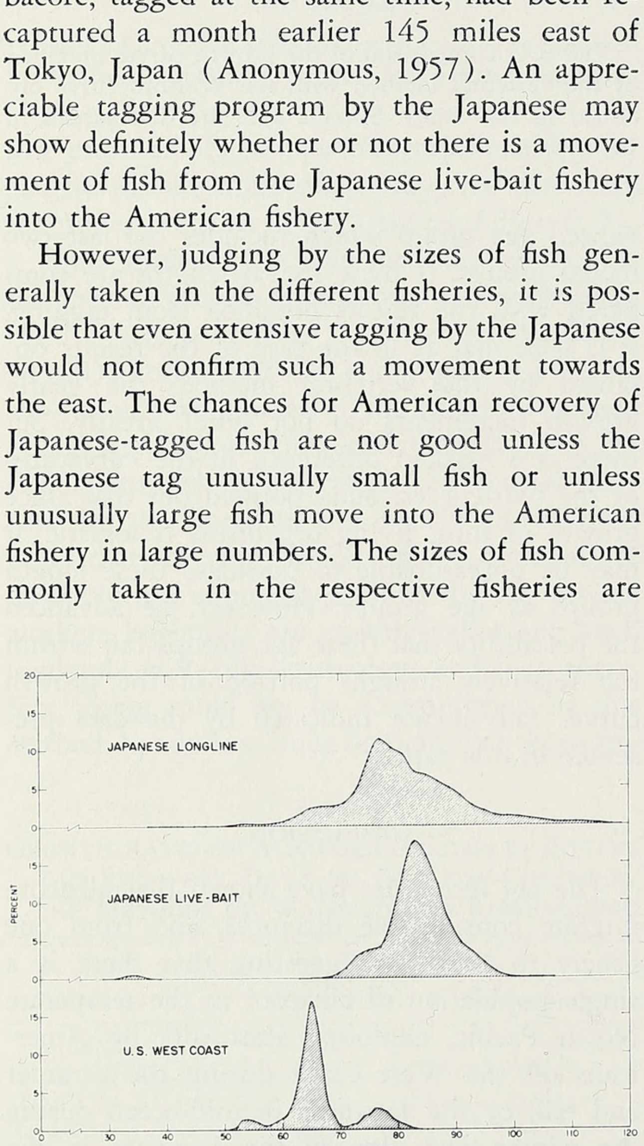

FIG. 9. Examples of albacore sizes taken by the major North Pacific fisheries. The Japanese size-frequencies were obtained from Nankai Regional Fisheries Research Laboratory (1951). The West Coast length frequency is based on unpublished data of the Oregon Fish Commission and are measurements made on albacore landed in Oregon during the 1957 season.

shown in Figure 9. The American West Coast fishery generally takes smaller albacore than either the Japanese live-bait fishery or their long-line fishery; the fish range in size from about 50 to 85 cm. with the predominant sizes around 65 cm. The bulk of the fish taken by the Japanese is larger than 70 cm. in length, and these sizes comprise only a very small part of the American landings. On the other hand, small albacore under 70 cm. may be present in larger numbers in the Japanese live-bait fishery than indicated in Figure 9. Suda (1955) states that such small fish constitute a significant portion of the landings during certain years. The chances for recovery would seemingly be improved if tagging is concentrated on such small fish.

Although there appears to be little chance for fish tagged in the western Pacific to be recovered in the American fishery, a large-scale tagging program by the Japanese stands to serve an equally important purpose, that of elucidating the relationship between the albacore of the temperate and tropical Pacific Ocean. There is at present no direct knowledge concerning the movements of the larger albacore. The larger fish of the temperate North Pacific appear to move south into tropical and subtropical waters, perhaps to form the reproductive segment of the population. If there is such a southward migration of the larger fish, this may be shown someday by the recovery of a tagged fish. With Japanese vessels exploiting wide areas in the tropical Pacific, chances for recovery of fish tagged in the north should be favorable.

With respect to the growth curve obtained in this study, there are certain implications which merit brief consideration. If the Gompertz curve (Fig. 7) is a true representation of albacore growth, then the following points may be made: (a) the albacore is a relatively slow-growing tuna; (b) this species has a relatively long life span. Furthermore, as mentioned, it is believed that an albacore attains sexual maturity at a length of about 90 cm. If this is so, then it requires between 7 and 8 years for an albacore to become sexually mature. This is a significant portion of the life span. Since albacore enter the fisheries in substantial numbers at around 50 cm. in length (Fig. 9), a year-class is thus exploited for about 4 years before it even attains maturity.

SUMMARY

Of 1,201 albacore tagged in the temperate North Pacific Ocean by POFI between January, 1954, and August, 1957, 15 recoveries (1.2 per cent) were reported. These recoveries indicate considerable movement of fish in the North Pacific. Albacore tagged in mid-ocean north of Hawaii have been retaken in the American West Coast fishery as well as in the Japanese fisheries. Certain recoveries were of fish which migrated across the Pacific from the American West Coast to the vicinity of Japan. There is indication that Americans and the Japanese are exploiting the same population of albacore in the temperate North Pacific Ocean.

The data on growth, although insufficient for a conclusive study, were subjected to a preliminary analysis by Walford's method of growth curve transformation, and the resulting data were also fitted in a Gompertz equation. The derived growth curves are presented.

At least those portions of the growth curves for which there are observed data appear to be a reliable representation of albacore growth. These curves are curvilinear, contrary to several linear albacore growth curves reported in the past by workers who based their studies mainly on the vertebral method. The linearity of the latter curves suggests that the age of albacore cannot be determined by the vertebral method; the rings on the centra are probably directly associated with growth rather than with age.

The results indicate that the albacore is a relatively slow-growing tuna with a rather long life span. A significant portion of the life span is passed in the immature state.

Although POFI in cooperation with the Japanese has tagged 270 albacore in the Japanese live-bait fishery, and the Japanese have recently started a tagging program in the western Pacific, none of these fish has been recovered in the American fishery. In view of the fact that the Japanese exploit generally larger albacore than the Americans, the chances for recovery in the American fishery of Japanese-tagged albacore are far less than for Japanese recovery of American-tagged fish.

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