UNITED STATES DEPARTMENT OF THE INTERIOR, OSCAR L. CHAPMAN, *Secretary*
FISH AND WILDLIFE SERVICE, ALBERT M. DAY, *Director*

ESTIMATION OF AGE AND GROWTH OF YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) IN HAWAIIAN WATERS BY SIZE FREQUENCIES

BY HARVEY L. MOORE

March 3, 1849

FISHERY BULLETIN 65
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 52

UNITED STATES GOVERNMENT PRINTING OFFICE — WASHINGTON : 1951

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. — Price 15 cents

CONTENTS

ESTIMATION OF AGE AND GROWTH OF YELLOWFIN TUNA (*NEOTHUNNUS MACROPTERUS*) IN HAWAIIAN WATERS BY SIZE FREQUENCIES

By Harvey L. Moore, *Fishery Research Biologist*

With a commercially important species, such as the yellowfin tuna (*Neothunnes macropterus* Temminck and Schlegel), knowledge of age and growth is essential in both the management and development of a fishery. To be able to assign ages and to determine the rate of growth makes it possible to determine the number and strength of the year classes that comprise the fishable stock. A fishery dependent on a few age groups or year classes is greatly affected by the marked success or failure of the brood produced in any one year. The reduction or increase in numbers is strongly evident in the total catch when that particular year class enters the commercial fishery. If, however, the fishery is composed of many age groups, the success or failure of spawning in any one year will have little effect on the total stock. It is only when there are several consecutive years of marked failure or success that any appreciable differences in numbers are evident.

The vital statistics necessary for quantitative study of fish populations are based on knowledge of the age composition of the stock. It would be difficult indeed to determine such statistics as rates of increase, decrease, fishing, and natural mortality without some knowledge of age and growth. These vital statistics are fundamental in the management of a fish stock.

The age and growth rate of tunas may also be of value in the study of migrations, since it seems logical to expect, in general, that short-lived, fast-growing fish travel shorter distances than fish which are long lived and slow growing.

Since Petersen's first application of the method of size-frequency study to age and growth determination of plaice (1922) many such studies of different species have been made. Much improvement in the original method has been made, and the application of mathematical formulae to describe the growth of fishes has contributed much toward its refinement.

Application of length- or weight-frequency analysis to study of growth of tunas has been limited. Kimura (1932) calculated growth curves for bluefin (*Thunnus orientalis*) and yellowfin (*Neothunnus macropterus*) from weight frequencies of fish taken in Japanese waters from 1924 to 1931. Although the data were collected over a long period of time, those for yellowfin were based on a few specimens if all data were included in the graphs. An examination of the data, as presented, shows that the values plotted in the graphs are based on a few specimens of yellowfin.

Westman and Gilbert (1941) employed length-frequency distributions in their study of the Atlantic bluefin (*Thunnus thynnus*). The ages of bluefin as determined by this work were based primarily on scale readings although the conclusions were correlated with the results of the length frequencies. Westman and Neville (1942), in another study of the Atlantic bluefin tuna, used length frequencies of tuna samples from chumming and trolling catches made during August and September 1941. The results of this study were also correlated with scale readings. Brock (1944) applied the method of length frequencies in a study of albacore (*Germo alalunga*) taken in the North Pacific and was able to demonstrate the growth of size groups through the albacore season. Partlo (1950) has produced weight-frequency distributions of albacore (*Thunnus alalunga*) taken in the waters of British Columbia during 1949. Sampling was not sufficient to show changes in length throughout the albacore season, but the frequency distributions show the definite size groups which make up the fishery. Okamoto (1940) applied Petersen's method to weight data of skipjack (*Katsuwonus vagans*) taken in Japanese waters. It was possible to follow definite modal groups through 5 months of the fishing season. The question whether modes represented age groups or whether they represented different strains of skipjack was raised. The conclusion was in favor of age groups.

There has been little study of age and growth determination of Hawaiian tunas. Some measurements of the skipjack (*Katsuwonus pelamis*) were collected by Bonham (1946) in 1944 and 1945, and length frequencies were plotted from these data. Bonham suggested the possibility that two successive year classes were present, but recognized the limitations of his data and did not attempt to assign ages. Brock (ms.) made a rather detailed study of size frequencies of skipjack. He was able to identify modal groups in the catches of successive years and to demonstrate progression of the modes during the year, whence he concludes they are year classes. No previous studies have been made of the Hawaiian yellowfin tuna.

SOURCES OF DATA AND METHODS OF COLLECTION

The data for this study were obtained from two different types of fishery, the long-line or flag-line fishery, and the pole or live-bait fishery. The long-line fishery in Hawaii is carried on throughout the year in most of the waters around the main Hawaiian Islands. The catch from this fishery is sold primarily to the fresh-fish markets by auction. The live-bait fishery, on the other hand, is more seasonal and the catch is primarily for the cannery, although some of the fish are sold on the fresh-fish market, especially when the cannery is not operating during the slack season.

The long-line fishery is conducted by means of setlines made up of units of gear known as baskets. The term "basket" is derived from woven bamboo baskets in which the units of gear are stowed. A vessel fishes a long-line composed of about 30 baskets, each of which is from 140 to 203 fathoms in length and has 4 to 6 branch lines with hooks. When the baskets are fastened together and the long-line is set, the hooks fish from 30 to 50 fathoms in depth (June 1950).

Long-lines are set in the early morning and are fished only during the daylight hours. Usually a few tunas are taken each day, and the catches may also contain several marlin, swordfish, and sharks. Fish taken by this method are generally large in comparison with those taken in the live-bait fishery. Yellowfin tuna caught by this method average about 140 pounds in weight, and the big-eyed tuna (*Parathunnus sibi*) are heavier. The total landings, by months, vary considerably in both the numbers and the species of fish caught. The yellowfin is the most abundant species taken during the summer months, and the big-eyed tuna dominates the winter catch. Albacore also are caught on the long-lines during the winter months, but the numbers are small in comparison with either of the other two species. Although the tunas are definitely seasonal in availability, some fish of all three species usually are taken during the entire year.

The second source of data was the live-bait fishery. This fishery is seasonal; most of the catch is taken during the summer months. The fishery is dependent on small live fishes which are used as chum to lure the tunas within reach of the feather lures or live bait on hooks on the poles of the fishermen. The fish caught by this method are much smaller than those taken by the long-line method; the largest weigh near 25 pounds. The fact that no large fish are caught on the surface by the pole or live-bait fishery and no small fish are caught at depths fished by the long-line gear indicates that there may be a possible vertical migration downward of yellowfin tuna during the early years of life.

Although this fishery is primarily for the skipjack, mixed schools of skipjack and yellowfin or skipjack and big-eyed tuna are sometimes found. Approximately 12 to 15 catches from mixed schools are landed at the cannery each season. It was from schools such as these that the data on small yellowfin were collected for this study. Schools of tuna, whether a pure school of skipjack or mixed with either yellowfin or big-eyed tuna, tend to contain fishes with little range in size. Brock (ms.) says of skipjack schools, "no individual school of fish sampled contained fish differing by more than 20 centimeters in length and usually much less." Differences in sizes of fish from different schools, however, were as much as 50 centimeters.

Weight and length frequencies of the long-line catch were taken from fish sold at auction by the Kyodo Fishing Co., Ltd., Honolulu. The officials of this company were kind enough to allow measuring of the fish on the auction floor before the bidding had begun. As the fish are sold individually, it is necessary for the company to keep accurate records of the weight of each fish sold. Weights as determined by the auction company were taken from the auction records which were available beginning with November 1947. Weights of tunas caught by the live-bait fishery during 1949 were recorded by Fish and Wildlife Service scientists at the cannery of Hawaiian Tuna Packers, Ltd. This study includes only the data of 1948 and 1949.

The data for the 2 years consist of 4,793 individual weights of yellowfin tuna ranging from 5 to 265 pounds. Of the total number of weights taken, 124 are of small fish most of which were representative of four mixed schools caught by live-bait methods. A few of this group were taken incidentally by trolling or hand-lining. The remainder of the data were obtained from the auction records.

Since small yellowfin and big-eyed tuna are likely to be confused, a check of the reliability of species determination by the auction company was made during October 1949. During this period 95 yellowfin and 272 big-eyed tuna were identified by various Fish and Wildlife Service scientists. In no case was there found to be an auction record in disagreement with our identifications. It was concluded that the assignment of species as shown by the auction records was accurate.

The auction records provided an excellent source of weight-frequency data for several reasons. Because Honolulu is the center of population in the Hawaiian Islands, most of the long-line catch is landed there, and most of this long-line catch passes through the auction of the Kyodo Fishing Co., which supplied the auction records. Fish taken by long-line gear are generally few in number per day's fishing, which would suggest that either the fish tend to be solitary in habit or, if they are schooled, only a few fish from several to many schools are caught during a fishing trip. Since tunas tend to school by size (Brock, in unpublished ms.; Schaefer 1948), samples of this sort which are composed of a few fish from each of many schools will tend to be more nearly representative than large samples drawn from only a few schools as are the samples from the cannery.

Weights of fish in the round, that is, the entire uncleaned fish as landed at the dock, were weighed on the auction company's scales or on those of the Hawaiian Tuna Packers. Weights were recorded to the nearest pound for long-line fish and to the nearest quarter pound for small fish taken by live-bait fishing.

ANALYSIS OF WEIGHT FREQUENCY DATA

The initial step in processing the raw data (see the appendix) was to plot the weights of individual fish as frequency distributions for monthly periods. A class interval of 10 pounds was arbitrarily chosen, with midpoint values of 4.5, 14.5, and so on. Because the monthly catches varied considerably in numbers of fish, they were made comparable by converting the class frequencies into percentages of the total for the month. The average frequency distribution for each year was calculated by averaging the 12 monthly-percentage curves. The results are plotted in figures 1 and 2 for 1948 and 1949. In order to show more clearly the presence of modes, positive deviations from the mean curve for the year are shaded on the graph for each month. The scale at the bottom of each graph is in terms of both weight in pounds and length in centimeters. The length scale was derived from the equation $\log L = 1.45660 + 0.33290 \log W$ which was calculated from a sample of 200 length-weight measurements of yellowfin tuna collected during 1949 by Fish and Wildlife Service scientists.

Because there were many irregularities evident in the frequency curves of each month's catch in both 1948 and 1949, and because the 2 years were similar in monthly frequency distributions, it was convenient to combine the 1948 and 1949 data. The combination of the data for the 2 years was then treated in the same manner as that of the the individual years with the exception of a process of first smoothing the data by the formula $\frac{a+2b+c}{4}$, where a, b, and c, are actual values for consecutive class intervals. After smoothing, the data were transformed into percentages of monthly catch. The resulting monthly distribution curves of the combined data with the superimposed mean-percentage curve for the 2 years calculated in the same manner as for individual years is shown in figure 3.

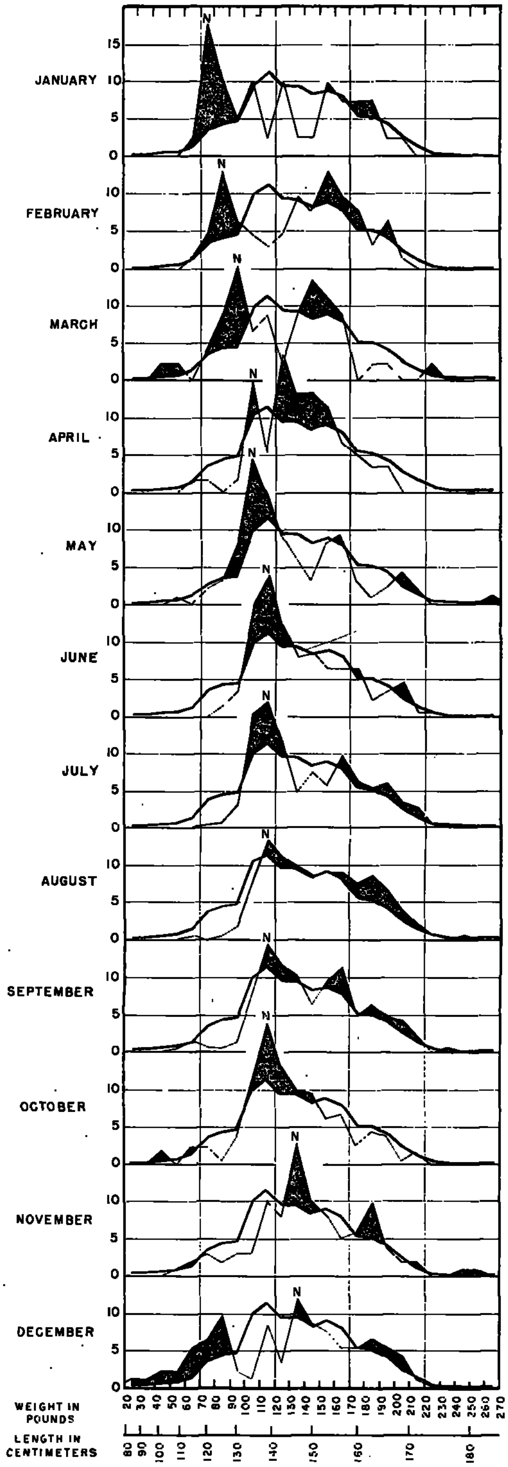

FIGURE 1.—Weight-frequency distributions (in percentage) of long-line catches of yellowfin tuna landed at Honolulu, 1948. Monthly frequency distributions are shown by fine line, and mean monthly frequency distributions by heavy line. Positive deviations from the mean are shaded.

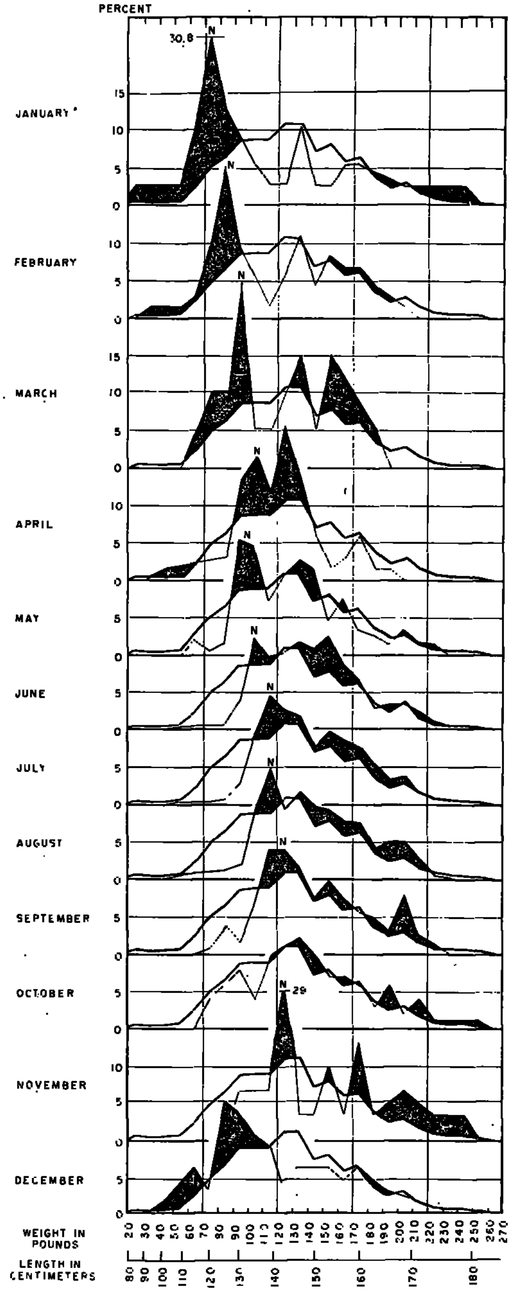

FIGURE 2.—Weight-frequency distributions (in percentage) of long-line catches of yellowfin tuna landed at Honolulu, 1949. Monthly frequency distributions are shown by fine line, and mean monthly frequency distributions by heavy line. Positive deviations from the mean are shaded.

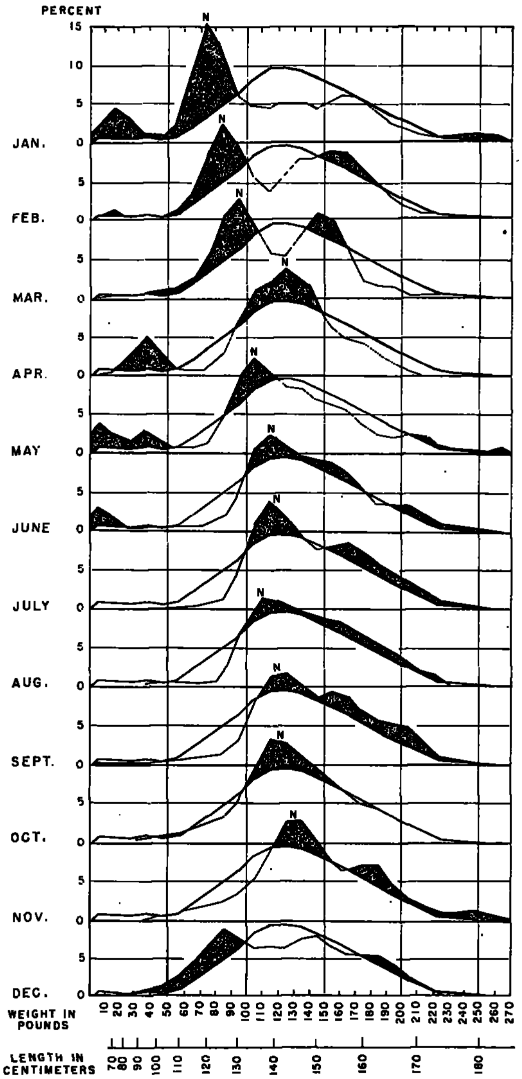

FIGURE 3.—Weight-frequency distributions (in percentage) of long-line and live-bait catches of yellowfin tuna landed at Honolulu. Smoothed data of 1948 and 1949. Monthly frequency distributions are shown by fine line, and mean monthly frequency distributions by heavy line. Positive deviations from the mean are shaded.

Initial examination of the plotted data in figures 1 and 2 shows the presence of a modal group of fishes which can be followed through most months of both 1948 and 1949. The group was designated *N* for reference. In the 1948 data the progression of the modes representing this group indicates gradual growth until June, followed by a 5-month period in which no growth is indicated. Following this there appears to be a short period of rapid growth from October through December. From January through December, modal group *N* shows a gain in weight from 75 to 135 pounds, a gain of 60 pounds in 1 year. Also present in the plotted data is a smaller size group which becomes evident in the long-line fishery in October 1948 and in December 1949. This suggests the entrance of a modal group 1 year younger than group *N*.

The 1949 data (fig. 2) presented a similar trend in modal progression, except for the last 3 months of the year where rather erratic modal peaks were evident. Because the catches for these months were not large in comparison to catches of the summer months (table 1) any unusual distributions of weights of fish landed would cause erratic modal peaks to appear in the percentage frequency distributions.

TABLE 1.—*Numbers of yellowfin tuna taken by long-line fishing and auctioned at the Kyodo Fishing Company, Ltd., Honolulu, in 1948 and 1949*

Month	1948	1949
January	40	39
February	61	73
March	45	20
April	60	67
May	97	158
June	362	514
July	530	545
August	542	400
September	381	165
October	179	102
November	99	31
December	92	67
Total	2,488	2,181

For a more detailed study of the combined data of the 2 years, a criterion was set up to determine what should be designated a mode and to designate its position. Modal peaks of positive deviations, evident in the combined 2-year data, when plotted as deviations from the mean curve (fig. 4) which met either of the two following conditions were treated as modes in this study:

(1) Any positive deviation of a class which shows a difference of 0.5 or more from values of both adjacent classes (fig. 5–A).

(2) When the difference between frequency values of positive deviations of two adjacent classes is less than 0.5, and when the frequency values of the classes above and below these two adjacent values are at least 0.5 less than the adjacent values, the intersection of the extrapolation of the lines connecting the two classes with the adjacent classes was considered the position of the mode (fig. 5–B).

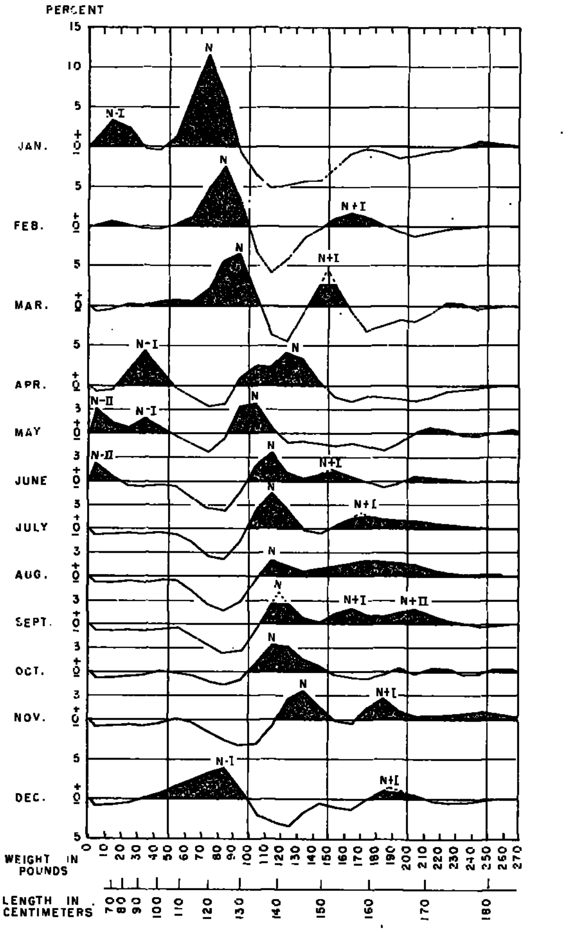

FIGURE 4.—Deviations of monthly frequency distribution from the mean monthly frequency distribution (in percentage) for combined and smoothed 1948 and 1949 data.

Using the above criterion, values of modes were selected as shown in figure 6. Each mode has been labeled with the age group to which it was presumed to belong. In order to plot modal positions against successive months, January of group *N* was arbitrarily assumed to occur in month 37. Thus the mode of group *N* in February, March, April, and so on, was plotted in figure 5 against 38, 39, 40, and so on. Modes corresponding to groups which are presumed to be a year younger or older were then plotted 12 months above or below the month value corresponding to group *N*.

Assuming group *N*—I to be 1 year younger than *N* and group *N*+I to be 1 year older, *N*+II 2 years older, and so on, we proceeded to determine whether a regular growth curve fitted the data. This was done by the "transformation" method of Walford (1946). This is a graphic method of describing the growth of animals above the point of inflection, the self-inhibiting phase of growth.

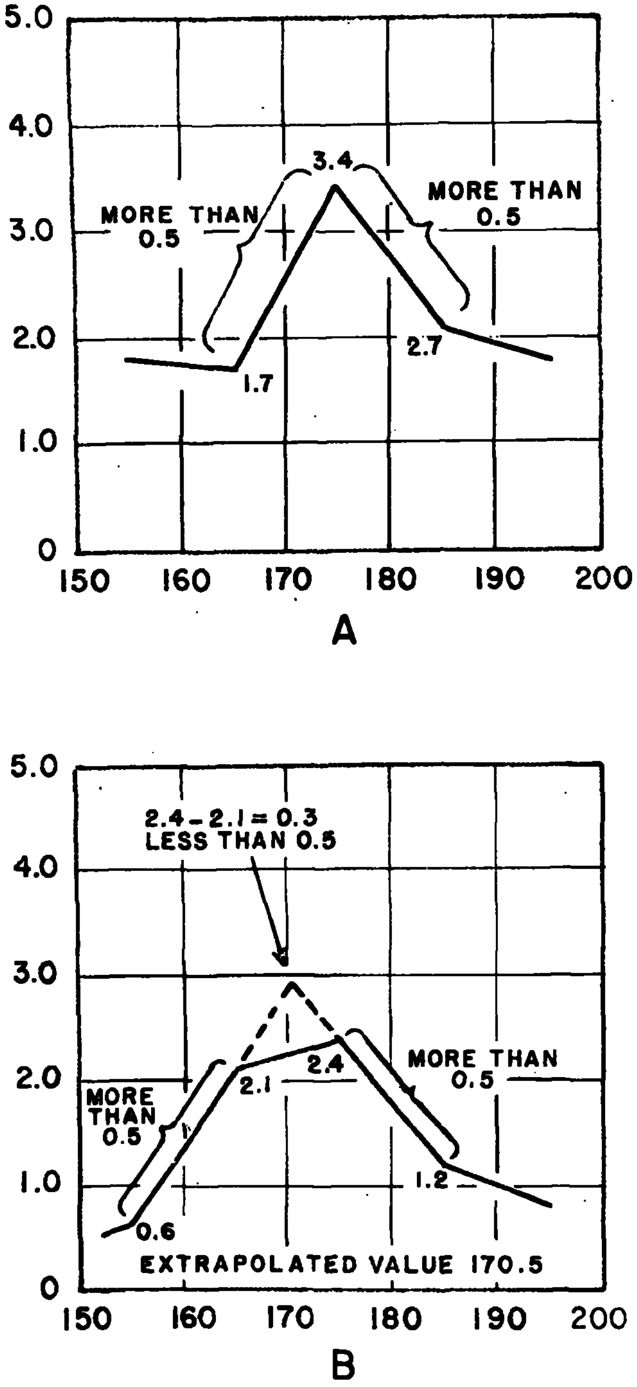

FIGURE 5.—Theoretical conditions demonstrating the criterion used in selection of modes.

Size of fish in figure 6 was plotted in terms of length rather than weight since this method of fitting a growth curve is applicable to sizes above the inflection point. It was obvious from a plot in terms of weights (fig. 9) that the inflection point is within the range of our data, whereas our data in terms of length appear to be above the inflection point.

For the growth of a number of species of animals, Walford's graphic transformation method gives a straight line when the lengths at age 1, 2, 3, 4, . . . n, represented on the x axis, are plotted against the lengths at age 2, 3, 4, 5, . . . $n+1$, on the y axis. This method assumes the growth during each period to be of constant ratio to that of the previous period. It has already been noted that the modes make all their progress during half the year and none in the remainder. This should and does show as a stepwise or sinuous deviation from the straight line. Also, this method requires length values for each consecutive unit of time, in this case for each month. Within the limits of our data (fig. 6) there were 28 months for which no modal values were evident in the plotted data. To furnish estimates of the missing values, linear interpolations were made between observed monthly values.

The series of actual values and interpolated values was then smoothed twice by a running average of three and resulting values of length at age n were plotted against lengths at age $n+1$ where age is in months. The plotted data are well fitted by the least-squares line $Y=7.04-0.96336\ X$, where Y is length at age $n+1$, and X is length at age n (fig. 7). From this straight line the upper limit of growth or the upper asymptote can be derived according to Walford's method by taking the point of intersection of the line fitted to the plotted data and the line of no growth represented by a line of slope 45° through the zero point (fig. 7). In the case of the yellowfin tuna data used herein, the value in length at the point of intersection of the two lines is at 190.0 centimeters, which in terms of weight is equal to 294.9 pounds. A maximum weight of this magnitude is within reason for this species; several specimens approaching this limit have been taken in the local flag-line fishery. The largest specimens included in this study, however, were between 260 and 269 pounds.

Because the plot of n against $n+1$ is a constant-percentage rate and not actual-length values, it is possible to choose the point through which the curve should be passed. As the period from

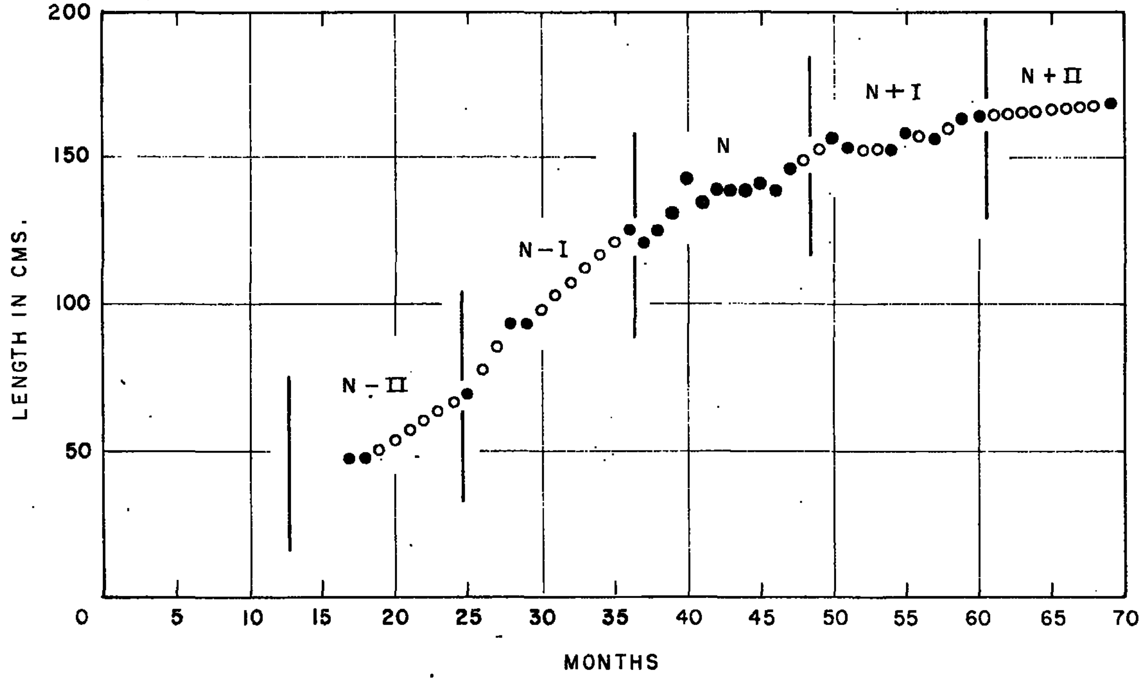

FIGURE 6.—Actual and interpolated values in length plotted against months and showing assigned modal groups. Solid points are actual values and circles are interpolated values. From combined and smoothed 1948 and 1919 data.

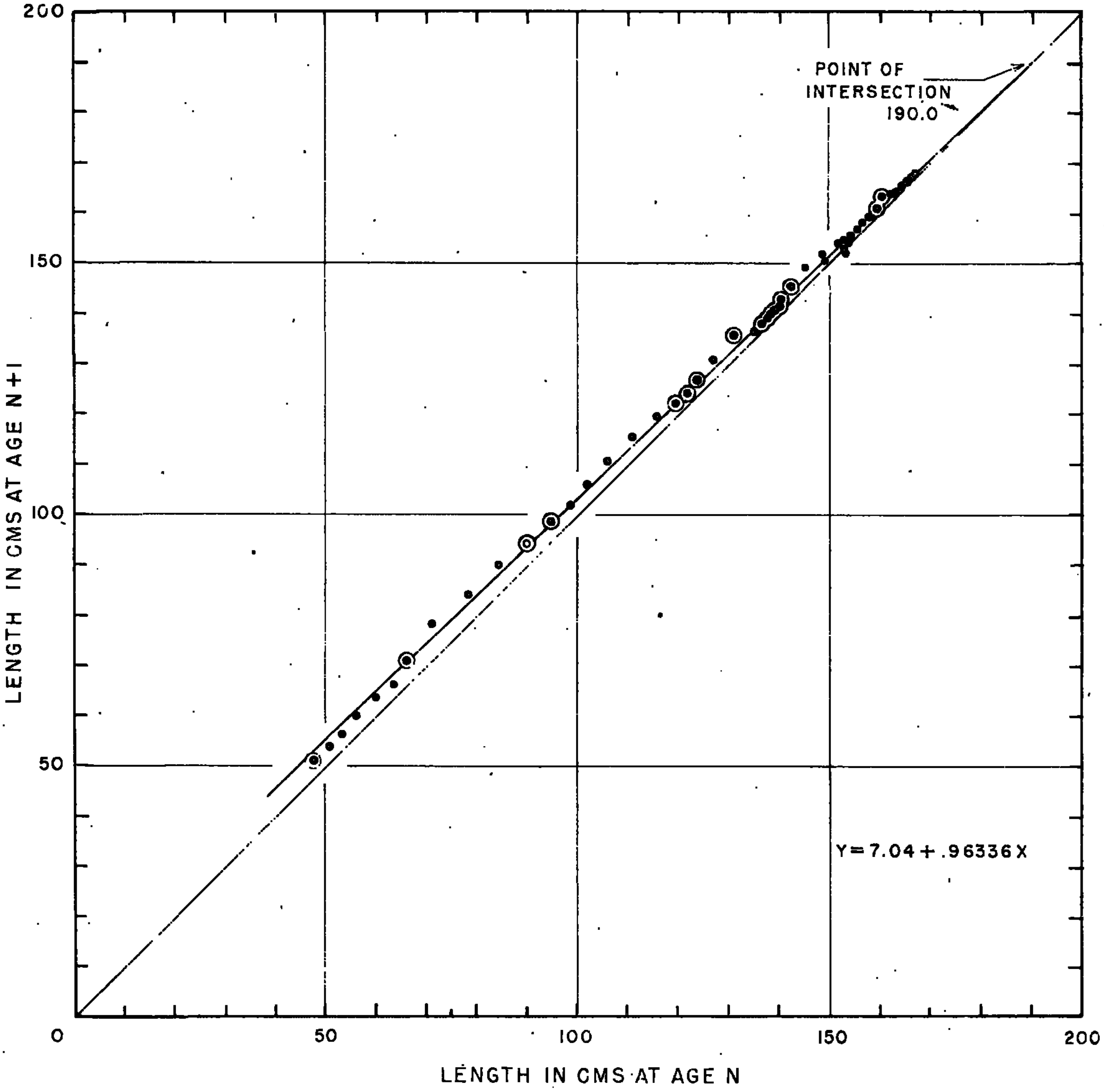

FIGURE 7.—Combined 1948 and 1949 length data are plotted by the method of Walford (1946) and fitted with a straight line. The intersect of the straight line and the line at 45° through the zero point indicates the upper asymptote of the yellowfin tuna. Points marked by ⊙ are observed values.

month 37 through month 47 is the time group *N* and is most evident in the plotted data, the mean month and mean length of fish occurring in this period were used as the initial point for computing the relation between fish length and time.

The reconstructed growth curve of length on time and the plotted values of the original modes are shown in figure 8. Since figures 7 and 8 indicate that the position of plotted mode values are well fitted by the calculated growth curve, this serves as verification of the assumption that modal group *N*—I is a year younger than *N*, group N+I is a year older than *N*, and so on, is correct. Since the original data were in terms of weight, the calculated curve was also transformed back to those terms. The growth curve of weight on time is shown in figure 9.

From the results of figures 8 and 9, it is possible to determine approximate age of fishes. Extrapolation of the curves downward suggests the origin of the fish to be in year *N*—III. Examination of the gonads of yellowfin taken in local waters indicates the spawning period to be centered about the summer months. Assuming this to be true, the month of June may be selected to represent the mean spawning period; thus, the period from June *N*—III to June *N*—II represents age group *0*, or fish in their first year of life, June *N*—II to June N—I, age group I, and so on. Owing to possible error in extrapolating the curves downward to the origin, the ages thus assigned may not be quite correct. It is felt, however, that ages through group IV cannot be more than 1 year in error.

Sella (1929) states that bluefin tuna hatched in June weigh 300 to 500 grams by September. This is a weight of approximately 1 pound and would fall very close to our growth curve as calculated. Kishinouye (1923) says of the common tunny (*Thunnus orientalis*), "such small individuals are found in August and in September. Some of them grow to a length of 30 cm. or more. By next spring they grow to a length of ca 60 cm. When 2 years old they are about 1 meter in length and 11 kg. in weight." These values when plotted on our curve are not much in disagreement. Specimens of yellowfin tuna have been taken during the month of December in Hawaiian waters weighing 2 pounds; these weights when plotted, also fall very close to the curve of figure 9. Lengths and weights by age groups may also be assigned from figures 8 and 9 as has been done in table 2.

Table 2.—*Lengths and weights by age groups of yellowfin tuna taken in Hawaiian waters determined by the method of growth analysis of Walford (1946)*

Age group	Length in centimeters	Weight in pounds
0	Less than 54	Less than 7.
I	54–103	7–46.
II	103–136	46–108.
III	136–155	108–163.
IV	155–168	163–208.

DISCUSSION

In fairly close agreement with this study are the observations of Schaefer (1948) of the yellowfin in the waters off Central America, where modes in length-frequency distributions were observed at approximately 60 cm., 85 cm., and 115 cm. These modes, when plotted against the assumed age and the month at which the fish were taken, showed a close similarity to the age-length curve of the Hawaiian yellowfin (fig. 10). The conclusion of

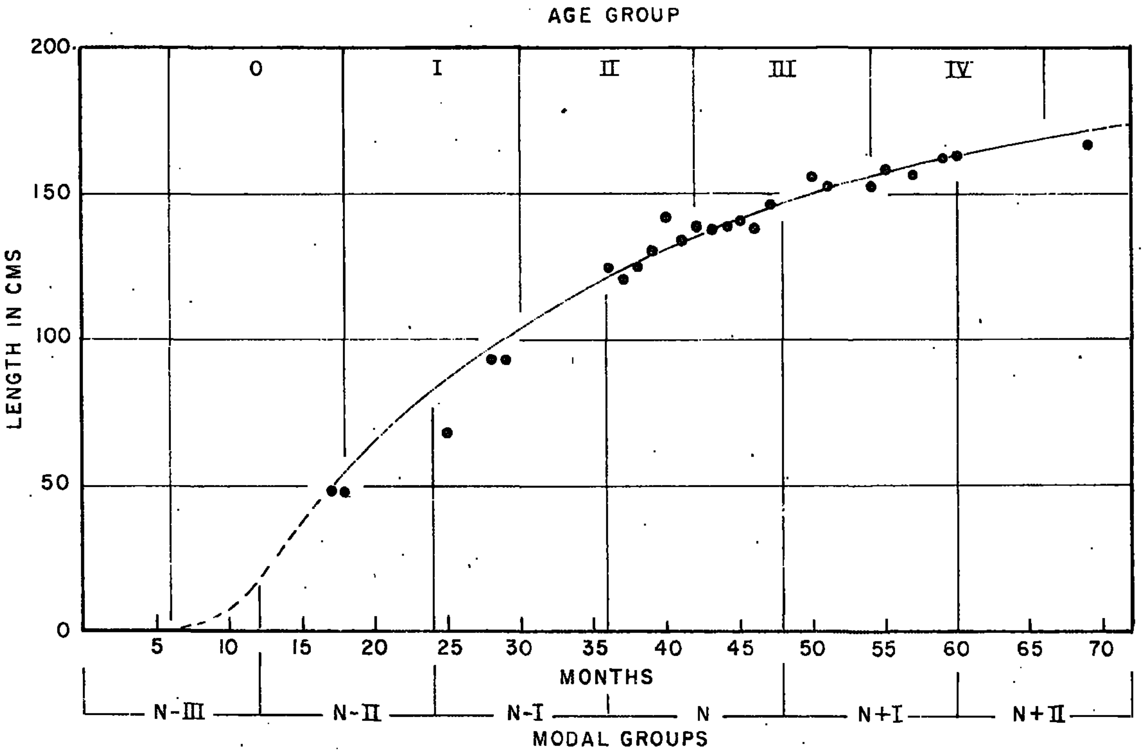

Figure 8.—Growth curve of yellowfin tuna taken in Hawaiian waters fitted to lengths with actual modal values in length superimposed.

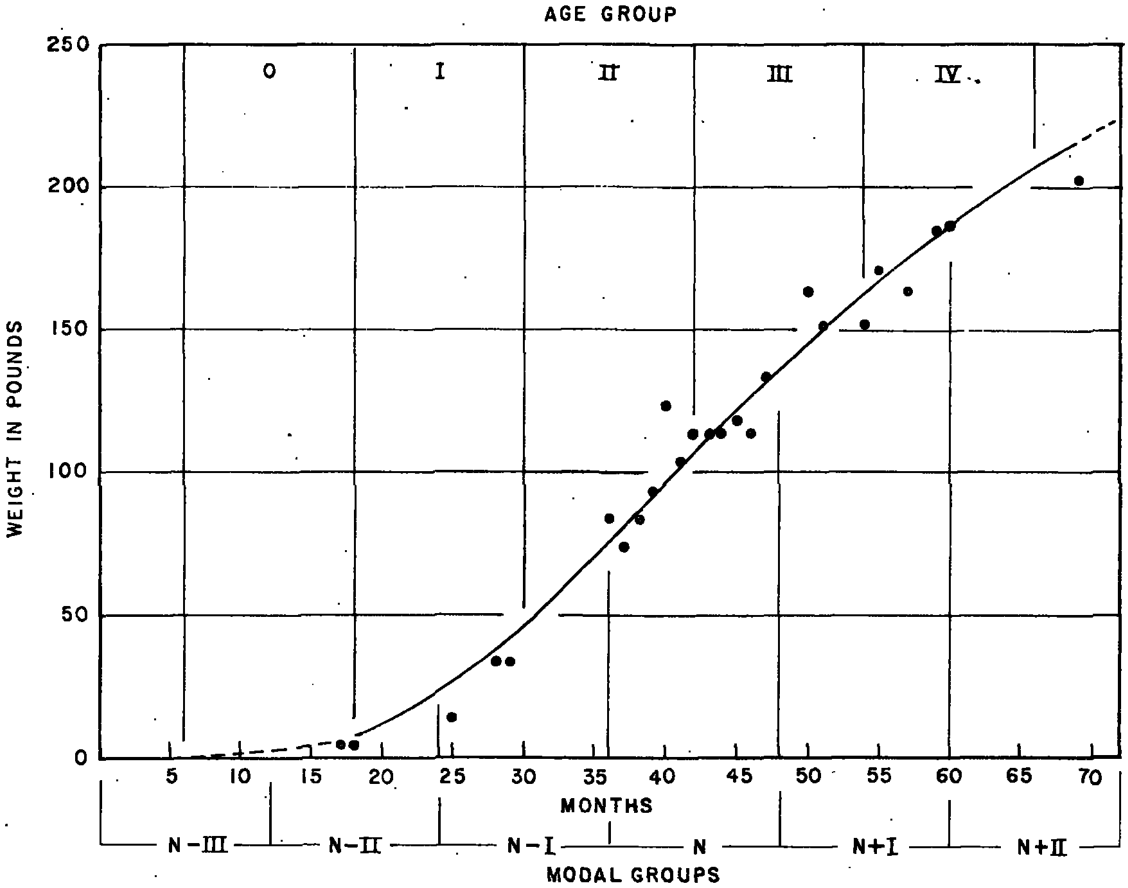

FIGURE 9.—Growth curve of yellowfin tuna taken in Hawaiian waters fitted to lengths and transformed into terms of weight. Actual modal values in weight are superimposed.

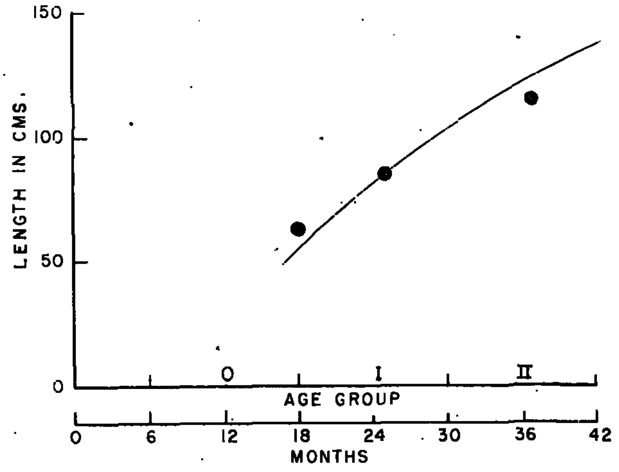

FIGURE 10.—Lengths of dominant size groups of yellowfin taken in waters off Central America by Schaefer (1948) plotted against calculated growth curve of Hawaiian yellowfin.

Schaefer that the 60-cm. fish probably are 1 year old and the 85-cm. fish a year older is also in close agreement.

Our growth curve indicates that the yellowfin tuna grows rapidly during at least the earlier years of life. Group *N* demonstrates a gain in weight of approximately 60 pounds in 1 year. Aikawa and Kato (1938) and Kimura (1932) have studied age and growth of the yellowfin tuna in Japanese waters. Aikawa and Kato assigned ages by the study of marks on vertebral centra which they considered to be annuli. The resulting age-weight relation is shown in figure 11. In plotting these data, which are from table 3, it was assumed that the maximum values were representative of the end of the year of life because the length and weight values for age group O were maximum values. As the month of June has been used in our study as being the approximate center of the

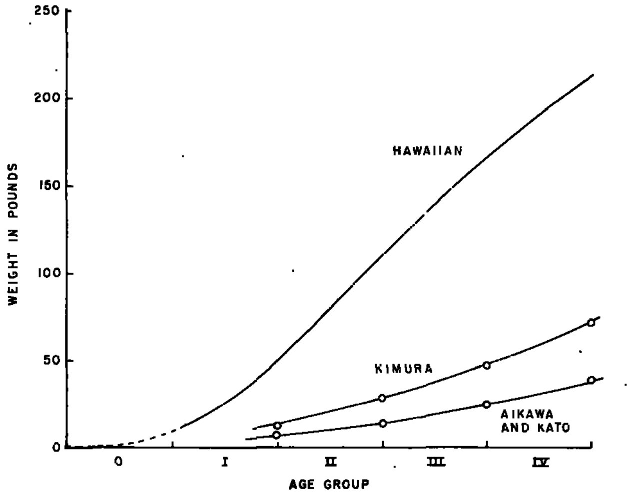

FIGURE 11.—Growth in weight plotted against age for Hawaiian yellowfin as compared to growth curves calculated by Aikawa and Kato (1938) and Kimura (1932).

spawning period, the maximum values as given by Aikawa and Kato have been plotted for the month of June, the assumed last month for any age group. Regardless of the month of the year these values are plotted against, the values for any given age group differ greatly from the values resulting from our study of the Hawaiian yellowfin.

TABLE 3.—*Age, length, and weight range of yellowfin tuna from Japanese waters, from Aikawa and Kato (1938)*

Age group	Length in centimeters	Weight in kilograms	Weight in pounds
0	Less than 38	Less than 1.5	Less than 3.3.
I	38 to 54	1.5 to 4.3	3.3 to 9.5.
II	54 to 70	4.3 to 8.6	9.5 to 19.0.
III	70 to 85	8.6 to 14.0	19.0 to 30.9.
IV	85 to 100	14.0 to 21.4	30.9 to 47.2.
V	100 to 115	21.4 to 34.0	47.2 to 75.0.
VI	115 to 130	34.0 to 44.0	75.0 to 97.0.
VII	130 to 145	44.0 to 57.5	97.0 to 126.8.
VIII	145 to 160	57.5 to 75.0	126.8 to 165.4.

The results of Kimura's (1932) age-weight study also are shown in figure 11. This study is based on a few specimens taken over a long period with no defined method of determining modal values in frequency distributions. The presentation of Kimura's data is based on values of weight taken directly from his growth curve shown in figure 12. Values were converted to pounds for comparison with our data. This growth curve demonstrates more rapid growth than the curve of Aikawa and Kato but still does not agree with the present Hawaiian study.

Figure 13 gives growth curves of other species of tuna taken from various areas in the world compared to the growth curve of Hawaiian yellowfin. We have plotted these from the published data. This graph shows no other tunas as having a growth rate as rapid as that of the yellowfin tuna of Hawaiian waters. The curve of bluefin tuna of the Mediterranean Sea (Sella 1929) is based on more than 1,500 vertebrae samples. This growth curve, like the growth curve of yellowfin based on vertebra-centra analysis (Aikawa and Kato 1938), shows a very slow growth rate and infers a very long-lived fish, for most of the plotted data are below the point of inflection.

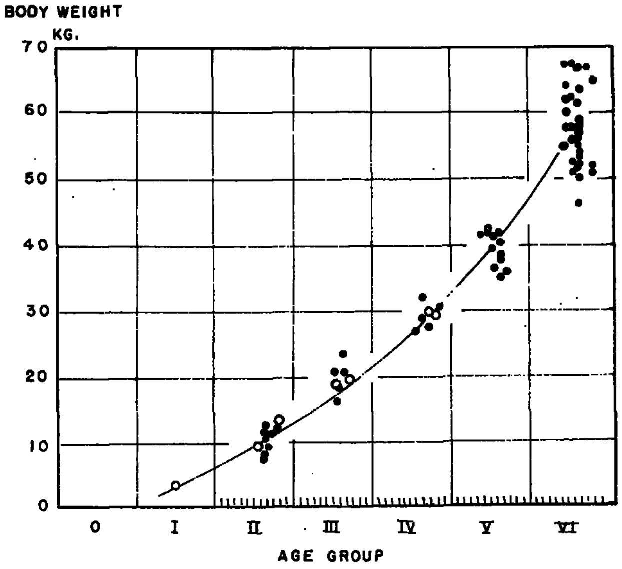

FIGURE 12.—Growth curve of yellowfin tuna in Japanese waters from Kimura (1932). Circles show average weight of a large number of fish of roughly equal weight taken at one time. Solid dots are weights of single fish.

Aikawa and Kato (1938), in addition to their study of the yellowfin, determined ages and growth of the black tuna (*Thunnus orientalis*), the bonito or skipjack (*Katsuwonus vagans*), and the albacore (*Germo germo*) by vertebral-centra analysis. Because the skipjack and albacore are smaller species of tuna not comparable to the yellowfin, they have not been included in the graph. The growth curve of the black tuna, a species more comparable in size, indicates a more rapid growth rate but the curve has only the slightest suggestion of an inflection point. The growth curve of bluefin tuna (black tuna of Aikawa and Kato, *Thunnus orientalis*) by Kimura (1932) from weight frequencies

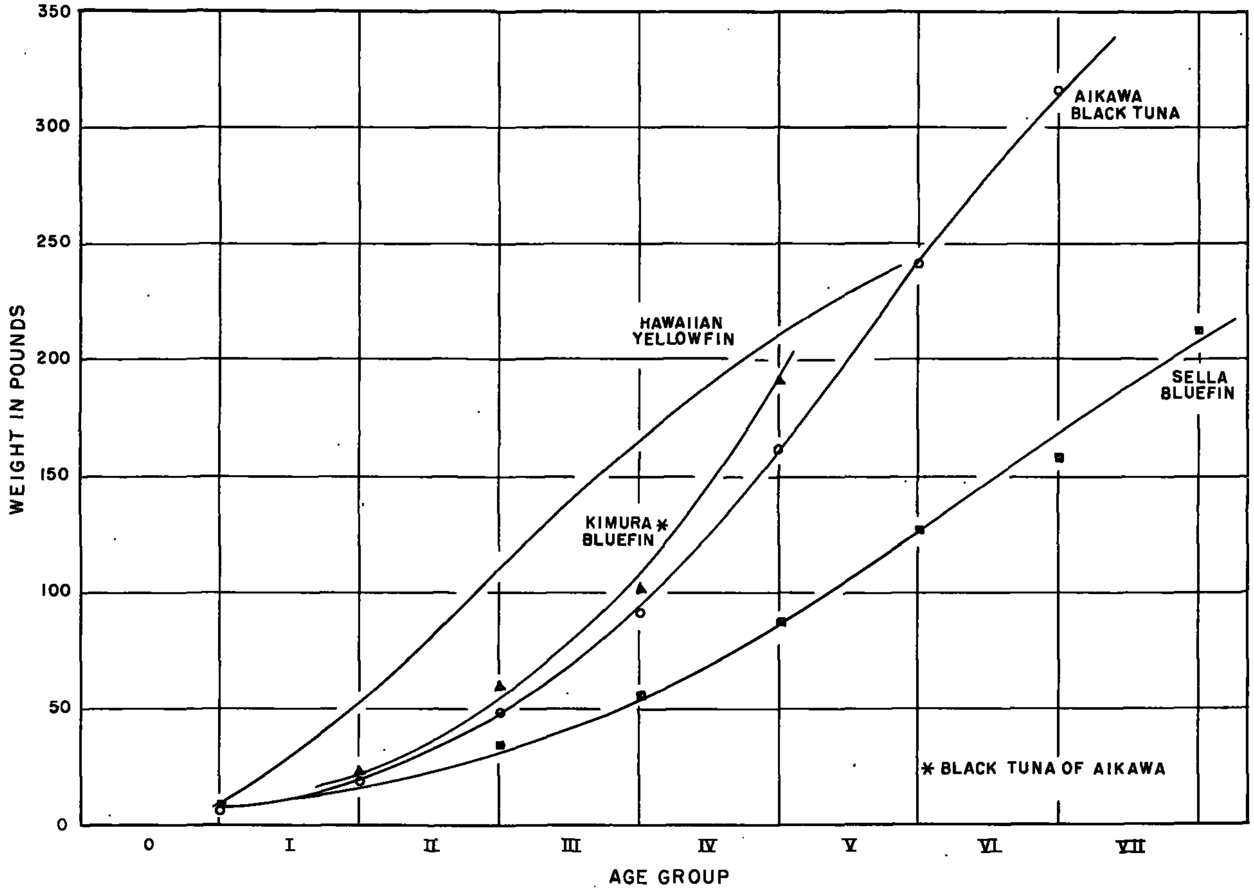

Figure 13.—Age-weight curves of tunas from waters off Japan and Mediterranean Sea compared to curve of Hawaiian yellowfin.

demonstrates the most rapid growth but shows no semblance of a point of inflection. As the curves have been fitted to the data by eye, there may be errors in the interpretation, but the curves show the great variation in results of age and growth studies of tunas.

Westman and Neville (1942), in a study of 751 length frequencies of bluefin tuna (*Thunnus thynnus*) taken in waters off New York by both the troll and chum fisheries, show the catch to be made up of three distinct age groups. Ages were assigned by scale readings. A comparison of size of fish by ages with the Hawaiian-yellowfin study shows more similarity than the curves indicate in figure 13. Even so, the growth rate of the Atlantic bluefin as shown by plotted data (fig. 14) is not so rapid as yellowfin growth during the early years of life.

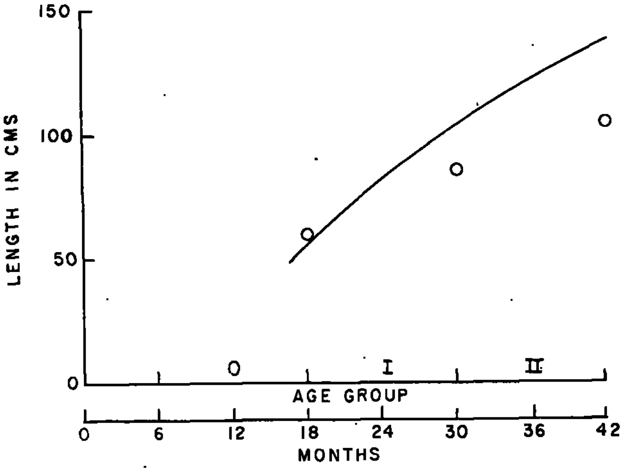

Figure 14.—Lengths of dominant size groups of bluefin tuna taken off Long Island, New York, by Westman and Neville (1942), plotted against the calculated growth curve of Hawaiian yellowfin.

In general, the results of our study of weight frequencies of Hawaiian yellowfin tend to disagree with results of some studies of other species of tuna and even with comparable yellowfin studies. Group *N*, present in the Hawaiian long-line catches of both 1948 and 1949, is with little doubt an age group demonstrating a weight gain of about 60 pounds in the calendar year. Whether or not our conclusions about age are correct in other respects, the yellowfin tuna of Hawaiian waters undoubtedly is a rapid-growing species.

CONCLUSIONS

1. The yellowfin tuna (*Neothunnus macropterus*) in Hawaiian waters is a rapid-growing fish demonstrating at least during part of its life a growth of approximately 60 pounds in one calendar year.
2. Positions of modes of size frequencies are well fitted by a growth curve calculated by Walford's graphic transformation method, having an upper asymptote at 294.9 pounds.
3. Extrapolation of the calculated curve downward shows the spawning period in reference to mode *N* to be in year *N*—III. If this interpretation is valid, mode *N* is composed of fish which were completing their third year of life and entering their fourth in the middle of the calendar year of observation.

Using the customary designation of age groups according to completed years of life, they would be designated age group II until the middle of the spawning season which occurs in the middle of the calendar year, and then become age group III.

LITERATURE CITED

AIKAWA, HIROAKI and M. KATO.
1938. Age determination of fish (Preliminary Rept. 1). Bull. Jap. Soc. Sci. Fish., vol. 7, No. 1, pp. 79–88, 8 figs. In Japanese with English summary. Translation from the Japanese by W. G. Van Campen.

BONHAM, KELSHAW.
1946. Measurements of some pelagic commercial fishes of Hawaii. Copeia, 1946, No. 2, pp. 81–84, 2 figs.

BROCK, VERNON E.
1944. Contribution to the biology of the albacore (*Germo alalunga*) of the Oregon coast and other parts of the North Pacific. Stanford Ichth. Bull., vol. 2, No. 7, pp. 19–248, 19 figs.

JUNE, FRED C.
1950. Preliminary fisheries survey of the Hawaiian-Line Islands area: Part I—The Hawaiian long-line fishery. U. S. Fish and Wildlife Service, Comm. Fish. Review, vol. 12, No. 1, pp. 1–23, 18 figs.

KIMURA, KINOSUKE.
1932. Growth curves of the blue-fin tuna and yellowfin tuna based on the catches near Sigedera, on the west coast of Prov. Izu. Bull. Jap. Soc. Sci. Fish., vol. 1, No. 1, pp. 1–4, 5 figs. In Japanese with English summary. Translated from the Japanese by W. G. Van Campen.

KISHINOUYE, KAMAKICHI.
1923. Contributions to the comparative study of the so-called scombroid fishes. Jour. College of Agric., Imperial Univ. Tokyo, vol. 8, No. 3, pp. 293–475, 26 figs.

OKAMOTO, GOROZO.
1940. On the weight composition of skipjack schools in the northeastern sea area. Bull. Jap. Soc. Sci. Fish., vol. 9, No. 3, pp. 100–102, 2 figs. In Japanese with English synopsis. Translation from the Japanese by W. G. Van Campen.

PARTLO, J. M.
1950. A report on the 1949 albacore fishery (*Thunnus alalunga*). Fish. Res. Bd. Canada, Pac. Biol. Sta., Cir. 20, pp. 1–37.

PETERSEN, C. G. J.
1922. On the stock of plaice and the plaice fisheries in different waters. A survey. Rept. Danish Biol. Sta., vol. 29, pp. 1–36, Copenhagen.

SCHAEFER, MILNER B.
1948. Size composition of catches of yellowfin tuna (*Neothunnus macropterus*) from central America, and their significance in the determination of growth, age, and schooling habits. U. S. Fish and Wildlife Service, Fish. Bull., No. 44, vol. 51, pp. 197–200, 4 figs.

SELLA, M.
1929. Migrazioni e habitat del tonno (*Thunnus thynnus* L.) studiati col metodo degli ami, con osservazioni su l'accrescimento sul regime delle tonnare, ecc. R. Comit. Talasso. Ital. Memoir 156, pp. 1–24, 2 figs.

SNEDECOR, GEORGE W.
1946. Statistical methods. Iowa State College Press, Ames, Iowa. 4th Ed., xvi+485.

WALFORD, LIONEL A.
1946. A new graphic method of describing the growth of animals. Biol. Bull., vol. 90, No. 1, pp. 141–147, 4 figs.

WESTMAN, J. R. and P. W. GILBERT.
1941. Notes on age determination and growth of the Atlantic bluefin tuna, *Thunnus thynnus* (Linnaeus). Copeia, 1941, No. 2, pp. 70–72, 3 figs.

WESTMAN, J. R. and W. C. NEVILLE.
1942. The tuna fishery of Long Island, New York. Pp. 1–31, 12 figs. Board of Supervisors, Nassau County, Long Island, New York.

APPENDIX

The following tables of data on yellowfin tuna are those on which the figures and calculations in the text are based.

TABLE A.—*Weight frequencies of yellowfin tuna taken by long-line fishing and landed at Honolulu during November and December 1947*

Class interval	November	December	Number of tuna landed
70 to 79 pounds	--------	2	2
80 to 89 pounds	1	1	2
90 to 99 pounds	--------	2	2
100 to 109 pounds	2	--------	2
110 to 119 pounds	1	2	3
120 to 129 pounds	1	5	6
130 to 139 pounds	3	9	12
140 to 149 pounds	4	9	13
150 to 159 pounds	--------	10	10
160 to 169 pounds	4	14	18
170 to 179 pounds	9	11	20
180 to 189 pounds	7	10	17
190 to 199 pounds	1	5	6
200 to 209 pounds	6	3	9
210 to 219 pounds	2	3	5
220 to 229 pounds	2	--------	2
230 to 239 pounds	1	2	3
240 to 249 pounds	--------	--------	--------
250 to 259 pounds	--------	--------	--------
260 to 269 pounds	1	--------	1
Total	45	88	133

TABLE B.—*Weight frequencies of yellowfin tuna taken by long-line fishing and landed at Honolulu during 1948*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Number of tuna landed
20 to 29 pounds	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1	1
30 to 39 pounds	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	1	1
40 to 49 pounds	--------	--------	1	--------	--------	--------	--------	--------	--------	3	--------	2	6
50 to 59 pounds	--------	--------	1	--------	1	--------	--------	--------	1	--------	1	2	6
60 to 69 pounds	1	1	--------	1	--------	--------	--------	2	5	4	2	5	21
70 to 79 pounds	7	3	2	1	2	--------	1	--------	2	4	3	6	31
80 to 89 pounds	4	8	4	--------	3	6	3	3	2	1	2	9	45
90 to 99 pounds	2	4	7	1	8	13	16	10	6	7	3	2	79
100 to 109 pounds	4	3	3	9	19	54	80	41	31	20	3	1	268
110 to 119 pounds	1	2	4	3	15	68	90	71	55	34	10	8	361
120 to 129 pounds	4	3	1	11	9	45	60	59	45	24	8	3	272
130 to 139 pounds	1	6	4	8	6	29	25	53	39	18	18	11	218
140 to 149 pounds	1	5	6	8	3	30	40	46	25	17	10	8	199
150 to 159 pounds	4	8	5	7	8	24	30	49	37	11	8	7	198
160 to 169 pounds	3	6	4	4	9	24	51	49	44	12	5	5	216
170 to 179 pounds	3	5	--------	3	3	24	34	40	19	5	6	5	147
180 to 189 pounds	3	2	1	2	1	9	29	46	25	8	10	6	142
190 to 199 pounds	1	4	1	2	2	13	30	37	19	7	4	5	125
200 to 209 pounds	1	1	--------	--------	4	17	18	21	16	1	2	4	85
210 to 219 pounds	--------	--------	--------	--------	3	3	15	11	8	3	2	1	46
220 to 229 pounds	--------	--------	1	--------	--------	3	3	3	--------	--------	--------	--------	10
230 to 239 pounds	--------	--------	--------	--------	--------	--------	2	--------	2	--------	--------	--------	4
240 to 249 pounds	--------	--------	--------	--------	--------	--------	2	1	--------	--------	1	--------	4
250 to 259 pounds	--------	--------	--------	--------	--------	--------	1	--------	--------	--------	1	--------	2
260 to 269 pounds	--------	--------	--------	--------	1	--------	--------	--------	--------	--------	--------	--------	1
Total	40	61	45	60	97	362	530	542	381	179	99	92	2,488

TABLE C.—*Weight frequencies of yellowfin tuna taken by long-line fishing and landed at Honolulu, 1949*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Number of tuna landed
20 to 29 pounds	1												1
30 to 39 pounds		1											1
40 to 49 pounds				1								1	2
50 to 59 pounds	1	1				1	1	2					6
60 to 69 pounds	4	2	1		3							4	14
70 to 79 pounds	12	7	2		1		1		1	4		2	30
80 to 89 pounds	5	15	2	2	2	2	3	4	6	6		10	57
90 to 90 pounds		7	5	9	24	20	16	7	2	8	2	9	109
100 to 109 pounds	2	4	1	11	23	62	52	39	10	4	2	7	217
110 to 119 pounds	1	1	1	8	11	51	77	58	23	10	2	6	249
120 to 129 pounds	1	4		14	16	52	68	37	23	11	9	3	238
130 to 139 pounds	4	8	3	9	20	60	65	46	19	12	1	4	251
140 to 149 pounds	1	3	1	4	18	56	42	39	12	10	1	4	191
150 to 159 pounds	1	6	3	1	7	63	51	37	16	7	3	4	199
160 to 169 pounds	2	5		2	12	43	47	31	12	7	1	3	165
170 to 179 pounds	2	5		4	5	33	42	30	9	6	4	4	144
180 to 189 pounds		3	1	1	4	15	28	17	8	3	1	3	84
190 to 199 pounds				1	2	17	17	20	5	6		2	76
200 to 209 pounds	1				5	18	21	20	13	2	2		82
210 to 219 pounds		1			3	13	9	10	4	4		1	45
220 to 229 pounds					2	5	4	2	2	1	1		17
230 to 239 pounds						3	1	1			1		6
240 to 249 pounds	1										1		2
250 to 259 pounds										1			1
260 to 269 pounds													
Total	39	73	20	67	158	514	545	400	165	102	31	67	2,181

TABLE D.—*Weight frequencies of yellowfin tuna taken by long-line fishing and landed at Honolulu, 1948 and 1949 combined*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Number of tuna landed
20 to 29 pounds	1											1	2
30 to 39 pounds		1										1	2
40 to 49 pounds			1	1						3		3	8
50 to 59 pounds	1	1	1		1	1	1	2	1		1	2	12
60 to 69 pounds	5	3	1	1	3			2	5	4	2	9	35
70 to 79 pounds	19	10	4	1	3		2		3	8	3	8	61
80 to 89 pounds	9	23	6	2	5	8	6	7	8	7	2	19	102
90 to 99 pounds	2	11	12	10	32	33	32	17	8	15	5	11	188
100 to 109	6	7	4	20	42	116	132	80	41	24	5	8	485
110 to 119 pounds	2	3	5	11	26	119	167	129	78	44	12	14	610
120 to 129 pounds	5	7	1	25	25	97	128	96	68	35	17	6	510
130 to 139 pounds	5	14	7	17	26	89	90	99	58	30	19	15	469
140 to 149 pounds	2	8	7	12	21	86	82	85	37	27	11	12	390
150 to 159 pounds	5	14	8	8	15	87	81	86	53	18	11	11	397
160 to 169 pounds	5	11	4	6	21	67	98	80	56	19	6	8	381
170 to 179 pounds	5	10		7	8	57	76	70	28	11	10	9	291
180 to 189 pounds	3	5	2	3	5	24	57	63	33	11	11	9	226
190 to 199 pounds	1	4	1	3	4	30	47	57	24	13	4	7	195
200 to 209 pounds	2	1			9	35	39	41	29	3	4	4	167
210 to 219 pounds		1			6	16	24	21	12	7	2	2	91
220 to 229 pounds			1		2	8	7	5	2	1	1		27
230 to 239 pounds						3	3	1	2		1		10
240 to 249 pounds	1						2	1			2		6
250 to 259 pounds							1			1	1		3
260 to 269 pounds					1								1
Total	79	134	65	127	255	876	1,075	942	546	281	130	159	4,669

TABLE E.—*Weight frequencies of yellowfin tuna taken by live-bait fishing and trolling and landed at Honolulu during 1949*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Number of tuna landed
0 to 9 pounds					22	54							76
10 to 19 pounds	6	3			1	1		1					12
20 to 29 pounds	1		1	1	1								4
30 to 39 pounds				13	15	2	1	1					32
Total	7	3	1	14	39	57	1	2					124

TABLE F.—*Weight frequencies of yellowfin tuna taken by long-line and live-bait fishing and landed at Honolulu during 1948 and 1949*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Number of tuna landed
0 to 9 pounds					22	54							76
10 to 19 pounds	6	3			1	1		1					12
20 to 29 pounds	2		1	1	1							1	6
30 to 39 pounds		1		13	15	2	1	1				1	34
40 to 49 pounds			1	1						3		3	8
50 to 59 pounds	1	1	1		1	1	1	2	1		1	2	12
60 to 69 pounds	5	3	1	1	3			2	5	4	2	9	35
70 to 79 pounds	19	10	4	1	3		2		3	8	3	8	61
80 to 90 pounds	9	23	6	2	5	8	6	7	8	7	2	19	102
90 to 99 pounds	2	11	12	10	32	33	32	17	8	15	5	11	188
100 to 109 pounds	6	7	4	20	42	116	132	80	41	24	5	8	485
110 to 119 pounds	2	3	5	11	26	119	167	129	78	44	12	14	610
120 to 129 pounds	5	7	1	25	25	97	128	96	68	35	17	6	510
130 to 139 pounds	5	14	7	17	26	89	90	99	58	30	19	15	469
140 to 149 pounds	2	8	7	12	21	86	82	85	37	27	11	12	390
150 to 159 pounds	5	14	8	8	15	87	81	86	53	18	11	11	397
160 to 169 pounds	5	11	4	6	21	67	98	80	56	19	6	8	381
170 to 179 pounds	5	10		7	8	57	76	70	28	11	10	9	291
180 to 189 pounds	3	5	2	3	5	24	57	63	33	11	11	9	226
190 to 199 pounds	1	4	1	3	4	30	47	57	24	13	4	7	195
200 to 209 pounds	2	1			9	35	39	41	29	3	4	4	167
210 to 219 pounds		1			6	16	24	21	12	7	2	2	91
220 to 229 pounds			1		2	8	7	5	2	1	1		27
230 to 239 pounds						3	3	1	2		1		10
240 to 249 pounds	1						2	1			2		6
250 to 259 pounds							1			1	1		3
260 to 269 pounds					1								1
Total	86	137	66	141	294	933	1,076	944	546	281	130	159	4,793

TABLE G.—*Weight frequencies of yellowfin tuna taken by long-line and live-bait fishing during 1948 and 1949 as percentages of monthly catch with mean frequency distribution in percentage*

Class interval	January	February	March	April	May	June	July	August	September	October	November	December	Mean
0 to 9 pounds					7.5	5.8							1.1
10 to 19 pounds	7.0	2.2			0.3	0.1		0.1					0.8
20 to 29 pounds	2.3		1.5	0.7	0.3							0.6	0.4
30 to 39 pounds		0.7		9.2	5.1	0.2	0.1	0.1				0.6	1.3
40 to 49 pounds			1.5	0.7						1.1		1.9	0.4
50 to 59 pounds	1.2	0.7	1.5		0.3	0.1	0.1	0.2	0.2		0.8	1.3	0.5
60 to 69 pounds	5.8	2.2	1.5	0.7	1.0			0.2	0.9	1.4	1.5	5.7	1.7
70 to 79 pounds	22.1	7.3	6.1	0.7	1.0		0.2		0.6	2.8	2.3	5.0	4.0
80 to 89 pounds	10.5	16.8	9.1	1.4	2.6	0.8	0.6	0.7	1.5	2.5	1.5	11.9	5.0
90 to 99 pounds	2.3	8.0	18.2	7.1	10.9	3.5	3.0	1.8	1.5	5.3	3.8	6.9	6.0
100 to 109 pounds	7.0	5.1	6.1	14.2	14.3	12.4	12.3	8.5	7.5	8.5	3.8	5.0	8.7
110 to 119 pounds	2.3	2.2	7.6	7.8	8.8	12.8	15.5	13.7	14.3	15.7	9.2	8.8	9.9
120 to 129 pounds	5.8	5.1	1.5	17.7	8.5	10.4	11.9	10.2	12.4	12.5	13.1	3.8	9.4
130 to 139 pounds	5.8	10.2	10.6	12.0	8.8	9.5	8.4	10.5	10.6	10.7	14.6	9.4	10.1
140 to 149 pounds	2.3	5.8	10.6	8.5	7.1	9.2	7.6	9.0	6.8	9.6	8.5	7.6	7.7
150 to 159 pounds	5.8	10.2	12.1	5.7	5.1	9.3	7.5	9.1	9.7	6.4	8.5	6.9	8.0
160 to 169 pounds	5.8	8.0	6.1	4.2	7.1	7.2	9.1	8.5	10.3	6.8	4.6	5.0	6.9
170 to 179 pounds	5.8	7.3		5.0	2.7	6.1	7.1	7.4	5.1	3.9	7.7	5.7	5.3
180 to 189 pounds	3.5	3.6	3.0	2.1	2.6	2.6	5.3	6.7	6.0	3.9	8.5	5.7	4.4
190 to 199 pounds	1.2	2.9	1.5	2.1	1.4	3.2	4.4	6.0	4.4	4.6	3.1	4.4	3.3
200 to 209 pounds	2.3	0.7			3.1	3.8	3.6	4.3	5.3	1.1	3.1	2.5	2.5
210 to 219 pounds		0.7			2.0	1.7	2.2	2.2	2.2	2.5	1.5	1.3	1.4
220 to 229 pounds			1.5		0.7	0.8	0.6	0.5	0.4	0.4	0.8		0.5
230 to 239 pounds						0.3	0.3	0.1	0.4		0.8		0.2
240 to 249 pounds	1.2						0.2	0.1			1.5		0.2
250 to 259 pounds							0.1			0.4	0.8		0.1
260 to 269 pounds					0.3								

TABLE H.—*Time and position of recognized and interpolated modes from the combined 1948 and 1949 data*

Month	Number	Observed length, in centimeters	Interpolated length, in centimeters
May	17	47.2	
June	18	47.2	
July	19		50.4
August	20		53.6
September	21		56.8
October	22		60.0
November	23		63.2
December	24		66.5
January	25	69.7	
February	26		77.5
March	27		85.2
April	28	93.0	
May	29	93.0	
June	30		97.6
July	31		102.2
August	32		106.8
September	33		111.4
October	34		116.0
November	35		120.7
December	36	125.3	
January	37	120.2	
February	38	125.3	
March	39	130.1	
April	40	142.6	
May	41	134.5	
June	42	138.7	
July	43	138.7	
August	44	138.7	
September	45	140.3	
October	46	138.7	
November	47	146.3	
December	48		149.7
January	49		153.0
February	50	156.4	
March	51	152.1	
April	52		152.2
May	53		152.3
June	54	152.4	
July	55	158.2	
August	56		157.3
September	57	156.4	
October	58		159.4
November	59	162.5	
December	60	163.1	
January	61		163.6
February	62		164.1
March	63		164.6
April	64		165.1
May	65		165.6
June	66		166.1
July	67		166.6
August	68		167.1
September	69	167.6	

○