SIZE FREQUENCIES AND GROWTH OF CENTRAL AND WESTERN PACIFIC BIGEYE TUNA

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By

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ABSTRACT

Bigeye tuna (Parathunnus sibi) weight data from the Honolulu market for the period 1947-54, length data collected aboard Japanese tuna motherships in the equatorial western Pacific in 1951, and published length frequency distributions from the Japanese longline fishery in the northwest Pacific were compared and studied for evidence of growth and of local differences in the size composition of the population. In the data from both the equatorial western Pacific and Hawaiian waters the modes of the male size distributions were found to be about 14 cm. or 30 pounds larger than the corresponding female modes. Monthly weight frequencies of Hawaiian bigeye showed a consistent progression of modes, yielding a provisional growth curve that indicates that these fish may gain as much as 50 pounds in 1 year and may live about 6 or 7 years. Relatedness of the bigeye in Hawaiian waters and in the Japanese North Pacific fishery is suggested by the approximately similar growth rates and by the presence of a complementary 2-year cycle of dominant size groups in the catches of both areas. Data from equatorial waters showed no progression of the modes with time.

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The purpose of this analysis of bigeye tuna, Parathunnus sibi (Temminck and Schlegel) = P. mebachi (Kishinouye)[1/], measurements is to learn about growth and migration of this species from the size composition of commercial longline catches. Consideration of size frequencies from the Hawaiian and the Japanese North Pacific fisheries yields evidence of a relationship which suggests that there is but a single stock of bigeye being exploited by both fisheries. These data also furnish evidence of rapid growth of bigeye tuna. Other facets of the biology of the species, such as size differences associated with sex, are revealed by Japanese catches in the equatorial Pacific and Hawaiian catches. Measurements obtained on Japanese mothership expeditions in the western equatorial Pacific, which will be discussed, supply information on size differences associated with sex and evidence pointing to a migration of this species. (The size frequencies on which this study is based are presented in tabular form in the appendix.)

The bigeye tuna is of considerable importance in the Hawaiian longline (flagline) fishery, where catches are sold on the Honolulu fresh fish market. The operation of the Hawaiian fishery has been described and catch statistics analyzed by June (1950) and Otsu (1954). In 1952, a year of high abundance, the value of the landings to the fishermen is given by Otsu as $684,726. The same author also describes the seasonal trend in apparent abundance, pointing out that the lighter catches occur from June to September and the heavier catches from October to May. The catch of this species increased sharply from 126,000 pounds

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[1/] Parathunnus sibi (Temminck and Schlegel) is regarded as a synonym of P. mebachi (Kishinouye) by numerous authors, among them Brock (1949) and Nakamura (1949). For the purpose of this paper they will be considered a single species.

in 1946 to 2,193,000 pounds in 1952. The years 1953 and 1954 similarly show high catches of 2,826,000 pounds and 2,759,000 pounds respectively.[2/]

The bigeye tuna is also important in the Japanese high seas longline fishery, which covers vast areas of the western and central Pacific Ocean, extending as far east as Hawaii. Following World War II, Japanese mothership expeditions, described by Shimada (1951a and b), Ego and Otsu (1952), Van Campen (1952), and Murphy and Otsu (1954), landed considerable numbers of bigeye tuna. These expeditions operated from about 1° to 10°N. latitude and 134° to 179°E. longitude. Farther to the north there is a Japanese longline fishery for deep-swimming tunas, including bigeye, which has been described by Shapiro (1950). The area covered by this North Pacific fishery is usually north of 26°N. latitude and between 130°E. and 165°W. longitude.

ACKNOWLEDGEMENTS

Appreciation is extended to the individuals, too numerous to mention, who have aided in the collection of measurements and offered direction in preparing this report. To the Hawaii Fishing Co., Ltd., and the United Fishing Agency indebtedness is acknowledged for permission to examine sales records. To Mr. T. Nakata thanks are extended for the preparation of figures in this report.

MATERIAL AND METHODS

For most of the Hawaiian specimens only the weight (obtained from market sales slips) is available. Length measurements taken on the Japanese mothership expeditions were in millimeters from the tip of the snout with jaws closed to the median portion of the caudal fork (with fleshy flap depressed) as described by Marr and Schaefer (1949). Additional length frequencies were obtained from Japanese reports. Prior to analysis length measurements were tabulated in 2-centimeter intervals, and weight measurements in 10-pound intervals. When it was necessary to convert from length to weight, the relationship log weight (pounds) = -7.1167 + 2.9304 log total length (millimeters), based on Hawaiian samples, was used. To smooth data, a moving average of three was applied.

[2/] From unpublished records of the Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Territory of Hawaii.

Since the successful interpretation of growth from time series of size frequency distributions depends on an objective and realistic method of locating modes, the following criteria were adopted:

1. No modes have been sought in distributions containing less than 100 fish.

2. Each mode must be separated from every other mode by troughs dipping at least 5 fish below modes after smoothing.

3. Each mode must be present in the data for at least two not too widely separated months.

4. At least two of the groups making up the mode must have no less than 15 individuals each before smoothing, or at least 10 individuals if the modal peak is present in two adjacent months.

5. The mode must be the center group of a peak of the smoothed distribution or the center group of two or more minor peaks which differ by less than 5 fish in height.

SIZE DIFFERENCE BY AREAS

Bigeye tuna taken on commercial longline gear are smaller in the western than in the central Pacific (Kamimura and Honma 1953, Murphy and Shomura 1953b, and Murphy and Otsu 1954). In their report, Murphy and Shomura state that longline fishing west of 180° longitude yielded bigeye that averaged about 40 pounds lighter in weight than those taken between 180° and 120°W. longitude. This interesting phenomenon is believed by them to be related to ecological conditions, however, Iversen[3/] points out that this type of size segregation can be the result of migration.

SEXUAL DIFFERENCE IN CATCH

The bigeye males achieve a larger average size than the females, for all recognizable male modes are to the right of the corresponding female modes. Size distributions from the Hawaiian Islands (fig. 1) and the western Pacific (137°- 165°E. longitude) (fig. 2) show a parallel size differential between the sexes.

[3/] MS. Size variation of central and western Pacific yellowfin with age and area.

In view of this size difference it is of interest to examine the sex ratio for possible variation throughout the year. Aside from intrinsic interest, this is advisable because a periodic change in the sex ratio could shift the positions of the modes of unsexed samples and make an analysis of growth misleading. The mean percentage of males for Hawaiian bigeye for the year 1949 was 59.2 percent and for 1951, 57.5 percent (Otsu 1954). The larger samples (over 100 specimens) from these same years and December of 1950, when tabulated by months (table 1), indicate that the sex ratio remained rather constant at about 60 percent males throughout the year.

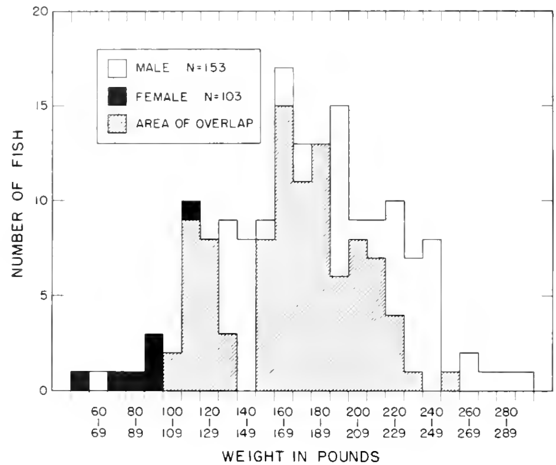

Figure 1.--Weight frequency distributions of bigeye tuna landed at the Honolulu market from May to August 1951.

The possibility that the sex ratio changes as the fish grow requires examination because this could affect the position of modes based on unsexed samples. Otsu (1954) states "....the sex ratio in the catch /fifth Japanese mothership expedition/ below 80-90 pounds is about equal, whereas the males predominate among the larger bigeye and yellowfin." However, if the female bigeye size frequency distribution is shifted a distance equal to the average growth lag between sexes, the apparent change in sex ratio with increase in fish size disappears.

Figure 3, lower panel, shows the sex ratios plotted by size groups from the data used by Otsu (fig. 2). The proportion of males increases with an increase in the size of the fish. (The small numbers in the extreme groups connected with dashed lines are better ignored.)

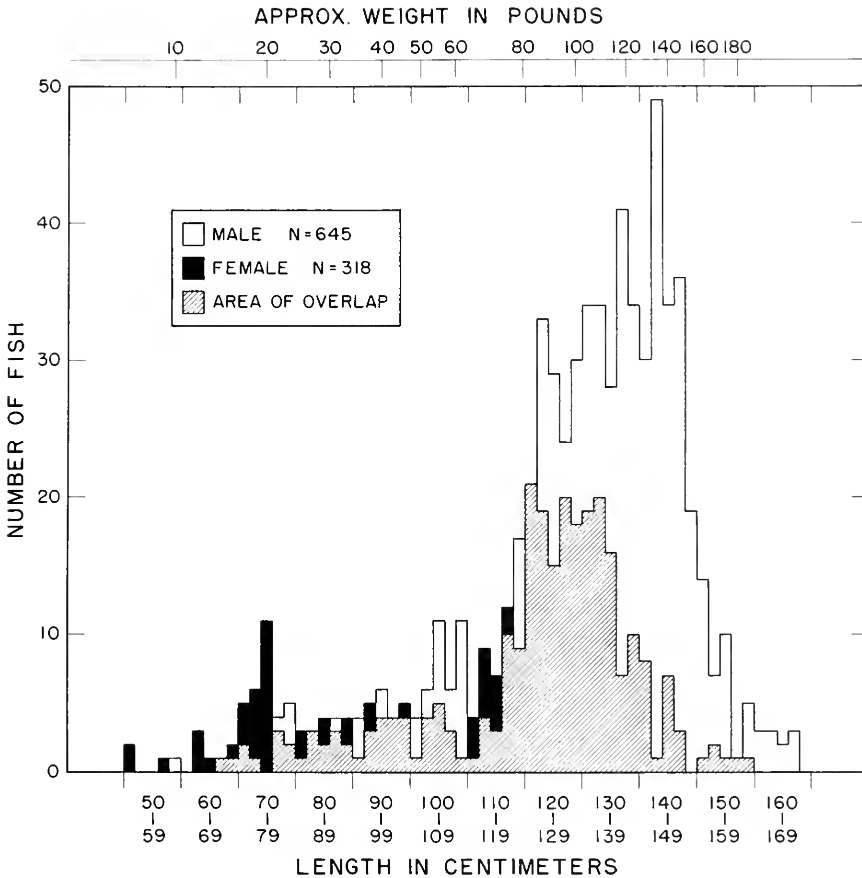

Figure 2.--Length frequency distributions of bigeye tuna from 137°- 165°E. longitude taken between March 29 and May 28, 1951.

In the upper panel the female size groups have been moved 14 cm. to the right (approximate average difference in size related to sex), and the resultant trend indicates that the sex ratio is constant at about 60 percent males throughout the size range studied.

Table 1. --Monthly sex ratio of Hawaiian bigeye tuna

Months	Males	Females	Total	Percent Males
1949				
Jan. -Feb.	32	18	50	64.0
Mar.	16	16	32	50.0
Apr.	5	10	15	33.3
May	7	3	10	70.0
June-Aug.	10	1	11	90.9
Sept.	30	11	41	73.2
Oct.	41	35	76	53.9
Nov.	100	65	165	60.6
Dec.	105	79	184	57.1
Total	346	238	584	59.2
1950				
Nov.	5	9	14	35.7
Dec.	102	59	161	63.4
1951				
Jan.	38	24	62	61.3
Feb.	24	25	49	49.0
Mar.	42	57	99	42.4
Apr.	65	39	104	62.5
May	82	43	125	65.6
June	51	34	85	60.0
July	57	50	107	53.3
Aug.	35	25	60	58.3
Sept.	40	43	83	48.2
Oct.	89	70	159	56.0
Total	630	478	1108	56.9

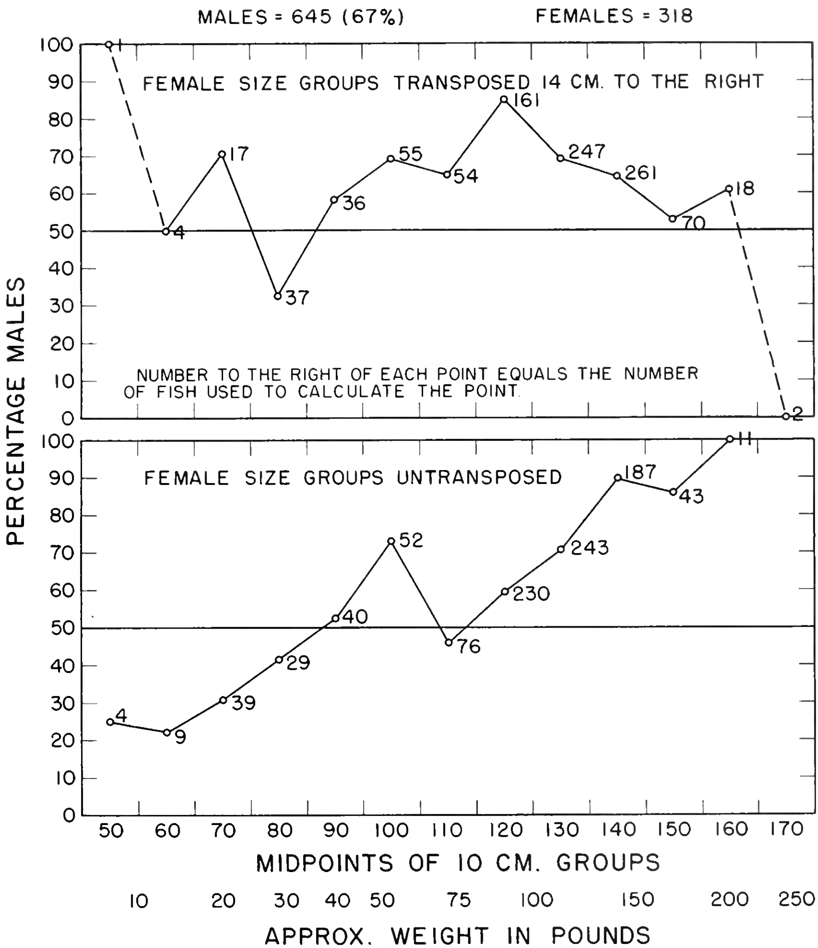

Figure 3.--Percentage bigeye tuna males in sample by size groups. Sample from 137°-165°E. longitude taken between March 29 and May 28, 1951. Lower panel shows the sex ratios of each size class of the sample in figure 2 (same data used by Otsu (1954)).

INTERYEAR SIZE DIFFERENCES

Before examining size distributions for evidence of growth, it is important to look for groups of similar sizes that appear each year. If detected in the same position year after year these dominant groups can be looked upon as the progeny of annual spawnings (year classes). To make this interyear comparison, monthly Honolulu market weights from November 1947 through December 1954 were plotted as weight frequency graphs (figs. 4-11).

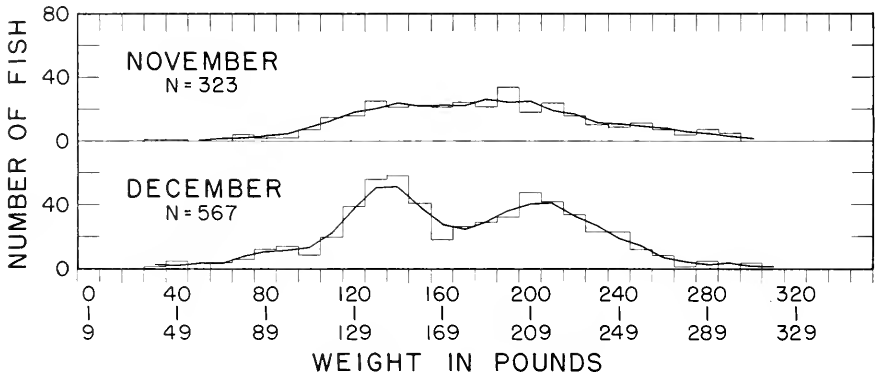

Figure 4. --Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1947.

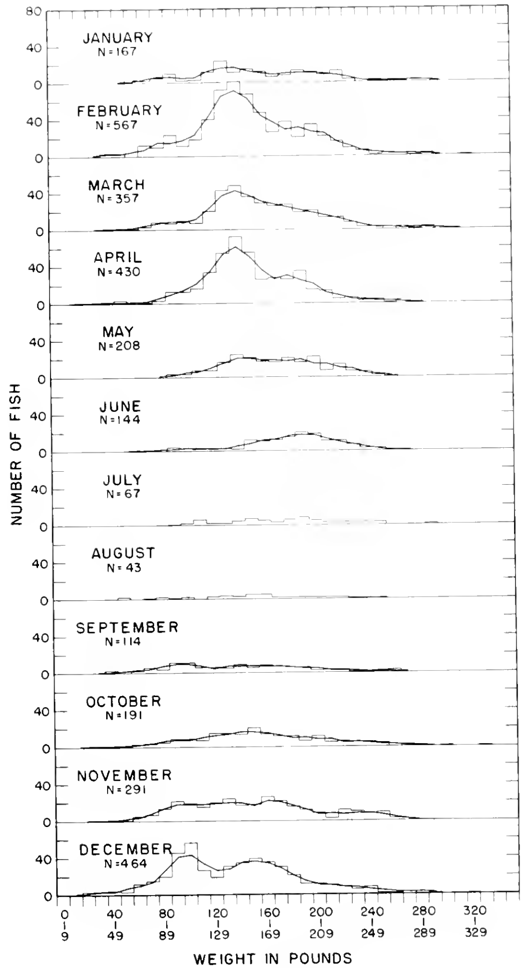

Figure 5.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1948.

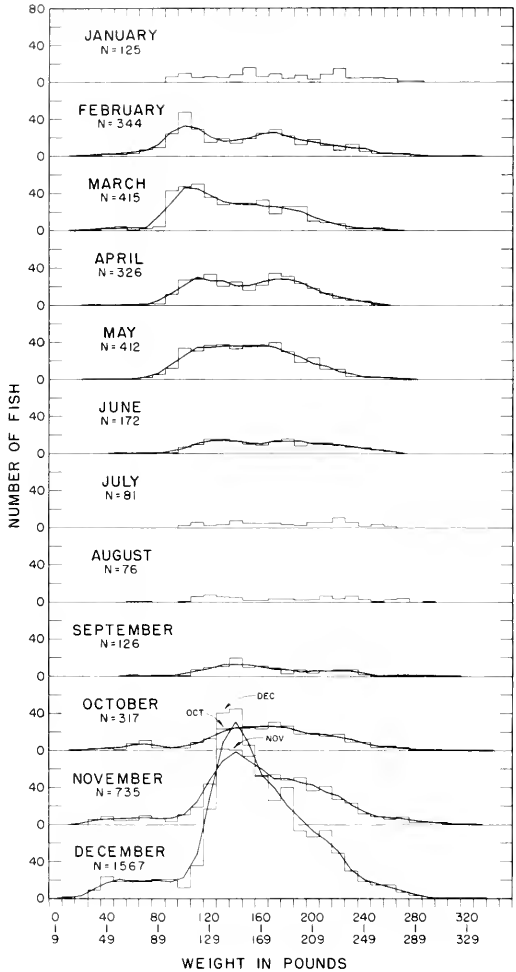

Figure 6.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1949.

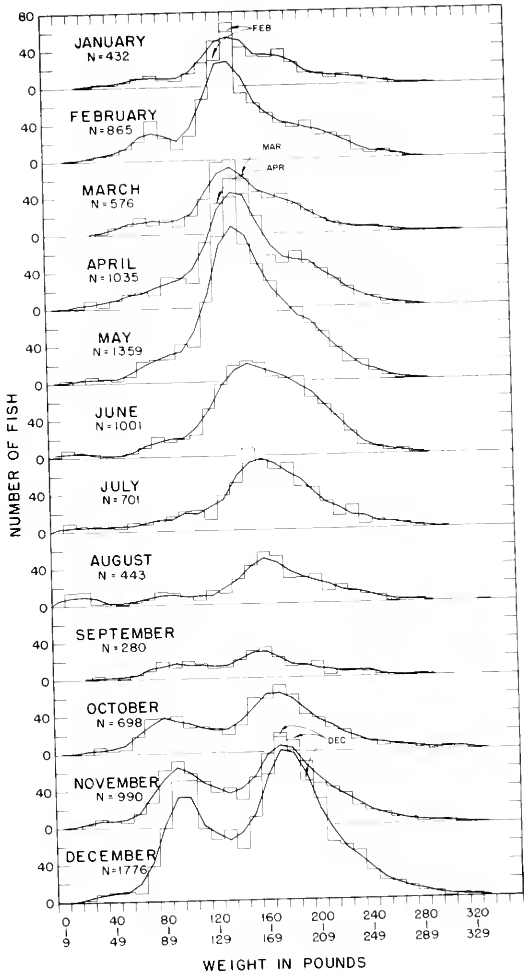

Figure 7.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1950.

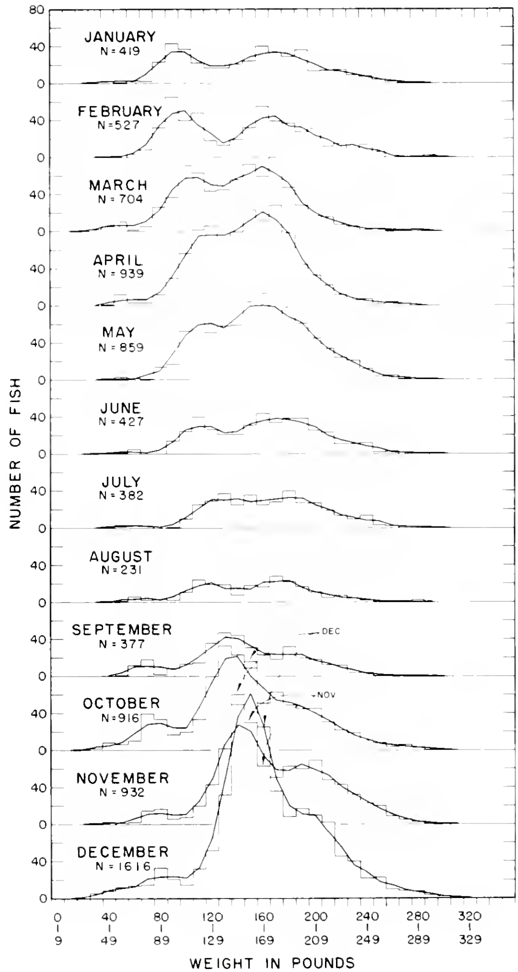

Figure 8. --Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1951.

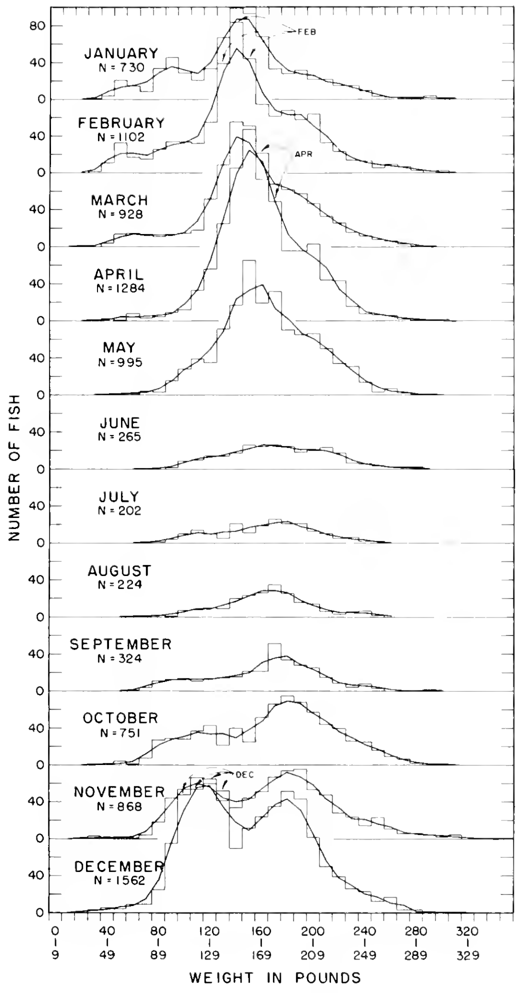

Figure 9.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1952.

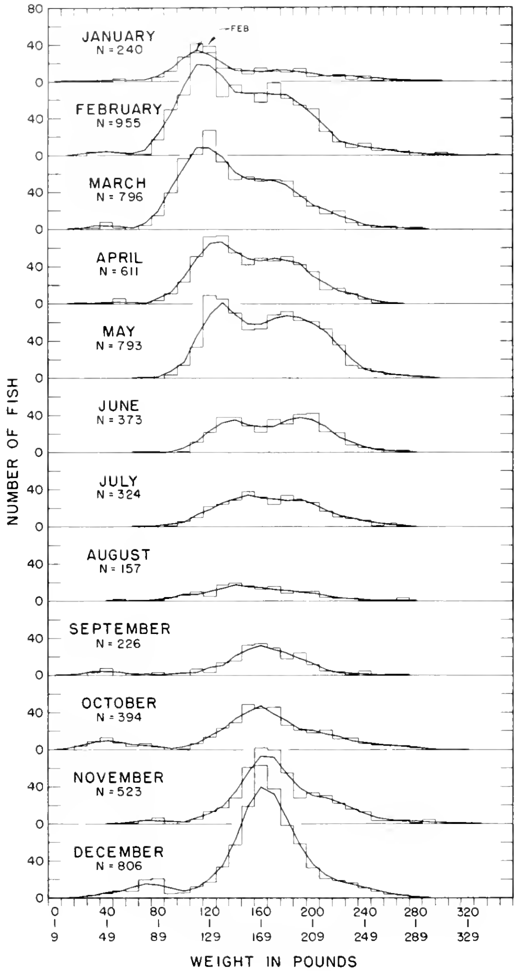

Figure 10.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1953.

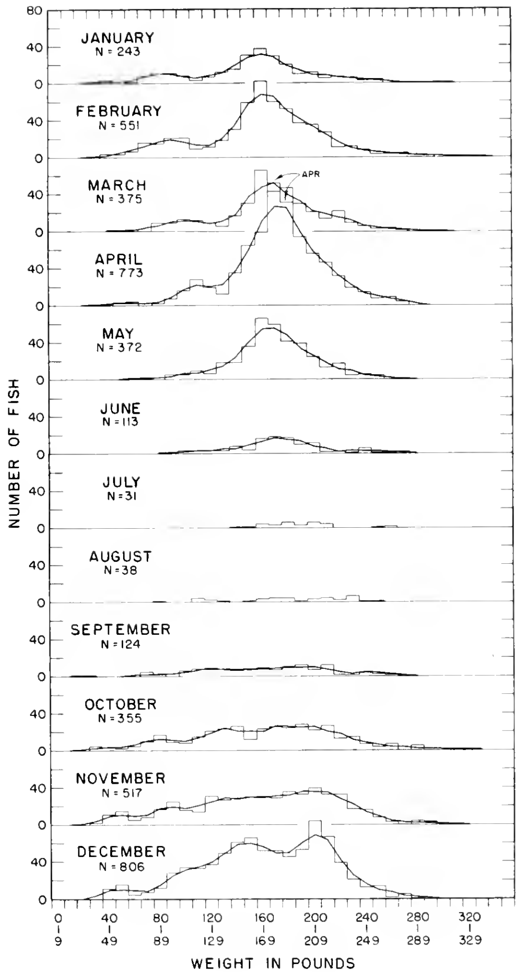

Figure 11.--Monthly weight frequency distributions of bigeye tuna from the Honolulu market for 1954.

An interesting aspect of these graphs is the noticeable difference in the positions of the dominant modes between adjacent years. For example, the year 1952 (fig. 9) has a dominant mode at about 150 pounds in January that progresses to 185 pounds by December and a secondary mode beginning at about 95 pounds in January that moves to about 120 pounds in December. The year 1953 (fig. 10), on the other hand, has but a single dominant mode, which is apparent for nearly all months of the year. This can be seen at about 115 pounds in January and progresses to about 165 pounds in December. In comparing the same month there is no evidence of similarly situated dominant modes in the 1952 and 1953 data. This lack of agreement between the dominant modal size groups of adjacent years holds true for all years examined.

There are, however, strong resemblances between the distributions of sizes in alternate years. To illustrate the differences between adjacent years and the resemblances of alternate years, December samples of all available years (1947-1954) have been plotted as percentage weight frequencies in figure 12. It is self-evident that there is a persistent difference between but a similarity within the series of odd- and even-numbered years. This points to a cycle of dominant weight groups with a period of about 2 years.

Dominant modes are not found in exactly the same position each second year, but increase in size (fig. 12). Looking at odd-numbered years first, in December 1947 the dominant mode was centered at 140 pounds, but by December 1953 it had progressed to 165 pounds. For the even-numbered years there are two dominant modal groups that act similarly. A small dominant mode at 105 pounds in the December 1948 sample can be traced through each even-numbered year until it reaches 150 pounds in December 1954. A larger dominant mode that occurred at 155 pounds in 1948 can be seen progressing through all the December samples of even-numbered years, reaching 205 pounds in the 1954 sample.

An average of less than 24 months elapses between the appearance of dominant size groups in the Hawaiian fishery. This is indicated by the "growth lines" fitted by eye (fig. 13) to the modes from the monthly distribution (figs. 5-11, table 2), and by the increasing size of apparently homologous modes as they reappear in the fishery every 2 years (fig. 12). If these modes represent year classes, this could mean that the peak of spawning or spawning survival takes place a little later every second year, which seems unlikely. It is more to be expected that spawning recurs at about the same time each year and that the increase in the size of the dominant modes (of both the even- and odd-numbered years) from 1947 to 1954 is related to some other change in the population.

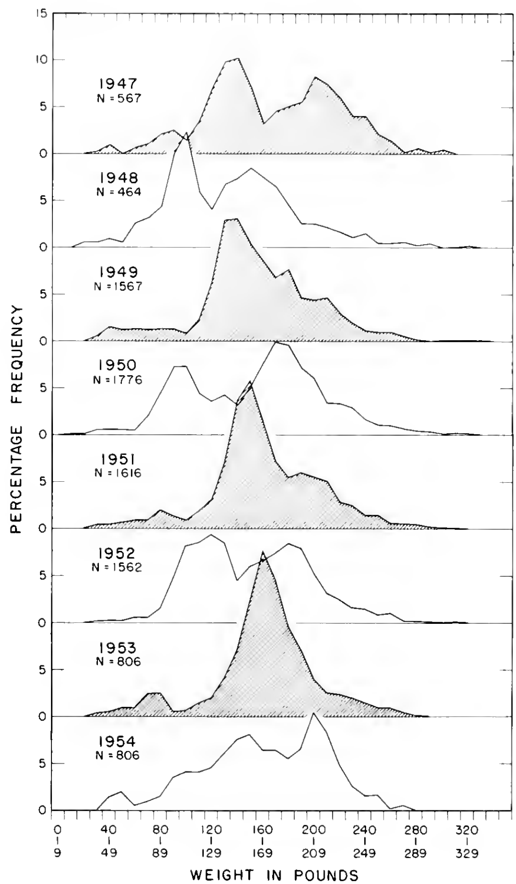

Figure 12.--Hawaiian bigeye tuna weight frequency distributions (percentage) for December samples, 1947 to 1954.

The alternate-year occurrence of certain size groups also takes place in the western Pacific (fig. 14) and it is enlightening to compare the modes of bigeye tuna from the two regions. Kamimura and Honma (1953) and Nakamura et al. (1953) report a "biennial" occurrence of dominant size groups taken in the Japanese North Pacific bigeye fishery. (The sizes of their fish are given in centimeters and were converted to pounds by the Hawaiian length-weight formula.) Nakamura et al. report the modes for November 1948 to March 1949 (1948 season) and for October 1949 to April 1950 (1949 season) (see table 3). Kamimura and Honma list the ranges for all modal groups through the 1952 season and have included the data of Nakamura et al.

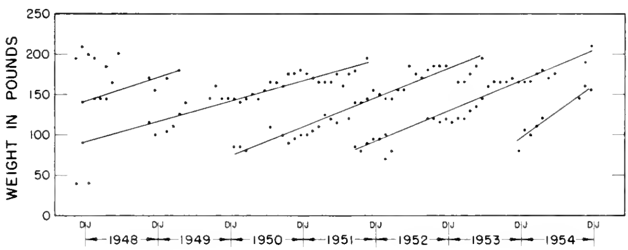

Figure 13.--"Growth lines" of Hawaiian bigeye tuna as determined by modal values, based on the locations of modes in figures 5-11.

Where the Japanese investigators have not indicated modes, they have been selected from their data. Thus modes are available for each of five fishing seasons (1948-1952) (table 3). These modes, plotted as fishing season midpoints on figure 15, together with the growth lines from the Hawaiian fishery (fig. 13), show that modes in the Japanese fishery alternate with those of the Hawaiian fishery within a year, and that the slopes of the "growth lines" for both areas are very similar.[4/] The similarities in the slopes of the growth lines and the presence of complementary cycles of approximately 2 years suggest that the same bigeye population contributes to both fisheries.

[4/] The modes in the Japanese landings have been connected by the present author.

Table 2.--Time and position of observed modal mid-points of Hawaiian bigeye weight frequency distribution (from figures 5-11)

Month and year	Weight (pounds)			Month and year	Weight (pounds)		
1947				1950 (cont'd.)			
November	40	195	-	December	100	180	-
December	90	140	210	1951			
1948				January	100	175	-
January	40	200	-	February	105	170	-
February	145	195	-	March	110	165	-
March	145	-	-	April	125	165	-
April	145	185	-	May	120	165	-
May	165	-	-	June	115	175	-
June	200	-	-	July	160	-	-
July	-	-	-	August	120	175	-
August	-	-	-	September	85	140	180
September	-	-	-	October	80	140	-
October	-	-	-	November	90	145	195
November	115	170	-	December	95	155	-
December	100	155	-	1952			
1949				January	95	150	-
January	-	-	-	February	70	100	145
February	105	170	-	March	80	145	-
March	110	-	-	April	155	-	-
April	125	180	-	May	155	-	-
May	140	-	-	June	185	-	-
June	-	-	-	July	175	-	-
July	-	-	-	August	170	-	-
August	-	-	-	September	120	180	-
September	145	-	-	October	120	185	-
October	160	-	-	November	115	185	-
November	145	-	-	December	120	185	-
December	145	-	-	1953			
1950				January	115	-	-
January	85	145	-	February	120	165	-
February	85	140	-	March	120	165	-
March	80	145	-	April	130	175	-
April	150	-	-	May	135	185	-
May	145	-	-	June	145	195	-
June	155	-	-	July	160	-	-
July	110	165	-	August	165	-	-
August	165	-	-	September	165	-	-
September	100	160	-	October	165	-	-
October	90	175	-	November	170	-	-
November	95	175	-	December	80	165	-

Table 2.--Time and position of observed modal mid-points of Hawaiian bigeye weight frequency distribution (from figs. 5-11)(cont'd)

Month and year	Weight (pounds)			Month and year	Weight (pounds)		
1954							
January	105	165	-	July	-	-	-
February	100	165	-	August	-	-	-
March	110	175	-	September	-	-	-
April	120	180	-	October	145	-	-
May	170	-	-	November	160	190	-
June	175	-	-	December	155	210	-

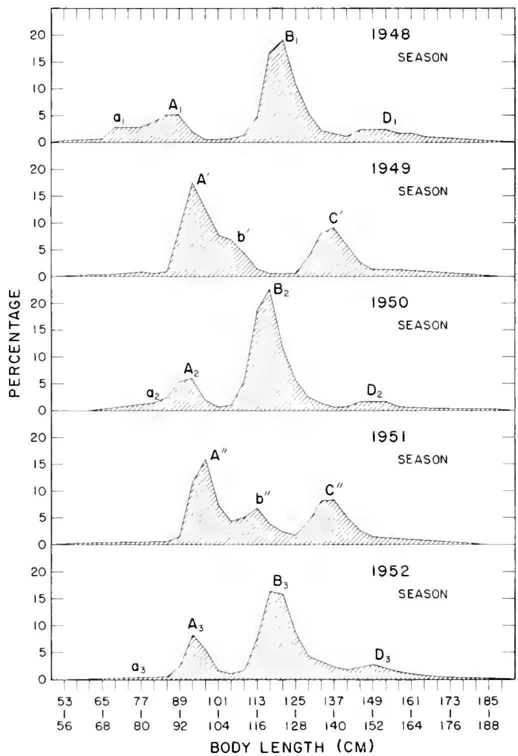

Figure 14.--Bigeye length frequencies by seasons (October-March) for the years 1948-1952. Samples drawn from landings of Japanese commercial vessels operating north of 26°N. between 130°E. and 165°W. longitude. (From Kamimura and Honma (1953))

Table 3.--Modal mid-points and modal ranges from Japanese North Pacific bigeye size frequency distributions

Fishing season	Modal ranges		Modal mid-points	
	From Kamimura and Honma (1953)	Equivalent weight*	From Nakamura et al. (1953)	Equivalent weight*
	centimeters	pounds	centimeters	pounds
1948 season	69-80	16-25	73-76[1/]	19-21
December 1948-	81-96	25-42	85-88	29.4-32.5
March 1949	113-132	68-107	121-124	82.6-88.8
	145-164	140-201	149-152	152-161
1949 season	89-100	34-47	93-96	38.2-41.9
October 1949-	101-116	49-73	105-108[1/]	54.5-59.1
March 1950	132-148	107-149	137-140	119-127
			Located by Iversen	
1950 season	85-100	29-47	92-93	37-38.2
October 1950-	109-128	61-97	117-120	79.4-80.6
March 1951	141-164	129-201	152-153	161-164
1951 season	89-104	34-53	97-100	43.2-47.3
October 1951-	105-124	54-89	113-116	67.7-73.0
March 1952	129-152	100-161	136-137	116-119
1952 season	89-104	34-53	93-96	38.2-41.9
October 1952-	113-136	68-116	120-121	80.6-82.6
March 1953	141-160	129-187	149-152	152-161

* All equivalent weights are estimated from the formula

Log weight (pounds) = -7.1167 + 2.9304 log total length (millimeters)

1/ Obscure

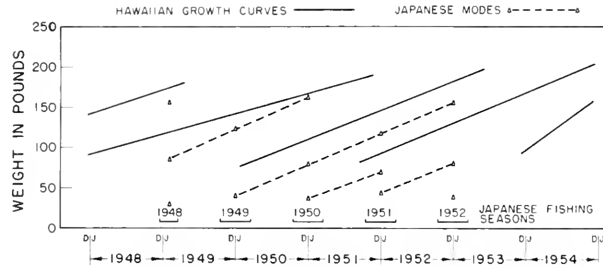

Figure 15.--Comparison of Hawaiian and Japanese bigeye tuna "growth lines" using data from the Japanese North Pacific fishery taken from Kamimura and Honma (1953) and Nakamura et al. (1953).

Nakamura et al. (1953) propose and Kamimura and Honma (1953) discuss at length three hypotheses to explain the "biennial frequency" which they observe in the Japanese North Pacific fishery. These hypotheses are:

"i. Difference in annual propagation;
ii. Difference in annual growth rate;
iii. Difference in annual course of migration."

Kamimura and Honma are unable to decide which hypothesis best fits this phenomenon. They feel that perhaps that of differences in annual propagation (i) is the most reliable and that an annual migratory pattern (iii) may be accepted as a reasonable hypothesis "provided that the fish should take the same migratory route every two years."

Unfortunately even with the added knowledge that this cycle occurs in the Hawaiian fishery there is still insufficient information on the biology of the species to permit a definitive explanation. Some sort of a migratory pattern would seem to best satisfy the relationship of the sizes of bigeye in the two areas. There is considerable circumstantial evidence to indicate that this species may be moving about over a vast expanse of the Pacific. Spawning apparently takes place only over a large area near the Equator, from about 150°E. to 140°W. longitude, and mature or nearly mature females are found there at all times of the year (Kikawa 1953, Yuen 1955). Neither of these authors could find evidence of a spawning area farther to the north. If the equatorial region is the only area of spawning, those groups of fish from Hawaii and the Japanese North Pacific fishery would have to make an extensive migration to reach this area. Evidence from commercial fishing operations in the western Pacific indicates that there is migration in a north-south direction (Nakamura 1949, Honma and Kamimura 1955).

Further evidence for extensive migration of Pacific bigeye can be seen in modes resulting from measurements of fish at the Equator. Murphy and Otsu (1954) give length frequencies for bigeye measured during the Japanese mothership expeditions west of 180° longitude. These have been plotted using their 5-cm. groups in figure 16. The distributions, which cover June 1950 through October 1951, show that throughout the year a mode is present at about 130-135 cm. (102-114 pounds) that does not appear to progress. During September and October of 1951 a lesser mode appears at about 92-97 cm. (37-43 pounds) that is not present in the other samples. The lack of modal progression with time indicates a constant movement of bigeye into and out of the depths sampled by the longline gear or into and out of the geographic area fished. The occurrence of modes during September and October of 1951 that are not present in the other distributions is also an indication of the migration of a size group into the sampling area.

Additional evidence of migration is found in the Japanese North Pacific fishery, where there is an increase in abundance of the larger size groups with an accompanying decrease in the smaller size groups as one goes from west to east (Nakamura et al. 1953). Since it seems safe to assume that the species grows, the difference in size with area indicates that there are regular and perhaps complex migrations. In figure 15 it can be seen that the Japanese catches have smaller modes (30-40 pounds) than can be found in the Hawaiian catches (the smallest in the Hawaiian data are usually about 80-90 pounds). However, it is also interesting to note that these very small modes appear to be present each year rather than biennially, and that the large modes that occur at about 180-200 pounds in the Hawaiian fishery are not seen in the Japanese fishery.

By way of review, the modal groups of bigeye tuna in the several areas (fisheries) present several puzzling problems. Near the Equator, where ripe fish are taken, there is no progression of modes. In the more northern areas, where spawning has not been noted, the modes progress with time, but there is a curious alternation of modes between years when considering a single area. Considering two well

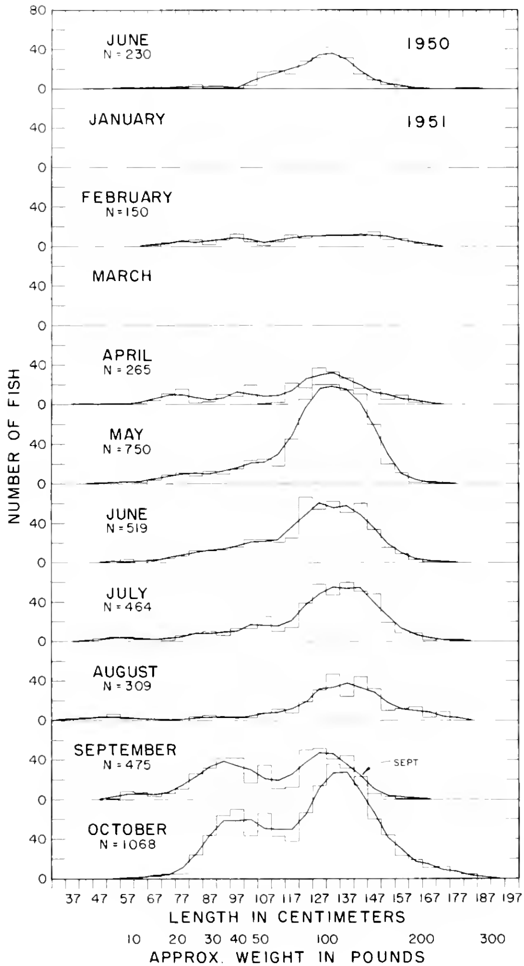

Figure 16.--Length frequencies of bigeye tuna measured during the Japanese mothership expeditions, 140° - 179°E. longitude.

separated fisheries (Hawaiian and Japanese), there is also complementary alternation of modes for a given year. Finally, it appears that once a dominant modal group enters a fishery (e.g. Hawaiian) it may be followed in that fishery for several years. Taken as a whole, these phenomena suggest that the bigeye undertake poorly understood, recurrent, and probably complex migrations.

GROWTH

Incomplete knowledge of some aspects of the life history of bigeye tuna results in a lack of understanding of the usual behavior of the dominant modes in the western and central Pacific. Hence any interpretation of the modes as year groups and interpretation of the movement of those modes as growth must be very tentative.

It is readily apparent from the weight frequency curves covering the period November 1947 through December 1954 in the Hawaiian fishery that clear-cut modal progression is displayed by bigeye tuna (figs. 4-11, table 2). Figure 13, which shows these dominant modes fitted with straight lines, indicates the apparent rate of growth. Table 4 lists the average annual weight increase of these groups as determined from the "growth lines." Assuming that the progression of the modes represents growth, these size groups increase as much as 40-50 pounds in one calendar year. Judging from the slope of the growth curves (fig. 13) and the maximum sizes attained by Hawaiian bigeye, about 6 or 7 years would seem to be a fair estimate of the life span of the species in Hawaii.

However, in the equatorial region the description of growth by the modal progression method is not feasible, since it appears that dominant modes in the size distribution do not progress.

Table 4.--Estimated increase in weights of modes from Hawaiian bigeye tuna distributions

Year	Position of modes (pounds)		Annual increase (pounds)
	January 1	December 31	
	Group A		
1949	110	145	35
1950	145	170	25
1951	170	185	15
	Group B		
1950	80	105	25
1951	105	145	50
1952	145	185	40
	Group C		
1952	90	120	30
1953	120	170	50
1954	170	195	25

SUMMARY

1. A difference in size between the sexes is exhibited by bigeye tuna in samples from the western Pacific and the Hawaiian Islands. The modes of the male size distributions are about 14 cm. or 30 pounds larger than those in female size distributions.

2. Dominant modal groups do not occur in the Hawaiian commercial catch every year, but rather exhibit a cycle that appears to have a period of about 2 years, apparently the complement of the cycle in the Japanese North Pacific fishery.

3. Homologous modes that appear during alternate years in the Hawaiian fishery are not identical in size; rather they increase slightly in size with each recurrence.

4. Approximately similar growth rates and the presence of approximately 2-year cycles of dominant size groups in the catches of both the Hawaiian fishery and the Japanese North Pacific fishery suggest there is a relationship between the bigeye tuna of the two areas.

5. A plot of bigeye weight frequencies by months from the Honolulu market for the period November 1947 through December 1954 reveals modes that progress consistently from smaller to larger sizes.

6. A provisional growth curve plotted by connecting modes found in these size distributions indicates that Hawaiian bigeye may gain as much as 50 pounds in 1 year and may live about 6 or 7 years.

7. In the vicinity of the Equator bigeye modes do not progress with time.

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APPENDIX

Table 5.--Weight frequencies of Hawaiian bigeye, Honolulu market, May-August 1951

Class intervals	Male	Female
lbs.		
50-59	-	1
60-69	1	-
70-79	-	1
80-89	-	1
90-99	-	3
100-109	2	2
110-119	9	10
120-129	8	8
130-139	9	3
140-149	8	-
150-159	9	8
160-169	17	15
170-179	13	11
180-189	13	13
190-199	15	6
200-209	9	8
210-219	9	7
220-229	10	4
230-239	7	1
240-249	8	-
250-259	1	1
260-269	2	-
270-279	1	-
280-289	1	-
290-299	1	-
Total	153	103

Table 6.--Length frequencies of equatorial bigeye by sexes, 5th Japanese mothership expedition March 29-May 28, 1951

Class intervals	Males	Females	Class intervals	Males	Females
cm.			cm.		
50-51	-	2	110-111	1	4
52-53	-	-	112-113	4	9
54-55	-	-	114-115	3	7
56-57	-	1	116-117	10	12
58-59	1	-	118-119	17	9
60-61	-	-	120-121	21	21
62-63	-	3	122-123	33	19
64-65	-	1	124-125	29	15
66-67	1	1	126-127	24	20
68-69	1	2	128-129	30	18
70-71	2	5	130-131	34	19
72-73	1	6	132-133	34	20
74-75	-	11	134-135	28	16
76-77	4	3	136-137	41	7
78-79	5	2	138-139	34	10
80-81	1	3	140-141	30	8
82-83	3	3	142-143	49	1
84-85	2	4	144-145	34	7
86-87	4	3	146-147	36	3
88-89	2	4	148-149	19	-
90-91	4	1	150-151	14	1
92-93	3	5	152-153	7	2
94-95	6	4	154-155	10	1
96-97	4	4	156-157	1	1
98-99	4	5	158-159	5	1
100-101	4	1	160-161	3	-
102-103	6	4	162-163	3	-
104-105	11	5	164-165	2	-
106-107	6	3	166-167	3	-
108-109	11	1			
Total				645	318

Table 7.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1947

Class intervals	Nov.	Dec.
lbs.		
30-39	1	1
40-49	1	5
50-59	-	-
60-69	-	4
70-79	4	6
80-89	2	12
90-99	2	14
100-109	7	8
110-119	15	20
120-129	16	39
130-139	25	56
140-149	21	58
150-159	22	41
160-169	21	18
170-179	24	26
180-189	21	29
190-199	34	32
200-209	18	47
210-219	24	42
220-229	16	34
230-239	10	23
240-249	8	23
250-259	11	12
260-269	6	8
270-279	3	1
280-289	6	4
290-299	4	1
300-309	-	3
340-349	1	-
Total	323	567

Table 8.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1948

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
20-29	-	-	-	1	-	-	-	-	-	1	-	3
30-39	-	-	-	-	-	-	-	-	-	1	1	3
40-49	-	3	1	1	-	-	-	-	3	-	1	4
50-59	-	3	1	3	-	-	-	2	-	1	1	3
60-69	3	-	1	-	-	1	-	-	2	3	5	12
70-79	2	12	3	1	-	1	-	1	6	4	7	15
80-89	5	10	8	3	-	-	-	2	4	5	14	20
90-99	10	23	7	12	3	4	1	1	11	9	22	46
100-109	2	11	10	12	3	3	2	2	11	9	19	57
110-119	3	18	7	16	7	2	6	-	6	7	15	27
120-129	12	40	20	34	7	3	2	3	6	15	20	19
130-139	23	72	43	54	16	3	2	4	5	15	24	31
140-149	11	81	48	72	24	2	4	3	9	14	17	34
150-159	15	61	36	55	21	12	7	5	6	21	18	39
160-169	12	47	29	26	17	11	5	5	8	14	26	35
170-179	6	26	26	28	16	12	3	2	7	12	22	30
180-189	8	37	27	26	21	15	6	2	6	12	16	21
190-199	13	21	19	35	16	20	8	2	6	7	12	12
200-209	11	34	21	15	22	18	5	2	3	12	9	12
210-219	8	22	14	13	7	11	3	2	4	5	3	10
220-229	12	16	14	5	14	11	3	2	4	6	12	8
230-239	3	9	8	6	6	7	3	1	1	5	8	5
240-249	-	6	3	3	5	3	3	1	1	5	6	7
250-259	2	2	3	4	2	3	3	1	1	4	7	2
260-269	1	4	-	1	1	1	-	-	3	-	3	2
270-279	1	3	3	3	-	1	-	-	-	2	2	3
280-289	2	1	1	1	-	-	-	-	-	-	1	1
290-299	2	4	3	-	-	-	1	-	-	-	-	2
300-309	-	-	-	-	-	-	-	-	1	1	-	-
310-319	-	-	1	-	-	-	-	-	-	-	-	-
320-329	-	1	-	-	-	-	-	-	-	-	-	1
330-339	-	-	-	-	-	-	-	-	-	1	-	-
Total	167	567	357	430	208	144	67	43	114	191	291	464

Table 9.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1949

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
10-19	-	-	-	-	-	-	-	-	-	-	-	2
20-29	-	1	1	-	1	-	-	-	-	1	-	-
30-39	-	1	1	1	1	-	-	-	-	2	6	9
40-49	-	3	3	-	1	-	-	-	-	2	9	24
50-59	-	2	4	-	-	1	-	-	-	1	4	18
60-69	-	3	1	-	-	-	-	1	2	8	5	20
70-79	-	7	2	2	2	-	-	1	-	11	10	18
80-89	-	9	4	2	5	1	-	-	-	3	7	21
90-99	6	24	43	12	12	1	-	-	2	3	3	21
100-109	10	47	47	27	34	7	3	1	1	3	11	12
110-119	5	29	50	28	31	10	6	6	7	9	19	36
120-129	6	15	36	33	37	16	3	8	10	13	44	97
130-139	5	19	28	21	38	16	4	6	11	24	82	202
140-149	8	14	30	25	33	13	8	5	20	25	81	205
150-159	16	19	28	16	37	10	5	2	10	27	74	166
160-169	6	25	33	22	36	9	5	2	11	24	52	133
170-179	9	29	18	35	40	12	5	4	9	31	54	106
180-189	4	22	26	31	30	16	3	4	3	27	48	121
190-199	7	12	26	23	18	8	2	3	7	18	51	74
200-209	3	18	10	18	23	12	6	3	4	19	37	67
210-219	8	11	8	13	11	12	6	7	6	16	42	74
220-229	15	6	7	7	11	9	11	4	7	18	27	49
230-239	4	13	2	5	3	7	6	7	7	9	23	30
240-249	4	5	2	4	3	6	2	3	2	9	12	18
250-259	4	3	3	1	2	4	4	1	1	3	9	15
260-269	3	3	1	-	2	2	2	3	-	4	6	15
270-279	1	3	-	-	1	-	-	4	2	3	9	7
280-289	1	-	-	-	-	-	-	-	1	1	3	3
290-299	-	-	-	-	-	-	-	1	1	-	3	-
300-309	-	-	-	-	-	-	-	-	1	1	3	1
310-319	-	-	-	-	-	-	-	-	1	-	-	1
320-329	-	1	-	-	-	-	-	-	-	1	1	1
330-339	-	-	-	-	-	-	-	-	-	1	-	1
340-349	-	-	-	-	-	-	-	-	-	-	-	-
350-359	-	-	1	-	-	-	-	-	-	-	-	-
Total	125	344	415	326	412	172	81	76	126	317	735	1567

Table 10.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1950

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
0-9	-	-	-	-	-	1	-	-	-	-	-	-
10-19	-	-	-	1	3	8	9	14	-	1	-	1
20-29	-	2	-	1	-	4	4	15	-	-	4	2
30-39	1	3	-	9	7	4	6	2	4	7	9	8
40-49	4	5	2	2	5	-	4	3	-	3	7	10
50-59	3	7	8	9	2	2	3	1	1	4	5	11
60-69	5	13	10	16	7	4	9	3	5	18	15	9
70-79	10	21	18	18	23	10	7	6	9	37	27	38
80-89	13	43	10	14	25	22	10	14	19	38	62	79
90-99	7	24	16	34	25	16	16	13	12	40	71	130
100-109	6	12	8	33	41	19	21	9	19	27	58	130
110-119	14	26	20	26	38	23	22	5	16	28	49	78
120-129	26	66	38	71	86	51	12	15	11	26	37	66
130-139	49	108	77	113	157	77	38	12	12	19	42	76
140-149	68	139	80	140	200	97	51	27	20	29	29	56
150-159	42	72	59	123	148	102	88	42	29	58	53	90
160-169	32	61	45	99	126	100	75	56	33	57	78	136
170-179	30	50	38	56	108	85	65	51	22	72	100	176
180-189	38	38	42	47	75	83	72	27	12	61	81	172
190-199	24	35	31	60	79	84	46	28	13	40	69	128
200-209	13	41	23	46	61	62	44	31	17	36	45	109
210-219	12	25	15	41	53	54	30	13	2	25	41	62
220-229	7	27	11	29	35	42	14	19	7	22	35	58
230-239	10	22	6	21	19	24	25	13	7	12	21	52
240-249	8	8	5	10	21	10	5	9	5	11	15	30
250-259	4	5	6	10	9	8	9	7	2	5	13	19
260-269	4	8	4	3	4	3	7	1	-	7	7	18
270-279	-	3	1	2	1	5	5	3	1	6	6	13
280-289	1	1	1	1	1	1	3	3	2	2	2	7
290-299	1	-	1	-	-	-	-	-	-	1	3	6
300-309	-	-	-	-	-	-	1	-	-	3	4	1
310-319	-	-	1	-	-	-	-	-	-	2	1	3
320-329	-	-	-	-	-	-	-	-	-	1	1	2
330-339	-	-	-	-	-	-	-	1	-	-	-	-
Total	432	865	576	1035	1359	1001	701	443	280	698	990	1776

Table 11.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1951

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
20-29	-	-	1	-	-	-	-	-	-	1	-	-
30-39	2	-	2	-	-	1	-	-	-	2	2	5
40-49	3	1	5	1	2	1	1	1	-	8	3	8
50-59	1	-	10	12	3	1	3	1	1	6	2	12
60-69	3	3	2	3	2	5	3	6	12	10	3	14
70-79	2	8	5	3	1	-	2	2	18	40	15	15
80-89	23	32	26	12	14	-	-	3	2	34	17	33
90-99	43	65	37	30	17	14	1	2	9	17	6	21
100-109	37	40	71	57	53	24	10	11	14	20	8	15
110-119	22	48	63	82	75	40	25	24	15	34	20	31
120-129	17	18	43	86	51	26	29	19	36	80	43	52
130-139	17	13	44	62	58	21	37	19	47	113	82	112
140-149	21	19	56	79	59	21	25	8	44	103	130	221
150-159	24	32	72	103	84	31	34	18	31	89	110	256
160-169	40	55	59	91	93	43	25	16	23	51	63	186
170-179	33	39	80	108	63	34	28	28	18	63	51	116
180-189	29	37	47	78	78	38	40	22	32	49	63	88
190-199	36	27	28	44	61	38	27	17	20	45	60	97
200-209	13	31	17	33	45	25	27	11	18	45	69	90
210-219	14	12	15	22	34	23	19	5	13	31	48	83
220-229	15	15	7	12	24	11	14	7	12	22	43	45
230-239	9	9	5	6	21	11	10	4	4	19	32	40
240-249	7	14	2	7	12	12	14	2	4	11	23	22
250-259	4	6	3	2	3	2	3	1	1	8	20	23
260-269	2	-	1	4	4	3	2	1	1	4	9	10
270-279	1	-	1	2	1	-	1	1	-	6	5	8
280-289	1	1	2	-	-	1	1	2	1	3	3	7
290-299	-	2	-	-	1	1	1	-	1	1	1	3
300-309	-	-	-	-	-	-	-	-	-	1	1	2
310-319	-	-	-	-	-	-	-	-	-	-	-	1
Total	419	527	704	939	859	427	382	231	377	916	932	1616

Table 12.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1952

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
20-29	-	-	1	-	-	-	-	-	-	-	-	-
30-39	1	2	-	1	-	-	-	-	-	1	3	3
40-49	4	11	4	2	1	-	-	-	-	-	1	5
50-59	21	33	14	1	1	-	-	-	-	4	2	4
60-69	15	17	15	8	1	-	-	1	1	1	1	9
70-79	9	15	14	3	4	1	1	1	4	7	4	9
80-89	34	25	11	4	3	-	1	2	11	27	18	25
90-99	46	34	14	9	16	2	4	1	13	29	44	75
100-109	29	34	15	12	28	9	10	7	14	28	54	128
110-119	21	32	18	33	39	10	14	8	11	37	66	134
120-129	34	55	52	56	35	14	10	10	14	43	60	145
130-139	67	119	89	105	71	14	5	9	15	22	42	132
140-149	99	163	136	166	97	17	21	20	16	40	34	70
150-159	93	124	131	207	145	26	11	23	22	25	44	92
160-169	68	75	73	182	99	24	19	26	22	52	51	104
170-179	34	62	68	129	112	26	26	35	52	66	67	115
180-189	28	68	62	76	70	24	21	25	34	75	74	131
190-199	32	58	58	76	65	18	21	16	28	68	76	123
200-209	22	64	47	83	66	20	13	14	25	57	54	82
210-219	22	33	33	44	50	23	10	6	15	44	48	50
220-229	15	23	26	43	34	17	5	3	9	40	28	39
230-239	15	14	16	16	31	6	6	5	4	26	24	26
240-249	10	13	12	8	14	5	2	6	8	25	15	23
250-259	3	6	8	7	3	3	2	2	3	16	23	13
260-269	2	9	6	6	6	2	-	-	-	9	11	17
270-279	1	7	3	2	2	2	-	1	-	6	6	3
280-289	1	3	1	1	1	2	-	2	-	2	6	3
290-299	3	-	1	2	1	-	-	-	2	-	4	1
300-309	1	3	-	2	-	-	-	-	-	1	2	-
310-319	-	-	-	-	-	-	-	-	-	-	4	1
320-329	-	-	-	-	-	-	-	-	-	-	-	-
330-339	-	-	-	-	-	-	-	-	-	-	-	-
340-349	-	-	-	-	-	-	-	-	-	-	1	-
350-359	-	-	-	-	-	-	-	-	-	-	1	-
360-369	-	-	-	-	-	-	-	1	-	-	-	-
380-389	-	-	-	-	-	-	-	-	1	-	-	-
Total	730	1102	928	1284	995	265	202	224	324	751	868	1562

Table 13.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1953

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
10-19	2	-	-	-	-	-	-	-	1	-	-	-
20-29	1	-	2	1	-	-	-	-	-	4	-	-
30-39	1	4	2	-	-	-	-	-	3	9	-	3
40-49	1	4	8	1	-	-	-	-	8	13	-	5
50-59	3	3	2	6	-	-	-	-	-	7	1	8
60-69	-	1	-	-	-	-	-	2	2	3	1	7
70-79	-	1	4	1	1	1	1	-	-	6	4	20
80-89	5	17	15	3	-	-	-	-	3	3	7	21
90-99	11	49	40	11	3	-	1	1	-	-	-	5
100-109	27	65	77	23	14	1	6	4	-	1	2	6
110-119	41	111	81	51	34	11	10	6	7	7	5	12
120-129	31	118	107	72	89	22	22	10	3	14	14	17
130-139	15	63	73	73	85	38	24	5	14	23	17	34
140-149	14	76	54	55	70	38	29	18	16	29	28	57
150-159	8	62	57	42	52	29	38	20	33	49	61	99
160-169	15	57	52	49	53	22	32	17	35	45	82	143
170-179	11	78	54	46	68	36	24	13	30	46	80	118
180-189	10	62	52	51	71	31	34	16	18	26	56	78
190-199	14	54	36	41	62	41	28	9	24	21	28	58
200-209	5	50	25	35	61	42	26	11	12	19	34	33
210-219	6	25	17	15	53	22	17	11	5	21	31	21
220-229	7	14	20	17	36	21	11	4	4	12	22	19
230-239	2	8	7	11	14	8	9	3	1	13	16	16
240-249	5	12	4	5	11	5	7	3	5	7	13	11
250-259	1	5	2	1	7	3	1	1	-	5	4	7
260-269	2	6	3	1	4	-	3	-	1	4	4	4
270-279	1	4	-	-	3	2	1	-	1	4	5	3
280-289	-	-	2	-	2	-	-	3	-	2	2	1
290-299	1	2	-	-	-	-	-	-	-	-	5	-
300-309	-	3	-	-	-	-	-	-	-	-	-	-
310-319	-	-	-	-	-	-	-	-	-	1	-	-
320-329	-	-	-	-	-	-	-	-	-	-	1	-
340-349	-	1	-	-	-	-	-	-	-	-	-	-
Total	240	955	796	611	793	373	324	157	226	394	523	806

Table 14.--Weight frequencies of Hawaiian bigeye, sexes combined, Honolulu market, 1954

Class intervals	Month											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
lbs.												
20-29	-	-	-	-	-	-	-	-	1	-	-	-
30-39	1	-	-	1	-	-	-	-	-	4	2	-
40-49	3	3	-	1	-	-	-	-	-	3	11	11
50-59	-	3	1	3	-	-	-	-	-	2	15	16
60-69	1	6	2	4	-	-	-	-	-	4	5	4
70-79	8	16	-	-	2	-	-	-	5	10	8	7
80-89	10	15	9	2	-	-	-	1	2	17	17	12
90-99	11	21	9	7	5	1	-	-	-	9	25	28
100-109	8	21	13	16	5	3	-	-	6	8	16	34
110-119	3	9	12	28	9	3	-	4	8	15	14	33
120-129	6	11	9	19	6	3	-	2	9	21	31	37
130-139	12	18	5	12	18	3	-	1	8	23	27	49
140-149	15	30	17	35	18	8	1	-	6	26	29	61
150-159	30	59	30	64	36	4	1	1	8	12	30	66
160-169	37	82	66	79	66	16	4	3	9	23	31	52
170-179	29	60	43	132	59	18	3	4	7	25	29	52
180-189	20	52	47	111	41	17	6	4	10	24	36	45
190-199	10	37	30	74	39	10	3	1	12	28	33	53
200-209	12	35	21	56	24	12	6	3	7	22	40	84
210-219	5	27	14	46	13	2	4	4	12	26	33	67
220-229	7	11	22	32	17	2	-	2	2	13	33	39
230-239	6	12	9	19	4	1	-	6	2	15	17	21
240-249	3	8	6	14	5	6	-	1	4	7	16	13
250-259	4	3	3	7	4	1	1	1	3	4	8	14
260-269	-	3	4	8	-	1	2	-	2	7	3	2
270-279	1	4	2	3	1	2	-	-	1	-	-	5
280-289	-	2	-	-	-	-	-	-	-	5	4	1
290-299	-	1	-	-	-	-	-	-	-	-	3	-
300-309	1	-	1	-	-	-	-	-	-	-	-	-
310-319	-	1	-	-	-	-	-	-	-	1	1	-
320-329	-	-	-	-	-	-	-	-	-	1	-	-
330-339	-	1	-	-	-	-	-	-	-	-	-	-
Total	243	551	375	773	372	113	31	38	124	355	517	806