STUDIES ON THE FISHERY AND GROWTH RATE OF OCEANIC SKIPJACK *KATSUWONUS PELAMIS* (LINNAEUS) AT MINICOY ISLAND FROM 1966 TO 1969

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ABSTRACT

Although the skipjack fishery at Minicoy extends all through the year the peak fishery is during November-April. The size in the commercial catches ranges between 350 and 695 mm. The total catches fluctuate appreciably from year to year. The catch composition and the catch rate in different months are presented. Employing the probability-plot method (Harding 1949, and Cassie 1954) 4 year classes have been recognised, and it is found that the fish attains 402.2, 494.0, 562.6 and 620.5 mm respectively when it is 1-year, 2-year, 3-year and 4-year old. By length-frequency study 5 year classes were traced, having the size of 410, 500, 570, 630 and 680 mm respectively for the 1-, 2-, 3-, 4- and 5-year classes. Von Bertalanffy's growth equation was fitted to the observed values and the growth parameters were estimated both graphically and arithmetically which gave identical results. The calculated values of the parameters were L_{∞} = 843 mm, t_0 = 11.95 years and K = 0.22314. The length at age, annual increment and the average monthly growth rate obtained in these different methods were almost identical.

INTRODUCTION

The oceanic skipjack (*Katsuwonus pelamis* (Linne)) fishery at Minicoy Island, Laccadive Sea, has been the subject of investigations in recent years in India since it forms the major fishery of the Island which brings an annual income of over Rs. 50,000 to the Islanders (Jones 1958). This fishery has a special position in Minicoy as the economy of the island is completely depended on it. Though there are some recent studies on the fishery (Jones and Kumaran 1959), food and feeding habits (Raju 1964, Thomas 1964) and fecundity and spawning (Raju 1964, 1964a) of this species, there is practically no information on its age and growth rate.

Some important aspects of biology of tunas can be efficiently investigated by observing the changes in space and time of the size composition of the commercial catches. These changes provide information on the composition, rate of growth, occurrence of dominant year classess, changes in mortality rate as related to changes in fishing effort, racial division and migration. Monthly samples provide information about the rate at which the age groups enter into or depart from the catchable population of a particular area. Assignment of absolute age to skipjack has not met with general agreement by the few investigators who have worked on this problem (Batts 1972).

In the present study data on size composition of catch for the years 1966 to 1969 have been studied to determine the year-class composition, age and growth of skipjack from Minicoy Island. In the first section of this paper a brief review of the fishery of the Island for the above period is made and in the latter part the results of observations on the age and rate of growth are given.

FISHERY

The fishing industry of the Minicoy Island with special reference to the tuna fishing methods has been comprehensively dealt with by Jones and Kumaran (1959). In Minicoy skipjack tuna is caught entirely with pole and line and live-bait fishes. Appreciable fluctuation has been noticed in the catches of tuna in the Island from year to year.

The seasonal character of the skipjack fishery at Minicoy is shown by the monthly catch average for a period of four years (Fig. 1). Usually the poorest catches were observed in the months of June to October. The catches tend to increase gradually from November to March with peak in March. From April again the catches decline till October. This trend is almost uniformly followed all the four years. Though the skipjack is the major fishery of the

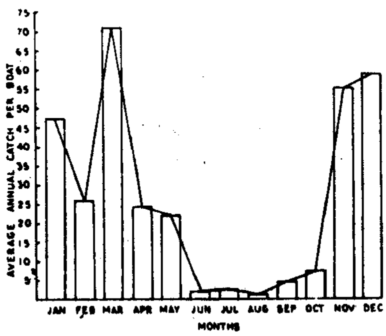

FIG. 1. Monthly averages of catch of skipjack at Minicoy during 1966-69.

Island and fishing for it continues all round the year, the five-month period (November-March) can be considered as the peak season. June to October is the lean period; the reason for the low catches during this period may be attributed mainly to the suspension of or decrease in the fishing activity due to the onset of southwest monsoon in the Island.

Annual catches of skipjack tuna also vary widely (Table 1). The average total catch for the four years from 1966 to 1969 at Minicoy for skipjack was about 338.6 tonnes. The total catch was considerably below the average in 1967 and the highest catch recorded was in 1969, being 522 tonnes. The monthly averages of catch per unit are given in Table 1. The catch per unit was as low as 114.6 kg in 1967 and as high as 202.3 kg in 1969. The average for the four years was 149.1 kg. The total catch showed an increase in these years and this is mainly due to introduction of a number of mechanised boats during recent years (Varghese 1970).

Age Composition In The Commercial Catch

Based on the size of the fish at successive ages estimated from von Bertalanffy's growth equation, the monthwise fluctuation in the percentage occurrence of various age groups in the commercial fishery at Minicoy from 1966 to 1967 is presented in Table 2. Six age groups were recognised in the fishery, viz. 0-group, I-group, II-group, III-group, IV-group and V-group. Fish below age 1 are termed 0-group, those between 1 and 2 are termed the I-group, those between ages 2 and 3 are termed the II-group and so on.

As could be seen from Table 2, the 0-group ranged from a minimum of 0.3% in January 1966, November 1966, May 1967 and February 1968 to a maximum of 10.6% in May1966. From 1968 March to 1969 December this group was totally absent from the fishery.

The I-group was ranging from a minimum of 2.3% in January 1966 to a maximum of 54.2% in June 1967. The annual percentage of this year-class was above 15.00% in all the four years and even reached 24.3% in 1967 (Table 3). During August and September 1966 and August 1969 this group was not represented in the fishery.

The II-group was found to be the dominant one ranging from 20% in September 1966 to 79.3% in June 1968. During 1968 and 1969 this group represented well above 50% in all the months.

The III-group showed a minimum of 15% in June 1968 and a maximum of 53.7% in August 1966. This group was also well represented in the commercial catches during this four-year period.

The IV-group was present to a lesser extent in the fishery throughout the months of observation with a minimum of 0.3% in November 1966 and a maximum of 26.1% in June 1966. The annual percentage ranged from 3.4 in 1968 to 7.7 in 1966 (Table 3). In June 1969 this group was not represented in the commercial catches.

The V-group occurred only in 25 months of the entire period of observation. A minimum of 0.2% was recorded in 1968 June and a maximum of 6.4% in June 1966.

TABLE 1. *Total catch and catch per unit for* Skipjack *at Minicoy by pole and line fishery for* 1966-1969.

	1966			1967			1968			1969		
	Landings in kg.	Total unis operated	Catch per unit in kg.	Landings in kg,	Total units operated	Catch per unit in kg.	Landings in kg.	Total units operated	Catch per unit in kg.	Landings in kg.	Total units operated	Catch per uni in kg
Jan	15864.5	226	70.2	47055.0	272	172.9	97487.7	406	240.1	31139.5	291	107.0
Feb	16972.0	176	96.4	17050.0	165	163.3	21478.0	195	110.1	52616.0	269	195.6
Mar	88229.0	230	383.6	38899.0	180	216.1	45814.5	261	175.5	113466.0	264	429.7
Apr	53914.0	225	239.6	19848.5	174	114.1	22145.5	129	171.6	32988.0	250	131.9
May	5492.5	161	34.1	34255.0	205	167.1	20422.0	162	126.1	27914.5	168	166.1
June	6003.0	163	36.8	1143.5	107	10.6	758.5	47	16.1	2021.5	144	14.0
July	6860.0	169	40.5	1858.5	124	14.9	1481.5	124	11.9	1351.5	139	9.7
Aug	688.8	102	6.7	535.5	136	3.9	2909.5	178	16.3	827.5	119	6.9
Sep	293.5	97	3.0	4367.5	147	29.7	12523.0	160	78.3	946.0	183	5.2
Oct	7239.0	183	39.5	2054.6	130	15.8	18655.0	227	82.2	1197.0	149	8.0
Nov	48061.0	431	111.5	36864.5	178	207.1	6273.0	175	36.4	129601.5	267	485.3
Dec	72985.0	289	252.5	25085.5	188	133.4	30276.0	225	134.6	128604.5	341	377.0
TOTAL	322602.3	2452	131.6	229017.1	2006	114.2	280324.2	1889	148.4	522673.5	2584	202.3

TABLE 2. *Month-wise age-group composition (in percent) of the commercial catches of* Skipjack *at Minicoy* (1966-1969).

	1966						1967					
	0	I	II	III	IV	V	0	I	II	III	IV	V
January	0.3	2.3	23.7	51.3	22.0	0.3	—	23.4	33.7	30.2	12.7	—
February	—	11.7	38.8	44.6	3.9	1.6	—	36.9	32.4	29.1	1.7	—
March	1.2	19.3	48.5	25.2	4.9	0.7	—	12.4	58.0	22.8	6.1	0.8
April	—	19.7	44.0	34.8	0.6	0.9	0.4	14.9	63.0	10.2	7.1	1.6
May	0.6	10.7	30.3	42.8	1.8	3.6	0.3	22.4	49.3	23.0	4.5	0.3
June	1.5	5.1	20.8	40.1	26.1	6.4	0.6	54.2	40.0	3.9	1.2	—
July	2.0	12.2	38.7	27.2	16.9	2.9	0.4	35.9	47.4	6.7	7.6	1.7
August	—	—	20.4	53.7	26.0	—	—	36.5	51.7	11.0	0.7	—
September	—	—	20.0	40.0	40.0	—	2.0	36.0	46.0	12.0	4.0	—
October	—	32.0	36.3	29.4	1.4	—	—	36.0	40.0	13.0	11.0	—
November	0.3	28.4	43.6	27.4	0.3	0.3	—	11.7	58.6	22.1	7.0	0.3
December	0.5	22.0	50.0	27.0	0.5	—	—	14.4	66.4	11.9	6.5	0.5
	1968						1969					
January	0.6	16.6	66.6	12.0	4.0	0.2	—	11.4	66.0	15.5	6.4	0.8
February	0.3	23.5	57.9	13.7	3.6	0.7	—	20.7	72.4	7.2	7.2	0.4
March	—	14.7	65.1	16.8	2.4	0.9	—	15.4	65.3	11.9	7.2	0.4
April	No sample						—	20.2	68.4	9.7	1.7	—
May	—	22.1	61.8	12.4	3.5	—	—	18.1	53.7	16.4	11.2	0.7
June	—	16.1	79.3	1.5	2.9	—	—	23.1	72.5	4.4	—	—
July	—	10.7	73.6	13.9	1.8	—	—	13.4	58.8	20.1	7.2	0.3
August	—	15.7	64.0	16.0	4.4	—	—	—	53.9	38.5	7.7	—
September	—	12.2	63.1	20.4	3.9	0.3	—	12.6	70.4	14.7	2.3	—
October	—	22.8	63.2	12.0	2.0	—	No sample					
November	—	15.2	74.2	9.9	0.5	—	—	14.8	59.1	13.9	10.6	1.5
December	—	16.6	60.2	17.5	1.3	—	—	10.1	50.7	23.7	12.0	3.5

TABLE 3. *Year-wise age-group composition (in percent) of the commercial catches of* Skipjack *at Minicoy* (1966-1969).

	O-group	I-group	II-group	III-group	IV-group	V-group
1966	0.9	16.2	39.1	34.3	7.7	1.1
1967	0.2	24.3	51.7	17.0	6.1	0.5
1968	0.2	17.1	64.9	14.3	3.4	0.2
1969	—	15.5	62.5	14.4	6.9	0.9

It could be noticed that even though the 0-group was observed in the catch, *K. pelamis* enters the main fishery only when it is in the I-group. The II-group formed the mainstay of the fishery followed by I-group and III-group in the order of abundance in all the years except for 1966 (Table 3). IV-group was found in almost all the months in lesser quantities. Like the 0-group the V-group was very insignificant in their occurrence in the commercial catches. This indicates that the fishery of *K. pelamis* depended mainly on individuals belonging to the I, II and III groups.

Material And Methods

The material for the present study was collected from the commercial catches of skipjack tuna taken in pole-and-line fishing with live baits, operated at a distance of about 6 to 12 km around Minicoy Island during the period January 1966 to December 1969. A total of 11,481 specimens were measured to the nearest millimetre for the fork length (total length of Marr and Schaefer 1949). All the samples obtained in a month were pooled to provide a monthly length-frequency distribution. The measurements were grouped into 20 mm-size groups starting from 361-380 mm. The numerical value selected to name each size group is the midpoint of the respective class intervals, viz. 370, 390, 410 mm, etc. The resultant frequency was converted to respective precentage frequency. The age and rate of growth were determined by employing the probability-plot technique described by Harding (1949) and Cassie (1954). Peterson method of length frequency was also used in the present study.

Age and Growth

Age determination of K. pelamis by probability plot technique

The technique by which the probability paper can be used in solving bimodal and polymodal frequency distributions has been described by Harding (1949) and later revised by Cassie (1954). This has been found very effective in identifying the different age groups of *K. pelamis* resulting from the contribution of different spawning. The use of probability paper allows the overlapping flanks to be more readily detected, thereby giving a wider range of points which may be used in curve fitting.

In a fish with single restricted spawning the modal lengths of different size groups are usually taken to be yearly in nature. *K. pelamis* in Minicoy waters was observed to have a single spawning season in an year (Raju 1964). Hence it may be possible to assign the modal lengths of different size groups to those of yearly modes representing the lengths at different ages.

The length-frequency data were pooled yearwise and the cumulative percentage frequency was calculated and plotted on arithmatic probability paper for each year (Fig. 2). In the curves thus obtained, the points of inflexions were noted, and the modal values were then calculated. For the year 1966 the graph shows four distinct points of inflexion at 1.4, 26, 86 and 99.8 percents. It is found that the first modal length is at 405 mm followed by the second one at 485 mm, third one at 570 mm and the fourth at 620 mm. The monthly size-frequency data shows that the majority of the fishes belonging to the smaller size groups appear in the commercial catch during March-July which is the spawning season for *K. pelamis* in Minicoy waters (Raju 1964). Therefore, the first mode observed at 405 mm may be considered as the brood of the previous year, and hence one year old. The subsequent modes represent the two-year old, three-year old and four-year old respectively. During the year 1967 the points of inflexion are at 0.4, 56, 95 and 99.8 percents (Fig. 2) and the modal values obtained are 410 mm for the first year, 498 mm for the second year, 565 mm for the third year and 628 mm for the fourth year. Similarly in the year 1968 the points of inflexion are at 0.2, 56, 93 and 99.9 percents (Fig. 2).

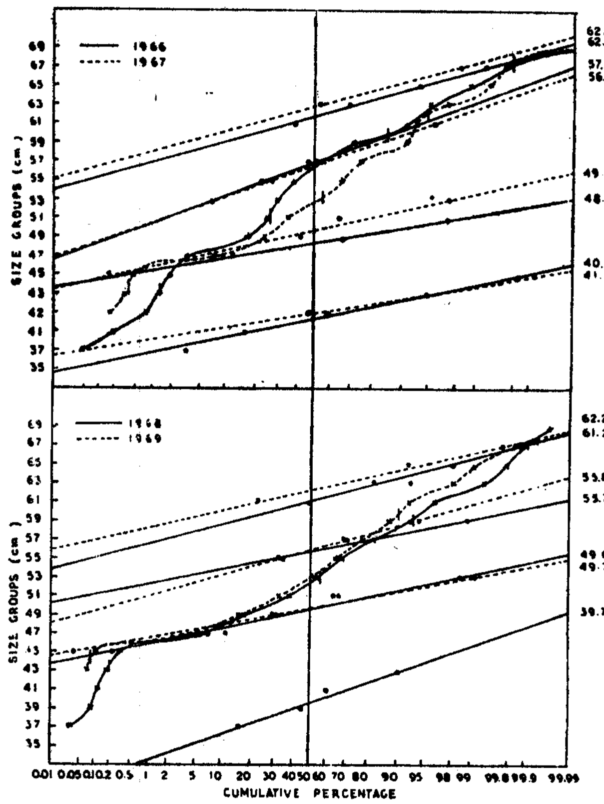

FIG. 2. Probability plot of length-frequency distribution (cumulative percentage) of skipjack during 1966-69.

Here the modal values for the corresponding years are 398 mm, 496, 558 and 612 mm. Since the smaller size groups were not sufficiently available in the year 1969, the first modal size obtained is at 498 mm, which corresponds to the second year. The modal sizes for the third and the fourth year are 558 and 623 mm respectively. The points of inflexion are at 0.09, 52, 90 and 99.85 percents (Fig. 2).

From the above results it is clear that the modal sizes for different ages in different years are more or less identical. The average value of each age group for four years indicates that *K. pelamis* attains a size of 404 mm in the first year, showing a monthly growth rate of 34 mm; 494 mm in second year with a monthly increment of 7.5 mm; 563 mm in the third year with a monthly growth rate of 5.7 mm and 621 mm in the fourth year showing a growth increment of 4.8 mm per month.

Growth-rate of K. pelamis based on Peterson method of length-frequency analysis

An examination of the data presented in Fig. 3 reveals some conspicuous modes together with some smaller modes. Repetition of some of the clear modes in successive months has been noticed, which may be attributed to the prolonged spawning of this species as observed by Jones (1959) and Raju (1964). In

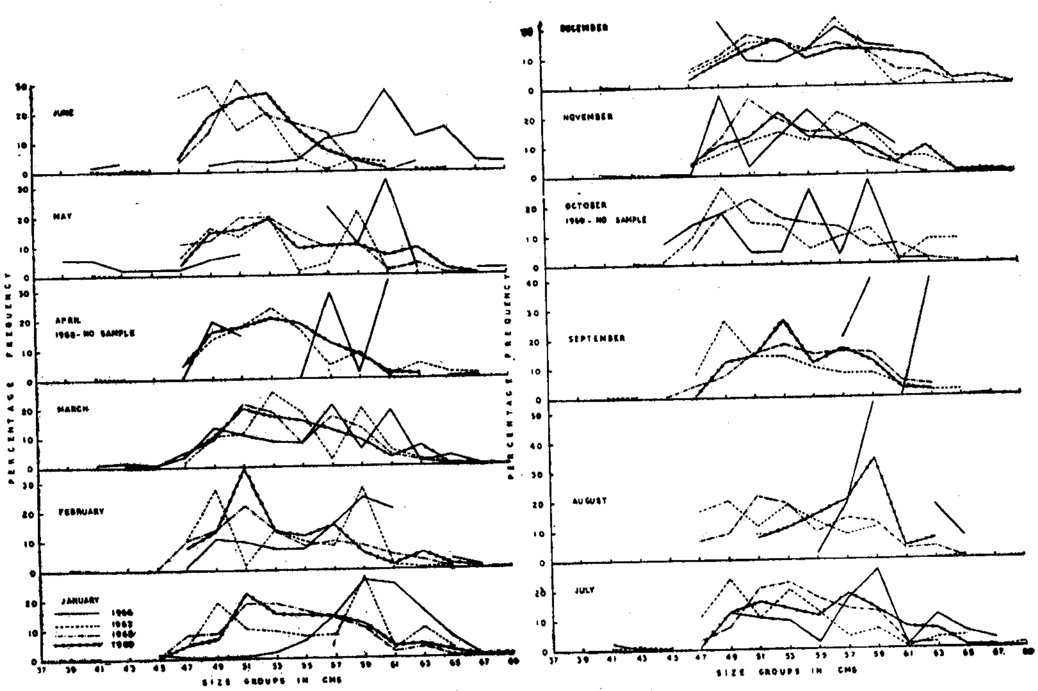

FIG. 3. Length-frequency distribution in percentage of skipjack during 1966-69.

spite of the overlapping of the modes, some of them could be traced to longer periods when the four year data are put together. The modes, both bigger and smaller, are mentioned as such and the growth rate is calculated by tracing the progression of some important modes in the length-frequency curves. The position of different modes found in the length-frequency curves, from January 1966 to December 1969 is given in Fig. 4.

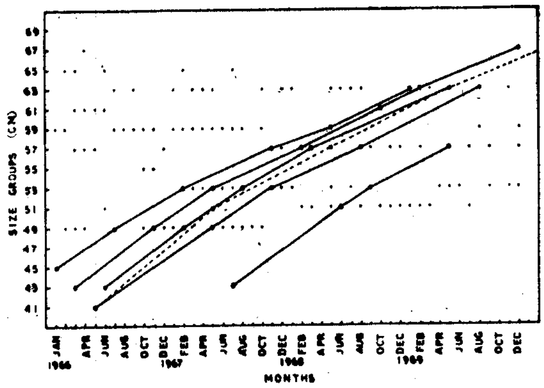

FIG. 4. The monthly modal positions of length-frequency curve of skipjack with the progressions of 5 important broods. The dotted line represents the average annual growth.

In the light of the results obtained from the probability technique, an attempt was made to trace the monthly progression of the modal sizes of the frequency curve. In Fig. 4 is given the possible progression of 5 important broods which are traceable for a longer period through months from the minimum modal size that contributed to the fishery. It may be noticed that the growth pattern of each brood is more or less identical and therefore the progression seems to be justified. The average growth of these broods at the end of each year after it entered the fishery is obtained by following the method of average growth estimation described by Thomas (1969) and the result is represented in Fig. 4 by doted line. The breeding season of *Katsuwonus pelamis* in Minicoy waters was observed as February to July (Raju 1964). So, the 410 mm modal size of May 1966 cannot be the brood of that year, but of the previous year. Thus it is possible that 410 mm size group of May 1966 is one year old. If it is so, the first year's average monthly growth rate could be calculated as 34.2 mm. Again, it can be seen that by the 24th month it attains 500 mm, giving an average monthly growth rate of 7.5 mm in the second year. Similarly, in the subsequent years it grows to a size of 570 mm at the end of the third year (36th month) showing an average monthly growth rate of 5.8 mm, 630 mm at the end of the fourth year (48th month) at a monthly growth rate of 5 mm, and to 670 mm by the 58th month showing a monthly growth rate of 4.2 mm. At this rate when it completes the fifth year the length could be 680.4 mm.

Fitting of von Bertalanffy's growth equation

Based on the concept that growth is the net result of anabolism and catabolism von Bertalanffy (1938) formulated a growth equation, which, according to Beverton (1954) and Beverton and Holt (1957), produced a growth curve that fits well the growth of many species. This equation gives a linear relationship between length at time t and at time t + x and is expressed as

$$L_t = L_\infty \left(1-e^{-k(t-t_0)} \right) \qquad \ldots\ 1$$

where l_t = length at age t; L_∞ = maximum or asymptotic length a fish can theoritically reach; e = base of the naperian or natural logarithm; k = coefficient of catabolism; t = age of fish; t_0 = arbitary origin of the growth curve.

Estimation of growth parameters

Two different methods are in use to estimate the growth parameters mentioned in equation 1, viz. the arithmetic method and the graphic method.

Estimation of growth parameters by arithmetic method

von Bertalanffy's growth equation can be rewritten in the following form:

$$L_t + 1 = L_\infty (1-e^{-k}) + L_t\ e^{-k} \qquad \ldots\ 2$$

This is a linear equation in terms of L_t and L_{t+1}, which Beganel (1955a, 1955b) used to study the growth of rough dab.

This is the same as:

$$L_{t+1} = a + b\,L_t \qquad \ldots\ 3$$

$$\text{in which } a = L_\infty (1-e^{-k}) \qquad \ldots\ 4$$

$$\text{and } b = e^{-k} \qquad \ldots\ 5$$

The constants L_∞ and e^{-k} can be solved by applying the least square method as shown below; using, values of L_t and L_{t+1} in the age length data of *K. pelamis* obtained from the probability plot technique.

	L_t	L_{t+1}
1.	404	494
2.	494	563
3.	563	621

The estimated values of b and a are, b = 0.7972 and a = 170.7636.

$$b = e^{-k} = 0.7972$$

substituting the values of e_{-k} and a in equation 4 we have 170.7636 L_∞ (1 — 0.7972) therefore:

$$L_\infty = \frac{170.7636}{1-0.7972} = \frac{170.7636}{0.2028} = 843$$

That is L_α 843 mm.

The values of K. can be determined from the values of e^{-k} using the formula.

$$K = \log_e \frac{1}{e^{-k}} = \log_e \frac{1}{0.7972} = \log_e 1.2544 = 0.22314$$

t_o can be determined by using the formula

$$t_o = \frac{1}{K} \left(\log_e L_\infty - \log_e (L_\infty - L_t) \right) - t \qquad \ldots. \quad 6$$

Based on the formula 6 the average value of t_o calculated for different ages was found to be – 1.95 years for *K. pelamis.*

Thus the length equation 1, when the values for L_∞, K and t_o are used. becomes

$$L_t = 843 \left(1 - e^{-0.22314(t-(-1.95))} \right) \qquad \ldots. \quad 7$$

Estimation of growth parameters by graphical method

The parameters of the growth equation 1 may also be obtained graphically by the method developed by Ford (1933) and Walford (1946) by plotting L_t against L_{t+1} (Fig. 6). The point of interception of the growth line by the bisector gave the value of L_∞ as 842 mm. The slope of the growth line is equal to e_{-k} of equation 1 from which K was found to be 0.22314. When the values of $\log_e (L_\infty - L_t)$ are plotted against the corresponding ages, a straight line is obtained (Fig. 7) whose Y intercept is equal to $\log_e L_\infty + K t_o$ which, in this case was found to be 6.29. According to the formula of Ricker (1958).

$$t_o = \frac{(\text{Log}_e L_\infty + K t_o) - \log_e L_\infty}{K}$$ Substituting the values to the formula $t_o = \frac{6.29 - 6.72}{0.22314} = -1.93.$

Thus the equation 1 can be rewritten as

$$L_t = 842 \left(1 - e^{-0.22314\,(t - (-1.93))}\right) \quad \ldots\ldots 8$$

which is almost the same as formula 7.

Using the equation 7 the theoritical values of L for fish upto the sixth year of age were calculated. The values are 407.29 mm for one-year old, 493.34 mm for two-year old, 562.39 mm for three-year old, 620.05 mm for four-year

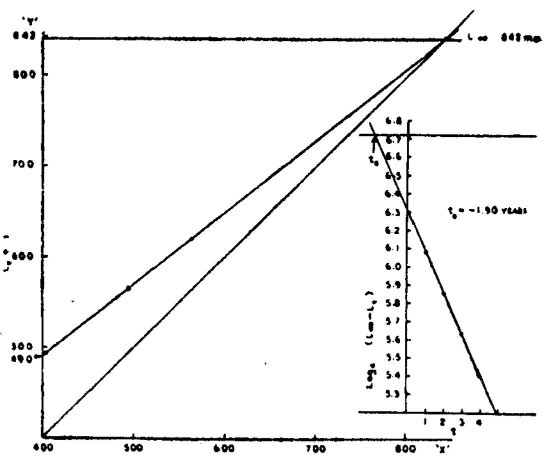

FIG. 5. Ford-Walford plot of the growth of skipjack. The inset figure shows log (L — ltP) plotted against age for estimation of to.

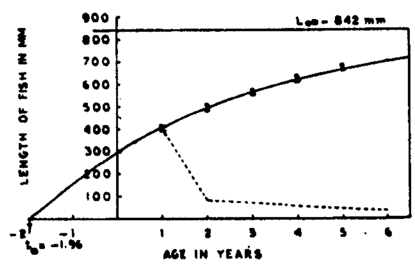

FIG. 6. Calculated length increments of skipjack by fitting von Bertalanffy equation.

old 664.08 mm for five-year old and 699.41 mm for six-year old. The monthly growth increments during the first six years were calculated as 33.9, 7.2, 5.8, 4.8, 3.7 and 2.9 mm respectively (Fig. 5).

Discussion

Growth of skipjack has been estimated by earlier workers by the interpretation of annuli on the hard parts, modal progression in length-frequency distribution and length increments of tagged fish. Aikawa and Kota (1938) determined the age of 20 skipjack taken from Palau in August 1937 by using the centra of the first five vertebrae and indicated that the one-year olds were 270-370 mm, while the four-year olds were 550-640 mm long. Batts (1972) and some earlier workers observed that the scales of skipjack cannot be used for age studies. Brock (1954) found three modes in the Hawaiian skipjack landings from 1946 to 1951 and recognised three age groups. The 12-month-old skipjack has a mean length of 43 cm. Schaefer (1960) and Rothschild (1965) also examined length-frequency distribution of Pacific skipjack and found that the one-year olds were about 450 mm whereas the three-year olds varied from 500 to 800 mm. Rothschild (1966) used tagging in 1958 and estimated the ultimate length as 823 mm. Batts (1972) studied dorsal spine sections and back-calculated the age from spine radius by direct proportion; the one-year olds average 406 mm two- year olds 493 mm three - year olds 569 and four-year olds 638 mm. It was found that all the three methods, viz. the probability-plot technique, length-frequency, and the statistical, gave significantly similar results in the present study. These results also show very much agreement with that of Batts (1972), who used cross sections of dorsal spines in assigning the age. In the present study the minimum and maximum lengths observed were 350 mm and 695 mm respectively. Raju (1964) has reported that the size group of 700-800 mm total length was very rarely available in the fishery, and that there was high percentage of males with the increase of size over females. The maximum length derived by using the statistical method is 843 mm. Batts (1972) reported it as 872 mm and 784 mm for males and females respectively. According to Rothschild (1966) it is 823 mm and Shomura (1966) recorded this as 850 mm. The difference in the L_α estimated by various investigators has been attributed to the difference of the subpopulations of fish sampled, difference in growth among years and the kind of data used (Rothschild 1966).

References

Aikawa, H. and M. Kato. 1938. Age determination of fish, I. *Bull. Jap. Soc. Scient. Fish.*, 7 (2): 79-88. *Transl.* in *Spec. Scient Rep. Fish. Wildl. Serv., U.S.* (21): 22 pl.

Batts, B. S. 1972. Age and growth of the skipjack tuna, *Katsuwonus pelamis* (Linnaeus), in North Carolina waters. *Chespeak science;* 13 (4): 237-244.

BEGANEL, T. B. 1955. The growth rate of the Long Rough Dab *Hippoglossoides platessoides* (Farb.). *J. mar. biol. Ass. U.K.*, 34: 297-311.

BEGANEL, T. B. 1955a. The growth rate of Long Rough Dab *Hippoglossoides platessoides* (Farb.). — a correction — *J. mar. biol. Ass. U.K.*, 34: 634-637.

BERTALANFFY, L. VON. 1938. A quantitative theory of organic growth, (Inquiries on growth laws, II). *Human Biology*, 10 (2): 181-213.

BEVERTON, R. J. H. 1954. Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. *U.S. Fishery Lab., Misc. Contrbs.*, (2): 181 pp.

BEVERTON, R. J. H. AND S. J. HOLT. 1957. On the dynamics of exploited fish populations. *Fish. Invest. London*, (11) 19: 53 pp.

BROCK, V. E. 1954. Some aspects of the biology of the aku, *Katsuwonus pelamis*, in the Hawaiian Island. *Pacific. Sci.*, 8 (1): 94-104.

CASSIE, R. M. 1954. Some uses of probability paper in the analysis of size frequency distributions. *Aust. J. mar. Freshwat. Res.*, 5: 515-522.

FORD, E. 1933. An account of the herring investigations conducted at Plymouth during the year from 1924 to 1934. *J. mar. biol. Ass. U.K.*, 19: 305-384.

JONES, S. 1958. The tuna live bait fishery of Minicoy Island. *Indian J. Fish.*, 5 (2): 300-307.

HARDING, J. P. 1949. The use of probability paper for the graphical analysis of polymodal frequency distributions. *J. mar. biol. Ass. U.K.*, 28: 141-153.

JONES, S. 1959. Notes on eggs, larvae and juveniles of fishes from Indian waters III *Katsuwonus pelamis* (Linnaeus) and IV *Neothunnus macropterus* (T & S). *Indian J. Fish.*, 6 (2): 330-373.

JONES, S. AND M. KUMARAN. 1959. The fishing industry of Minicoy Island with special reference to the tuna fishery. *Indian J. Fish.*, 6 (1): 30-57.

MARR, J. C. AND M. B. SCHAEFER. 1949. Definition of body dimensions used in describing tunas. *U.S. Fish and Wildlife Service, Fish. Bull.* No. 47, Vol. 51: 241-244.

RAJU, G. 1964. Observations on the food and feeding habits of the Oceanic skipjack *Katsuwonus pelamis* (Linnaeus) of the Laccadive Sea during the years 1958-59. *Proc. Symp. Scombroid Fish., Mar. biol. Ass. India*, Pt. II: 607-630.

RAJU, G. 1964a. Studies on the spawning of the Oceanic skipjack *Katsuwonus pelamis* (Linnaeus) in Minicoy Waters. *Proc. Symp. Scombroid Fish., Mar. biol. Ass. India*, Pt. II: 744-768.

ROTHSCHILD, B. J. 1965. Hypothesis on the origin of exploited skipjack tuna (*Katsuwonus pelamis*) in the eastern and central Pacific Ocean. *Spec. Scient. Rep. U.S. Fish Wild. Serv. Fisheries*, 512: 20 pp.

ROTHSCHILD, B. J. 1966. Estimates of the growth of skipjack tuna (*Katsuwonus pelamis*) in the Hawaiian Island. *Proc. Indo-Pacif. Fish. Coun.*, 12 (11): 100-111.

SCHAEFER, M. B. 1960. Report on the investigations of Inter-American Tropical tuna commission for the year 1959. *Rep. inter. Am. Trop. tuna comm.*, 1959: 39-156.

SHOMURA, R. S. 1966. Age and growth studies of four species of tunas in the Pacific Ocean; 203-219 in Thomas A. manar (ed), *Proceedings Governor's Conference on Central Pacific Fishery Resources, State of Hawaii.*

THOMAS, P. T. 1964. Food of *Katsuwonus pelamis* (Linnaeus) and *Neothunnus macropterus* (Temminck and Schlegel) from Minicoy waters during the season 1960-61. *Proc. Symp. Scombroid fishes, Mar. biol. Ass. India,* Pt. II: 626-630.

THOMAS, P. A. 1969. The Goat fishes (Family Mullidae) of the Indian seas, *Memoir,* III, *Mar. biol. Ass. India.*

VARGHESE, G. 1970. Comparative merits of mechanised boats over non-mechanised boats on Oceanic skipjack tuna — live bait fishery. *Seafood Exporter,* III (1): 115-121.

WALFORD, E. A. 1946. A new graphic method of describing the growth of animals. *Biol. bull. mar. biol. lab. Woodshole,* 90: 141-147.