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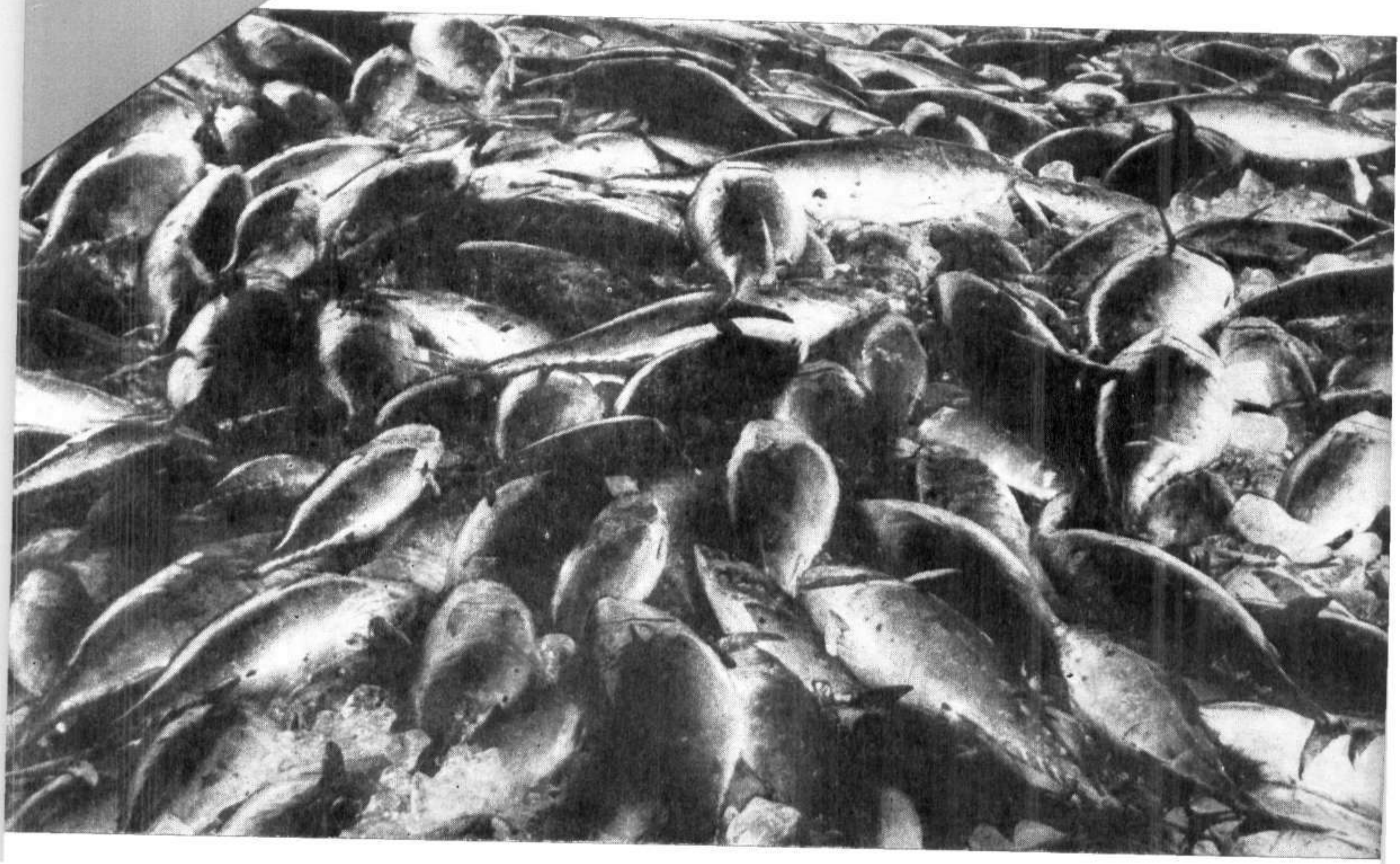

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AGE AND GROWTH OF *KATSUWONUS PELAMIS* (LINNAEUS) AND *THUNNUS ALBACARES* (BONNATERRE) FROM MINICOY WATERS

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1. SKIPJACK TUNA

The earliest estimate of growth of skipjack tuna in the Pacific Ocean was that of Aikawa (1937) who examined 20 specimens from the islands off the southern part of Izu Peninsula in the western Pacific and later Aikawa and Kato (1938) examined 20 specimens from the Palau Island area. Kawasaki (1955) estimated the growth of skipjack from the south western sea off Japan, based on the progression of modal groups. In a later publication Kawasaki (1963) gave additional estimates of growth rates based on the data from the area off north eastern Japan. Yokota *et al.* (1961) estimated the growth rates based on modal progression of skipjack from the Sulu Sea. Brock (1954) studied the growth of skipjack in the area of the Hawaiian islands by examining the progression of modes computed from length frequency studies. Rothschild (1967) estimated the parameters of growth for this species on the basis of 35 recoveries of fish tagged in Hawaiian waters in 1958 which were at liberty upto 420 days. In the eastern Pacific, Schaefer *et al.* (1961) examined the growth of skipjack tagged during 1955-1959. In another publication, Schaefer (1961) reported the results of growth studies of skipjack tuna in the Pacific, north of 15.N. on estimates from modal progression. Batts (1972) estimated age and growth of skipjack from north Carolina, from annuli in cross sections of dorsal spines. A review and critique of the methods and results of numerous investigations of growth rate in adult skipjack has been made by Josse *et al.* (1979). Wild and Foreman (1980) have counted the increments on otoliths of skipjack from the Revillagigado Islands and off Baja California which were tagged, injected with tetracycline, released and captured. Matsumoto and Skillman (1984) have tabulated the growth parameters for the von Bertalanffy growth equation and compiled the lengths at various ages from different investigations on skipjack.

From the Indian ocean, Shabotiniets (1968) calculated the length at different ages of skipjack from Madagascar area based on the growth marks in the first spine of the first dorsal fin. The only published information on the age and growth of skipjack tuna from Indian waters is that by Appukuttan *et al.* (1977) based on data collected from 1966 to 1969 from Minicoy waters.

Random samples of skipjack tuna, *katsuwonus pelamis* caught by pole and line tuna fishing off Minicoy were selected for taking length measurements. Length was measured from the tip of the snout to the caudal fork (Fork length) upto the nearest half centimetre. Care was taken not to include any specimen where the tail portion was suspected to be broken. The length measurements were grouped at two cm intervals and length frequency curves were plotted.

Length frequency distribution and progression of modal groups

These studies are based on 1140 specimens measured during 1981 and 752 in 1982. The fork length of the individual fish ranged from 280 to 680 mm. The results are plotted in the form of length frequency curves.

The analysis of data revealed certain regular modes together with some minor modes. The identity of some of the smaller modes appeared doubtful, and in the description given below they are mentioned as such and growth rate has been calculated only by tracing a few conspicuous modes in the length frequency curves.

In April 1981, two modes (A and B) may be seen at 440 and 540 mm (Fig. 9: See paper 12). In May two modes can be recognised at 480 and 580 mm. In June three modes are observed at 420, 480 and 540 mm. While the mode at 480 mm of June can be traced back as mode A of April indicating a growth of 4 cm, mode at 540 mm and 420 mm could not be traced back. In July, modes are seen at 420, 480 and 560 mm. Samples were not available in August. In September mode A of June progressed to 540 mm and mode B of April appeared at 620 mm with a growth of about 10 cm increment in six months. In October mode A progressed by 2 cm and a new mode C appeared at 320 mm which could be considered as an addition of new individuals to the fishery. Three small modes also appeared at 400, 460 and 500 mm. In November five modes at 360, 420, 480, 500 and 620 mm can be seen but only one of them could be traced back *i.e.*, mode B of September which did not show increment in growth.

Following the progress of the modes during the course of another year in January 1982 mode A of October, 1981 appeared at 600 mm with a growth of 4 cm. In February, mode A showed growth of 2cm and progressed to 620 mm. In March two modes were observed at 440 and 480 mm. Mode C at 440 mm which was evidently not represented in the immediate preceding four months appeared again with growth of 10 cm in four months. In April, the modes were at 340 and 480 mm. Again the appearance of a fresh mode at 340 mm (mode D) in April reveals the recruitment of new individuals to the fishery. There were no samples during May and June. In July two modes can be seen at 400 and 480 mm. Mode at 400 mm is due to 6 cm growth of mode D of April, at 340 mm and mode at 480 mm is due to 4 cm growth of mode C of April. In August there is only one mode at 460 mm which could not be traced back. In September two modes are seen at 460 mm and 520 mm. Mode at 460 mm can be traced back to mode D of July at 400 mm and mode at 520 mm is due to 4 cm growth of mode C of July at 480 mm. In October there are two modes at 420 and 480 mm. Mode D of September has progressed by 2 cm and a new mode has come up at 420 mm. In November, mode C of September has again appeared at 540 mm. There are four other modes at 360, 420, 500 and 620 mm. Mode at 360 mm is because of the entry of new individuals to the fishery. In December three modes can be seen at 480, 560 and 620 mm. While mode at 480 mm can be traced back at 480 mm in October which did not show any growth increment, mode C of November progressed by 2 cm.

Age and Growth

The determination of the age at the time of recruitment to the fishery has been a problem. Appukuttan *et al.* (1977) have given the length of one year old skipjack as 406 mm at Minicoy while other workers have given different sizes of one year old skipjack : Aikawa and Kato (1938) as 270 mm ; Brock (1954) as 523 mm ; Yokota *et al.* (1961) as 370 mm ; Schaefer (1961) as 304 mm ; Rothschild (1966), Joseph and Calkins (1969) as 304 mm and Batts (1972) as 406 mm.

Yoshida (1971) while studying the growth rate of juveniles of skipjack tuna from Hawaii and South Pacific Ocean has stated that larval skipjack tuna grow 9 cm during the first month and thereafter 2 cm per month for the next 11 months. Thus he calculated length of one year old skipjack as 31 cm. Fish in 35 cm length form a prominent mode during winter Hawaiian skipjack fishery (Rothschild 1965).

It can be seen from fig. 9 (see paper 12) that prominent mode of the smallest fish appeared at 320 mm in October 1981 and at 360 mm in November 1981. Again mode of smallest fish appeared at 340 mm in April 1982 and at 360 mm in November 1982. The occurrence of 360 mm fish in the month of November of both the years is significant pointing to the possibility that they are one year old. Presuming one month old skipjack to be 10 cm long, the growth rate during first year will be about 23.6 mm per month during the rest of the 11 months assuming that the one year old skipjack is 360 mm. During 1981, the mode of the smallest fish seen at 320 mm progressed to 560 mm by December 1982. Thus in 14 months, the mode has progressed by 240 mm *i.e.*, a monthly growth rate of 17.14 mm. In the same way mode D of April 1982 at 340 mm could be followed upto December 1982 at 480 mm and thus in 7 months it progressed by 140 mm with monthly growth rate of 17.5 mm. Mode A of April 1981 at 440 mm could be followed upto March 1982 when it attained 620 mm length in 11 months with monthly growth rate of 16.3 mm. Mode B at 540 mm in April 1981 could be followed upto November 1981 when it attained 620 mm in 7 months *i.e.*, a growth rate of 11.4 mm per month. Thus with age there is a reduction in growth rate. The length of 3 years old skipjack will be about 682 mm. Fish longer than 680 mm were not recorded during these observations.

Fitting von Bertalanffy's growth equation

von Bertalanffy's (1938) growth equation $L_t = L_\infty (1 - e^{-K(t - t_0)})$ is applied in the present study to estimate the growth parameters.

For assigning ages to certain sizes of fish, it is essential to estimate the size at birth. Earlier workers have estimated size at age on length frequency data which were utilised to interpret modal progression in time. Hence there is a wide range of such estimations.

Joseph and Calkins (1969) used size at hatching to assign ages to skipjack tuna. Same has been considered for these studies. From the data published by Raju (1964) an average circumference of 3.00 mm of skipjack eggs has been calculated. Jones (1959) has given length of skipjack larvae from 5.08 to 6.17 mm from Minicoy area and from 2.63 mm to 7.08 mm from other areas of Laccadive Sea. So length at hatching has been taken as 3 mm.

The values of other growth parameters were calculated as follows :

$L\infty$ = 900 mm
k = 0.4898 (annual basis)
t = —0.06

Based on these parameters age of skipjack was calculated. For one year old skipjack the size observed was 367 mm, for two years old 573 mm, for three years old 690 mm and for four years old 777 mm. The monthly growth rate for four years were calculated as 30.58 mm, 17.16 mm, 9.75 mm and 7.25 mm respectively.

Discussion

A summary of growth studies in different parts of the world Oceans by various authors are given in Table 1.

A review and critique of the methods and results of the numerous investigations of growth in adult skipjack has been made by Jose *et al.* (1979). They compared their tagging data from Joseph and Calkins (1969) for the eastern Pacific and the tagging data from the Papua New Guinea area for the fish of smaller size (40-60 cm). They found no significant difference in the growth of skipjack from both the areas. An estimate of 17.4 cm per year from modal progression was estimated for the eastern Pacific similar to that obtained from tagging data.

From daily growth increments on otoliths, Uchiyama and Struhsaker (1979) estimated growth of 28.2 cm between one and two years, 10.8 cm between 2 and 3 years from central Pacific and that skipjack from eastern Pacific grew 23.6 cm between 1 and 2 years of age. According to Josse *et al.* (1979) these differences in growth rates among areas are probably not statistically significant.

Age and growth studies of skipjack from the Indian Ocean are very few. Shabotiniets (1968) calculated the size at age of skipjack tuna from Madagascar area based on the growth marks in the first spine of the first dorsal fin. Since he could not validate the marks on spine sections as annuli, the age and growth and length at different ages seems to be doubtful. He stated 40-45 cm long fish to be 3 years old and 40-60 cm 4 years old.

Appukuttan *et al.* (1977) estimated the values of k and $L\infty$ from Minicoy waters to be 0.22 and 843 mm when the length of the fish ranged between 350 and 695 mm. They applied three methods i.e. probability plot technique, length frequency and the statistical method and found almost similar results by these methods. Employing the probability plot method they found that fish attains 402.2, 494, 562.6 and 620.5 mm respectively when it is 1 year, 2 year, 3 year and 4 year

TABLE 1. *Size in mm, at given ages in months for various estimates (By* von Bertalanffy equation) *of the growth of skipjack*, Katsuwonus pelamis

Age in months	Aikawa & Kato 1938	Brock 1954 k = 0.95	Yokota 1961	Schaefer 1961 k = 0.44	Kawasaki 1963 k = 0.19	Rothschild 1966 k = 0.77	Joseph & Calkins 1969 k = 0.41	Skillman (MS) k = 0.47	Batts 1972	Appukuttan *et al.* 1977 k = 0.22	Shabotiniets 1968	Present study k = 0.48
0	.. ..	3	..	3	3	3	3	..	..	..	..	3
6	.. ..	323	..	170	131	265	203	..	..	..	..	..
12	.. 270	523	370	304	247	443	366	430	406	407	..	367
18	.. ..	647	..	411	352	564	498	..	..	..	..	..
24	..270-370	724	520	498	449	647	605	610	493	493	..	573
30	.. ..	771	..	567	536	703	693	..	..	..	..	..
36	..370-460	802	645	623	615	741	764	730	569	562	400-450	690
42	.. ..	820	..	668	688	767	822	..	..	..	..	..
48	.. 460-550	832	750	704	754	785	869	800	638	620	400-600	777
L	.. 800	851	1400	851	1418	823	1075	924	..	843	..	900

old. By length frequency study they observed that fish attains 410, 500, 570, 630 and 680 mm in one year to 5 year old respectively. By fitting Von Bertalanffy growth equation they estimated the length of 1 year 2 year, 3 year, 4 year, 5 year and 6 year old fish as 407.29, 493.34, 562.39, 620.05, 664.08 and 699.41 mm respectively. They calculated monthly growth rate for six years as 33.9, 7.2, 5.8, 4.8, 3.7 and 2.9 mm respectively.

A review of the literature on growth of skipjack tuna (Table 1) reveals that according to the majority of the studies fish grow from 15 to 28 cm between first and second year of its age, 8 to 16.7 cm between 2 and 3 years and 8 to 13.9 cm between 3 and 4 years. The only exception to these results are that by Batts (1972) who observed 7.2 cm growth between 1 and 2 year, 7.6 cm between 2 and 3 years and 6.9 cm between 3 and 4 years and Appukuttan *et al.* (1977) who estimated 8.6 cm between 1 and 2 years, 6.9 cm between 2 and 3 years and 5.8 cm between 3 and 4 years. The results of the present studies show that skipjack grow 21 cm between 1 and 2 years, 12 cm between 2 and 3 years and 8.7 cm between 3 and 4 years.

According to published information from the Pacific and elsewhere monthly growth rate of skipjack during the first year ranged between 20.58 and 43.58 mm, for the second year between 12.5 and 23.3 mm, during third year between 6.6 and 13.91 mm and during fourth year between 4 and 11.58 mm. In majority of the studies these values fell around 30, 15-20, 10-13 and 8 cm during first, second, third and fourth year respectively. But according to Appukuttan *et al.* (1977) the monthly growth increments during the first six years were 33.9, 7.2, 5.8, 4.8, 3.7 and 2.9 mm respectively. While monthly growth rate in their studies from second onwards can be considered, the fall in growth rate from 33.9 mm during first year to 7.2 mm during second year is very low. The results of the present studies show a monthly growth rate of 30.58 mm during first year, 17.16 mm during second year, 9.75 mm during third year and 7.25 mm during fourth year.

Josse *et al.* (1979) in their critical review of the methods and results of numerous investigations of growth rate of skipjack concluded that counting seasonal marks on vertebrae, scales and dorsal spines and following modal progression of length frequencies are the least reliable, that counting daily increments on otoliths is more reliable and that measuring the growth between tagging and recapture is the most reliable. There is no published information on the tagging experiments of skipjack tuna from Indian waters. Although growth rates observed during the present investigation agrees well with many other studies in the Pacific and elsewhere, till tagging experiments are conducted in Indian waters and growth is estimated, age and growth estimated in present studies may be treated with some reservations.

2. Yellowfin tuna

A number of investigations have been made on the age and growth of yellowfin tuna, *Thunnus albacares* caught by pole and line from the Pacific Ocean and elsewhere. Different methods have been applied to estimate age and growth such as analysis of annual marks on scales and vertebrae (Aikawa and Kato 1938 ; Nose *et al.* 1957 ; Yabuta *et al.* 1960 ; Tan *et al.* 1965 ; Yang *et al.* 1969), by the modal progression of length frequencies (Moore 1951 ; Yabuta and Yukinawa 1957 and 1959 ; Hennemuth 1961 ; Davidoff 1963), incremental growth (Diaz 1963) and data from tagging experiments (Blunt and Messersmith 1960 ; Schaefer *et al.* 1961 ; Bayliff 1973). Uchiyama and Struhsaker (1981) and Wild and Foreman (1980) studied the age of yellowfin tuna by counting growth increments from otoliths.

Suzuki (1971) has reviewed the methods and results of age and growth determination by the scales and vertebrae, length frequency model progression and by incremental growth method.

There is no published information on age and growth of yellowfin tuna from Indian seas. This paper deals with age and growth studies of yellowfin tuna at Minicoy by length frequency method and by estimating the parameters of Von Bertalanffy growth equation.

Random samples of yellowfin tuna, *Thunnus albacares* were selected for recording fork length of fish. Care was taken not to include such specimens were tail portion was suspected to be broken. Totally 912 length measurements were recorded from January 1981 to December 1982. The length measurements were grouped at two cm interval and length frequency curves were plotted.

Length frequency distribution and progression of modal groups

The percentage frequency in the various size groups are plotted as length frequency curves in Figs. 14 & 15 (see paper 12).

It can be observed from the Fig. 14 that there are three modes in January at 380 mm, 440 mm (Mode B) and 540 mm (Mode A). In February there is one prominent mode at 460 mm which could not be traced back. In March three modes were observed at 440, 520 and 580 mm, and mode at 520 mm and 580 mm can be traced back as mode B and mode A of January with 8 cm and 4 cm growth respectively. In April there are three modes at 460, 560, and 600 mm. While mode at 560 mm can be traced back as mode B of March with 4 cm growth. In May, mode A which was not represented in April appeared at 640 mm. Samples were not available during June. In July, two modes were observed at 620 and 680 mm. Mode at 620 mm can be traced back as mode B of April which has shown a growth of 6 cm in three months and mode at 680 mm as mode A of May at 640 mm. During August, samples were not available. In September there were 3 modes at 560, 660 and 780 mm. Only one mode at 660 mm can be traced back as mode B of July with 4 cm growth. In October, a new prominent mode (Mode C) appeared at 460 mm which could be considered as entry of new individuals to the commercial tuna fishery. In November there were two modes at 500 mm and 540 mm. Mode at 500 mm is due to 4 cm growth of mode C of October.

Following the progress of the length frequency modes during the course of 1982 (Fig. 15: paper 12), in February three modes were observed at 460, 520 and 620 mm. The mode at 520 mm can be traced back as mode D of December 1981 at 480 mm and mode at 620 mm as mode C of December at 540 mm. Data are not available for March. In April there were three modes at 340, 380 and 560 mm. While mode at 560 mm is due to 4 cm growth of mode D of February, other two modes at 340 mm (Mode E) and 380 mm are because of the entry of new individuals to the fishery. Samples were not available in May and June. In July two modes can be seen at 420 and 480 mm. Mode at 420 mm can be traced back as mode E of April. In August three modes were observed at 560, 680 and 760 mm. Mode at 680 mm can be traced back as mode E of April which was not represented in immediate preceding 3 months. In the same way, mode at 760 mm can be traced back as mode C of February at 620 mm which was not represented during the last 5 months. In September there were modes at 460, 520 and 620 mm. Out of the three modes, only one mode at 520 mm could be traced back as mode E of July at 420 mm. In October two modes at 400 and 440 mm have been represented by the addition of new individuals to the fishery.

Age and Growth

It is clear from the above description that only few modes could be clearly followed for some months. As can be seen from the Fig. 15 (paper 12) that mode of smallest fish at 340 mm (Mode E) in April 1982 could be followed upto September when it attained a length of 520 mm in five months with a monthly growth rate of 36 mm. It is clear from the progression of other modes (Mode A, B, C and D) that the fish grew 40 mm per month in the beginning of the modal progression. Occurrence of 500 mm long fish during November of both the years clearly indicates the fish to be one year old.

Mode A of January 1981 at 540 mm could be followed upto July 1981 when it attained 680 mm length in six months with monthly growth rate of 23.3 mm. Mode B of January 1981 at 480 mm could be followed upto September 1981 when it progressed by 180 mm in 8 months with a monthly growth rate of 22.5 mm. Mode C of October 1981 at 460 mm could be followed upto August 1982 when it grew 300 mm in ten months with a monthly growth rate of 30 mm. In the same way mode D of December 1981 at 480 mm could be followed upto August 1982 with 200 mm growth in 8 months and a monthly growth rate of 25 mm.

It is interesting to note here that yellowfin after attaining 500 mm length, grew at a slower rate. It is evident from the Figs. 14 & 15 (paper 12) that mode B progressed from 520 to 660 mm in 6 months with monthly growth rate of 23.3 mm. Mode A also has shown monthly growth rate of 23.3 mm. So it can be concluded that yellowfin grow 23.3 mm per month between first year and second years of its life and two years old fish will be around 780 mm, as seen in September 1982, when a prominent mode at 780 mm representing two years old fish is present.

Although fork length of fish ranged between 270 and 1370 mm during both the years, fish more than 780 mm could not be used for length frequency analysis as they were caught only as stray numbers.

Fitting von Bertalanffy's growth equation

The growth equation developed by von Bertalanffy (1938) has been used in the present study. The values of the different parameters were calculated by using length data of the year 1981 and the following results were obtained. The length of the individual fish ranged from 270 to 1370 mm.

L_∞ = 145 cm
k = 0.32 (Annual basis)
t_0 = —0.34

Based on these parameters, age of yellowfin tuna from Minicoy waters was estimated as follows :

Age in years	*Fork length in mm*
1	506
2	769
3	952
4	1088
5	1187
6	1259
7	1311

Monthly growth increment for seven years was calculated as 42.16 mm, 21.91 mm, 15.25 mm, 11.33 mm, 8.25 mm, 6.0 mm and 4.33 mm respectively.

Discussion

The earliest study on growth of yellowfin tuna was that of Kimura (1932) who collected weight frequency data from Suruga Bay between 1924 and 1931. Nose *et al.* (1957) converted these weight data given by Kimura (1932) into length and estimated lengths of yellowfin upto five years as 62, 81, 106, 120 and 134 cm respectively.

Aikawa and Kato (1938) estimated age of six yellowfin out of which four were small and two were of large size. They used the 5th and 10th vertebrae to read annual marks on them. Nose *et al.* (1957) converted the weights at estimated ages into lengths and concluded that fish was 54, 70, 85, 100, 115, 130, 145 and 160 cm long from one to eight years respectively.

Schaefer and Marr (1948) calculated the growth of yellowfin tuna based on length frequency records for Pacific Oceans near Costa Rica and opined that fish of one and two years old to be 85 and 115 cm respectively.

Moore (1951) used modal length progression of 4793 fish from Hawaiian waters for estimating age of yellowfin tuna upto 4th year of fishlife. He calculated length of fish from first to fourth year to be 103, 136, 155 and 168 cm respectively.

Annual marks formation on body scales were used by Nose *et al.* (1955) for calculating the ages of 300 yellowfin tuna collected from Tokyo market and later (1957) from several areas of western Pacific. Yabuta and Yukinawa (1957) used length frequency modal progression of 54,473 specimens which were caught from Japanese waters, and estimated the age upto third year to be 100, 133 and 146 cm respectively. In a later publication (1959) they calculated age of yellowfin upto fourth year when fish were 100, 125, 137 and 145 cm long respectively. Yabuta *et al.* (1960) used annulus formation on body scales for estimating ages and stated fish of 92.3, 120.1, 139.9 and 154.1 cm long to be 1, 2, 3 and 4 years old respectively. Hennemuth (1961) estimated yellowfin age by modal length progression method and stated that the estimation of rate of growth and age determination by direct methods for tropical tunas is not reliable. He estimated the length of 1, 2, 3 and 4 years old fish to be 55, 85, 123 and 144 cm respectively. He concluded that the rates of growth of fish from the western, central and eastern Pacific regions were quite similar.

Schaefer *et al.* (1961) reported on the growth of recovered tagged yellowfin tuna from the eastern Pacific Ocean and found that tagging data showed considerably lower growth rate than that obtained from length frequency modal progression for fish of similar age. Blunt and Messersmith (1960) based on the three tagged yellowfin recoveries stated that first specimen with fork length of 601 mm at the time of tagging showed 332 mm growth in 372 days, second 495 mm at the time of tagging with 210 mm in 367 days and third with 570 mm at the time of tagging with 768 mm growth in 842 days.

Diaz (1963) utilized length frequency modal progression for age determination for the fish caught from western coast of America from 1951 to 1956. He estimated length of 1, 2, 3, 4 and 5 years old fish to be 65, 110, 140, 165 and 180 cm respectively. Tan *et al.* (1965) estimated age and growth of 170 yellowfin from Pacific (0°-10°N ; 155°-175°E) by reading annual marks on centra and stated the size of 1, 2, 3 and 4 years old fish to be 50, 82, 115 and 130 cm respectively. Yang *et al.* (1969) utilised annual marks formation on body scales of 200 yellowfin from Pacific Ocean (3°-33°N ; 133°-270°E) during 1965. He estimated the length of 1, 2, 3, 4 and 5 years old fish to be 55, 90, 120, 145 and 160 cm respectively.

From Philippine waters, Yesaki (1983) calculated values of k as 0.29 and L_∞ value as 181 cms. He estimated length of 1.5 years old male as 64 cm and female 66 cm.

Age and growth estimation by reading annual marks on body scales and vertebrae, length frequency modal progression and incremental growth methods for yellowfin tuna have been reviewed by Suzuki (1971). He concluded that there is a general agreement among the tuna researchers that yellowfin tuna grow rapidly in early life and at a similar rate in the major regions of the Pacific Ocean.

During the present investigation by length frequency analysis length of 1 and 2 years old fish has been estimated as 50 and 77.9 cm respectively. But by fitting von Bertalanffy's growth equation length upto seven years was 50.6, 76.9, 95.2, 108.8, 118.7, 125.9 and 131.1 cm respectively.

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