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STUDY OF THE GROWTH AND POPULATIO'N PARAMETERS OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE ANDAMAN AND NICOBAR WATERS BASED ON THE LENGTH FREQUENCY DATA

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ABSTRACT

The exploitation level of tuna is meagre to the total marine fish landings in India. The Exclusive Economic Zone(EEZ) of India around A&N islands is 30% of the Indian EEZ. Three species of oceanic tunas are commonly recorded in the Andaman and Nicobar waters. The tuna landings is only 4.2 % of the total marine fish landings in the Island groups. The growth pattern of yellowfin tuna appears to be complex in the Indian Ocean. Very limited studies are available on the growth and population parameters of yellowfin tuna in the Andaman and Nicobar waters. Hence an attempt has been made to study the growth and population parameters of yellowfin tuna in the Andaman and Nicobar waters based on the data collected by the departmental vessel M.F.V Blue Marlin in the Indian EEZ around Andaman and Nicobar during the period 2002-11. The study indicated that the M:F ratio was 1:0.5. The mean fork length and weight for the male was 125.9cm and 36kg and for female it was 117.7cm and 28.3 kg respectively. The morphometric relationship shows a linear growth among the various parameters. The length weight relationship for male was $W = 0.00001 L^{3.12}$ (r = 0.98) and for female it was $W= 0.00002 L^{2.96}$ (r = 0.95). The pooled data shows the relationship as $W = 0.00002 L^{2.97}$ (r = 0.98). The growth of the species was calculated as 60.01 cm, 96.89 cm, 121.56 cm, 138.27 cm, 149.58 cm, 157.24 cm,162.42 cm and 165.93 cm at 1 to 8 years respectively and the longevity of the species was estimated to be 7.6 years. Mortality estimates were M=0.51, F=0.83 and Z=1.34. The exploitation rate was 0.62 and E_{max} was 0.80.Virtual Population Analysis (VPA) indicated that the fishing mortality started at 105cm midlength.

(Key words: Growth, population parameters, yellowfin tuna, A&N waters, sex ratio, mortality)

Introduction

The coastal waters of India have been subjected to enormous fishing pressure and the resultant depletion of coastal resources is very much seen in the past years. Hence the need of the hour is the diversification of fishing activities by extending the fishing operation in the oceanic waters. Oceanic tunas and allied resources have a prominent role in the fishery policies in India as these are among the least exploited stocks in the EEZ of India. Resource estimates indicate that the exploitation level of tuna is only 2 % of the total marine fish production in Indian waters (Anon, 2011a). The tuna fishery of India continues to be the coastal tunas caught mainly by the traditional sector. Very recently the oceanic tuna exploitation has gained momentum in the Indian EEZ. The exclusive economic zone of India is 2.02 million sq km and 30 % of that i.e 0.6 million sq km is around Andaman and Nicobar Islands. The geographical location of A&N islands has made it distinct in the world map in terms of biodiversity. Apart from mackerels, sardines, carangids, perches, elasmobranches,

shrimp and crabs and coastal tunas contribute substantially to the marine fish landings of these Islands. The oceanic tunas recorded in the Andaman seas are yellowfin tuna(*Thunnus albacares*), bigeye tuna(*Thunnus obesus*) and skipjack tuna(*Katsuwonus pelamis*). The yellowfin tunas are able to forage in the upper part of thermocline layer hence their distribution and abundance is greatly influenced by the oceanographic conditions. Studies on the biology, age and growth and population parameters of the yellowfin tuna are of crucial importance for managing the tuna fishery in the Andaman sea. The potential of the neritic as well as oceanic tunas in the A&N Islands is estimated as 64,500 T . But the exploitation level of these species is meagre. At present only 4.2%(Anon, 2012) of the potential is being exploited. The species are exploited by gillnet, hook and line, troll line and long line in the Island waters. Till 2008 it was mostly by the traditional fishermen only. Recently the Ministry of Agriculture, India have allowed the private longliners for the exploitation of oceanic tuna in Andaman waters on commercial basis by giving licence to them. The oceanic tunas are known to be highly migratory in nature, hence for a clear understanding of the stock structure of these resources it is essential to know the biological aspects of the tunas. Various researchers have studied the biology as well as growth parameters of yellowfin tunas in the west coast as well as the east coast of India (Mohan and Kunhikoya, 1985; John *et al.*,1989; Sudarsan *et al.,* 1991; Pillai *et al.,* 1993*;* Sudarsan *et al.,* 1994; John,1995;Varghese *et al.*, 2002; Somavanshi *et al.*, 2003; Sivaraj *et al.*, 2005; Pandian *et al.*, 2007; Prathibha Rohit *et al*.,(2008,09, 12). However the growth parameters of yellowfin tuna occurring in the Andaman sea is attempted by limited researchers (John, 1995, Somvanshi *et al*.,2003). Keeping in view of the proximity of the EEZ of India around A&N islands to the neighbouring south east Asian countries and also the stock nature of yellowfin tuna which is shared by different countries it is utmost important to study the growth and population parameters of this species. This paper is an attempt to study the age , growth and population

parameters of the species based on the data collected by the departmental tuna longliner MFV Blue Marlin(OAL 35.76m, GRT : 310 T) attached to Port Blair Base of Fishery Survey of India.

Materials and methods

The tuna long line survey data collected during the period of 2002-11 in the Indian EEZ around A&N Islands (**Fig.1**) are used in the present study. A total of 966 specimens were taken for in depth analysis. The data was analysed for morphometric analysis. The linear equation (Y = a + b X) was fitted among various parameters such as TL-FL, FL-HL and FL-(S- 1D) .Where TL is total length, FL is fork length, HL is head length and (S-1D) is snout to first dorsal length. Regression analysis was performed to determine the constants 'a' and 'b' and also 'r'. The relationship $W= aL^{b}$ (Le Cren, 1951) was used for the length and weight relationship where W is the weight of the fish in Kg and L is the fork length in cm. Sexes are identified by the gonad observation and accordingly male to female ratio was calculated. Length frequency data grouped into 10cm interval was used for the estimation of growth and population parameters. The $L\infty$, K ,and Φ was estimated using the ELEFAN I of FiSAT (FAO-ICLARM stock assessment tools, Ver 1.2.2, 2005) and t_0 was calculated by Pauly's empirical equation (1979). Longevity was calculated by the formula $t_{max} = 3/K+t_0$ (Pauly, 1983a).Natural mortality (M) was calculated from Pauly's empirical formula(Pauly,1980) and the total mortality (Z) from length converted catch curve by taking the mean annual habitat temperature as 20˚ C (Pauly,1983b) .The fishing mortality was calculated as F = Z-M. The length structured virtual population analysis (VPA) of FiSAT was carried out to ascertain the loss due to natural causes and fishing pressure at different length classes. The length at first capture (the length at which 50% of the fishes are vulnerable to capture, L_{50}) was estimated from the length converted catch curve analysis. The exploitation rate (E) was obtained by dividing F by Z.

Results

Length frequency distribution

The percentage of frequency distribution of different size ranges of yellowfin tuna recorded is shown in **fig.2**. The male specimen was recorded from 48cm to 169cm with dominance at 131-150cm, 111-130cm and 91-110cm respectively. However female specimens were recorded at 52cm and up to 150 cm with dominance at 111-130cm, 131-150cm and 91-110 cm respectively. The mean fork length and weight of male yellowfin tuna was found to be 125.9 cm and 36kg respectively where as in case of female it was 117.7 cm and 28.3 kg. It could be observed that the females are smaller and lighter than the males. The male to female ratio is given in **table.1**. The overall male to female ratio of yellowfin tuna was found to be 1:0.5. The dominance of male was noticed in almost all size groups except 91-100 cm where both the sexes contribute equally. The dominance of male was noticed in the higher length range and that of female was in the lower length range.

Morphometric Relationship

250 specimens of various size groups were measured for morphometric relationships. The relationship obtained are as follows.

FL= 1.62 – 0.9 TL (r = 0.99)

HL = 4.42 + 0.22 FL (r = 0.94)

(S-1D) = 2.15 + 0.28 FL (r = 0.93)

It could be seen that a linear relationship exists among all the parameters.

Length Weight analysis

The length weight relationships obtained for yellowfin tuna are as follows.

$W = 0.00001\ L^{3.12}$ (r = 0.98) for male

$W = 0.00002\ L^{2.96}$ (r = 0.95) for female

and

$W = 0.00002\ L^{2.97}$ (r = 0.98) for the pooled data of male and female

Analysis of variance (ANOVA) was performed to test the significant difference in the length weight relationship between the sexes and the relationship was found to be significant. The present study indicated that the growth of the fish is isometric and it follows the cube law. Some of the biological parameters of yellowfin tuna obtained by various researchers in Andaman sea is shown in the **table 2.**

Population parameters

The growth parameters obtained from ELEFAN I viz $L\infty$, K, t_0, and Φ were found to be 173.3 cm, 0.39/year, -0.0999 and 4.069 respectively. The Von Bertalanffy growth equation (Von Bertalanffy, 1938)was

$L_t = 173.3\ [\ 1\text{-}e^{-0.39(t+0.0999)}]$

The Von Bertalanffy growth curve obtained is shown in **fig 3**. Taking t_0 = -0.0999 the growth of the species was calculated as 60.01 cm, 96.89 cm, 121.56 cm,138.27 cm,149.58 cm, 157.24 cm,162.42 cm and 165.93 cm at 1 to 8 years respectively(**fig.4**). **Table 3** shows the growth parameters obtained in A&N waters and adjacent areas. Taking the mean habitat temperature as 20°C, the natural mortality of the species was found to be 0.51. The total mortality obtained from the length converted catch curve was 1.34. Hence the fishing mortality (Z-M) was 0.83. The E_{max} was 0.80 and the exploitation rate was 0.62. The virtual population analysis (VPA) indicated that the mortality due to natural causes only was up to 95cm middle length(i.e 91-100cm class interval). The fishing pressure started at 105 cm

middle length and it was extensive up to 140cm and steadily decreased thereafter. At the size 155cm the mortality was completely due to fishing pressure only (**fig.5**). The length at first capture (L_{50}) was 132 cm. The length at which 75% of the fish are retained in the gear (L_{75}) was estimated as 142.1 cm. The growth was observed to be rapid during the first three years and started declining in the subsequent years. The longevity (t_{max}) of the species was estimated as 7.6 years.

Discussion

The biological aspects such as length frequency, length weight analysis , sex ratio , food and feeding etc. has been studied by various researchers viz., John(1995), Pillai and Pillai(2000) , Varghese *et al.*(2002) and Pillai and Gopakumar(2003), Sivaraj *et al.*(2005), Somvanshi *et al.* (2003) and Pandian *et al.* (2007).The mean length and mean weight estimated by John(1995) for A&N waters is 129.3 cm and 37.7 kg respectively. Sivaraj *et al.*(2005) studied the biological aspects and reported the mean length of male and female yellowfin tuna as 121.93 cm and 111.54cm and mean weight as 33.8kg and 26.72 kg respectively. Also the dominance of male and female was noticed at 131-140cm and 111-130cm respectively. Pandian *et al.*(2005) reported the mean length for male and female as 123.1 cm and 115.6cm respectively and mean weight for male and female as 32.88 kg and 26.55 kg. The modal class for male and female were at 111-150 cm and 111-140cm respectively. The size of yellowfin tuna exploited in the Indian Ocean ranges from 30-180 cm fork length and males are predominant in the catches of larger yellowfins of size more than 140cm (Anon , 2011b). All these studies showed the larger size of male than the female in the population. In the present observation also similar results are obtained and the mean length for male and female of the species was found to be 125.9 cm and 117.7cm respectively and the mean weight was 36 kg and 28.3 kg. In the present study 48% of male population was 130cm+. It agrees with the previous observations (Maldeniya and Joseph, 1986 ; Sudarsan *et al*., 1991 and John, 1995)

that the males are dominant at large size. The previous studies like John(1995), Sivaraj *et al.*(2005) and Pandian *et al.*(2007) has indicated the dominance of male in the population with a ratio of 1:0.39, 1:0.46 and 1:0.44 respectively. The present observation agrees well with the previous ones and it was 1:0.5. Earlier observations has indicated a linear relationship between fork length and other morphometric characters(Schaefer and Walford, 1950). John(1995) got similar relationship in Andaman waters. In the present study also it could be seen that the relationship between total length , fork length, head length, Snout to 1st dorsal length is linear. The length weight relationship of the Andaman sea tunas showed an isometric growth trend with the b value at 2.8423(John 1995). Pandian *et al.*(2005) reported it as 2.91 and 2.62 respectively for male and female respectively. The present study also showed an isometric growth for the species and for the pooled data of male and female the 'a' and 'b' values obtained were 0.00002 and 2.97 respectively. The growth parameters of yellowfin tuna has been studied extensively in the Arabian sea, Bay of Bengal, Indian ocean, Atlantic ocean and the Pacific ocean with the help of different methods such as rings on the dorsal fin spines, scales and otoliths and length frequency based studies and the parameters obtained by different methods are identical in different regions. Growth parameters of yellowfin tuna were studied by various researchers viz. John & Reddy(1989), John and Sudarsan(1993), Pillai *et al.*(1993), Somvanshi *et al.*(2003) from the Arabian sea and Bay of Bengal. As the growth of a species can be highly variable according to time and area hence separate studies on the growth parameters of the tunas recorded in various parts of Indian coast is of importance to have a clear understanding on the stock structure. Due to lack of large scale tagging data in the study area as well as the otolith measurements, the length frequency data available for the yellowfin tunas in the A&N waters was analysed in the present study to project the growth parameters. Large movements of yellowfin tunas supports the assumption of a single stock for the Indian ocean. As it is known to be a

straddling stock and the proximity of Andaman and Nicobar Islands to the Southeast Asian countries than the mainland India, the growth parameters obtained for the yellowfins in Andaman waters can be comparable with the parameters obtained at these countries as well as east coast and west coast of India. From the **table 3** it can be seen that in Andaman sea and adjacent area the L∞ value varied from 170-197.42cm and K was in between 0.20 and 0.66. The longevity varied from 6 to 15 years for different studies. The growth pattern of yellowfin tuna appears to be complex at various places. A number of studies were carried out on the growth of yellowfin tuna in the 3 oceans and a lot of deliberations were made on the growth rate in the IPTP/IOTC workshops on stock assessment of yellowfin tuna in the Indian Ocean. Studies for calculating age from otoliths, spines, vertebra and scales, length frequency analysis and tagging data suggest a two stanza growth i.e slower growth and faster growth. In the Indian Ocean, the initial growth rate was estimated at between 1.3 and 2.9 cm per month and the fast growth rate of larger fishes being between 2.5 and 4.8 cm per month (Marsac and Lablache, 1985; Anderson, 1988; Marsac, 1991; Firoozi and Carrara,1992 ; Lumineau, 2002). In Indian waters John (1995) suggested a faster growth of yellowfin tuna. Chantawong (1998) reported a faster growth rate for yellowfin tuna in Eastern Indian Ocean. Somvanshi *et al*.(2003) were of the opinion of a slower growth rate in their study for Arabian sea and A&N waters. Prathibha Rohit *et al.* (2012) found the growth of the species at 3.6 cm and 2cm per month in the first three years of growth. **Fig.4** shows the growth curve obtained by various researchers for yellowfin tuna in Andaman & Nicobar waters. In the present study in the first three years the growth rate was 3.0 cm/month and 2.1 cm/month which is suggestive of a faster growth rate in Andaman waters. The natural mortality of yellowfin tuna in Andaman sea is 0.51. The fishing mortality of 0.83 suggested that the fishing pressure has increased a little in this area in the recent past. The VPA indicated that the mortality due to natural causes

was up to 95cm and the fishing pressure starts at 105cm midlength which suggests the selectivity of the gear.

Yellowfin tuna fishery in India is still in the infant stage and there is ample scope for expansion of the fishery and enhancing the exploitation level in the oceanic realm. Tuna research in India has gained momentum in recent past however a lot more needs to be done as far as the complicated growth parameters are concerned particularly the dominance of male in the population as well as in the higher size ranges and the growth rate . Probably it could be due to various factors such as difference in natural mortality for males and females or different growth rates for both the sexes which is yet to be established in the study area. Along with these parameters other parameters like the oceanographic conditions and the availability of prey in the area has to be considered also. Hence to have better understanding of the unusual sex ratio as well as the growth rate it is imperative to study the growth parameters and natural mortality separately for both the sexes in the Andaman sea and also the oceanographic conditions affecting the growth for both the sexes. Also more studies on the otolith measurements and tagging exercises need to be undertaken in the study area so as to validate the results obtained by the length frequency studies.

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Table 1. Sex ratio of *Thunnus albacares* in the A&N waters

Fork Length(cm)	Male	Female	Sex Ratio
41-50	3	0	--
51-60	5	1	1:0.2
61-70	9	1	1:0.1
71-80	15	6	1:0.4
81-90	31	15	1:0.5
91-100	27	26	1:1.0
101-110	61	42	1:0.7
111-120	90	64	1:0.7
121-130	106	68	1:0.6
131-140	127	62	1:0.5
141-150	98	16	1:0.2
151-160	80	0	--
161-170	12	0	--
Total	**664**	**302**	**1:0.5**

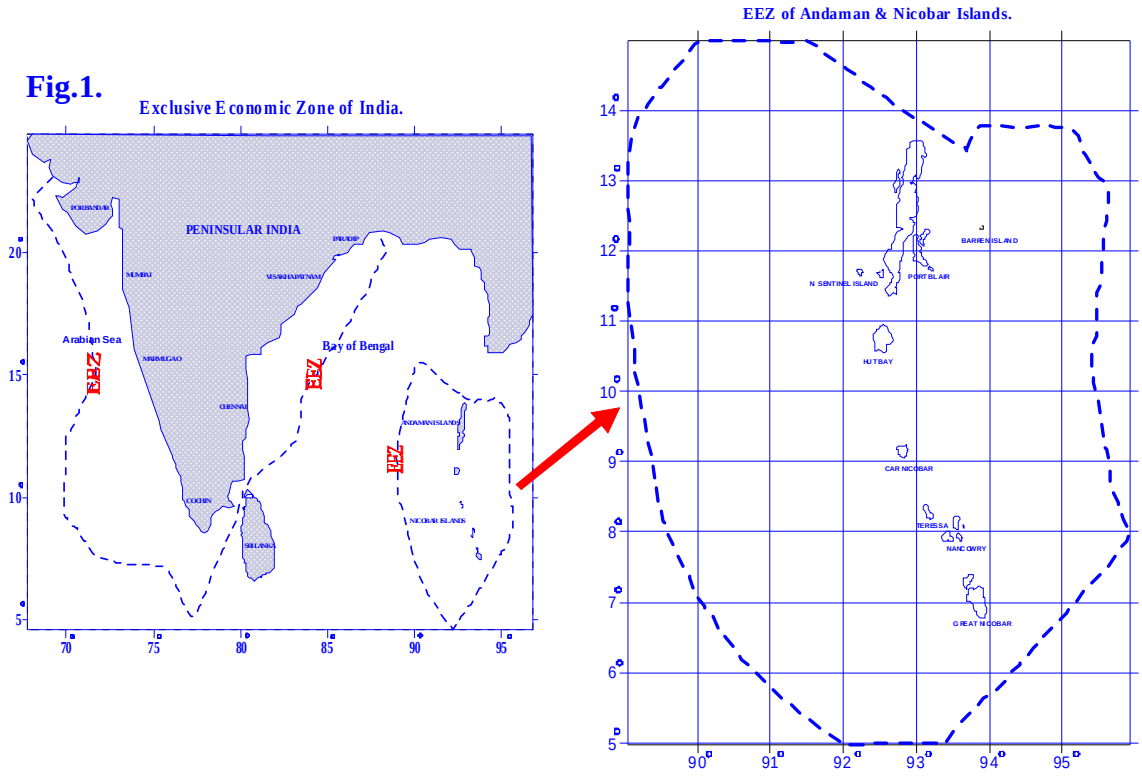
Table 2. Some biological parameters of *Thunnus albacares* by various researchers in A&N waters

Area	Size range (fork length)	Sex ratio(m:f)	L-W relationship	Source
Andaman & Nicobar waters	M:48-169 F:52-150 Pooled: 48-169	1:0.5	$W = 0.00001\ L^{3.12}$ (r = 0.98) $W= 0.00002\ L^{2.96}$ (r = 0.95) $W = 0.00002\ L^{2.97}$ (r = 0.98)	Present study
Andaman & Nicobar waters	M: 69-176 F:48-145	1:0.44	$W=0.000025972\ L^{2.9088}$(r=0.926) $W=0.00010376L^{2.6184}$(r=0.9093)	Pandian *et al*.(2007)
Andaman & Nicobar waters	M: 51-178 F:55-150	1:0.46	--	Sivaraj *et al*.(2005)
Andaman & Nicobar waters	100-150	--	$W=0.000038812L^{2.8507}$	Sudarsan and John, 1993
Andaman & Nicobar waters	M:58-163 F:59-147 M+F:58-163	1:0.44	$W=0.000034569L^{2.8653}$ $W=0.0000551847L^{2.7565}$ $W=0.000038062L^{2.8423}$	John(1995)

Table 3. Growth and population parameters of *Thunnus albacares* in A&N waters and adjacent areas

Area	**L∞**	**K/year**	**t_0**	**Longevity (yrs)**	**Natural Mortality(M)**	**Source**
Andaman & Nicobar waters	173.3	0.39	-0.0999	7.69	0.51	Present study
West & South of Srilanka	178.0	0.47	-0.208	6.38	--	Maldeniya & Joseph(1985)
West & South of Srilanka	179.0	0.48	-0.213	6.25	--	
Sumatra	170.0	0.50	--	6	--	Anon,1987
Andaman & Nicobar waters	171.5	0.316	-0.305	9.49	0.60	John(1995)
Eastern Indian Ocean	194.0	0.66	0.27	11.1	--	Chantawong (1998)
Arabian sea and A&N waters	193.93	0.20	--	15	--	Somvanshi *et al*.(2003)
East coast of India	197.42	0.30	-0.1157	10.1	0.4	Prathibha *et al*.(2012)
West coast of India	175.0	0.29	--	10.3	--	John & Reddy(1989)

Fig.1.


Exclusive Economic Zone of India.
PENINSULAR INDIA
Arabian Sea
Bay of Bengal
EEZ
EEZ
EEZ
EEZ of Andaman & Nicobar Islands.
BARREN ISLAND
N SENTINEL ISLAND
PORT BLAIR
HUTBAY
CAR NICOBAR
TERESSA
NANCOWRY
GREAT NICOBAR

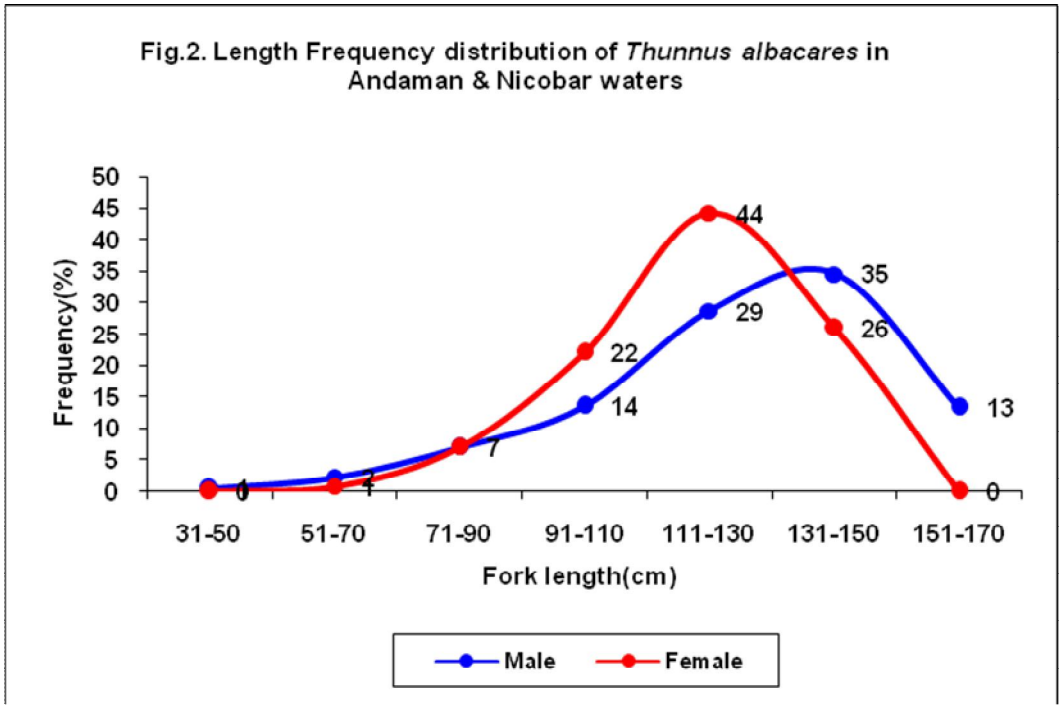
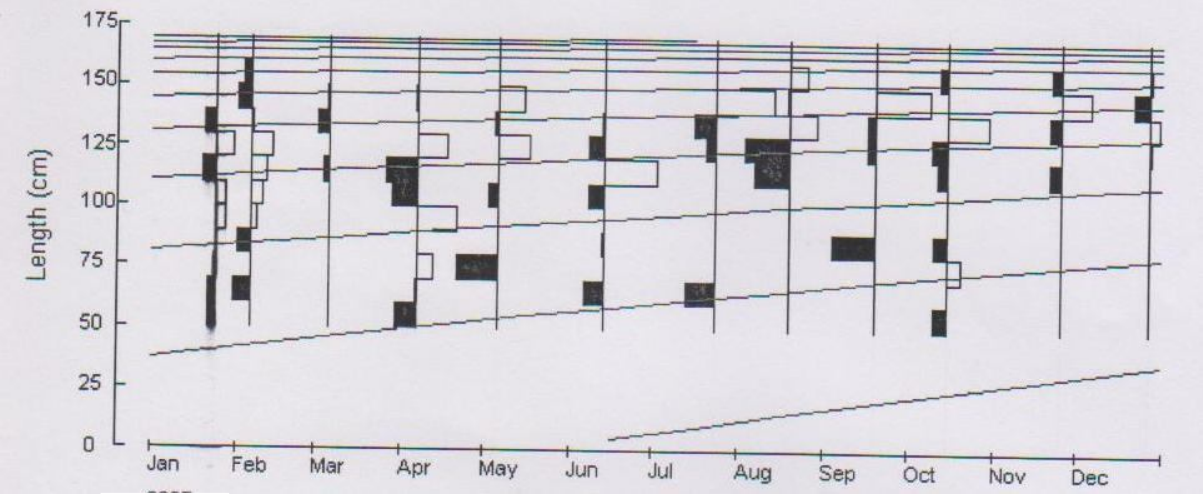


Fig.2. Length Frequency distribution of Thunnus albacares in Andaman & Nicobar waters
Frequency(%)
Fork length(cm)
31-50
51-70
71-90
91-110
111-130
131-150
151-170
Male
Female

Fig.3.Von Bertalanffy growth curve for *Thunnus albacares* in Andaman &Nicobar waters



2007

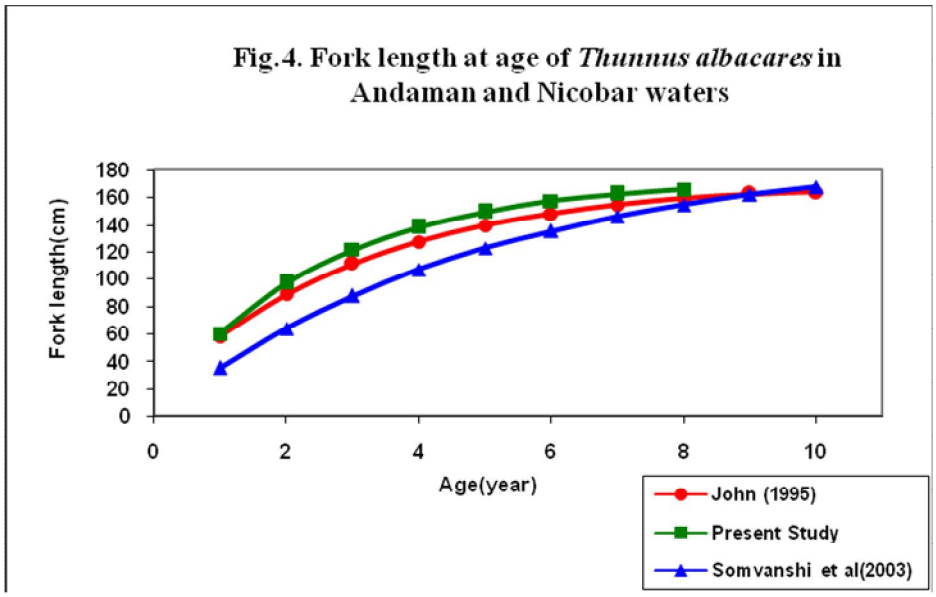


Fig.5. Virtual Population Analysis (VPA) of *Thunnus albacares* in Andaman &Nicobar waters