REVIEW OF BIOLOGICAL ASPECTS OF YELLOWFIN TUNA (*THUNNUS ALBACARES*) FROM THE INDIAN OCEAN

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ABSTRACT

*In Indian Ocean oceanic tunas are exploited using different gears depending on target species. With the production of tunas in the ocean reaching 1.1 million tonnes apprehensions are expressed of their over exploitation and depletion of stocks. To assess the stocks it is imperative to know about biological features of the fishery. In Indian Ocean yellowfin tuna (**Thunnus albacares**) is the principal stock targeted in the tuna fisheries. Biological research on yellowfin tuna (**Thunnus albacares**) in the oceanic sector of the Indian Ocean is of recent origin though information on the coastal tunas is reported. India has initiated studies on various aspects of the biology of yellowfin tunas caught in the longline gears in the oceanic sectors of the Indian EEZ. These studies include the Length-weight relationship, size frequencies, growth parameters, food and feeding habits, spawning season etc, with respect to the yellowfin tuna stock occurring in the oceanic sector of the Indian EEZ in general and for different sectors in particular. The paper provides a review of the biological studies carried out on yellowfin tuna caught by different gears by the scientists working in several regions of Indian Ocean on various aspects of the biology of the species occurring in Indian Ocean. Information on the biological characteristics of this highly migratory species is valuable for assessing stocks and devising measures for conservation and management for sustainable exploitation of the resources.*

INTRODUCTION

The Yellowfin tuna (*Thunnus albacares*) is the major component of the tuna fishery in the Indian Ocean. A review of studies on the biological aspects of the species are essentially required to provide upto date results and information on vital aspects such as length frequencies, growth parameters, length weight relationship, maturity and spawning, minimum size of maturity and food and feeding habits. A review of the results of studies carried out on Yellowfin tuna by the scientists on different aspects of the biology of the species occurring in Indian Ocean are presented in this paper.

India has initiated action to study the biology of Yellowfin tunas caught on the long line gears in the oceanic sectors of the Indian EEZ. The studies undertaken by the Fishery Survey of India (FSI) on the large deep swimming yellowfin tunas include biological aspects such as size frequencies, length-weight relationship, growth parameters, reproductive biology and the food and feeding habit of the species. The Yellowfin tunas caught on the longline gears operated by FSI vessels during the course of survey in different sectors of the EEZ during different periods of survey (1983 to 1998) were subjected to biological investigations by the investigators. The population dynamics of yellowfin tunas, *Thunnus albacares*, from the Indian EEZ was studied by John and Reddy (1989) based on the data collected in long line survey during the period 1983-88 whereas some of the biological aspects of yellowfin tuna was investigated by Sudarsan et.al., (1991) using data collected during 1983-91. Subsequently, Vijayakumaran **et al**., (1992) analysed the gut content of yellowfin tuna caught from Andaman waters of Indian EEZ from September 1989 to August 1990. John and Sudarsan (1993) investigated the stomach contents of individuals of Yellowfin tuna caught from the west coast, east coast and Andaman & Nicobar waters during the period 1991-92. John **et al** .,(1998) made observation on some aspects of reproductive biology of yellowfin tuna obtained in the longline catches from Bay of Bengal during January 1991 to July 1995. John (1995) carried out biological investigation utilising the data of the two survey vessels, **Yellowfin** collected during September 1989-August 1991 and **Blue Marlin** from December 1991 to September 1994 . Govindraj **et al** .,.(2000) conducted the study with respect to the stock occurring in the north west sector of the Arabian Sea using the data from 1994-98 collected on board the vessel **Yellowfin** operating from Porbandar. Such information and results from earlier studies are provided here as review of the biological aspects of Yellowfin tuna.

LENGTH FREQUENCIES

Length frequency of yellowfin tuna, *Thunnus albacares*, in the oceanic sector of the EEZ based on the longline catches of survey vessels of FSI is reported from south west coast (John and Reddy, 1989), north west coast of India in Arabian Sea and Bay of Bengal (Sudarsan **et al.,** 1991), different sectors of EEZ (John and Sudarsan, 1993: John, 1995) and north west coast (Govindaraj, **etal**., 2000).

Following is the sector-wise information on length frequencies obtained from the EEZ.

Area/ Sector	Period of 0bservation	Size range (FL in cm)	No. of observations	Source
South-west coast	1983-1986	58-164	968	John & Reddy (1989)
North-west coast	1989-1991	56-181	398	Sudarsan **et.al.** (1991)
Bay of Bengal	1989-1990	72-164	407	
Indian EEZ	1991-1992	48-168	468	John & Sudarsan (1993)
South-west coast	1983-1987	56-168		
North-west coast	1989-1993	58-181	3508	John (1995)
Andaman & Nicobar Seas	1989-1994	44-172		
North-west coast	1996-1998	50-165	850	Govindraj **et.al.** (2000)

The total number of specimens considered for length frequency studies in different sectors was 6599 John (1995) reported the fork length of specimens obtained during oceanic long lining to be in the range of 44-181 cm. The mean length observed from Andaman& Nicobar waters is 121.8 cm, south west coast 125.14 cm and North West coast 130.19 cm. Along north western region of Indian EEZ (Govindraj **et al**., 2000) the specimens were in the range of 50-165 cm fork length with mean length of 102.8 cm and common size group was 06-130 cm length. By converting the length frequencies into weight frequencies applying the length- weight relationship the mean weight of the stock was worked out (John, 1995). The results thus obtained indicate that the mean weight observed in the Andaman & Nicobar waters is 34.42 kg, south west coast 36.97 kg and North West coast 41.96 kg. The stability of mean weight over the years observed in the Indian waters indicates the healthy state of yellowfin tuna stock in the region. Summary of length frequency studies in Indian Ocean using different gears is presented in Table 1. It may be seen that model length of Yellowfin tuna observed as 60 cm, 39-50 cm, 67 cm, 31-54 cm and 90-155 cm by gillnet, pole and line, troll line, purse seining and long line fishing respectively. The modal length, in general, is lower and common (31-54 cm excepting one value of 89 cm fork length) for the specimens caught by fishing gears, gill nets, pole and line, troll lines and purse seines. The modal values of Yellowfin tuna from different parts of Indian Ocean caught by long lines, it stands apart with values of 126-155 cm.

LENGTH-WEIGHT RELATIONSHIP

In the oceanic fishery results of length - weight relationship of Yellow-fin tuna available with respect to the stock occurring in different sectors of the Indian Ocean (Morita, 1973, Silas **et al.,** 1985, John and Reddy, 1989, ,Sudarsan **et al.,** 1991, John and Sudarsan, 1993, Pillai **et al**., 1993 John, 1995 Stequert, **et al**., 1996 and Govindaraj **et al.,** 2000). A comparison of the length-weight relationship observed in different studies is presented below.

Region	Gear	Sex	Sample size	Size range	Length-weight relationship	Source
Arabian Sea	Long line	M +F	210	50-170	$W=0.0001036\ L^{2.66410834}$	Silas **et.al**., 1985
Arabian Sea	Long line	M+F	98	92-153	$W=0.000049557L^{2.8055}$	John & Reddy 1989
Arabian Sea	Long line	M+F	133	-	$W=0.000040697L^{2.8496}$	Sudarsan **et.al.**, 1991
Indian EEZ	Long line	M+F	243	59-155	$W=0.000039528L^{2.8318}$	John & Sudarsan, 1993
Andaman Sea	Long line	M+F	351	100-150	$W=0.000038812L^{2.8507}$	Sudarsan and John, 1993
Andaman Sea	Long line	M F M+F	304 118 422	58-163 59-147 58-163	$W=0.000034569L^{2.8653}$ $W=0.0000551847L^{2.7565}$ $W=0.000038062L^{2.8423}$	John, 1995)
Northern Arabian Sea	Long line	M+F	850	50-165	$W=0.00004626L^{2.8012}$	Govindraj **et.al.**, 2000
Western Indian Ocean	Purse Seine	M+F		> 64	$W=0.00005313L^{2.7536}$	Stequert **et al.,** 1996
Western Indian Ocean	Purse Seine	M+F		=> 64	$W=0.00001585L^{3.0449}$	Stequert **et al.,** 1996
Eastern Indian Ocean	Long line	M+F	1398	84-174	$Wx=0.000018L^{2.9841}$ $Wy=0.000691L^{2.7396}$	Morita, 1973
Indian Coastal	P. Seine & G.net	M+F	628	32-118	$W=0.00003852L^{2.7443}$	Pilllai, **et. al** 1993

There is no significant difference in the length weight relationship of the stocks occurring in different sectors as well as for the entire EEZ. The exponential value of "b" being about 2.8 from all the sectors of the Indian Ocean in general. The exponential values for males and females studied from Andaman Sea were found to vary marginally (2.8653 and 2.7565 respectively).

GROWTH PARAMETERS

From the oceanic sector of the Indian EEZ growth parameters of yellowfin tuna are estimated from southern Arabian Sea by John and Reddy (1989) and John (1995). The growth parameters of yellowfin tuna occurring in Andaman & Nicobar waters was estimated by John, (1994). The data used for the studies pertains to the period from September 1989 - September 1994. The size range of the samples was 44 -172cm in fork length (FL) and the total number of observations were 1494 fishes.

The growth parameters Loo, and K calculated for the species following different methods are given below.

Method	Loo_(cm)	K (per year)	Source
Gulland and Holt plot	173.78	0.335)	John (1995)
Ford-Walford method	170.33	0.315)	
Chapmans method	170.33	0.315)	
Powell-Wetherall method	171.42	---)	
von Bertalanffy method	-	0.300)	
Shepherd 's method	196.00	0.42)	Kaymaram (1998)

On fitting the estimated parameter values to the von Bertalanffy growth equation, the length (cm) was calculated as 57.9, 88.7, 111.2, 139.4, 148.1, 154.4, 159.1, and 162.4 cm for the age one to nine years respectively. The longivity (t max) of the species calculated by the formula (Pauly, 1983).

t max = 3/ k it was estimated as 9.49 years.

John and Reddy (1989) calculated the growth parameters Loo and K for the species occurring in the western region coast of Indian EEZ. The values obtained using different methods alongwith results obtained by Yang **et al**., 1969 and Kayamaram (1990) are given belo w.

Method	Loo (cm)	K (per year)	Source
Gulland and Holt plot	176	0.30)	John and Reddy (1989)
Ford- Walford method	179	0.27)	
Von Bertalanffy plot	175	0.29)	
ELEFAN 1	170	0.30)	
ELEFAN	194	0.66	Yang **et al** (1969)
ELEFAN 2	196	0.42	Kaymaram . (1998)

The length at different ages were calculated following von Bertalanffy growth equation. The length thus calculated for the species is 44.1,77.0, 107.7, 120.1, 134.0, 144.3, 152.0, and 157.8 cm respectively for one to eight years.

NATURAL MORTALITY:

Region	Method	M (per year)	Source
Indian Ocean		M = 0.8 (Fishes age 0 + and 1) M=0.6 (Fishes age 2 to 6)	TWS/91/04
Indian Ocean		M = 0.61 to 0.70	TWS/91/09
Indian Ocean		M = 0.74	TWS/91/11
Indian Ocean		M = 0.54	TWS/91/21
Oman Sea	Pauly's	M=0.57	Kayamaram, .(1998)
Lakshadweep Sea		M=0.49	Silas et al.(1985)
Arabian Sea	Pauly's	M=0.74	John and Reddy(1989)
Lakshadweep	Rikhter and Effanov (1976)	M=0.52	Pillai et al. (1993)
Andaman & Nicobar	Pauly's	M=0.60	John (1995)

FOOD AND FEEDING HABITS

Food is an important factor influencing the growth, migration and abundance of the fish stocks in time and space. By identifying the feeding ground and feeding habit exploitation strategy can be evolved and improved upon. Several authors have reported the food and feeding habits of yellowfin tunas from different Oceans as well as from the Indian waters. In the Indian waters observations on the food of yellowfin tunas caught on longline gears are reported by Silas **et al.,(**1985), Sudarsan **et al ., (**1991), Vijayakumaran **et al .,** (1992), John and Sudarsan (1993), John (1995) and Govindaraj **et al ., (**2000).

John (1995) investigated the food composition of yellowfin tunas by examining the gut contents of 411 specimens obtained in tuna longline survey from the Andaman and Nicobar waters during September 1989 to February 1994. The relative importance of different prey items in the diet was determined by "Index of preponderence" (Natarajan and Jhingran 1961). The composition of food contents by occurrence and gravimetric method revealed that squids (*Loligo spp*.) were the most dominant food item representing in 61.2% of the stomachs, and quantitatively 46.1% of the gut contents. The second major component of gut contents was teleost fish comprising a wide variety of species, in 41% of the specimens forming 36.7% of the gut contents by weight. The commonly occurring species identified were *Triacanthus sp., Priacanthus sp. Diodon sp. , Tetradon sp., Ostracion sp., Exocoetus sp., Gempylus sp., Coryphaena sp., Sphyraena barracuda, Hemiramphus., Fistularia sp., Hyppocampus sp., Syngnathus sp., Alepisaurus sp., Arioma sp., Engraulis sp., Decapterus sp., Selar sp., Acanthocybium solandri, Auxis sp., Katsuwonus pelamis, Thunnus albacares* (young), *Leiognathus sp., Cubiceps sp., Centrolophus sp.* and *myctophids.* The swarming crab *Charybdis smithe* was the next dominant food component to occur in 22.2% of the stomachs contributing 15.0% of the stomach contents by weight. Other components with lesser importance were cuttle fish, octopus, juveniles of squilla and shrimps. The great diversity in the food composition was represented by about 22 families of teleost fishes, 4 families of crustaceans and 3 families of cephalopods which indicate that they are non-selective feeders and that feeding depends on prey availability rather than selectivity.

The food of yellowfin tuna caught on the longline gears operated in Andaman waters was studied by analysing the gut contents of 188 specimens. Vijaykumaran et al.,(1992). The food items identified were deepsea fishes, **Centrolophus spp. Priacanthus spp.**, flying fish, carangids, ribbon fish, pipe fish, cephalopods, crustaceans, etc. The cephalopods consisted of squids and cuttle fish and crustaceans included crabs, sqilla and deepsea shrimps. They have also estimated the average weight of prey items consumed by individuals per day and per year following the formula used by Olson (1982). The average estimated total consumption per day and per year worked out to 507 gm and 185 kg respectively.

The gut contents of yellowfin tunas from west coast, east coast and Andaman and Nicobar waters based on examination of altogether 286 specimens were analysed during 1991-92 (John and Sudarsan 1993 and Govindraj **et al**., 2000). Percentage occurrence of major prey items from the four sectors were : (i) **Arabian Sea (Southern) -** The prey items identified in 42 specimens in the order of preference are teleost fish (42.9%), squids (88.8%), crab (14.3%) and cuttle fish (4%). (ii) **Bay of Bengal -** The dominant prey items identified in specimens - 58 are squids (39%), teleost fish (26.8%), crab (22%), shrimps (12.2%) (iii) **Andaman and Nicobar waters –** The important food items in specimens - 368 identified are squids (45.1%), teleost fish (33.5%), crabs (17.8%), Octopus (2.1%), Cuttle fish (1.2%) and Stomatopods (0.3%) and (iv) **Arabian Sea (Northern) -** The gut content studies of 850 specimens from Arabian Sea (Northern), method indicates preponderence of squids (52.8%) and fin-fishes (40.7%). The other components observed were Cuttle fish (3.1%), Crabs (2.4%) and Octopus (1%). The study revealed significant seasonal variability in the prey organisms consumed by the Yellowfin tuna. However, squids formed the predominant food item during April-June and fin fish during July-September. Yug Niro (1991) analysed and compared stomach contents of Yellowfin tuna caught by purse-seine and by longlining in he western part of Indian Ocean. While Zamorov et al., (1991) analysed the diet of Yellowfin tuna from longline in same area. Both observed significant seasonal change in the prey organism ingested by Yellowfin tuna from the longline fishery : during winter season (December to January) a large dominance of cephalopods and crabs (Charibdis edwardsi) was observed: on the opposite, during summer season (April – July) Charibdis edwardsi was rare and great number of Auxis sp. were found in the stomachs, Yug Miro (1991) also observed that stomachs of Yellowfin tuna caught by purse seine around logs are generally empty.

Observations on the food composition of Yellowfin tuna as revealed from the stomach contents shows that squids, teleost fish, crabs, cuttle fish, octopus, shrimps and stomatopods were the major components of food items identified from different sectors of the Indian EEZ. However, squids (*Loligo spp*.) and fin fishes were the two predominant food items from all the sectors. There appears to be a great diversity in the consumption of fin fishes as about 22 families of fin fishes were identified altogether. The diversity in food consumption in different sectors is indicative of the non-selective feeding nature of the species whereas the difference in the percentage composition of food items could be inferred as the availability of particular prey species rather than selection of preferred food items. The occurrence of squids during November-April and crabs during July-October in the epi-habitat is an important factor influencing the abundance of yellowfin tuna in the Indian waters.

SPAWNING SEASON

Many studies are reported from the Indo-Pacific and Indian Ocean on the reproductive biology of Yellowfin tuna. In Indian waters the studies are limited to a few observations. These include the investigation carried out by John and

Sudarsan (1993), John (1995), John **et.al.** (1998) and Govindraj **et al** ,(2000).

John and Sudarsan (1993) estimated the spawning season of yellowfin tuna in the Indian EEZ by pooling the data from EEZ mainly consisting of samples from west coast for the period from September 1989 to June 1992 and there by observing general trend of the Gonad Index,

$$G1 = \frac{Wg}{FL3} \times 105$$

Where, Wg is weight of the gonad in gms., FL is Fork length in cm. The general trend of the Gonad Index suggests that the main spawning season in the Indian EEZ extends from January to April/ May. In the Andaman and Nicobar waters based on the data for the period from September 1989 to February 1994. The study is based on 508 specimens of which 360 were males and 148 were females.

The spawning season of yellowfin tunas occurring in the northern Arabian Sea falls between December to June Govindraj **et al**., (2000). In the Bay of Bengal in the Andaman & Nicobar waters the period of spawning is observed to be from November to April.

The spawning season estimated with respect to the stock occurring in different sectors and by pooling the data for the Indian EEZ in general by different workers is summarized below:

Area/Region	Spawning season	Source
North Arabian Sea	December to June	Govindraj et.al. (2000)
Andaman Sea	November to April	John (1995)
Bay of Bengal (EEZ around the mainland India and Andaman and Nicobar Islands)	November to April	John et.al. (1998)
Pooled data for the Indian EEZ	January to April/May	John and Sudarsan (1993)

The studies undertaken on the spawning potential of Yellow Fin Tuna in north-west sector is observed to be relatively low compared to Andaman and Nicobar Seas (John, 1995). The possible reason for the different level of reproductive activity is attributed to (a) stocks could be heterogonous (b) the low temperature of 25°C observed in areas north of Lat.20°N in winter extending upto March, compared to the temperature of 27°C observed in Andaman and Nicobar sector. Low temperature on the north-west sector during winter to early summer could be the cause of low reproductive potential and delayed spawning period in north-west coast. The group maturity observed in Andaman and Nicobar Seas during spawning season show high percentage of YFT in advanced reproductive activity during January to April.

Majid and Ahmed (1991) analysed substantial samples of gonads collected from USSR longliners operating in Seychelles EEZ. Over this period 1966-90. The analysis and maturity co-efficient values indicates that in the area sampled the spawning season falls in November – February period; it was also pointed out that the 3 months peak spawning period shifts from year to year within this period.

Observations on reproductive indices of YFT in long line catches in Indian Ocean is at variance compared to observations made in other Oceans where high reproductive indices are seldom observed in long line catches.

SIZE AND FIRST MATURITY

Bashmaker **et al**., 1991 studied this mean length at which all the Yellowfin tunas females are found to be matured in western part of Indian Ocean (Seychelles EEZ and northern part of Mauritius EEZ. They found that Yellowfin tuna females were found matured at 120 cm FL, while the minimum size at maturity found was 52 cm FL. Maldeniya and Joseph, 1987 reported first size at maturity (50% maturity at 100 cm FL in Sri Lanka while Hassani and Stequert reported 116 cm FL first size at maturity.

There is need for strengthening Indian Ocean-wide biological research of Yellowfin and other oceanic tunas with emphasis on estimating the growth characteristics, feeding and breeding pattern of the species so as to device necessary management measures for this highly migratory species.

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Table 1. Summary of length frequency studies on Yellowfin tuna in Indian Ocean

Gear	Author	Area	Period	Modal length (cm)
Gillnet	Maldeniya, R.and L.Joseph[9]	Srilanka	1987	60
Pole and line	Hafiz, A. and R.C.Anderson[7]	Maldives	1988	50
	R.C. Anderson[2]	Minicoy	1988	46
	R.C.Anderson[1]	Maldives	1985	89
Troll line	Chisara, P.K.[3]	Tanzania	1988	67-75
	Naomin, N. and B.Gafa[12]	West Sumatra Indonesia	1987	50
Purse seine	Lablachi, G. and J.Nagam de Lestang[8]	Mauritius	1983-87	54
	Dhammasak, P.	Indian Ocean	1995-96	54
	Praulai, C.[13]	Eastern Indian Ocean	1993-98	35
	Anderson, R.C.[2]	Minicoy	1988	46
	Marta, G.S.[10]	Indonesia	1985	48-51
	Cort, J.L.[4]	Western Indian Ocean	1985	45-49
	Dhammasak, P.[5]	Andaman Sea	1988	31
	Suzuki, Z.[14]	Indian Ocean	1978-83	40
Long line	Gorg, Leonard Kim[6]	Indian Ocean	1984-85	126
	Praulai, C.[13]	Eastern Indian Ocean	1993-98	130
	Miyabe, N. and T. Kardo[11]	Indian Ocean	1955-70	140
	Suzuki, Z.[14]	Indian Ocean	1978-83	Above 90

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