A SYNOPTIC REVIEW OF THE BIOLOGICAL STUDIES ON YELLOWFIN TUNA *(THUNNUS ALBACARES)* IN THE INDIAN SEAS

John, M. E.[1]

ABSTRACT

Though research on yellowfin tuna in Indian waters was initiated rather recently, some studies have been reported on the biology of the species from the coastal surface fishery as well as oceanic sub-surface fishery. A synoptic review of the different parameters reported including length-weight relationship, size frequencies, morphometric characters, growth parameters, natural mortality, reproductive biology and food and feeding habits is presented in this paper.

Introduction

Yellowfin tuna (*Thunnus albacares*) forms about 5-8 % of landings in the coastal tuna fishery in India where the species occurs in drift gillnetting and hook and line fishing along the mainland and pole and line and troll line fishing in Lakshadweep islands. In the oceanic longline fishery, yellowfin tuna is the predominant species. Preliminary estimates indicate vast potential for development of oceanic tuna fisheries in India, with yellowfin tuna as the target resource. Nevertheless, biological studies on the species has been very limited as a targeted fishery does not exist in the coastal sector and the production in the oceanic sector has been largely by foreign fishing vessels operated under charter, leasing and joint venture schemes, where all the catches are exported leaving no access or opportunity for biological investigations. Despite these limitations, there have been efforts to study the biology of the species by two national institutes. The studies from Central Marine Fisheries Research Institute (CMFRI) are on the young yellowfin tuna occurring in the coastal fishery and those reported from Fishery Survey of India (FSI) are on large deep-swimming yellowfin obtained in longline surveys. Different parameters such as length-weight relationship, size frequencies, morphometric characters, growth parameters, natural mortality, reproductive biology and food and feeding habits have been studied from different regions of the Indian EEZ.

Length-weight relationship

In the coastal fishery, the length-weight relationships are worked out for young yellowfin tuna obtained in pole and line fishing around Minicoy (Madan Mohan and Kunhikoya, 1985; Pillai *et al.,* 1991) and by assorted gears from different sectors (Pillai *et al.,* 1993). In the oceanic fishery, the length-weight relationship of larger fish taken in longline gear from the south-west coast was reported by Silas *et al.* (1985) and John & Reddy (1989). Sudarsan *et al.* (1991) and John & Sudarsan (1993) made further studies on pooled data from different regions of the Indian EEZ. John (1995) studied the length-weight relationship separately for males and females, based on 422 observations in the size range of 58-163 cm fork length obtained from longlines from the Andaman & Nicobar waters. The analysis of co-variance indicated that the difference in relationship for males and females is not statistically significant. Madan Mohan and Kunhikoya (1995) had also observed that the sex specific variations are not significant. A comparison of the length-weight relationships obtained in different studies is given in Table 1.

Size frequencies

Length frequency of yellowfin tuna from the coastal fishery has been reported from Minicoy (Madan Mohan *et al.,* 1985), Tuticorin (Pon Siraimeetan, 1985), Cochin (James and Jayaprakash, 1991) and other centres (Pillai *et al,* 1993). Data from oceanic waters obtained in tuna longline gear has been reported from the southwest coast (John and Reddy, 1989), northwest coast and Bay of Bengal (Sudarsan *et al*., 1991) and from different regions of EEZ (John and Sudarsan, 1993; Sudarsan and John, 1994). Recently a compilation of data from southwest coast, northwest coast and Andaman & Nicobar waters for the period 1983-1994 has been made (John, 1995). An inventory of the length frequency data of yellowfin tuna in Indian waters is given in Table 2.

While the fork length of the specimens from the coastal surface fishery was in the range of 26-128 cm, the fish obtained from oceanic longlining was in the length range of 48-181 cm. In the data from longlining, preponderance of younger fish below 120 cm fork length has been observed from the east coast (Sudarsan *et al.,* 1991; John and Sudarsan, 1993). John (1995) reported the mean length of the specimens from Andaman & Nicobar, southwest and northwest coasts as 121.81 cm, 125.14 cm and 130.19 cm respectively. The author has also observed the mean weight as 34.4kg, 37.0kg and 42.0kg from the three regions respectively and the overall mean weight from Indian waters as 36.7kg. Comparison of the time series information with the data from Indian Ocean reported from the Japanese longline fishery (IPTP, 1992) indicats that the stability of mean weight over the years observed in the Indian Ocean as well as Indian waters is indicative of the healthy state of the stock in the region.

Morphometric studies

Morphometric studies are of particular interest in studying the stock characteristics of tunas as variability of the relationship can provide insight to the population structure. Such studies have been demonstrated to be useful in identifying distinct regional groups of yellowfin tuna in the Pacific (Schaefer, 1989). In India, Silas *et al.* (1985) made some observations on the morphometry of yellowfin tuna taken in longline gear from the southwest coast. John and Sudarsan (1993) established the relationship of fork length with total length, head length and snout - 1st dorsal fin by

[1] Fishery Survey of India, Botawala Chambers, Sir P.M.Road, Fort, Mumbai-400 001

computing the linear least square regression for each dimension on the fork length. More recently, John (1995) reported detailed studies on morphometric relationship of the species based on specimens obtained in longline gear from Andaman & Nicobar waters. The linear association between the fork length and 21 other characters were studied and a correlation matrix was generated.

A comparison of the results with some of the morphometric relationships reported in the adjacent waters of Indonesia (Jacobus & Uktolseja, 1991) and western Indian Ocean (Montaudouin *et al.,* 1991) did not indicate any significant geographical variation in the morphometry of yellowfin tuna in Indian waters compared to the other regions of Indian Ocean.

Growth parameters

Four studies are reported on the age and growth of yellowfin tuna in Indian waters, all by length frequency modal progressions. Madan Mohan and Kunhikoya (1985) estimated the growth parameters with the data from pole and line fishing in Minicoy whereas Pillai *et al*. (1993) used the data from the small scale fishery at Cochin, Minicoy, Vizhinjam, Tuticorin and Veraval. From the oceanic fishery John & Reddy (1989) made estimates of growth parameters based on the data obtained in longline survey off the west coast of India. Recently, John (1995) estimated the growth parameters of the species based on samples obtained in longline catch from Andaman & Nicobar waters and applying different methods, viz., Gulland and Holt method, Ford-Walford method, Chapman's method, Wetherall method and von Bertalanffy method and reported the $L\infty$, K and t as 171.5 cm, 0.316 per year and **(-)**0.305 year respectively. A comparison of the different estimates of growth parameters reported is given in Table 3.

Among these studies, the $L\infty$ of 145 cm from Minicoy (Madan Mohan and Kunhikoya, 1985) and 144 cm mainly from Minicoy and Cochin (Pillai *et al.,* 1993) are apparently underestimates, perhaps because the samples covered only young individuals of the population occurring in the surface fishery in coastal waters. The estimate of 171.5 cm obtained by John (1995) from Andaman & Nicobar waters is closely comparable with the $L\infty$ of 175 cm (John & Reddy, 1988) reported from west coast of India. On fitting the estimated parameter values from Andaman & Nicobar waters the length at age was calculated as 57.9, 88.7, 111.2, 127.5, 139.4, 148.1, 154.4, 159.1 and 162.4 cm for age 1 to 9 years respectively. The corresponding annual growth increments range from 30.8 cm between age 1-2 to 3.3 cm between age 8-9.

Natural mortality

Silas *et al*. (1985) estimated the natural mortality coefficient (M) as 0.49 on applying the curvature parameter, K, obtained from pole and line fishery in Lakshadweep and assuming M/K = 1.5. Studies by John and Reddy (1989) on yellowfin tuna occurring in longline catch in the west coast, by Pillai *et al.* (1991; 1993) from coastal fishery from west coast including Lakshadweep and by John (1995) on yellowfin tuna occurring in longline gear in the Andaman and Nicobar waters were made following Pauly's empirical formula and the estimates obtained are in the range of 0.52 to 0.74. A comparison of the M estimates by different authors is given in Table 4.

Sex Ratio and spawning

The studies on sex ratio and spawning were based on data from oceanic longline fishing. The female:male ratio obtained in the different studies ranged from 1:2.25 to 1:2.73 (Table 5). The studies have shown that males were predominant at all sizes over 120/130 cm length.

The spawning season of the species has been assessed from different regions (Table 6). While studies based on the pooled data from EEZ, mainly consisting of samples from west coast (John and Sudarsan, 1993; Sudarsan and John, 1994) indicated main spawning season as January to April/May, the observations from Andaman and Nicobar (John *et al.,* 1998) indicated the spawning season as November to April with peak spawning from December/January to April.

Food and feeding habits

Gut content studies have been reported from different regions of India EEZ (Table 7). Except for a study from southwest coast where the sampling duration and sample size were relatively small, all studies indicated that squids are the most prevalent prey species accounting for 37-61.2 % of food items followed by teleost fishes and crabs **(***Charybdis* sp.). Cuttlefish, shrimps, octopus and stomatopods were the other components reported. More detailed studies have been undertaken in Andaman and Nicobar waters (John, 1995) where aspects such as index of preponderance, seasonal variability, gastro-somatic index etc. have been investigated. In view of the high preponderance of the squid *Loligo* spp. and the crab *Charybdis smithi,* it is inferred that the occurrence in abundance of these two species in the epipelagic habitat is an important factor influencing the occurrence in relatively higher abundance of yellowfin tuna in Indian waters.

References

IPTP, 1992. Report of the Workshop on Stock Assessment of yellowfin tuna in the Indian Ocean. Colombo, 7-12 October 1991: 90 pp.

Jacobus, C.B. and J. Uktolseja, 1991. Morphometric and body weight comparisons among yellowfin tuna (*Thunnus albacares*) from the waters adjacent to Simeuleu and Enggano Islands, Celebus and Molucca Seas. IPTP.Coll.VoI.Work.Doc., 4: TWS/90/48: 47-65.

James, P.S.B.R. and A.A. Jayaprakash, 1991. On the occurrence of yellowfin (*T. albacares*) in the drift gillnet catch at Cochin. IPTP Coll. VoI.Work.Doc., 6:170-177**.**

John, M.E. and K.S.N. Reddy, 1989. Some considerations on the population dynamics of yellowfin tuna, *Thunnus albacares* (Bonnaterre) in Indian seas. Studies on fish stock assessment in Indian waters. FSI Special publication 2: 33-54.

John, M.E. and D. Sudarsan, 1993. Fishery and Biology of yellowfin tuna occurring in oceanic fishery in Indian seas. In: Sudarsan, D. and M.E. John (Eds), Tuna Research in India: 39-61.

John, M.E., 1995. Studies on yellowfin tuna, *Thunnus albacares* (Bonnaterre, 1788) in the Indian seas, Ph.D. thesis submitted to Bombay University: 258 pp.

John, M.E., M. Neelakandan, V. S ivaji, Premchand, P.S. Parasuraman, M.K. Sajeevan and P.Sivaraj, 1998. Some aspects on the reproductive biology of yellowfin tuna (*Thunnus albacares*) in the Bay of Bengal. In: Somvanshi, V.S. and M.E. John (Eds). Contributions to fishery biology, Bull. Fish. Surv. India, 26: 42-50.

Madan Mohan and K.K. Kunhikoya, 1985. Age and growth of *Katsuwonus pelamis* (Linnaeus) and *Thunnus albacares* (Bonnaterre) from Minicoy waters. Bull.Cent.Mar.Fish.Res.Inst., 36: 143-148.

Madan Mohan and K.K. Kunhikoya, 1985. Length-weight relationship of Skipjack, *Katsuwonus pelamis* (Linnaeus) and yellowfin tuna, *Thunnus albacares* (Bonnaterre) from Minicoy waters. Ibid., 36: 122-137.

Montaudoin, K.D., J.P. Hallier and S. Hassani, 1991. Length-weight relationships for yellowfin (*Thunnus albacares*) and Skipjack (*Katsuwonus pelamis*) from western Indian Ocean. IPTP Coll.Vol.Work.Doc., 4: TWS/90/48: 47-65.

Pillai, P.P., K.P. Said Koya and T.M. Yohannan, 1991. Fishery, biology and status of stock of Yellowfin tuna. IPTP Workshop on Stock Assessment of yellowfin tuna in the Indian Ocean. Colombo, 7-12 October 1991.

PiIlai, P.P., K.P. Said Koya, N.G.K. PiIlai and A.A. Jayaprakash, 1993. Fishery and biology of yellowfin tuna occurring in coastal fishery in Indian Seas. In: Sudarsan, D. and M.E. John (Eds.) Tuna research in India: 23-38.

Pon Siraimeetan, 1985. On the occurrence, size distribution, morphometry and feeding habits of the juveniles of *Euthynnus affinis* (Cantor), *Auxis thazard* (Lecepede) and *Sarda orientalis* (Temminck and Schlegel) along the Tuticorin coast in the Gulf of Mannar, South-East coast of India. BuIl.Cent.Mar.Fish.Res.Inst., 36: 104-110.

Schaefer, K.M., 1989. Morphometric analysis of yellowfin tuna, *Thunnus albacares* from the eastern Pacific Ocean. IATTC Bull., 19(5): 389-427.

Silas, E.G., P.P. Pillai, A.A. Jayaprakash and M.A. Pillai, 1985. Observation on the fishery and certain aspects of the biology of yellowfin tuna, *Thunnus albacares* (Bonnaterre) taken by longline gear in the EEZ of India. (Ibid: 176- 183.

Sudarsan, D. and M.E. John, 1994. Further studies on biological aspects of yellowfin tuna in the Indian EEZ. Ibid: TWS/93/2/15: 135-140.

Sudarsan, D., M.E. John and K.N.V. Nair, 1991. Some biological considerations of the yellowfin tuna, *Thunnus albacares* (Bonnaterre) taken by longline gear in the Indian EEZ. Ibid: TWS/91/11: 18-26.

Table 1. Length-weight relationship of yellowfin tuna in Indian waters

Author	Area ground	Gear	Sex	Sample size	Size range (FL, cm)	Length-weight relationship
Madan Mohan& Kunhikoya (1985)	Minicoy	PL	M F M+F	67 67 134	42-68 41-62 41-68	LogW=-10.751095+2.961902 LogL LogW=-11.137845+3.010763 LogL LogW=-11.036032+3.001012 LogL
Silas *et al*. (1985)	S.W.Coast	LL	M+F	210	50-170	W=0.0001036 L2.66410834
John & Reddy (1989)	S.W.Coast	LL	M+F	98	92-153	W=0.000049557 L2.8055
Pillai *et al*. (1991)	Minicoy	PL	M+F	282	36-92	W=0.00003852 L2.6303
James & Jayaprakash (1991)	Cochin	GN	M+F	59	-	LogW= -9.3288514+2.535787 LogL
Sudarsan et.al. (1991)	Mainly West coast	LL	M+F	133	-	W = 0.000040697 L 2.8496
John & Sudarsan (1993)	Indian EEZ	LL	M+F	243	59-155	W = 000039528 L2.8318
Pillai *et al*. (1993)	India- coastal	PL,GN	M+F	628	32-128	W = 0.00003852 L2.7433
John (1995)	A & N	LL	M F M+F	304 118 422	58-163 59-147 58-163	W =0.000034569 L2.8653 W =0.000055847 L2.7565 W =0.000038062 L2.8423

(PL = Pole and line; LL = Longline; GN = Gill net)

Table 2. Inventory of length frequency data of yellowfin tuna in Indian waters

Source	Gear	Fishery (coastal/Oceanic)	Area	Period	Size range (FL, cm)	No. of observations
Madan Mohan Kunhikoya, 1985	Pole and line	coastal	Minicoy	1976-1982	26-92	NA
Pon Siraimeetan, 1985	Gillnet	coastal	Tuticorin	1979-1982	46-88	396
James & Jayaprakash, 1991	Gillnet	coastal	Cochin	1948-1987	48-116	1324
Pillai *et al*. 1993	Gillnet, Pole and line	coastal	different centres*	1989-1991	30-128	682
John & Reddy, 1989	Longline	oceanic	S.W.coast	1983-1986	56-164	968
Sudarsan *et al*. 1991	Longline	oceanic	N.W.coast Bay of Bengal	1989-1991 1989-1990	56-181 72-164	398 407
John & Sudarsan, 1993	Longline	oceanic	Indian EEZ	1991-1992	48-168	468
Sudarsan & John, 1994	Longline	oceanic	East coast West coast A&N waters	1991-1993 1991-1993 1991-1993	65-156 65-176 52-168	76 97 476
John (1995)	Longline	oceanic	S.W.coast N.N.coast A&N waters	1983-1987 1989-1993 1989-1994	56-168 58-181 44-172	3508

- Veraval, Cochin, Minicoy, Vizhinjam and Tuticorin

Tables 3. Estimates of growth parameters of yellowfin tuna in Indian waters

Author	Area	Gear	Growth parameters		
			Loo (cm)	K (/ year)	(t/year)
Mohan & Kunhikoya (1985)	Minicoy (Lakshadweep)	Pole & line	145.0	0.32	-0.34
John & Reddy (1989)	(West coast)	Longline	175.0	0.29	
Pillai *et al*. (1993)	(Mainly Minicoy & S.W. coast)	Pole & line Gillnet	144.06	0.44	-0.448
John (1995)	Andaman & Nicobar waters	Longline	171.5	0.316	-0.305

Table 4. Estimates of natural mortality coefficient of yellowfin tuna in Indian waters

Author	Area	Estimated M
Silas *et al*. (1985)	Lakshadweep	0.49
John & Reddy(1989)	West coast	0.74
Pillai *et al*. (1991)	Lakshadweep	0.52
Pillai *et al*. (1993)	West coast	0.6761
John (1995)	Andaman & Nicobar	0.6

Table 5. Sex ratio of yellowfin tuna in Indian waters

Author	Area	Sample size	Length-range (FL, cm)	Sex ratio (F:M)
Sudarsan *et al*.	West coast		56-181	1:2.73
(1991)				
John & Sudarsan (1993)	EEZ	305	60-178	1:2.28
Sudarsan & John (1994)	EEZ	485	60-180	1:2.25
John (1995)	Andaman & Nicobar	690	62-170	1:2.59
John *et al*. (1998)	Bay of Bengal	1021	40-180	1:2.45

Table 6. Spawning season of yellowfin tuna in Indian waters

Author	Area	Method	Spawning season	Peak spawning season
John & Sudarsan (1993)	EEZ	GI	January- May	
Sudarsan & John (1994)	EEZ	GI	January- April	
John (1995)	Andaman & Nicobar	GI & GMI	November- April.	January- April
John *et al*. (1998)	Bay of Bengal	GI & GMI	November- April	December- April

(GI = Gonad Index; GMI = Group Maturity Index)

Table 7. Food composition of yellowfin tuna in Indian waters

Region	S.W.coast	N.W.coast	W.coast	E.coast	East.coast	A&N	A&N	A&N
Author*	(1)	(2)	(3)	(2)	(3)	(3)	(4)	(5)
Method**	V	O	O	O	O	O	O	G
Food contents (%)								
Squid	2.1	46.9	38.8	37.0	39.0	45.1	61.2	46.1
Cuttlefish		16.0	4.0			1.2	1.4	0.4
Octopus						2.1	1.9	1.1
Crabs	58.5	14.1	14.3	26.0	22.0	17.8	22.2	15.0
Shrimps				14.3	12.2		0.4	0.2
Stomatopods						0.3	1.9	0.5
Teleost fishes	39.4	37.4	42.9	23.0	26.0	33.5	41.0	36.7

* 1 Silas *et al*. (1995); 2 Sudarsan & John (1994); 3 John & Sudarsan (1993); 4 John (1995); 5 John *et al*. (1995)

**V = Volumetric; 0 = Occurrence; G = Gravimetric