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Fishery and bionomics of the little tuna, *Euthynnus affinis* (Cantor, 1849) exploited from Indian waters

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ABSTRACT

Euthynnus affinis, with an average annual landing of 40,757 t during 2006-2010 formed the bulk (65.1%) of the total coastal tuna catch of the country. The fishery, biology, growth and stock structure of *E. affinis* was studied in detail. Hooks and lines, gillnets and purseseines were the major gears exploiting the fish. Fishery was sustained mainly by 1 - 2 year old fishes (34 to 50 cm). Size at first maturity was estimated at 37.7 cm and fecundity was 3,08,150 eggs. Spawning was observed round the year with peaks during July-August and November-January. *E. affinis* was found to be a nonselective generalist feeder foraging on fishes, crustaceans and molluscs. The length–weight is given by the relationship 0.0254 $L^{2.889}$ with no significant difference between males and females. Age and growth were estimated using length based methods. The von Bertalanffy growth parameters estimated were L_{∞} = 81.92 cm, annual K= 0.56 and t_0 = -0.0317. Mortality estimates were M= 0.93 and Z = 1.68 and F= 0.75 with the exploitation rate E=0.45. The maximum sustainable yield estimated was higher than the average annual catch indicating scope for further exploitation.

Keywords: Bionomics, Exploitation, *Euthynnus affinis*, Fishery, Kawakawa, Indian seas

Introduction

Euthynnus affinis popularly known as the 'little tunny' or 'kawakawa' is a medium sized tuna occurring throughout the nearshore continental shelf areas of the Indo-Pacific waters where water temperatures vary between 18 and 29 °C (Poisson, 2006). In the Indian Ocean, this species extends from Cape St. Francis, South Africa (Smith and Heemstra, 1986), along the coasts of East Africa, Arabian Peninsula, the Indian sub-continent, and Malaysian Peninsula. It is also found in the Red Sea, Persian Gulf, and off islands in the Indian Ocean, including Madagascar, Comoros Islands, Mauritius, Reunion, Seychelles, Lakshadweep, Andaman and Nicobar Islands, Sri Lanka and Maldives (Williams, 1963). Along the Indian coast, *E. affinis* is exploited in all the coastal states and the island systems and forms the bulk of the tuna landings of the country (Silas and Pillai, 1982; Pillai and Pillai, 2000; Khan, 2004). Being a coastal species, it has been extensively exploited and quite a few studies have been carried out on the fishery, biology and growth in different parts of the world including India. Yesaki (1989) reviewed the biology and fisheries of kawakawa in the Indian Ocean region. Earlier studies carried out on the distribution and abundance of *E. affinis* especially juveniles include those by Yabe *et al*. (1953) in Japan; Jones (1960) and Siraimeetan (1985) in India; Sivasubramaniam (1970) from Sri Lanka; Chamchang and Chayakul (1988) and Abuso (1988) from western Gulf of Thailand and Phillipines respectively and Griffiths (2009) from Eastern Australia. While Yoshida (1979), Williamson (1970), Chiampreecha (1978), Klinmuang (1978), Yesaki (1982), Silas and Pillai (1982), Silas *et al*. (1985), Joseph *et al*. (1987), Supongpan and Saikliang (1987), Yesaki (1989) and Taghvai *et al*. (2010) studied the age and growth of *E. affinis* using the length frequency distribution methods, Landau (1965), Shabotinets (1968), Uchiyama (1980) and Al-Zibdah and Odat (2007) reported on the same aspect using hard parts. In India studies on the species are limited (Silas *et al*., 1985; James *et al*., 1993; Pillai *et al*., 2002; Pillai and Ganga, 2002; Khan, 2004; Abdussamad *et al*., 2005) and confined to small geographical distributional areas. Genetic studies carried out on the species (Kumar *et al*., 2012) has indicated low genetic variation, suggesting *E. affnis* exploited along the Indian coast belong to a single stock. The present investigation was undertaken to study the fishery, biology, growth and exploitation of kawakawa on a national level including the island systems.

Materials and methods

Weekly data on catch and effort of kawakawa landed in all major fish landing centres in different states of the country was collected and raised to monthly and annual figures using the Stratified Random Sampling Technique developed by the Central Marine Fisheries Research Institute, Kochi. The state figures were then added to get the total landings of the country. Length measurements (fork length) were also taken at the landing centres and were raised to the monthly/annual catches. These formed the basic data for estimating the growth and population structure of *E. affinis* using length based models. Random samples were collected from the commercial landings and transported to the laboratory for further biological studies.

The fork length (cm) and wet weight (g) were taken and used to calculate the length-weight relationship using the method suggested by Le Cren (1951). The fish was then cut open, and their sex and gonad maturity stages identified. Structure and size of gonads were observed and classified as per the ICES scale adopted by Woods (1930). Size at first maturity was determined as suggested by Lockwood (1988) and King (1996). For the purpose of fecundity studies, fishes in stages IV and V alone were considered. Mature ova were counted and the total fecundity was estimated using the formula: (Total wt. of ovary/ Wt. of sample)* No. of ova in the sample.

Stomachs were carefully removed and food contents studied in detail to understand the food and feeding habit of *E. affinis*. Stomach fullness was visually classified into five categories as full, three-fourth full, half full, one-fourth full and empty based on the distension of the stomach due to the presence or absence of food. The average intensity of feeding was evaluated by point's method (Hynes, 1950; Bapal and Bal, 1958). The different items constituting one category were sorted and counted. For each item, identifiable organs were used to determine the number of prey present in the stomach. Prey was identified up to genus level and further to species level whenever possible using keys and descriptions found in Fischer and Whitehead (1974), Smith and Heemstra (1986) and by comparison with material available in our reference collection at the Institute.

Growth parameters *viz.*, asymptotic length (L_∞) and growth co-efficient (K) were estimated using the ELEFAN I module of FiSAT software and the Powell-Wetherall plot (Gayanilo *et al.*, 1996). The length based growth performance index Ø was calculated from L_∞ and K as in Pauly and Munro (1984). The probability of capture and size at first capture (Lc) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's (1979) empirical equation. Longevity was estimated from $t_{max} = 3/K + t_0$ (Pauly, 1983a).

Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980) and total mortality (Z) from length converted catch curve (Pauly, 1983b). Length structured virtual population analysis (VPA) was used to obtain fishing mortalities per length class. Exploitation rate was estimated from the equation, E = F/Z and exploitation ratio from $U = F/Z*(1-e^{-z})$; where, F is the fishing mortality rate.

Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F respectively; where Y is the annual average yield in tonnes. Maximum sustainable yield was calculated as in Gulland (1979) for exploited fish stocks. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F were estimated using Beverton and Holt (1957) model [FiSAT Software (Gayanilo *et al.*, 1996)]

Results

Fishery

E. affinis was exploited mainly by crafts using a combination of gillnets and hooks & lines (42%). Gillnets and hooks & line operated separately also contributed significantly to the catch. Ringseines, purseseines and trawls landed this species occasionally. The catch by other gears like the shoreseines and smaller monofilament trammel nets was insignificant (Fig.1). The annual catches of *E. affinis* during 2006-2010 (Fig. 2) ranged between

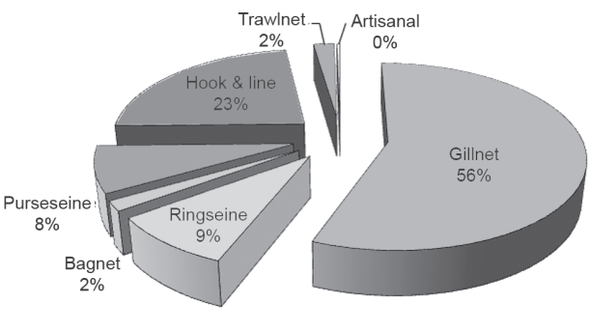

Fig.1. Contribution (%) of different gears to total *E. affinis* catch in India

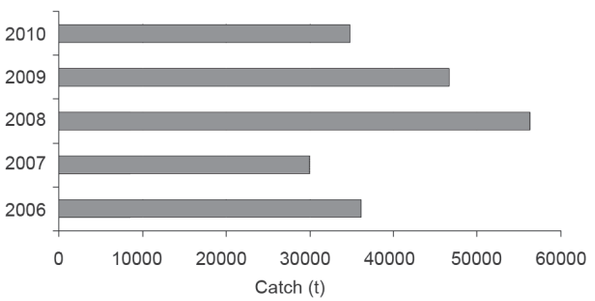

Fig. 2. Annual landings of *E. affinis* in India during 2006-2010

29,939 t (2007) and 56,322 (2008), with an average catch of 40,757 t forming 63.6% of the coastal tuna catches and 20.7% of the total tuna catch of the country. Thereafter the catch registered a decline and remained around 10,500 t. The decline was observed in all the gears exploiting kawakawa.

E. affinis formed the dominant tuna species in all states with a contribution of more than 72% in Odisha and West Bengal to a low of 7% in Goa. Andhra Pradesh with an annual average catch of 12,261 t recorded the maximum landings, followed by Kerala (10,416 t) and Tamil Nadu (6,229 t) (Fig. 3). Catch trends over the years remained more or less the same during the study period with high catches during 2008.

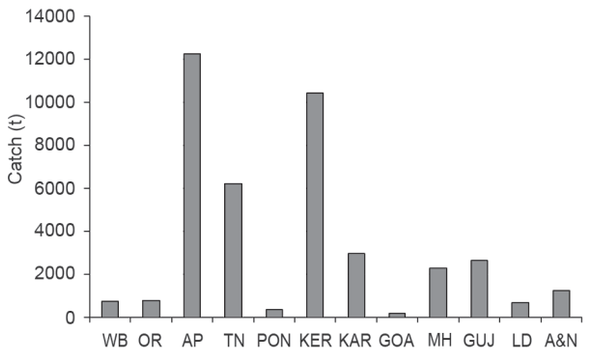

Fig. 3. Contribution of different states/islands to total *E. affinis* landings in India

WB : West Bengal; OR : Odisha; AP : Andhra Pradesh; TN : Tamil Nadu; PON : Pondicherry; KER: Kerala; KAR : Karnataka; GOA : Goa; MH : Maharashtra; GUJ : Gujarat; LD : Lakshadweep; A&N : Andaman and Nicobar.

Seasonal abundance

Landing of kawakawa was observed throughout the year with peak during September-October (Fig. 4) when 40.7% of the catch was landed. A second smaller peak was observed during December. The annual average monthly catch of kawakawa was highest in September (7,758 t) followed by October (3,858 t) and December (2,442 t). While December was the most productive month along the north-east coast, September recorded highest catch along the south-east region. Along the west coast, October and November were the productive months in the north-west and south-west regions respectively.

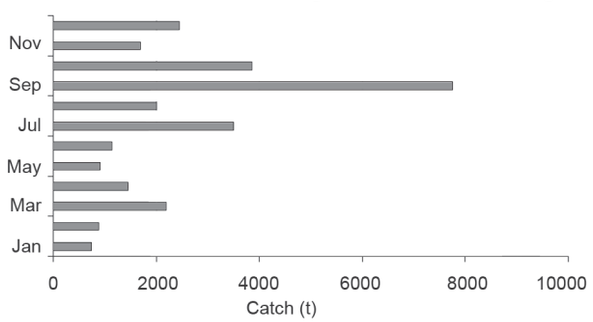

Fig. 4. Seasonal trends in landing of *E.affinis*

Length composition

The length range varied from a minimum of 14 cm to a maximum of 80 cm. States along the east coast recorded a wide range of length distribution (Fig. 5). Fishes in the length range of 34-54 cm dominated the catch and contributed 70% of the catch. Major modes were at 50 and 40 cm and the annual mean length of *E. affinis* landed for all states combined was 45.9 cm.

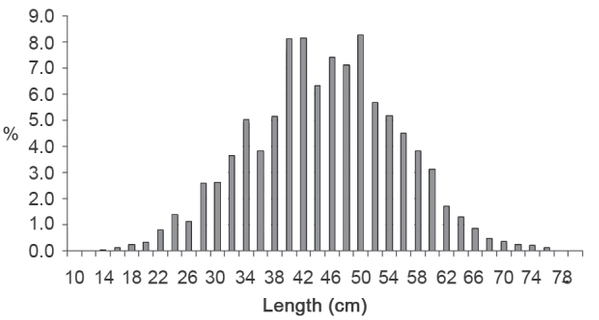

Fig. 5. Length frequency distribution of *E. affinis* in the fishery

Maturity, fecundity, spawning and recruitment

Minimum size at maturity was fixed at the length when 50% of the fishes were found to be mature. The size at first maturity for *E. affinis* was estimated at 37.7 cm (Fig. 6). Spawning was observed round the year with peaks during June and October. Two peaks in recruitment were also observed. The major recruitment period was during October - December and the second minor peak was observed during February-April (Fig. 7). The first pulse contributed 59.25% and the second 22.85% of recruits. The fecundity was estimated at 3,08,150 eggs per kg body weight.

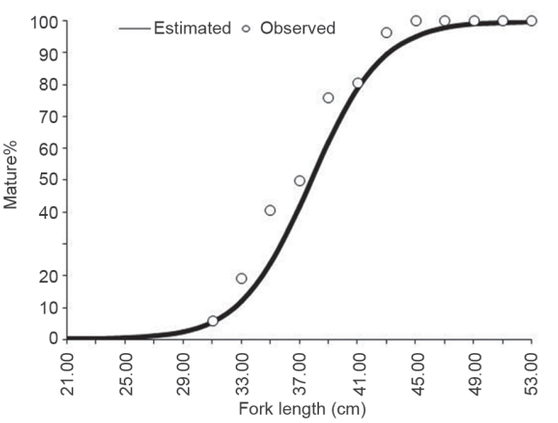

Fig. 6. Observed and estimated size at first maturity for *E. affinis*

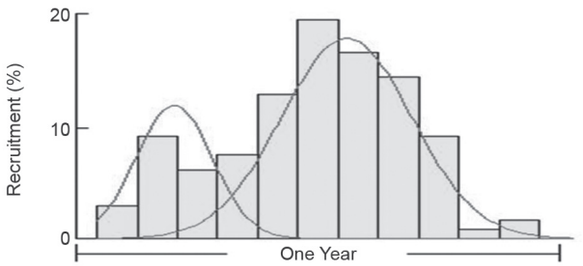

Fig. 7. Recruitment pattern in *E. affinis*

Food and feeding

Feeding intensity was generally low for the species with none of the sampled fish having gorged or full stomach condition. Stomach with one-fourth fullness formed the dominant group and contributed 50.7%. Fishes with empty stomach formed the next dominant group followed by fishes with half-full stomachs forming 10.7% (Fig. 8).

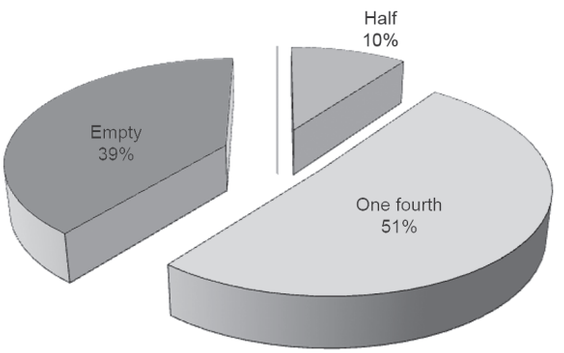

Fig. 8. Feeding intensity (stomach condition) of *E. affinis* during 2006-2010

Feeding habit indicated *E. affinis* to be a non-selective generalist feeder foraging mainly on finfishes, crustaceans and molluscs (Fig. 9). Fishes formed the dominant prey item and contributed 76.7% of the diet consumed. *Sardinella longiceps* (27.4%), *Encrasicholina devisi* (24.7%), *Decapterus* spp. (13.7%) and *Nemipterus* spp. (3.22%) were the major food items constituting the fish diet. Partially digested fish parts formed 4.99% of the diet. Crustacean component maily comprised partially digested limbs which formed 13.7% of the total diet. Molluscs were represented entirely by squids (*Loligo* spp.) and formed 9.6% of the diet.

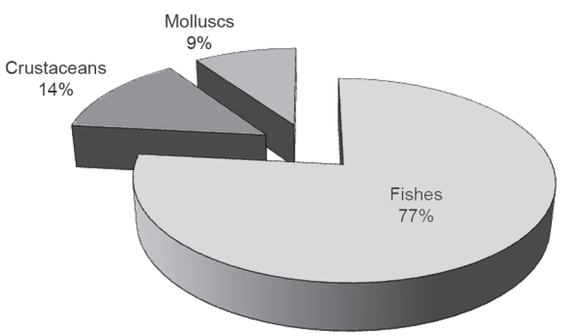

Fig. 9. Major food groups constituting the diet of *E. affinis*

Growth

The length-weight relationship for *E. affinis* estimated using the method suggested by Le Cren (1951) was $W = 0.0254\ L^{2.889}$ where 'W' is the weight of fish in g 'L' is fork length in cm. The different growth parameters in the von Bertalanffy growth equation $Lt = L_{\infty}\ [1 - e^{k\ (t - t_0)}]$ was $Lt = 81.92\ [1\text{-}e^{-0.56(t-0.0317)}]$.

The asymptotic weight was 8563 g and size at first capture (L_c) was 41.43 cm at an age (t_c) of 2.1 year. The growth performance index was 3.34. The longevity of *E. affinis* was 9.03 years and the length attained by the fish at the end of 1st and 2nd year were 42.7 and 59.5 cm respectively. Fishery was sustained mainly by the 1 to 2+ yr old fishes (34 to 50 cm).

Mortality, exploitation and virtual population analysis (VPA)

The natural mortality rate (M), fishing mortality rate (F) and total mortality rate (Z) computed were 0.93, 0.75 and 1.68, respectively (Fig.10). The exploitation ratio was 0.45 and exploitation rate was 0.36. E_{max} estimated was 0.811 which is much higher than the present exploitation, indicating further scope for exploitation of this species.

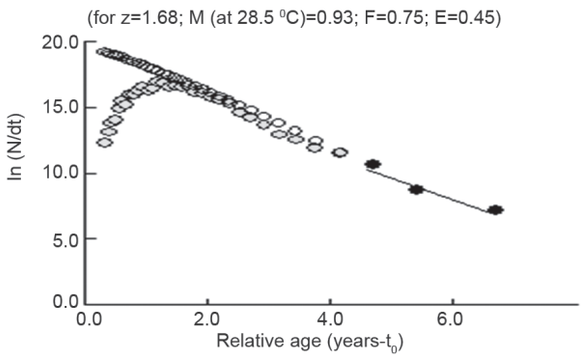

Fig. 10. Mortalities and exploitation rate of *E. affinis* estimated using length converted catch curve

Virtual population analysis (VPA) indicated that main loss in the stock up to 32 cm size was due to natural causes (Fig. 11). Fishes became more vulnerable to the gear after this size and mortality due to fishing increased. However, loss due to fishing still remained very low (Fig. 11).

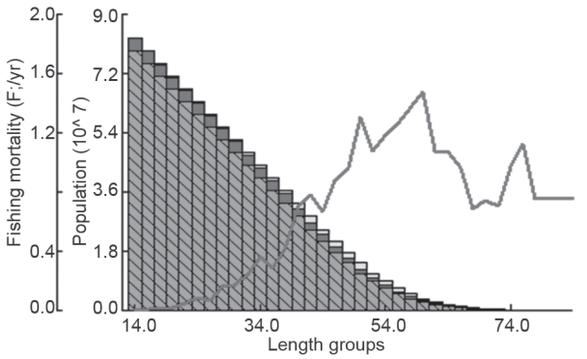

Fig. 11. Virtual population analysis of *E. affinis*

Stock and maximum sustainable yield (MSY)

The annual total standing stock, biomass and MSY of *E. affinis* were estimated at 1,12,208 , 54,342 and 45,647 t, respectively. The average annual yield was 40,757 t.

Yield/recruit

The yield and biomass/recruit and yield and biomass curves showed that the maximum yield and yield/recruit could be obtained by increasing the present level of fishing from 1 to 2.2 (Fig. 12). The maximum yield and yield per recruit obtained by increasing the present fishing effort by 2.2 times is 47,966 t and 509.31 g, whereas at the present level of fishing, it is 40,757 t and 432.76 g (Fig. 8 and 9). The increase in relative yield at the increased effort would be 117.7%.

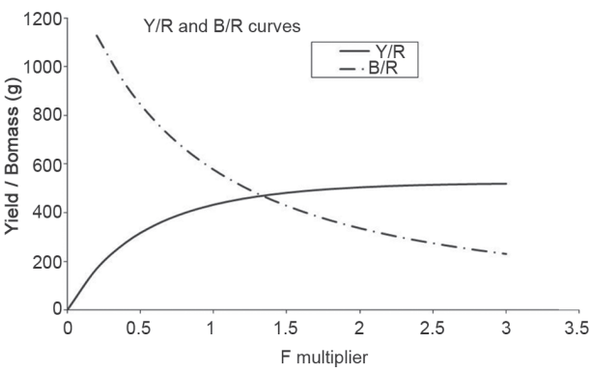

Fig. 12. Yield per recruit and biomass per recruit curves for *E. affinis*

Discussion

Tuna exploitation in India has mainly been supported by the smaller coastal species. Of these, *E. affinis* has been the dominant species distributed along both the coasts of India as reported earlier by Silas and Pillai (1981), Muthiah *et al.* (1985); Pillai and Pillai (2000) and Khan (2004). Mode of exploitation of these smaller tunas too have remained almost the same over the years with gillnets and the hooks and the line being the main gears operated for exploitation of the species. Availability of *E. affinis* throughout the year along the east and west coasts has been reported by Kasim and Abdussamad (2003) and Pillai *et al.* (2003) respectively. Al-Zibdah and Odat (2007) too have observed different age classes in the catch, irrespective of season in the Gulf of Aqaba, Red Sea. Balasubramanian and Abdussamad (2007) reported on the availability throughout the year and occurrence of juveniles along Tuticorin coast during June to August which incidentally is the peak fishing season for the species.

Silas *et al*. (1985) have reported that *E. affinis* along the Indian coast is supported by fishery having a length range of 12-76 cm and later on Pillai *et al*. (2002) stated that the fishery is supported by fishes having a length range of 10-78 cm. Kasim and Abdussamad (2003) observed that the fishery of *E. affinis* along east coast is supported by 18-83 cm length class fishes with 54-56 cm as modal class. The fishery along Maharashtra coast was supported by fishes with a length range of 26-73 cm (Khan, 2004). The size range reported earlier is smaller than that observed in the present study where the fishery was supported by fishes of the size range 14-80 cm. However, the modal length supporting the fishery across India (34-54 cm) during the study period was much smaller than the modal lengths (50-60 cm) reported by Pillai *et al*. (2002) and by Kasim and Abdussamad (2003). The modal length was between 34-58 cm (Pillai *et al*., 2002) and 40-60 cm (Pillai *et al*., 2003) along the west coast.

Muthiah (1985) estimated the length at first maturiy for males and females of *E. affinis* from Mangalore region as 44 and 43 cm respectively. Pillai and Gopakumar (2003) estimated the size at first maturity (pooled for males and females) as 43-44 cm. Earlier Rao (1964) has recorded females of 48 cm with ripe ova along Vizhinjam. Williamson (1970) reported the minimum size at first maturity as 50 cm for *E. affinis* along China. In the Indian Ocean also the fish attained maturity between a total length of 50-65 cm (Ommaney, 1953; Williams, 1956 and 1963). In the present study, the size at first maturity estimated for males and females combined was 37.7 cm. The estimated value in the present study is much smaller compared to the earlier studies but is comparable to that (38.5 cm) reported from Philippine waters by Wade (1950) and Ronquillo (1963).

Spawning in *E. affinis* was prolonged with peaks during June and October. James *et al*. (1993) and Pillai and Gopakumar (2003) too have made similar observations and have noted that the peak spawning for the species may be during October-November and March-June. Muthiah (1985) too observed a similar trend for *E. affinis* from Mangalore coast. Recruitment is a continuous process with

two peaks. A bimodal recruitment pattern as observed in the present study has also been reported by Kasim and Abdussamad (2003) along the east coast of India. Pillai and Gopakumar (2003) have reported March and June as the major recruitment period for *E. affinis* in the Indian seas.

Pon Siraimeetan (1985a, b) has studied in detail the food contents of *E. affinis* from Tuticorin coast and has reported that adults fed mainly on fishes while juveniles fed on both fishes and crustaceans (mainly larval stages). Pillai and Gopakumar (2003) reported that tunas in general are carnivores and the major food items include crustaceans, cephalopods and fishes. The present study also has revealed fish to be the major diet of *E. affinis* with crustaceans and molluscs forming a less dominant part of the diet. Similar observations in the diet preference of *E. affinis* from the Gulf of Aqaba, Red Sea and Eastern Australian waters have been reported (Al-Zibdah and Odat, 2007; Griffiths *et al*., 2009). Engraulids were the preferred diet in the present study as well as in the earlier reports. Griffiths (2009) reported that the diet of *E. affinis* primarily consisted of pelagic clupeids and demersal fish and the smaller fishes fed mainly on small pelagic crustaceans and teleosts.

The length-weight relationship of *E. affinis* caught from different regions along the Indian coast has been estimated by several earlier workers and the values of 'a' and 'b' obtained are comparable (Table 1). The fish exhibited isometric growth with the 'b' value close to 3. Earlier studies on the growth of *E. affinis* from different regions have indicated that growth as in most tuna species is fast with the fish having a longevity of 2 to 8 years. Growth parameters in the von Bertalanffy equation as estimated by earlier studies and the present study are given in Table 2. *E. affinis* is a fast growing fish attaining a maximum length of around 80 cm. The L_{∞} estimated by earlier workers is comparable to the estimate obtained in the present study. The values ranged from 81 cm to 89 cm. The 'k' value however, showed a wide range (Table 2) between 0.35 to 0.9 indicating variations in the length attained in different years. All studies however indicate *E. affinis* to be fast growing species, attaining a length of 31-44 cm in the first year. In the present study, *E. affinis* with size range of 20 cm was observed in the fishery from June to December. These recruits are from the first spawning peak during June to October of about 2-3 months. A total length of around 40-45 cm at the end of one year is quite expected. Growth parameters obtained in the present study indicated a similar trend in growth with longevity of 5.4 years. The mortality and exploitation rates of *E. affinis* from different regions are presented in Table 3. The exploitation rate along the east coast as reported by Kasim and Abdussamad (2003) is high and around optimum in Maharashtra and low in Veraval in the west coast. Pillai *et al.* (2003) too have stated that the fishery of *E. affinis* is confined to the inshore areas and is exploited to the maximum which could be a reason the catches have stabilised. However, values calculated for Indian seas in the present study showed that the present exploitation rate is well within limits with a healthy stock condition. A similar

Table 1. Estimated 'a' and 'b' of *E. affinis* in the length-weightt relationship

Region	'a' value	'b' value	Reference
Indian Ocean	0.0166	2.963	Morrow, 1954
Hawaii waters	0.0108	3.1544	Tester and Nakamura, 1957
Philippine waters	0.0334	2.83768	Ronquillo, 1963
Philippine waters	0.0211	2.94854	Ronquillo, 1963
Indian Ocean	0.0137	3.0249	Sivasubarmaniam, 1966
Indian Ocean	0.0138	3.0287	Silas, 1967
South China Sea	0.08853	2.5649	Williamson, 1970
Cochin, India	0.0000213	2.95244	Silas *et al*., 1985
Mangalore, India	0.0000314956	2.88626	Muthiah, 1985
Calicut, India	0.000012587	3.0871	Balan and Yohannan, 1985
Tuticorin, India	-12.1073	3.2944	Pon Siraimeetan, 1985a
Malwan, North-west India	0.001	2.50631	Silas *et al*., 1985c
Indian waters	0.0190906	2.95	James *et al*., 2003
Maharashtra, India	-1.432128	2.786	Khan, 2004
Red Sea	-2.11	3.1399	Al-Zibdah and Odat, 2007
Veraval, India	-1.9313	3.055823	Ghosh *et al*., 2010
Indian waters	0.0254	2.889	Present study

Table 2. Estimates of growth parameters of *E. affinis* from Indian waters and adjacent seas

Region	L_∞	k	t_0	Length attained				Reference
				1st yr	2nd yr	3rd yr	4th yr	
Indian waters	81.0	0.365	-0.3438	31.43	46.6	57.14	64.44	Silas *et al*., 1985
Indian waters	83.5	0.42	-0.044	29.6	48.1	60.2	68.2	James *et al*., 1993
Indian waters	-	-	-	31.4	46.6	57.1	64.4	Pillai and Gopakumar, 2003
East coast	87.5	1.5	-0.003	68.1	83.2	-	-	Kasim andAbdussamad, 2003
Maharashtra, India	81.7	0.79	-0.0227	44.6	64.9	77.4	-	Khan, 2004
Persian Sea of Oman	87.66	0.51	-0.23	40.3	58.9	70.2	77.1	Taghvai, 2010
Veraval India	72.5	0.56	0.0327	31.84	49.27	29.23	64.92	Ghosh *et al*., 2010
All India	81.92	0.56	-0.0317	42.7	59.5	69.1		Present study

Table 3. Estmates of mortality, exploitation rates and exploitation ratios of *E. affinis* from Indian waters

Z	F	M	E	U	Region	Reference
2.57		0.76		0.45		James *et al*., 1993
5.85	4.90	0.98	0.8			Pillai *et al*., 2002
9.79	8.03		0.82	0.82	East coast	Kasim and Abdussamad, 2005
2.24		1.16		0.6	Maharastra	Khan, 2004
10.63	8.7		0.821	0.83	Tuticorin	Kasim and Abdussamad, 2005
7.6	5.84		0.774	0.77	Chennai	Kasim and Abdussamad, 2005
2.37	1.72	0.65	0.65	0.72	Persian Sea of Oman	Taghvai, 2010
1.69	0.75	0.94	0.36	0.44	Veraval	Ghosh *et al*., 2010
1.68	0.75	0.93	0.36	0.45	All India	Present study

observation was made by James *et al*. (1993).The exploitation rate is low and preset yield is less than the estimated MSY. Further, the yield per recruit analysis indicated substantial increase in yield with increase in effort. Therefore an increase in effort may be considered to increase the present yield of *E. affinis* at least to the limit of estimated MSY. However in a multi-fishery scenario, the increase in effort as a management strategy for increasing production of *E. affinis* needs to be considered cautiously.

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