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Fishery and population dynamics of *Trichiurus lepturus* (Linnaeus) off Veraval, north-west coast of India

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ABSTRACT

The fishery and population dynamics of *Trichiurus lepturus* (Linnaeus) from Veraval was studied for the period 2003-2006. The average annual catch was 18,813 t, forming 27.63% of the total trawl catches at Veraval. September to December was the most productive period in terms of catch and catch rate. The length-weight relationship showed that growth was allometric and there was no significant variation between the sexes. The growth parameters L_∞ and K were 134.1 cm and 0.29 respectively and the length attained at the end of 1, 2, 3, 4 and 5 years were 35.28, 60.16, 78.77, 92.70 and 103.12 cm respectively. The growth performance index (ϕ) was 3.717 and longevity was 10.29 years. Recruitment pattern was trimodal with two major peaks during May - June and August - October and one minor peak during January - March and the length at first capture was 14.11 cm. The natural mortality, fishing mortality and total mortality were 0.51, 0.93 and 1.44 respectively and exploitation ratio was 0.64. The maximum sustainable yield was 14,565 t which was lower than the average annual catch indicating over-exploitation of the species. The yield per recruit and biomass per recruit was 43.34 g and 46.6 g respectively and increase in relative yield by 142.41% would be obtained by decreasing the present level of fishing by 60%.

Keywords: Fishery, Population dynamics, Stock assessment, *Trichiurus lepturus,* Veraval.

Introduction

Ribbonfish represents an important group of food fish in the waters along the Saurashtra coast. They form one of the major components of exploited marine fishery resources and have good domestic and export demand. The annual average catch of ribbonfish in Gujarat during 2002 – 2006 period was 58,196 t contributing 14% of the total marine fish catch (Mohanraj *et al*., 2009). However in 2006, there was a two-fold increase in the landings of ribbonfish and it was the highest contributor (18%) to the marine fishery of the state (Mohanraj *et al*., 2009). *Trichiurus lepturus* (Linnaeus) forms the major component of the ribbon fish catches along the Saurashtra coast while *Lepturacanthus savala* (Cuvier) and *Eupleurogrammus muticus* (Gray) occur occasionally. The fishery is confined to the shallow depth zone below 70 m. The resource is exploited by a variety of gears but the major contribution comes from multi-day trawl nets.

Information is available on the population parameters, mortality and exploitation of *T. lepturus* from Kakinada waters (Narasimham, 1983; Abdussamad *et al*., 2006), Visakhapatnam waters (Reuben *et al*., 1997) and from Mumbai waters (Chakraborty, 1990), but no published information is available till date on the yield and mortality parameters of *T. lepturus* from Veraval waters. The present study was aimed to provide an insight into the fishery, population characteristics and yield estimates of *T. lepturus* caught by trawlers at Veraval.

Materials and methods

Data on catch and effort expended for *T. lepturus* were collected weekly from commercial trawlers of Veraval for the four year study period from January 2003 to December 2006 except during monsoon season (June – August) due to suspension of the trawl net fishery. The monthly and annual estimates of catches were made following the procedure adopted by the Fishery Resource Assessment Division of Central Marine Fisheries Research Institute (Srinath *et al*., 2005). A total of 6,409 specimens of *T. lepturus* in the size range of 12 to 125.9 cm were collected on a weekly basis from Veraval for recording total length (cm) and body weight (grams to 0.01 g precision). The length - weight relationship of *T. lepturus* was calculated as $W=aL^b$ (Le Cren, 1951) separately for both sexes and difference between the slopes of the regression lines of males and females were tested by ANACOVA (Snedecor and Cochran, 1967).

For estimating von Bertalanffy growth parameters, L_∞ and K, the monthwise length composition data of four years were pooled and grouped with 2 cm class interval and analyzed using the ELEFAN I module of FiSAT software version 1.2.0 (Gayanilo *et al*., 1996). An additional estimate of L_∞ and Z/K values obtained using the Powell – Wetherall plot was compared with that obtained from ELEFAN I before arriving at final values. The growth performance index (ϕ) was calculated from the final estimates of L_∞ and K (Pauly and Munro, 1984). The probability of capture and size at first capture (L_c) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's (1979) empirical equation, $\text{Log}(-t_0) = -0.392 - 0.275\ \text{Log}\ L_\infty - 1.038K$. The growth and age were determined using the von Bertalanffy growth equation, $L_t = L_\infty (1-e^{-k(t-t0)})$. The mid point of the smallest length group in the catch was taken as length at recruitment (L_r). The recruitment pattern was studied from recruitment curves using final estimated values of L_∞, K and t_0. Longevity was estimated from $t_{max} = 3/K + t_0$ (Pauly, 1983a).

Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980), taking the mean sea surface temperature to be 27 ^{0}C (Asokan *et al*., 2009) and total mortality (Z) calculated from length converted catch curve (Pauly, 1983b) using FiSAT software. Fishing mortality (F) was estimated by F = Z - M. Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class. Exploitation ratio was estimated from the equation, E = F/Z and exploitation rate from $U = F/Z*(1-e^{-z})$ where, F is the fishing mortality rate.

Total stock (P) and biomass or standing stock (B) were estimated from the ratios Y/U and Y/F respectively, where Y is the annual average yield in tonnes. Maximum sustainable yield (MSY) was calculated by the equation (Gulland, 1979) for exploited fish stocks, MSY = Z*0.5*B. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated from Beverton and Holt Yield per Recruit model using Excel worksheet.

Results

Fishery

The average annual catch of *T. lepturus* for the period 2003 – 2006 was estimated at 18,813 t, forming 27.63% of the total trawl catches at Veraval. The annual catch increased from 10,195 t in 2003 to 13,613 t in 2004, then declined slightly in 2005 to 11,958 t and finally increased sharply in 2006 by more than three folds to 39,486 t, which was the highest catch recorded during the entire period. Contrary to the increase in catch, the effort expended by trawlers during the period decreased from 23.66 lakh fishing hours in 2003 to 16.38 lakh fishing hours in 2006. The average catch rate during the period was 10.77 kg h^{-1}. The catch rate exhibited an increasing trend over the years with the lowest of 4.31 kg h^{-1} recorded in 2003 and the highest of 24.1 kg h^{-1} recorded in 2006 (Fig. 1). The contribution of *T. lepturus* to the total trawl landings at Veraval similarly increased over the years from 19.2% in 2003 to 33.3% in 2006 (Fig. 1).

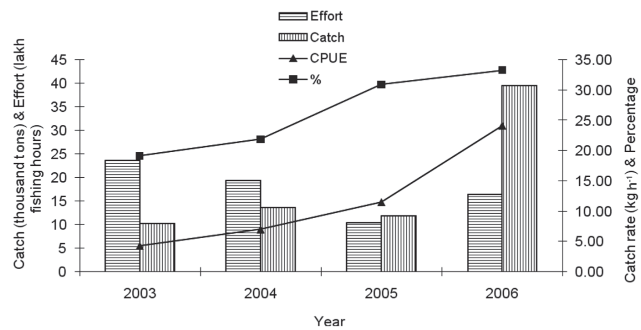


Fig. 1. Trend in fishery of *T. lepturus* landed by trawlers at Veraval (2003 - 2006)

Seasonal abundance

The studies on seasonal abundance revealed the post-monsoon season (September to December) to be the most productive in terms of catch and catch rate. This could be attributed to the increase in the average fishing hours of trawlers during this season. The average monthly catch of *T. lepturus* was highest in October (5,392 t) and lowest in May (221 t) and the catch rate was maximum in September (18.95 kg h^{-1}) and minimum in May (3.19 kg h^{-1}) (Fig. 2). The average monthwise contribution of *T. lepturus* to the trawl landings was higher during September to December (23.46% - 39.62%) and lowest in May (11.15%) (Fig. 2).

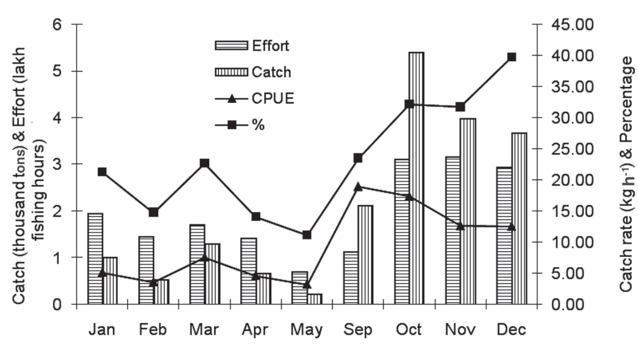


Fig. 2. Seasonal abundance of *T. lepturus* at Veraval

Length composition

The length frequency distribution of *T. lepturus* for the four year period indicated exploitation of juveniles (size range 12 – 19.9 cm) in March 2003, unlike the remaining years. The mean length decreased from 69.11 cm in 2003 to 67.56 cm in 2006. The higher mean lengths were recorded during September – November and in January and the lower during February – May (Fig. 3).

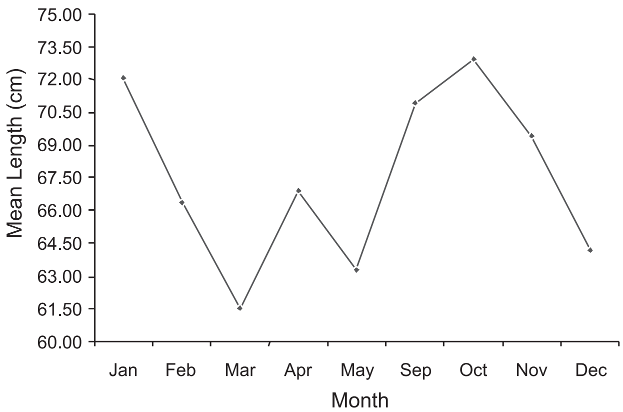


Fig. 3. Average monthly mean length of *T. lepturus* at Veraval

Length-weight relationship

A total of 532 (276 male and 256 female) specimens in the length range of 38 – 115.9 cm were used for determining the length-weight relationship separately for the two sexes.

The relationships estimated separately were:

Male: log W = -4.2805 + 3.58759 log L (r = 0.98)

Female: log W = -3.99724 + 3.4388 log L (r = 0.95)

Since there was no significant difference between the slopes at 5% level, a combined relationship was obtained for males and females.

log W = -4.18588 + 3.53745 log L (r = 0.97)

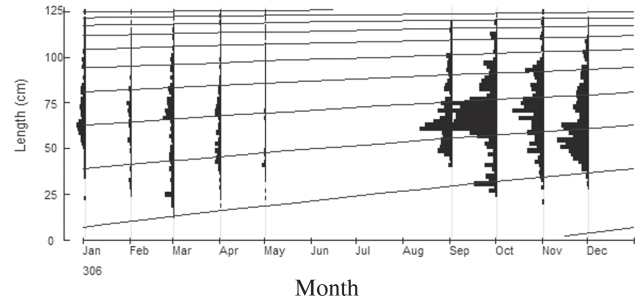
The study depicted that the slope of the regression equation for *T. lepturus* was significantly (5%) different (t_{cal} = 8 and t_{crit} = 4.3) from the isometric value of 3 indicating allometric growth for the species.

Growth

The growth parameters, L_∞ and K (annual) estimated using the ELEFAN I programme were 134.1 cm and 0.29 respectively at the highest Rn (goodness of fit index) value of 0.163. The computed growth curve over its restructured length frequency histograms is shown in Fig. 4. The growth performance index, ϕ was found to be 3.717 and t_0 was calculated at -0.0527 years. The von Bertalanffy growth equation can be written as:

$$L_t = 134.1\ [1 - e^{-0.29\,(t + 0.0527)}]$$

Accordingly, the fish attained a size of 35.28 cm, 60.16 cm, 78.77 cm, 92.70 cm and 103.12 cm respectively by the end of 1, 2, 3, 4 and 5 years. The longevity of *T. lepturus* was estimated at 10.29 years. The fishery was dominated by fishes of 1 year, 2 year, 3 year and 4 year classes. The length at first capture (Lc) was estimated at 14.11 cm which corresponds to an age (t_c) of 0.331 year.

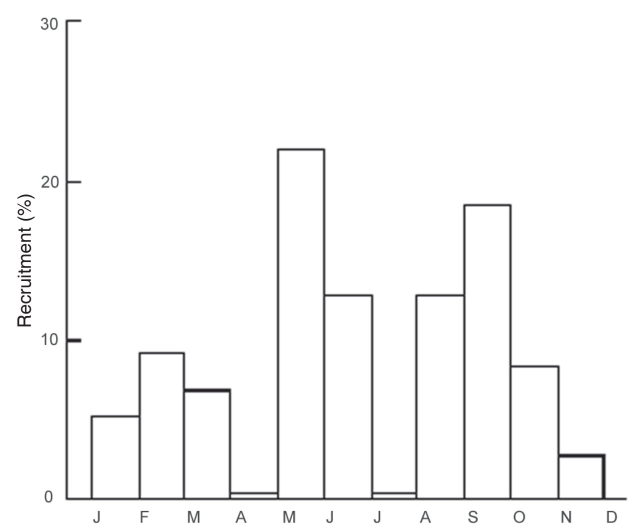


L_∞ = 134.1 cm, K = 0.29 yr^{-1}, C = 0, WP = 0 and Rn = 0.163

Fig. 4. Restructured growth curve of *T. lepturus*

Recruitment pattern

The recruitment of *T. lepturus* indicated a trimodal pattern with two major peaks during May – June and August – October and one minor peak during January – March (Fig. 5). The two peak pulses on an average produced 34.94% (May – June) and 39.66 % (August – October) of the recruits. The smallest length of recruitment was found to be 12.9 cm.



L_∞ = 134.1 cm, K = 0.29 yr^{-1} and t_0 = -0.0527 years

Fig. 5. Annual recruitment pattern of *T. lepturus*

Mortality, exploitation and Virtual Population Analysis (VPA)

The mortality rates M, F and Z computed were 0.51, 0.93 and 1.44 respectively. The length converted catch curve utilized in the estimation of Z, is represented in Fig. 6. The exploitation ratio (E) was 0.64 which was higher than the E_{max} of 0.4 obtained from the selection curve, indicating over-exploitation of the species.

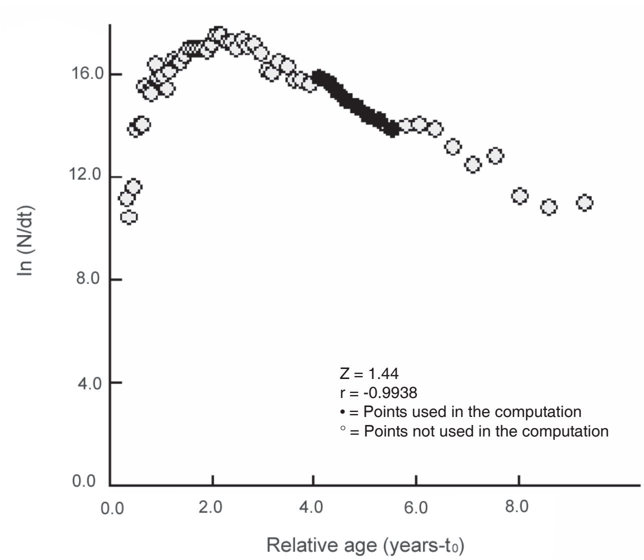


Fig. 6. Length converted catch curve of *T. lepturus* off Veraval

The VPA (Fig. 7) indicated that main loss in the stock up to 36.9 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually outnumbered the natural losses. Fishing mortality exceeded natural mortality from 70.9 cm onwards. The maximum fishing mortality of 1.178 was recorded at size of 118.9 cm. The mean value for fishing mortality was 0.337 and the mean value for exploitation ratio was 0.234.

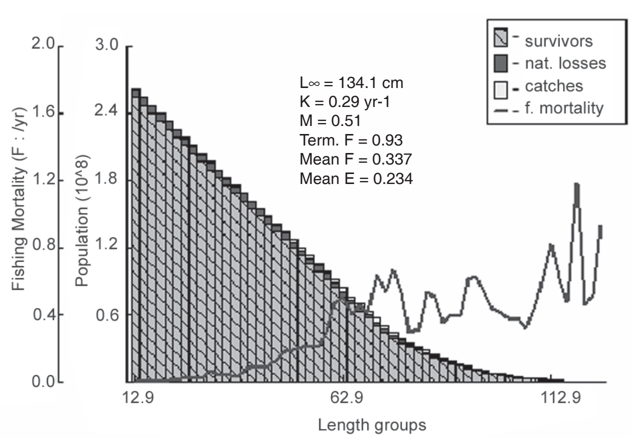


Fig. 7. Length structured VPA for *T. lepturus* for the period 2003 - 2006

Estimation of stock and MSY

The annual total stock, biomass (standing stock) and MSY of *T. lepturus* were estimated at 38,174 t, 20,229 t and 14,565 t, respectively.

Yield per recruit

The yield and biomass/recruit and yield and biomass curves showed that the maximum yield and yield/recruit could be obtained by decreasing the present level of fishing by 60% (Fig. 8 and 9). The maximum yield and yield per recruit that can be obtained at 40% of the present fishing effort is 26,792 t and 61.72 g, respectively. At the present level of fishing, it is 18,813 t and 43.34 g. The biomass and biomass per recruit achieved at 40% of the present effort is 72,021 t and 165.9 g respectively but with the present rate, the biomass and biomass per recruit is only 20,229 t and 46.6 g. At the reduced effort, the increase in relative yield would be 142.41% (Fig. 10). So to get optimum yield and biomass per recruit, the present fishing effort has to be reduced by 60%.

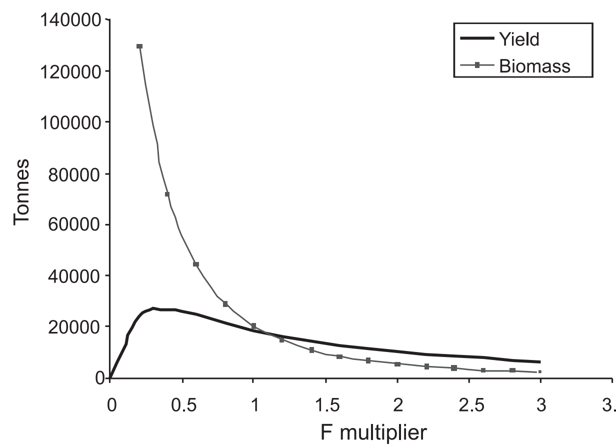


Fig. 8. Yield and biomass of *T. lepturus* for different multiples of F

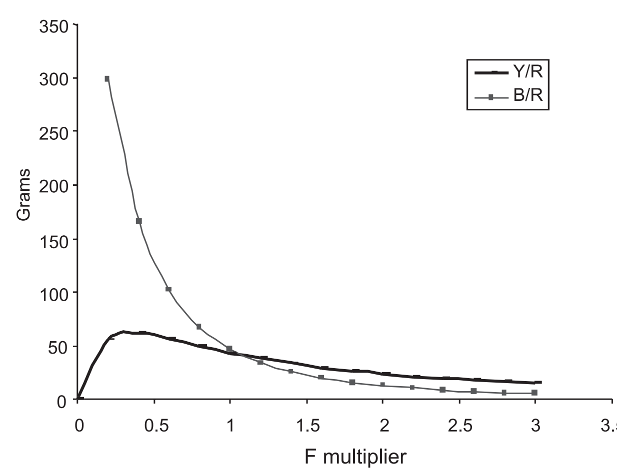


Fig. 9. Yield per recruit and biomass per recruit of *T. lepturus* for different multiples of F

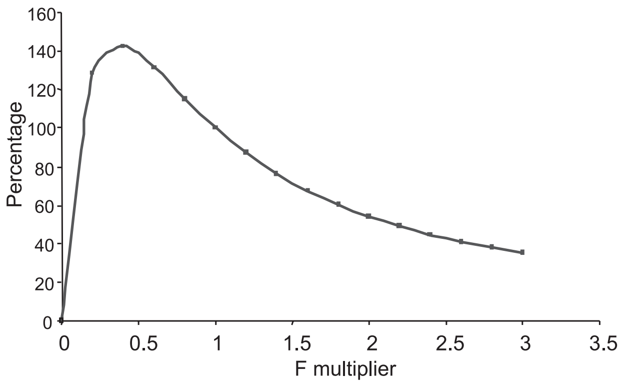


Fig. 10. Relative yield percentage of *T. lepturus* for different multiples of F

Discussion

The annual catch and catch rate of *Trichiurus lepturus* increased manifold from 2003 to 2006. The targeted fishing for ribbonfishes coupled with improvement in the operating efficiency of trawl nets has resulted in higher catches and catch rates of *T. lepturus* in 2006. The multi-day trawlers conduct voyage fishing lasting for 4 – 12 days at the depth of 30 – 60 m for *T. lepturus*. James *et al*. (1986) have reported the availability of the resource in waters at depths between 25 and 75 m. In the recent past, specially designed nets targeted to catch ribbonfishes have been implemented by the local fishermen owning multi-day trawlers. The nets possess large meshed cod end (4 - 6 cm) and have large mesh openings in the wing sections of the trawl (45 – 60 cm) which helped to reduce the drag resistance and increased the catch rate by decreasing the hours expended in fishing. This target oriented fishing for ribbonfishes also explains the increasing contribution of *T. lepturus* to the trawl landings. Moreover, the injudicious removal of large quantum of fishes which include competitors of ribbonfish by intensive fishing over the last decade might have created favourable conditions for *T. lepturus* to proliferate. The decrease in effort of trawls over the years is mainly because of switching over to target fishing for ribbonfishes and cephalopods coupled with several other socio-economic factors like labour problem, hike in fuel price *etc.*

The post-monsoon period (September to December) was found to be most productive in terms of catch and catch rate coinciding with increased fishing activity. At Veraval, protection is provided to the fishery resources during June – August when fishing is suspended which has contributed to the high catch and catch rates during the post-monsoon season. The seasonal fluctuations in the catch are an inherent feature of this fishery and are due to several biotic and abiotic factors *viz.,* environmental parameters, fishing intensity, fishing techniques, changes in the fishing pattern, fishing ground, food availability, spawning success, *etc.* The mean sizes of *T. lepturus* recorded for the four years were considerably higher than 52.1 cm recorded for the same species from Kakinada (Abdussamad *et al*., 2006).

The combined length-weight relationship showed that *T. lepturus* exhibited allometric growth. Similar result on length-weight relationship was reported by Narasimham (1972, 1983) from Kakinada. However, higher 'b' values individually for male and female were recorded in the present study as compared to Reuben *et al*. (1997) and Abdurahiman *et al*. (2004) who reported b values of 3.246 (male) and 3.299 (female) and 2.819 (male) and 3.029 (female) from Visakhapatnam and southern coast of Karnataka respectively. This variation is possibly due to factors related to ecosystem and biological phenomena like maturity stages, feeding behaviour, competition for food. *etc*.

The present estimate of L_∞ (134.1 cm) is higher than that reported by Ingles and Pauly (1984) from Philippines (78 cm), Somvanshi and Joseph (1989) from north-west coast of India (109 cm), Chakraborty (1990) from Bombay (129.7 cm), Reuben *et al*. (1997) from Visakhapatnam (106.83 cm) and Abdussamad *et al*. (2006) from Kakinada (128.2 cm). However, Narasimham (1976) recorded much higher value of L_∞ (145.2 cm) from Kakinada waters. The growth coefficient of 0.29 per year is in full agreement to Narasimham (1976; 1983), but much higher values of growth coefficient ranging from 0.5 to 0.72 were reported by other authors (Ingles and Pauly, 1984; Somvanshi and Joseph, 1989; Chakraborty, 1990; Reuben *et al*., 1997; Abdussamad *et al*., 2006). However, the growth performance index of 3.717 in the present study conforms fully to earlier published reports of Narasimham (1976); Ingles and Pauly (1984); Somvanshi and Joseph (1989); Chakraborty (1990) and Reuben *et al*. (1997). The fishery at Veraval was represented mostly by fishes of one to four year classes, as also observed from Visakhapatnam by Reuben *et al*. (1997). The life span of *T. lepturus* recorded in the present study (10.29 years) was much higher than that recorded by Narasimham (1983) and Reuben *et al*. (1997) from the south-east coast of India. Ribbonfishes are however known to live for upto fifteen years (Nakamura and Parin, 1993). The length at first capture of 14.11 cm was similar to that reported by Narasimham (1983) but lower than 40.9 cm reported by Abdussamad *et al*. (2006). The length at first capture was very low indicating that majority of them were caught before they could mature and spawn at least once in their life. This indicated stress on spawning stock and could be addressed by enhancing their size and age at exploitation, which meant that increase in mesh size of gears is required to avoid the catch of young fishes. The trimodal recruitment pattern of *T. lepturus* observed in this study with two major peaks during May – June and August – October correlated well with earlier published report by Narasimham (1976) who stated that the fish spawns twice in a year during May – June and September - December. Nevertheless, James *et al*. (1978) and Abdussamad *et al*. (2006) indicated continuous recruitment of *T. lepturus* from the waters of Kakinada.

Beverton and Holt (1956) pointed out that the natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_∞) and the life span. The same appeared to be true for *T. lepturus* which had lower growth coefficient of 0.29 per year and higher lifespan of 10.29 years was found to have relatively lower natural mortality coefficient of 0.51 per year. Various authors have reported natural mortality as 0.9 (Narasimham, 1983), 1.08 (Ingles and Pauly, 1984), 0.8 (Somavanshi and Joseph, 1989), 1.05 (Chakraborty, 1990), 1.0 (Thiagarajan *et al*., 1992), 0.89 (Reuben *et al*., 1997), 0.7 (Mohite and Biradar, 2001) and 0.98 (Abdussamad *et al*., 2006) for *T. lepturus*. The M/K ratio (1.76) obtained in the present study was well within the normal range of 1 – 2.5, as suggested by Beverton and Holt (1959). The fishing mortality (0.93) of *T. lepturus* recorded was similar to that reported by Chakraborty (1990) and Somavanshi and Joseph (1989) but lower than that reported by Reuben *et al*. (1997) and Abdussamad *et al*. (2006). The high exploitation ratio (E = 0.64) observed was an indication of intensive fishing of this species and was similar to that reported by Reuben *et al*. (1997) from Visakhapatnam. However, Chakraborty (1990) recorded lower ratio of exploitation (E = 0.46) for the species from Bombay and Abdussamad *et al*. (2006) recorded higher ratio of exploitation (E = 0.77) from Kakinada. It is evident from the results that since the value of E were higher than the E_{max} and MSY lower than the annual catch, the stock is under higher fishing pressure than the sustainable level warranting immediate reduction in fishing effort.

The yield per recruit of 43.34 g obtained in the present study for *T. lepturus* was far lower than 74.6 g reported by Abdussamad *et al*. (2006) but higher than 23 g reported by Narasimham (1983). The yield and biomass/recruit and yield and biomass curves depicted that the stock was subjected to overfishing by 150% with respect to its optimum fishing effort. Hence to get maximum yield and biomass, the fishing pressure has to be decreased by 60% from the present condition. It is therefore suggested that measures be taken for their judicious exploitation on a sustainable basis by reducing the fishing pressure so as to bring the catch to the MSY levels. The reduction in effort and increase in mesh size of cod end of trawl nets targeting cephalopods, prawns and other demersal resources from 10 mm to 40 mm are therefore suggested as regulations to improve the status of the resource. This will slowly aid in replenishing the fishery to a healthy and sustainable level. The present fishing grounds being under intensive exploitation, scope for further increase in production is limited. The only alternative left is to limit total fishing intensity in each fishing zone by diverting surplus effort to under-exploited grounds.

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