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Stock assessment of *Lepturacanthus savala* (Cuvier, 1829) along north-west sector of Mumbai coast in Arabian Sea

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ABSTRACT

Population parameters of *Lepturacanthus savala* from the trawl and dol net catches from Mumbai waters were estimated based on length frequency data using FiSAT and ELEFAN. The length-weight relationship for pooled data was log W = -7.9652 + 3.6117 log L_α (r = 0.962). The asymptotic length (L_α) and growth coefficient (K) were estimated to be 688 mm, and 0.87 year^{-1}, respectively. Based on these growth parameters, the instantaneous total mortality coefficient (Z) during the study period was estimated to be 4.15 year $^{-1}$. The natural mortality coefficient (M) was 1.30. Hence fishing mortality (F) was 2.85 year $^{-1}$ for *L. savala*. The estimated value for the exploitation ratio (E) was 0.68. The recruitment was continuous with two peaks per year. The estimated size of *L. savala* at 50 percent probabilities of capture was 463 mm. An isopleth diagram was obtained when E = 0.6 and L_c/L_α = 0.5.

Keywords: Age and growth, *Lepturacanthus savala*, Mortality, Stock assessment, Virtual population analysis

Introduction

With the rapid commercial growth of fisheries in the last two decades, India holds third position in world fish production with 5.65 mt. There has been manyfold increase in fishing fleet; the resources fluctuating widely and the catch per unit effort sometimes recording alarmingly low levels (CMFRI, 1997). Under such overexploited conditions, fishery resources requires scientific management (Sparre and Venema, 1998). For this, it is necessary to understand the stock dynamics of the resource under consideration (Gulland, 1983).

Among the exploited marine fishes of India, ribbonfish constitute an important pelagic resource, ranking fifth among the finfishes and seventh in the various groups of marine fish resources landed in 1998-99 (Rizvi *et al.,* 2003). The annual average production was 1.07 lakh tonnes for the period of 1997-99, contributing 4.57% to the total marine fish production. Ribbonfishes are represented in Indian waters by nine species, out of which four species namely, *Trichiurus lepturus* (Linnaeus) 1758, *Lepturacanthus savala* (Cuvier) 1829, *Eupleurogrammus muticus* (Gray) 1831 and *Eupleurogrammus intermidius* (Gray) 1831 are found in the coastal waters of Maharashtra in general and in Mumbai particular. Of the four species, *L. savala* ranks second in the order of abundance. During 1997-99, a total of 6,921 t of ribbonfishes were landed by trawlers in Mumbai coast with species composition of *T. lepturus* (78.8%), *L. savala* (21.8%) and *E. muticus* (3.4%) whereas dolnets landed a total of 304 t, with the percentage contribution of *T. lepturus, L. savala* and *E. muticus* being 18.3%, 17.8% and 63.9% respectively.

A good number of investigations on population dynamics of *T. lepturus* have been carried out by earlier workers (Narasimhan, 1976; Somavanshi and Joseph, 1989; Chakraborty, 1990; Thiagarajan *et al.,* 1992; Chakraborty *et al.,* 1997; Reuben *et al.,* 1997 from Bay of Bengal and Arabian Sea. Despite the magnitude of the fishery and commercial importance, no attempt has been made to study the population dynamics of *L. savala.* Therefore, the present study envisaged investigation on the growth, mortality, length-weight relationship and stock assessment of *L. savala,* a commercially important resource from Mumbai waters.

Materials and methods

Sample collection

The annual catch and effort data were collected for the trawlers based at New Ferry Wharf and Versova from the Fishery Resources Assessment Division of CMFRI for the years 1997-98 and 1998-99. The random samples of this species were also collected from dolnet landing centres at Versova and Arnala and from trawl catches at New Ferry Wharf during the same period. The sampled fish were measured and weighed at the landing centre. The length frequency was distributed in 20 mm groups, raised to the observed day's catch, monthly catch and finally to the annual catch of the species.

Analysis of data

FiSAT software (Gayanillo *et al.,* 1996), was used for the estimations of various parameters such as age and growth, mortality rates, recruitment patterns, probability of capture, length structured Virtual Population Analysis (VPA) or Cohort analysis, relative yield per recruit as well as biomass per recruit and also to obtain isopleth diagram.

Growth parameters such as L_α and K were obtained from both Bhattacharya (1967) and Gulland and Holt plot (1959). The total mortality coefficient (Z) was estimated by length converted catch curve method (Pauly, 1984). Natural mortality coefficient (M) was obtained by the empirical formula suggested by Pauly (1980) as:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\alpha + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where, $L\alpha$, K and T are asymptotic length, growth rate and mean annual environmental temperature respectively. Temperature was taken as 28 °C. The estimate of fishing mortality (F) was taken by subtracting M from Z. Exploitation rate (U) and Exploitation ratio (E) were expressed by the following formula (Gulland, 1971):

E= F/Z and U= F/Z (1-e -Z)

The probability of capture was determined by backward extrapolating of length converted catch curve, yield per recruit and biomass per recruit were estimated by keeping the L_c constant. With the help of different exploitation ratio (E) on the X axis and different size at the first capture (by using L_c / L_α ratio) on Y-axis, values of Y/R were plotted to generate the isopleth diagram. The length-weight relationship was determined by the least square method (Zar, 1984) for male and female separately by using the general formula:

$W = a L^b$ or its logarithmic form $\log W = a + b \log L$

where, W = weight of fish in grams, L = length of fish in mm, and 'a' and 'b' are the constant and regression coefficient respectively.

In order to estimate difference between and within the sexes of species, analysis of covariance was carried out to determine statistical difference in the length-weight relationship (Snedecor and Cochran, 1967) of males and females of the species.

The relative yield per recruit (Y/R) and biomass per recruit (B/R) was estimated by 'selection Ogive' method suggested by Sparre and Venema (1998).

Results and discussion

A total of 7,352 specimens of *L. savala* in the length range of 75 to 650 mm were measured during the two-year period. Weight asymptote (W_α) was calculated as 194 g. For length-weight relationship of *L. savala,* a total of 608 specimens ranging from 80 to 623 mm in total length and 0.2 to 235 g in total weight were measured. The specimens comprised of 220 females ranging from 315 to 623 mm in length and 13.5 to 235.6 g in weight, 123 males ranging from 282 to 585 mm in length and 8.4 to 104.6 g in weight. The remaining 265 specimens were indeterminate juveniles ranging in size from 80 to 281mm in length.

The length-weight relationships of *L. savala* in logarithmic form were shown as:

Males : Log W = -6.7808 + 3.1671Log L(r = 0.83)

Females : Log W = -7.4918 + 3.4409 Log L(r = 0.85)

Pooled : Log W = -7.9652 + 3.6117 Log L(r = 0.96)

or

For sexes combined: $W= 0.00000001\ L^{3.6117}$ (Fig. 1)

Gupta (1967) expressed the length-weight relationship of *L. savala* for the two sexes together as: Log W= -5.5396 + 3.30715 Log L in which the length was measured from snout to vent. Narasimham (1976) found the length-weight relationship of *E. muticus* for the two sexes together as Log W= -4.216 + 3.5233 Log L. Both authors found that the exponent 'b' was significantly different ($p<0.05$) from 3. In the present study also 'b' was significantly different for *L. savala* thus exhibiting allometric growth. The regression coefficient 'b' indicates that the weight of fish increases more or less in proportion to the cube of its length, but the females grow faster by weight than the males, as their exponential values are more. However, ANOCOVA showed that there was no significant difference between 'b' among the sexes of *L. savala,* which exhibited curvilinear (parabolic) relationship.

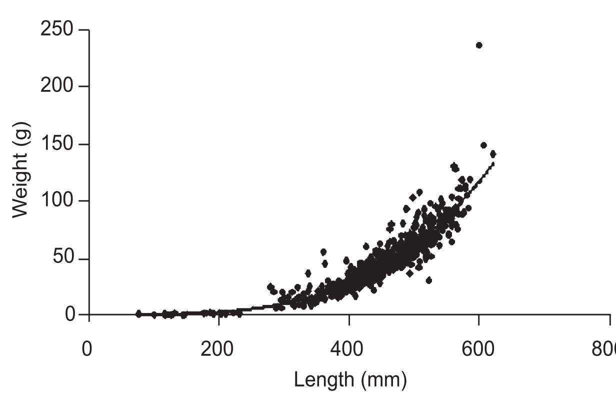

Fig. 1. Length-weight relationship of *L. savala* for combined sexes

Preliminary values of L_α = 683.3 mm; K = 0.86 year^{-1} and r^2 = 0.707 were obtained by employing Gulland-Holt method. The regression of mean length (L) and the growth increments ($\Delta L/\Delta t$) formed basis of the plot of L_α, K and r^2 with the estimate of 688.02 mm, 0.87 year^{-1} and 0.508 respectively (Fig. 2). The t_o found by von Bertalanffy's plot (1938) is 0.000251 year^{-1}. The parameters obtained by the Gulland-Holt plot (1959) were considered for the estimation of age and growth. The VBGF of growth for the species is expressed as:

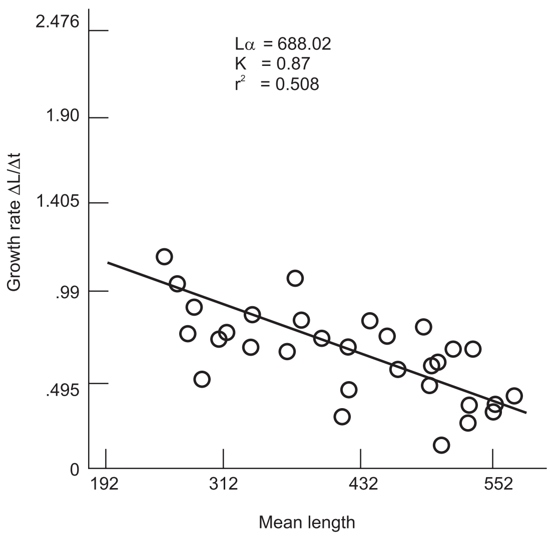

Fig. 2. Gulland - Holt plot for *L. Savala*

$$Lt = 688\ (1\text{-}e^{\ (-0.87\ (t\text{-}\ 0.000251))})$$

From the expression it is found that *L. savala* grows to the size of 399 mm, 567.2 mm and 637.4 mm at the end of 1, 2 and 3 years respectively. During the study, the largest specimen measured was 650 mm, the estimated age of which was 3.3 years.

Gupta (1967) from the east coast, estimated growth parameters for *L. savala* as L_α =1057.14 mm, K = 0.0887 year^{-1} and t_0 = 0.03953 years by employing the Ford- Walford plot. The length worked out to be 93.1, 174.9 and 249.8 mm for 1, 2 and 3 years respectively which is contradictory to his presumption because the growth of *L. savala* estimated by Gupta (1967) appear to be far slower than in the present investigation. James *et al.* (1986) have also commented that the growth of *L. savala* reported by Gupta (1967) is very slow and therefore, they called for more information on the age and growth of the species. In the present investigation, the methods employed to get the growth parameters yielded asymptotic length (L_α) in the close range of 680-688 mm. But, the growth coefficients 'K' obtained by ELEFAN method differed widely and hence were not considered. The growth parameters obtained by the Gulland-Holt plot, (L_α = 688 mm and K = 0.87) were reasonably good and fell within 95% confidence limit with other methods and therefore, considered for describing the growth of the species. Longhurst and Pauly (1987) and other workers have shown that the tropical fishes grow much faster than their temperate counterparts. Thus faster growth obtained in the present investigation is justified.

During the present study, the instantaneous rate of total mortality coefficient (Z) for *L. savala* estimated by length converted catch method were 3.63 and 4.85 during 1997-98 and 1989-99 respectively. The instantaneous pooled Z for two years being 4.15 (Fig. 3) which is close to the value of 4.82 obtained by Jones and Zalinge (1981). Hence the result of pooled instantaneous rate of total mortality coefficient (Z) as obtained by length converted catch curve method was computed as 4.15, which was selected for further estimation purposes. The instantaneous natural mortality (M) estimated by Pauly's empirical formula method was 1.30 year^{-1} for *L. savala.* Fishing mortality Z-M was calculated as 2.85 year^{-1}. The exploitation ratio (E) estimated was 0.64, 0.73 and 0.68 and exploitation rate (U) was 0.62, 0.72 and 0.66, respectively for 1997-98, 1989-99 and pooled for the two years.

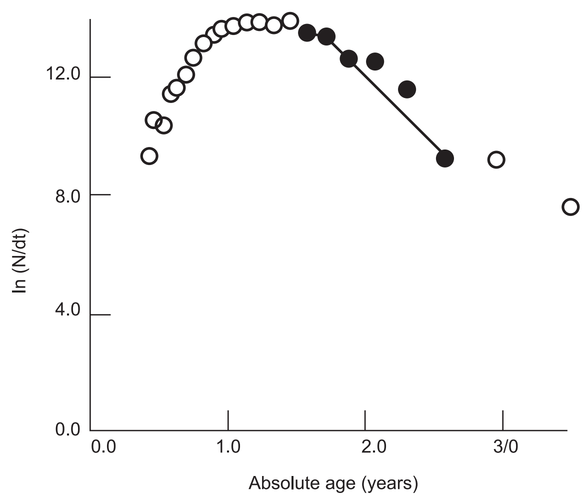

Fig. 3. Estimation of 'Z' by length converted catch curve method for *L. savala*

Beverton and Holt (1959) pointed out that the two parameters of growth, asymptotic length (L_α) and growth coefficient (K) are inversely related but natural mortality coefficient (M) is directly related to growth coefficient and indirectly related to life span. The widely investigated ribbonfish *T. lepturus* is relatively a large sized species reaching more than 1200 mm (Thiagarajan *et al.,* 1992) while *L. savala* grows to approximately 650 mm. Therefore, growth coefficient of *L. savala* (0.87) should be higher than 0.62 reported by Thiagarajan *et al.* (1992) for *T. lepturus*. This appears to be true for some of the species of ribbonfish *viz., E. muticus* with K of 0.78 year $^{-1}$, life span of 3.99 year, low natural mortality of 1.15 and L_α of 811 mm (Rizvi *et al.,* 2003). There are no comparative figures available on natural mortality of *L. savala* in Indian waters. However, *T. lepturus* which is bigger in size with long life span showed natural mortality coefficients of 0.9 (Narasimhan, 1983); 1.08 (Ingles and Pauly, 1984); 0.8 (Somavanshi and Joseph, 1989); 1.05 (Chakraborty, 1990); 1.0 (Thiagarajan *et al.,* 1992) and 0.9 (Mohite, 2000). As *L. savala* is a smaller species than *T. lepturus,* the present estimate of 1.30 appears fairly reasonable.

By pooling annual length-frequency, it was seen that there are two overlapping pulses of recruitment (Fig. 4). Major recruitment pulse was evident from May-December with peak in October (19%) when 70% recruitment took place and a minor pulse from December-July with peak in March (8%), when remaining 30% fishes were recruited. The selection of probability of capture gave L_α for *L. savala* as 463.3 mm in trawl (Fig. 5).

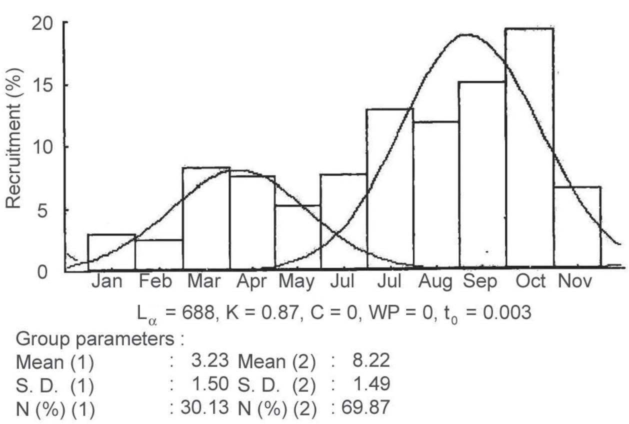

Fig. 4. Recrutiment pattern of *L. savala*

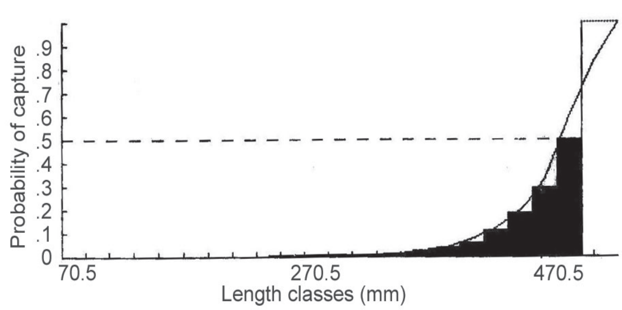

Fig. 5. Probability of capture analysis of *L. savala*

With input parameters of L_α = 688 mm, K=0.87, M=1.30, a =0.00000108 g cm^{-1}, b = 3.6117, the terminal exploitation ratio of 0.55 was obtained by iteration for *L. savala*. The estimated number of fish in the sea, including those lost due to natural causes and those caught and their fishing mortality are represented in Fig. 6. Thus, the number of fish recruited to the fishery in the size class of 60.5-80.5 mm was 18.72 million, their fishing mortality being meagre 0.02, catch (yield) was 0.07 t with biomass (standing stock) of 3.58 t. However, from the fully recruited (L_α = 463.3 mm) size group of 460.5-480.5 mm onwards, the mean fishing mortality was 2.65 which is close to 2.85. It is seen that with the estimated yield of 15,368 t, the steady state biomass was 14,185 t. The total annual stock estimated from Y/U expression was found to be 22,516 t.

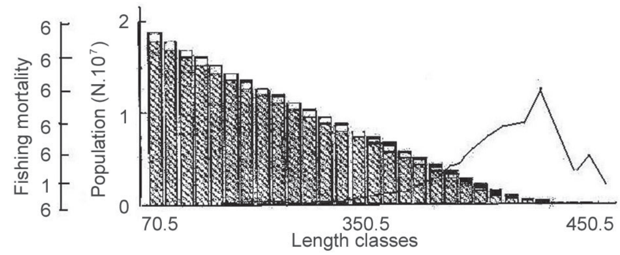

Fig. 6. Length structure virtual population analysis of *L. savala*

The magnitude of coefficient of total mortality in heavily exploited fish population is largely influenced by the extent of fishing intensity. The 'Z' was higher in 1998-99 than in 1997-98 on account of increased fishing effort in 1998-99 (Rizvi and Nautiyal, 2002). Similarly, after comparing the two species of ribbonfishes, it was found that *E. muticus* showed higher total mortality coefficient of 4.36 year^{-1} (Rizvi *et al.,* 2003) than *L. savalaas*, which may be attributed to higher fishing pressure on the former species. *E. muticus* is an inshore species occurring in waters less than 30 m depth. But, it is inadvertently fished out by large number of 'dolnets' as by-catch. The dolnets at Versova and Arnala regions are operated in a depth range of 20-30 m. Moreover, the practice of using smaller cod end mesh having 10-15 mm size for catching non-penaeid prawns (Raje and Deshmukh, 1989) may have resulted in the intensive exploitation of this resource. As compared to *E. muticus*, *L. savala* is an offshore pelagic species and therefore, it is not much vulnerable to dolnet fishing. In the offshore region (depth > 25-30 m) of Mumbai, fishing is largely carried out by gillnets and shrimp trawlers. Since gillnets are mainly bottom set, *L. savala* is caught only occasionally. The shrimp trawl being a demersal gear, does not seem to exercise heavy pressure on this pelagic species and hence the species did not show high exploitation ratio.

It is seen that the relative yield per recruit peaks at exploitation ratio (E_{max}) of 0.641. The yield isopleth diagram suggested that eumetric fishing is possible when exploitation is kept at E= 0.6 and L_c/L_α = 0.5 (Fig. 7).

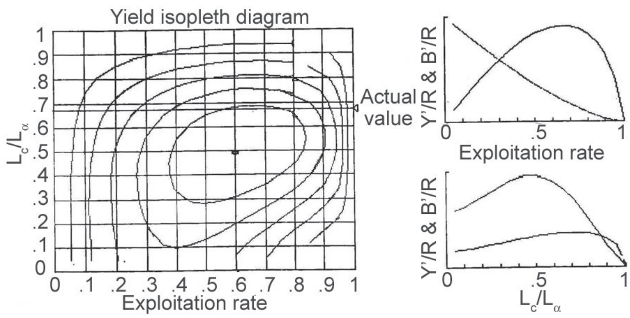

Fig. 7. Yield isopleth and relative yield and biomass per recruit of *L. savala*

Relative yield per recruit and isopleth diagram study show that MSY can be obtained at E= 0.64. Whereas the present E =F/Z is 0.68. Therefore, under present conditions of fishing, the maximum sustainable yield (MSY) can be achieved with an exploitation rate of 0.641 or fishing mortality of 2.506. But at E= 0.5, the biomass will be reduced to 37.9% of the unexploited biomass and at E = 0.64, it will be even less than 20%. With present exploitation ratio of 0.68, the model suggests that the exploitation of *L. savala* is optimal. This model suggests that E= 0.6 is safe for the stock and may be used as a guideline for short life span small size pelagic species such as *L. savala.*

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