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Population characteristics of greater lizardfish, *Saurida tumbil* (Bloch 1795) and brushtooth lizardfish, *Saurida undosquamis* (Richardson 1848) from the North western Indian EEZ

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Abstract
Population characteristics as length weight relationship, Age, growth, length at age (longevity) and mortality of two major lizardfishes, *Saurida tumbil* and *Saurida undosquamis* were analysed in the present study. The input data of length frequency distribution collected during 2010-2012 was considered. The length of *S. tumbil* ranged between 13.0-53.0 cm (Total length) and *S. undosquamis* ranged between13.0-41.0 cm (TL). The derived length weight relationship for *S. tumbil* was $38.64L^{0.729}$ and for *S. undosquamis* was $21.78L^{0.531}$. The asymptotic length ($L\infty$), the growth coefficient (K) and zero length at age (t_0) obtained for *S. tumbil* in the study are 53.00, 0.729 $year^{-1}$ and -1.097 $year^{-1}$ and for *S. undosquamis*, it was 41.00, 0.531 $year^{-1}$ and -0.493 $year^{-1}$ respectively. The total mortality (Z) was 2.71 $year^{-1}$, natural mortality (M) was 1.195 $year^{-1}$ and fishing mortality (F) was 1.515 $year^{-1}$ was estimated for *S. tumbil* while for *S. undosquamis*, it was calculated as 2.78 $year^{-1}$, 1.043 $year^{-1}$ and 1.173 $year^{-1}$ respectively. The exploitation ratio for *S. tumbil* was 0.56 $year^{-1}$ and for *S. undosquamis*, 0.62 $year^{-1}$ was obtained. Both the species showing isometric growth pattern in the present study.

Keywords: Exploitation ratio, asymptotic length, growth coefficient, mortality, Isometric growth, *Saurida tumbil*, *Saurida undosquamis*

1. Introduction
The two lizardfish's *viz.* greater lizardfish, *Saurida tumbil* and brushtooth lizardfish, *Saurida undosquamis* are important species occurring along the North western Indian EEZ. In India, the lizardfish fishery contributing to the tune of 77,838t in the year 2015 (Anon, 2016) [1] and has shown increasing trend, when compared to 2014 (54202t). The potential estimates for lizardfishes assessed during 2000 was 27,568t (Anon, 2001) [2] while the potential yield, estimates of these species during 2010 was 46,332t (Anon, 2011) [3] of which, major contribution was observed from 0-100m depth (39,388t) followed by 100-200m depth (5,666t) and 200-500m depth (1278t). In a decade, 18% increase in potential estimates has been observed. Information on the population charactistics of fish species is essential to meet one of the main objectives of fishery science, that of maximizing yield to fisheries, while safeguarding the long-term viability of populations and ecosystem (Jennings *et al.* 2000) [4]. As per the literature, some researcher have attempted studies on lizardfishes, among them Okada & Kyushin (1955) [5] on the stock of *S. tumbil* in East China and the Yellow seas, Tiews *et al.* (1972) [6] on biology of *S. tumbil* in Philippines waters and from north-west shelf off Australia, Ingles and Pauly (1984) [7] from Philippines waters, Tai-Shiang *et al.* (1987) [8] on the age and growth of lizardfish *S. undosquamis*. From Indian waters, some of the important works of Kuthalingam (1959) [9] on the developmental study of *S. tumbil,* Dighe (1977) [10] on fishery biology of *S. tumbil*, Rao (1983 and 1984) [11] on the age and growth of lizardfishes, Nair *et al.* (1990 and 1992) [13, 14] on the fishery of lizardfishes, Gulati *et al.* (1994) [15] on the stock assessment of *S. tumbil*, Chakraborty *et al.* (1994) [16] on the estimates of growth, mortality, recruitment patterns, and MSY of lizardfishes, Muthiah (1996) [17] on the fishery and biology of lizardfishes, Rajkumar *et al.* (2003) [18] on the biology and population dynamics of *S. undosquamis*, Jaiswar *et al.* (2003) [19] on the population dynamics of *S. tumbil*, Raje *et al.* (2004) [20] on fishery and biology of *S. tumbil* and Manjokumar and Sivakami (2005) [21] on the stock assessment of *S. tumbil*. Although, different studies on population characteristics have

been attempted by various researchers, detailed investigations required to be attempted from time to time to evaluate the stock composition status and the fishery, as the demand for seafood continuously increasing day by day. Therefore, the present study would be contributing to understand the lizardfish fisheries in the present scenario.

2. Material and methods

The length frequency data for *S. tumbil* and *S. undosquamis* was collected from the survey vessel MFV *Matsya Nireekshani* of Fishery Survey of India operated along the North West coast of India on monthly basis. The broader specifications of the vessel are 40m OAL, 2000HP, demersal trawl. Weekly data was also collected from the major commercial fish landings centers situated in the North western Indian EEZ. All the data was pooled on monthly basis. The data collected from 2010 to 2012 was considered for the present study. Fi SAT software package was used for adopting Bhattacharya (1967) [22] method to derive the number of cohorts in each sample and mean length of each cohort. Accordingly, no. of cohorts, maximum mean lengths and minimum mean lengths have been drawn. Through model progression, the mean length of a series of samples drawn through Bhattacharya analysis was plotted against time axis and mean lengths which correspond to the same cohort has been connected. The mean lengths derived based on Bhattacharya's method and model progression, Gulland and Holt plot was adopted to calculate the growth rates against mean lengths by formula:

$$\frac{\Delta L}{\Delta t} = \frac{L(t+\Delta t) - L(t)}{\Delta t}$$

From the above equation, the estimates of a (intercept) 'b' slope, L∞ (-a/b) cm, K= -b year^{-1} was derived.

For estimating growth parameters such as L∞, K and t_o Van Bertalanffy growth equation $L(t) = L\infty * [1-\exp^{(-K*(t-to))}]$ was followed, where L∞ is the asymptotic length, K is growth coefficient and t_0 is the length at zero age.

Length at age was estimated using Von Bertalanffy (1938) [23], VBGF plot. Natural mortality (M) estimates were obtained using Pauly's empirical formula (1980) [24]. Total mortality (Z) calculated by linearised catch curve method (Pauly, 1983, 1984a &b) [25, 26, 27] based on length composition data. After getting the estimates of growth parameters to evaluate the reliability phi prime test Pauly and Munro (1984) [28] was conducted by the equation (phi-prime) (ø) =Ln K +2 * Ln L∞.

3. Results

For deriving length weight relationship, a total of 1690 specimen with the size range between 13-53 cm (FL) for *Saurida tumbil* and 1236 specimens of *Saurida undosquamis* with the size ranging from 13-41 cm (FL) were considered for the analysis. A total of 1690 specimen of *S. tumbil* under the study, 990 males ranging from 13.0-51.0 cm in total length and weighing between 40-945 gm and 700 females ranging from 13.0-53.0 cm and weighing 30-1059.60 gm were sampled. For *S. undosquamis*, out of 1236 samples, 770 males ranging from 13.0-34.0 cm in total length and weighing between 15-243 gm and 466 females ranging from 14.0-41.0 cm and weighing 14-495 gm were sampled. The Length-Weight relationship was inferred from the general formula $W = aL^b$. The equation can be expressed logarithmically as Log W = Log a + b Log L. The graphical representation of length-weight relationships of both the species are shown in figs. 1-6. The length-weight relationship obtained for males, females and combined for both sexes in the present study are as follows:

Saurida tumbil

Male $W = 0.0071L^{3.0181}$ (r = 0.9463)
Female $W = 0.0102L^{2.9174}$ (r = 0.9397)
Combine $W = 0.0082L^{2.9788}$ (r = 0.9442)

The logarithmic form can represent as follows:

Male : Ln W = -0.3323 + 3.0181 Ln L
Female: Ln W = -0.2991 + 2.9174 Ln L
Combine: Ln W = -0.3197 + 2.9788 Ln L

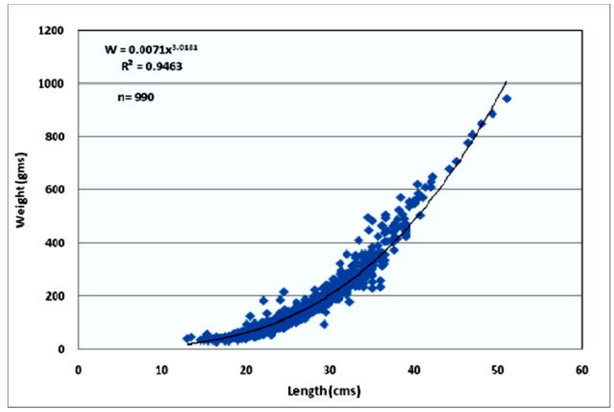

Fig 1: Length-Weight relationship of *S. tumbil* (Male)

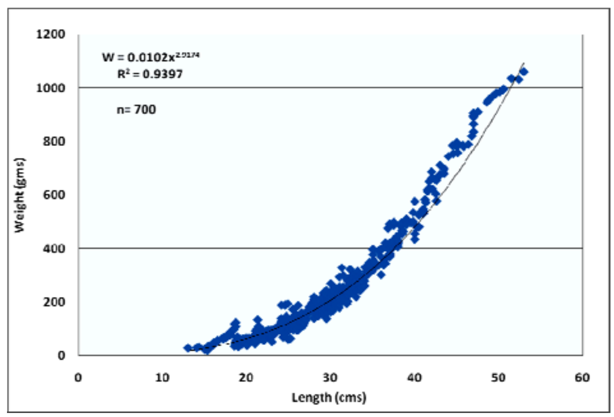

Fig 2: Length-Weight relationship of *S. tumbil* (Female)

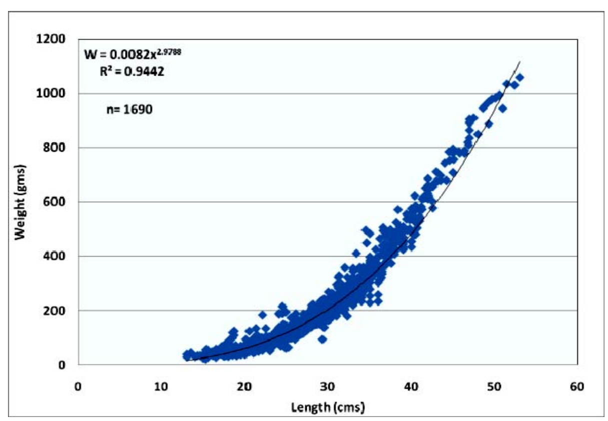

Fig 3: Length-Weight relationship of *S. tumbil* (Combined) *S. undosquamis*

Male $W = 0.0060L^{3.0344}$ (r = 0.9419)
Female $W = 0.0035L^{3.2184}$ (r = 0.9496)
Combine $W = 0.0046L^{3.1227}$ (r = 0.9468)

The logarithmic form can represent as follows:
Male : $\ln W = -0.3466 + 3.0344 \ln L$
Female: $\ln W = -0.3912 + 3.2184 \ln L$
Combine: $\ln W = -0.3684 + 3.1227 \ln L$

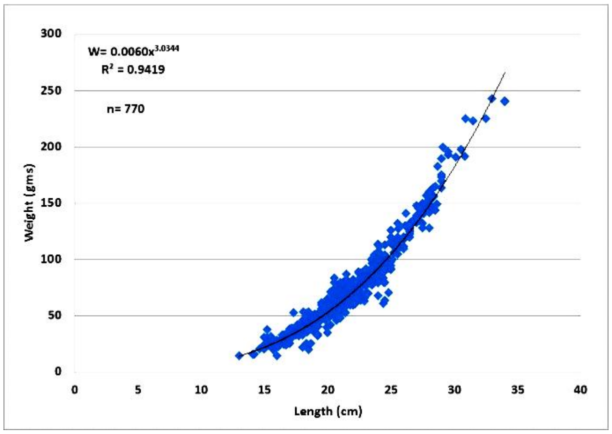

Fig 4: Length-Weight relationship of *S. undosquamis* (Male)

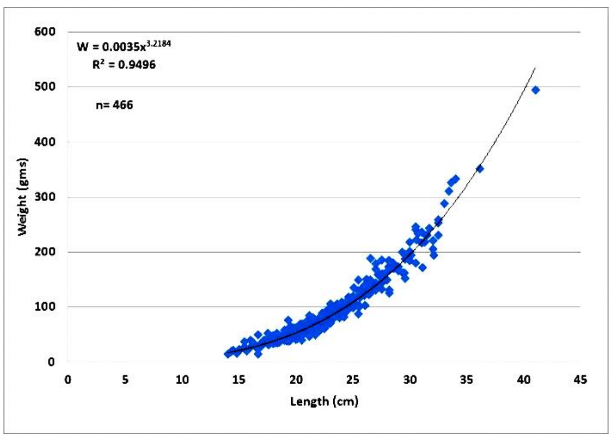

Fig 5: Length-Weight relationship of *S. undosquamis* (Female)

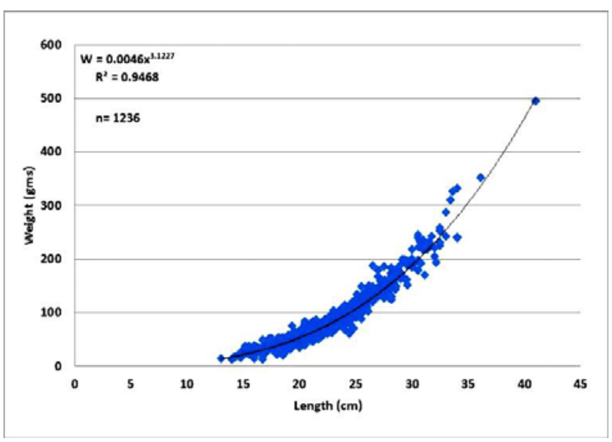

Fig 6: Length-Weight relationship of *S. undosquamis* (Combined)

Table 1: Comparison of a, b & r^2 of *S. tumbil* and *S. undosquamis*

Species	Sex	Constant		Correlation Co-efficient
		'a'	'b'	r^2
S. tumbil	Male	0.0071	3.0181	0.9463
	Female	0.0102	2.9174	0.9397
	Pooled	0.0082	2.9788	0.9442
S. undosquamis	Male	0.0060	3.0344	0.9419
	Female	0.0035	3.2184	0.9496
	Pooled	0.0046	3.1227	0.9468

A comparative account of the Length–Weight relationship computation of constant parameters 'a' and 'b', correlation coefficient (r^2) obtained for the males, females and combined specimens of *S. tumbil* and *S. undosquamis* is furnished in Table 1. From the table, it was observed that in *S. tumbil* the value of exponent 'b' was marginally lower in the females (b= 2.9174) than in the males (b =3.0181) whereas for combined samples of both sexes 'b' was found to be 2.9788 in *S. tumbil.* The correlation coefficient 'r^2' calculated was 0.9463 for males and 0.9397 females and 0.9442 for combined samples in *S. tumbil*. The value of exponent 'b' was marginally higher in females (b= 3.2184) than in males (b =3.0344) whereas for combined samples of both sexes 'b' was found to be 3.1227 in *S. undosquamis.* The correlation coefficient 'r^2' was 0.9419 for males, 0.9496 females and 0.9468 for combined samples indicating a high degree of association between the length and weight in both sexes among both the species. The values of 'b' for *S. tumbil* and *S. undosquamis* derived in the present study 2.9788 and 3.1227 respectively. These values are very close to 3 which indicate that both the species are showing isometric growth and following the cube law.

Month-wise summerised results obtained from Bhattacharya analysis provided number of cohorts in each sample and mean length of the cohort. In case of *S. tumbil*, the maximum mean length recorded in the study was 44.79 cm in May 2012 followed by 44.77 cm in August 2011 and 39.64 cm in March 2010 and the minimum mean length was observed at 20.73 cm in April 2011 and 20.77 cm in December 2010. The maximum mean length observed for *S. undosquamis* was 29.13 in February 2011 followed by 29.10 cm in June 2010 and 27.10 cm in March 2011 and the minimum mean length was reported at 16.44 cm in October 2012. In the model progression, the mean length of a series of samples obtained in Bhattacharya analysis was plotted against time axis. The mean lengths which compared to the same cohorts were connected and the same are presented in fig. 7 & fig. 8 for *S. tumbil* and *S. undosquamis* respectively.

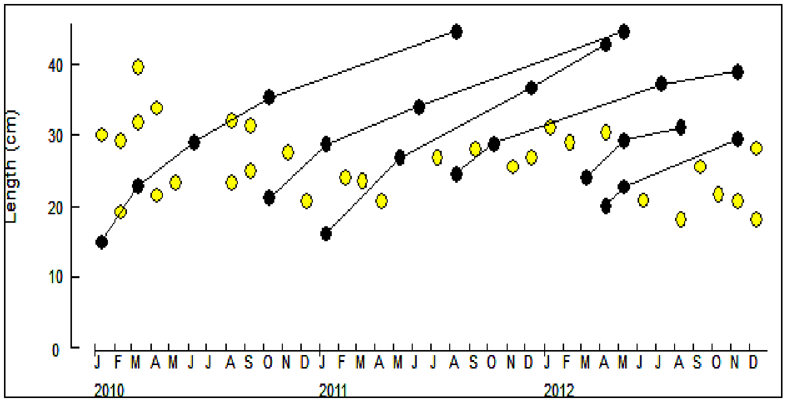

Fig 7: Model Progression in *S. tumbil*

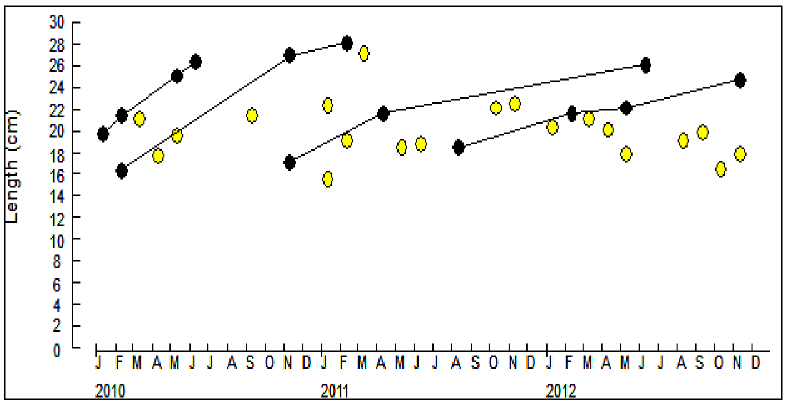

Fig 8: Model Progression in *S. undosquamis*

The results obtained by the Bhattacharya analysis and model progression and Van Bertalanffy equation were computed to describe the linear relationship and the values of a, b, L∞ and K were drawn as 38.64, 0.729, 53.00 cm and 0.729 year^{-1} for *S. tumbil* while for *S. undosquamis* it was estimated as 21.78, 0.531, 41.00 cm and 0.531 year^{-1} respectively and the graphs derived through Gulland and Holt plot are shown in fig.9 (*S. tumbil*) and fig. 10 (*S. undosquamis*).

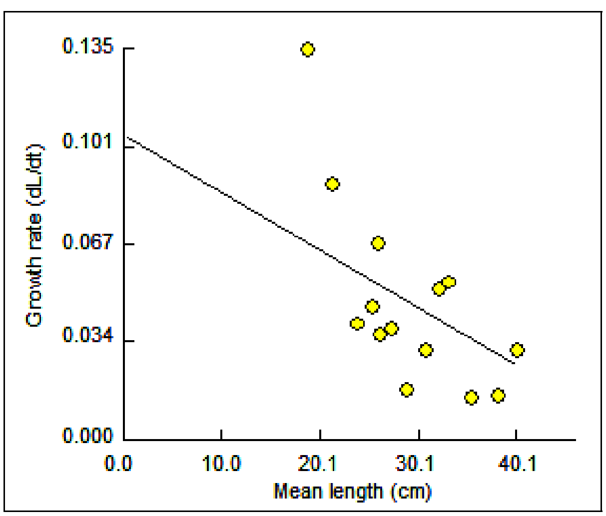

Fig 9: Gulland & Holt Plot for *S. tumbil*

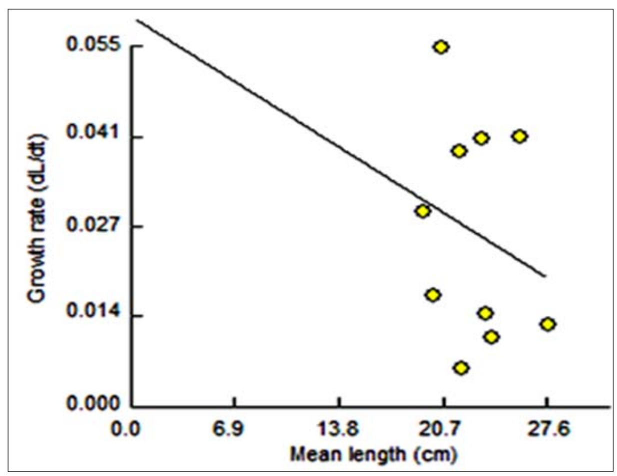

Fig 10: Gulland & Holt Plot for *S. undosquamis*

The length at age data shows that, the species *S. tumbil* indicated the minimum age of 0.5 years at the length range of 15.25 cm and maximum age of 8 years at the length range of 53.03 cm (fig.11) whereas, in case of *S. undosquamis* the size range at minimum age of 0.5 years was 13.46 cm and the maximum age of 8 years was 39.68 cm (fig. 12). The mean length of 34.14 cm was observed at the age of 1.75 years for *S. tumbil* and in case of *S. undosquamis*, 26.57 cm was observed at the age of 2.25 years. The restructured curves derived through VBGF are shown in fig. 13 for *S. tumbil* and fig. 14 for *S. undosquamis*. The growth parameters derived through different methods are given in table 2 for *S. tumbil* and for *S. undosquamis*.

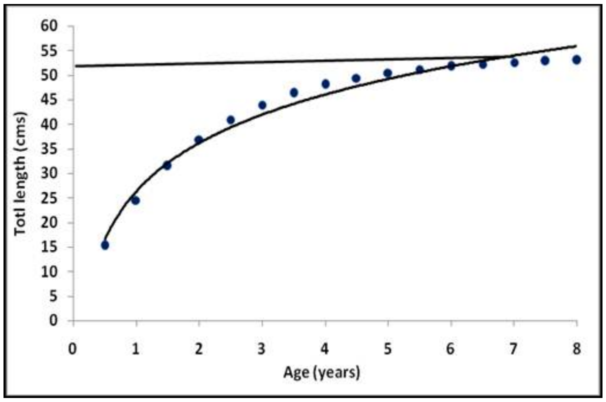

Fig 11: Von Bertalanffy growth curve for *S. tumbil*

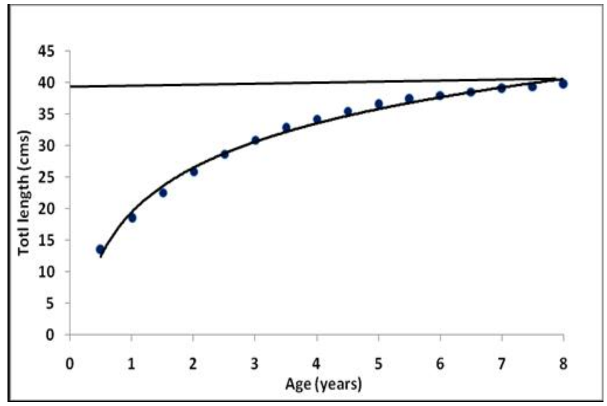

Fig 12: Von Bertalanffy growth curve for *S. undosquamis*

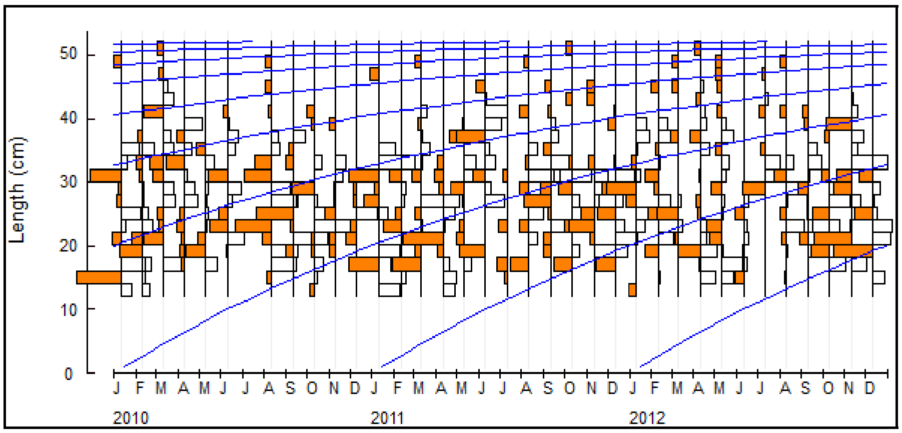

Fig 13: Restructured growth curve of *S. tumbil*

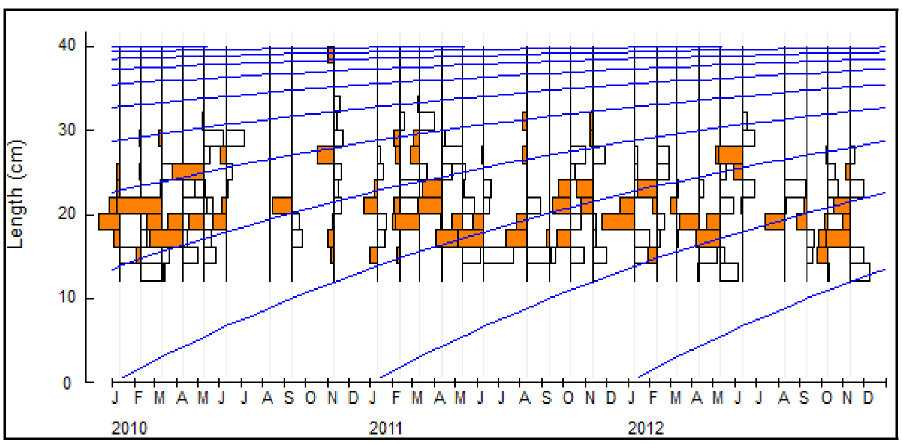

Fig 14: Restructured growth curve of *S. undosquamis*

Table 2: Comparative growth parameters by different methods

Methods	L∞ (cm)	K	t_o
S. tumbil			
Gulland and Holt plot	53.00	0.729	-
von Bertalanffy plot	53.65	0.470	-1.097
S. undosquamis			
Gulland and Holt plot	41.00	0.531	-
von Bertalanffy plot	41.05	0.400	-0.493

As per the above derived values, it is indicated that the L∞ value is more or less same whereas in K value, variations are observed in both the species. The 'K' values obtained in the present study indicate that the *Saurida undosquamis* is slow growing fish when compared to *Saurida tumbil*.

The natural mortality (M) is estimated based on Pauly's empirical equation which is 1.195 year^{-1} (*S. tumbil*) and 1.043 year^{-1}(*S. undosquamis*). The total mortality values derived through linearised catch curve based on length composition data. The values of Z estimated as 2.71 year^{-1} (*S. tumbil*) and 2.78 year^{-1}(*S. undosquamis*) and are shown in fig. 15 and 16. The fishing mortality (F) for *S. tumbil* 1.515 year^{-1} and 1.737 year^{-1} for *S. undosquamis* was obtained. The exploitation rate E= F/Z derived in the study is 0.56 year^{-1} and 0.62 year^{-1} for *S. tumbil* and *S. undosquamis* respectively. The M/K ratio obtained in the present study is 1.6 (*S. tumbil*) and 1.9 (*S. undosquamis*).

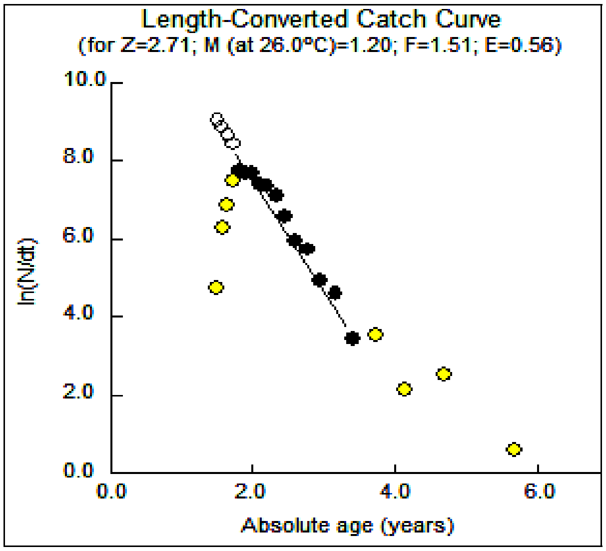

Fig 15: Linearised catch curve based on length frequency of *S. tumbil*

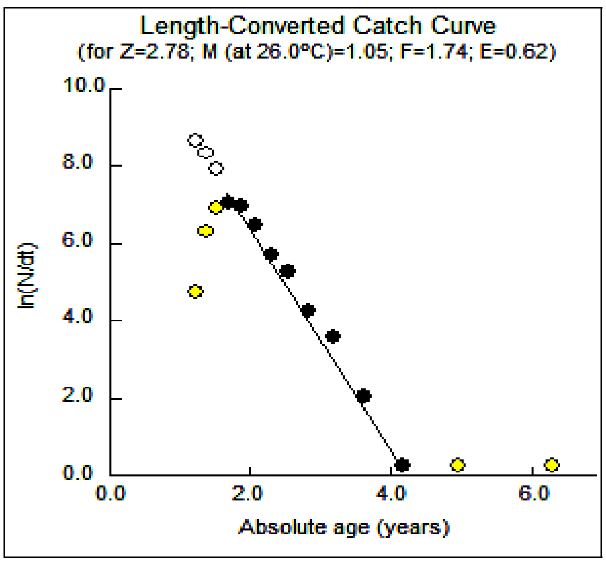

Fig 16: Linearised catch curve based on length frequency of *S. undosquamis*

4. Discussion

The length weight and growth studies have been undertaken by various researchers on lizardfishes. The values calculated for exponent 'b' in the present study for males and females in *S. tumbil* was 3.0181 and 2.9174 while for *S. undosquamis*, it was 3.0344 and 3.2184 respectively which is almost similar to the results obtained by Rao (*S. tumbil*, 3.2018 and 3.2957/ *S. undosquamis*, 3.0753 and 3.0271) from Visakhapatnam, East Coast of India. Rajkumar *et al.* (2003) [18] derived the value of 'b' for *S. undosquamis* as 3.115, 3.069 and 3.080 for males, females and pooled specimens along the East Coast. Raje *et al.* (2004) [20] reported the value of 'b' for males and females in *S. tumbil* as 2.86 and 2.97 respectively from Mumbai, West Coast of India which is almost similar to the values of the present study. The correlation coefficient r^2 value for the males and females of both the species were found as 0.92. Manojkumar & Sivakami (2005) [21] obtained a value of exponent 'b' for males, females and combined in *S. tumbil* as 3.1381, 3.1910 and 3.1522 respectively from Veraval Coast and the correlation coefficients for the male and female investigated were found as 0.99.

The growth coefficient K value obtained in the present study is 0.729 $year^{-1}$ (*S. tumbil*) which is almost similar to the values obtained by Ingles and Pauly, 1984 [7] (0.70 $year^{-1}$) from Philippines waters, Jaiswar *et al.*, 2003 [19] (0.73 $year^{-1}$) from Mumbai coast of India and Manojkumar and Sivakami (0.70 $year^{-1}$) from Veraval, North West Coast of India. The K value obtained for *S. undosquamis* was 0.531 $year^{-1}$ which is almost close to the value obtained by Chakraborthy *et al.* (0.51 $year^{-1}$) from west coast of India. The Phi prime (Ø) values derived by Ingles and Pauly (7.28 and 6.61), Chakraborty *et al.* (7.52 and 6.80) and Muthiah (7.54 and 6.72) and the present study Phi prime (Ø) values are 7.62 (*S. tumbil*) and 6.79 (*S. undosquamis*) which are comparable and reasonable.

The values for total mortality (Z) 2.71 year-1, natural mortality (M) 1.195 $year^{-1}$ and fishing mortality (F) 1.515 $year^{-1}$ was estimated for *S. tumbil which* is very similar to the values derived by Chakraborty *et al.* (2.80, 1.00 and 1.80) while for *S. undosquamis*, it was calculated as 2.78 $year^{-1}$, 1.043 $year^{-1}$ and 1.173 $year^{-1}$ respectively which was nearly similar to the values estimated by Chakraborty *et al.* (2.52, 1.10 and 1.42) along the Mumbai coast and Muthiah (2.62, 1.31 and 1.31) along the Karnataka coast of India. The exploitation rate (E) calculated for *S. tumbil* was 0.56 $year^{-1}$ and of *S. undosquamis* was 0.62 $year^{-1}$. The values estimated by Ingles and Pauly (0.65 $year^{-1}$), Chakraborty *et al.* (0.64 $year^{-1}$), Manojkumar and Sivakami (0.64 $year^{-1}$) in line to the values derived by Ingles and Pauly (0.65 $year^{-1}$), Rajkumar et al. (0.58 $year^{-1}$) and Chakraborty *et al.* (0.56 $year^{-1}$). Chakraborty *et al.* (2003) [19] was opined that the optimum exploitation rate (E) is at 0.5 $year^{-1}$ for both the species, which are in comparison with the values derived in the present study as the exploitation rate is closer to the optimum exploitation level.

5. Conclusion

In the present study, the values for *Saurida tumbil* and *S. undosquamis* derived from length weight relationship signifying that both the species showing isometric growth pattern. The L∞ and K values obtained in the present study indicate that both the species have fast growth in the first few years subsequently the growth rate slows down. This shows that these species are slow growing and long living. The value of 'M' for *S. tumbil* obtained was 1.195 $year^{-1}$ while in case of *S. undosquamis*, it was showing 1.043 $year^{-1}$ which gives an indication of intensive natural mortality and is moderately higher for both the species thereby, the catch of these species has shown fluctuating trends during the last ten years. The Exploitation rate (E) of *S. tumbil* was 0.56 $year^{-1}$ and of *S. undosquamis* was 0.62 $year^{-1}$ indicates that the fishery is close to the optimum rate of exploitation. Therefore, there is an urgent need to ensure sustainability of these resources through appropriate management interventions in the region as envisaged in the FAO Code of Conduct for Responsible Fisheries.

6. Acknowledgements

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