Growth, mortality, and stock assessment of brushtooth lizard fish *Saurida undosquamis* (Richardson, 1848) from Mumbai waters, northwest coast of India

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Stock characteristics *viz.* growth, mortality, and exploitation rate of *Saurida undosquamis* from Mumbai waters were studied based on commercial trawl landings during the period 2012-2015. Growth parameters ($L\infty$, K, and t_0) were estimated at 365 mm, 0.75 yr^{-1} and 0.00092 yr, respectively. Mortality parameters (Z, M, and F) were estimated at 4.70 yr^{-1}, 1.47 yr^{-1} and 3.23 yr^{-1} respectively. The longevity (t_{max}) was also estimated at 3.99 yr. The length at 1st capture (Lc_{50} = 159.25 mm) was found to be lower than length at first maturity (Lm_{50} = 206 mm). The current exploitation rate (E_{cur} = 0.69) clearly indicated that the species being overexploited. The bio-economic stock assessment model showed that at the present fishing level, there is depletion in the spawning stock biomass and also lower economic revenue from the fishery. Hence, reducing the effort would help to maintain the fishery at a sustainable level.

[**Keywords**: *Saurida undosquamis*; Growth; Mortality; Stock assessment; Spawning stock biomass]

Introduction

Lizard fishes (family Synodontidae) are one of the important demersal fishery resources along Indian coast contributing about 7.9 % of the total demersal landings during the year 2015[1]. They are caught by both single day and multiday trawls. Though considered as one of the supporting fishery, this group assumes importance by virtue of its high nutritive value and acceptance as food fish both in the fresh and dry condition. In Mumbai, lizard fishes are locally known as chor bombil and the fishery is dominated by three species viz. *Saurida tumbil, S. undosquamis,* and S. *gracilis. S. undosquamis,* commonly known as brushtooth lizard fish is widely distributed in tropical areas between 34^{0}N and 28 ^{0}S including the Indo-West Pacific, East to Southeast Asia and Australia[2]. It inhabits in muddy bottoms of continental shelf down to about 100 mt depth[3]. Studies on population dynamics of *S. undosquamis* from Indian waters is limited except for few[4-8]. In addition, the biology and dynamics of *S. undosquamis* have also been undertaken in different localities by several authors[9-23].

In the back drop of heavy exploitation and environmental degradation, a continuous assessment and monitoring programme is essential for sustainable management of fishery resources. In this context, the present study was conducted to estimate basic population parameters and current exploitation status of the brushtooth lizard fish relative to the sustainable reference point for providing requisite information on sustainable management of the fishery resources along Mumbai coast.

Materials and Methods

Length frequency data was collected on weekly basis from commercial catches at New Ferry Wharf landing centre (18^0 57′30″N, 72051′02″E) of Mumbai coast during September 2013 to June 2015 (Fig.1). Sampling was conducted on random selection covering the various size groups. Sample weight as well as the eye estimation of total catch of the species on the day of observation was recorded. Total length (from tip of the snout to the tip of the caudal fin) and weight of each specimen was measured to nearest mm and gm, respectively. Length–weight relationship was calculated according to the formula described by Le Cren[24]. The length frequency data were grouped into 10 mm class intervals and raised for the day and subsequently for the month following the standard method described by Sekharan (1962)[25].

Fig. 1 — Map showing New Ferry Wharf landing centre

Using FiSAT programme[26], the raised length frequency data were pooled for one year. The von Bortalanfy growth parameters *viz.* asymptotic length (L∞) and growth coefficient (K) were estimated by Bhattacharya method[27] and Gulland and Holt method[28]. The preliminary estimation of L∞ and K by Bhattacharya's method was further refined by Gulland and Holt's plot. The average length and weight at different age group was calculated by using von Bertanlaffy's growth equation and growth performance index (φ) was calculated by using formula: $\varphi = \log K + 2 \log L_\infty$[29]. The third parameter 't₀'of VBGF was estimated by reverse von Bertanlaffy's growth equation:

$-\ln [1-L_{(t)}/ L_\infty)] = -K*t_0 + K*t$. Longetivity was calculated from the equation, $t_{max}=3/K+t_0$[30].

Instantaneous total mortality coefficient (Z) was estimated by length converted catch curve[31]. The natural mortality coefficient (M) was estimated by Pauly's empirical formula[32] taking sea surface temp as 31^0C and fishing mortality (F) was calculated as F = Z-M. The exploitation rate (U) was estimated by applying equation $U = F/Z (1-e^{-z})$ and the exploitation ratio (E) was estimated as E = F/Z. Length structured virtual population analysis (VPA) of FiSAT II was carried out to obtain fishing mortalities for each length class.

The length at 1st capture was estimated by using trawl net selection curve and the optimum length of exploitation was calculated empirically from the equation $L_{opt} = 3L_\infty/3+M/K$[33]. Length at first maturity (L_m) *i.e.* the minimum size at which fish attains maturity was determined based on the examination of the maturity stages. Female specimens in stage III and above were considered as mature proportion of mature females for analysis. Percentage of cumulative frequency of matured female was plotted against the length groups. The size at which 50 % of fish population matured was considered as the length at first maturity.

For stock assessment, the relative yield per recruit (Y'/R) and relative biomass per recruit at different exploitation level were estimated by Beverton and Holt's relative yield per recruit analysis method[34] by using FiSAT II package. For setting management targets for brushtooth lizard fish along Mumbai coast, three important yield indices such as E_{max} (exploitation rate at Maximum Sustainable Yield), $E_{0.1}$ (exploitation rate at Maximum Economic Yield) and $E_{0.5}$ (Optimum Exploitation Rate) were estimated. yield (Y), biomass (B) and spawning stock biomass (SBB) was predicted at different fishing levels by using length based Thompson and Bell bio-economic model[35].

Results

Length–weight relationship

The total length of the sampled fish ranged from 12-31 cm while the total individual weights ranged between 7.5 and 380 g. The length–weight relationship of *S. undosquamis* was described by the power equation given in Table 1. High correlation was found between total length and total body weight for female (r = 0.94).

Age and growth

Employing Bhattacharya's method of FiSAT, L_∞ and K were estimated at 373.62 mm of 0.75 yr-1. Applying Gulland and Holt's plot, the value of growth parameters were further refined and estimated as L_∞=365, K=0.75. The growth performance index and t_0 were found to be 2.99 and 0.00092, respectively. The

Table no.1 (length-weight relationship of *S.undo*squamis)

Sex	TW=aTL^b	r
Male	TW=0.0000018TL$^{2.81}$	0.89
Female	TW=0.0000067TL$^{3.04}$	0.95
Pooled	TW=0.0000097TL$^{2.92}$	0.94

VBGF growth equation can be described as: $L_t = 365*(1-e^{-0.75 (t +-0.00092)}$. Using this equation in the 1st, 2nd and 3rd year the length of the fish was estimated at 192.47 mm, 283.50 mm and 326.50 mm, respectively. Longetivity of *S. undosquamis* was found to be 3.99 years. The growth increment curve showed that the maximum linear growth increment occurred by the end of the first year of life (192.5 mm), there after a gradual decrease in annual increments with a further increase in age was observed (Fig. 3). The average weight by the end of each year of life were estimated by using established length-weight relationship and it was noticed that, the annual growth increment in weight increased with a further increase in age. The maximum growth increment in weight occurred by end of 2nd year after which it showed a gradual decline with further increase in age (Fig. 3).

Instantaneous mortality rates, exploitation ratio and virtual population analysis

The estimation of mortality rates was applied to pooled sexes. The catch curve analysis based on

Pointer's parameters:
Mean: 199.5
No of Pairs:22
Cohort no:11

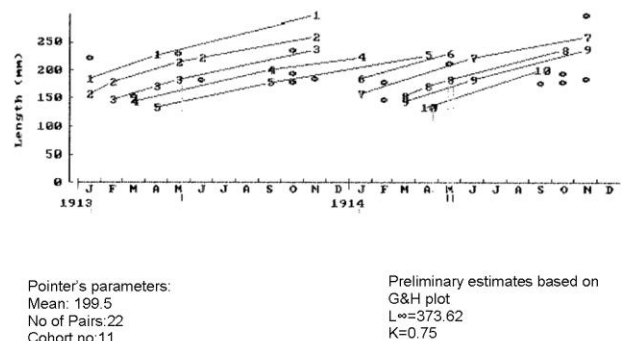Preliminary estimates based on G&H plot
L∞=373.62
K=0.75

Fig. 2 — Linking of means employing Modal Progression Analysis (Bhattacharya's method) for *S. undosquamis* using FiSAT
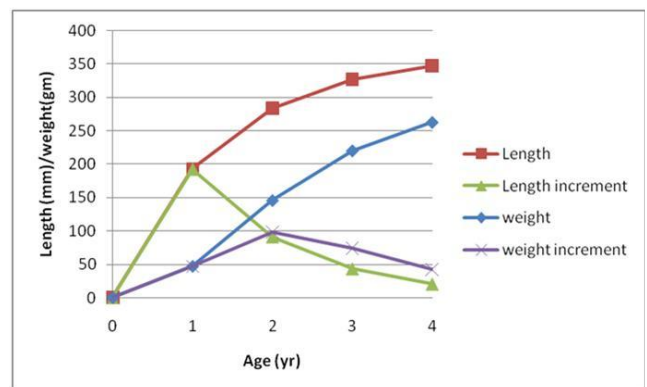

Fig.3 Growth (Length, weight) and growth increment (Length and weight) at the end of each year of *S. undosquamis*

length distribution was used and total mortality (Z) was found to be 4.70/year (Fig. 4). By using Pauly equation the natural mortality was estimated to be 1.47/year. Fishing mortality estimated as Z-M = 4.70-1.47 = 3.23/yr. The current exploitation ratio and exploitation rate were estimated to be 0.69 and 0.67, respectively. Length structured virtual population analysis was carried out by using the input parameters of L_∞ (365 mm), K (0.75 yr^{-1}), M (1.47 yr^{-1}), terminal F/Z as 0.6, and length weight parameters (in gm, cm): a (0.00081) and b (2.925). It showed that highest F of 4.02 was in the length group of 230-240 mm and fishing mortality was high for length groups 170-179 to 240-249 mm. The mean exploitation ratio (E) and fishing mortality for the whole length groups were estimated at 0.442 and 0.165, respectively (Fig. 5).

Length at 1st capture, length at optimum capture, and length at 1st maturity

The length at 1st capture of *S. undosquamis* was estimated at 159.25 mm (Fig. 6) while the L_{opt} was 220.76 mm. The length at first sexual maturity in the Mumbai coast during the period of study was obtained as 206 mm.
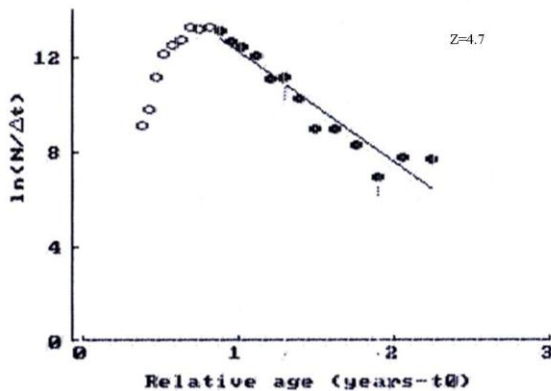
Stock assessment

"Selection ogive" was used for the analysis of relative yield per recruitment and biomass per recruit. Analysis showed that maximum allowable limit of exploitation rate that gives maximum relative yield per recruit was estimated at 0.57 and also the exploitation level which maintains the spawning stock biomass at 50% of the virgin stock biomass *i.e* $E_{0.5}$ at 0.33 (Fig.7). Similarly $E_{0.1}$ (the exploitation at which marginal increase in relative yield per recruit is 10% of its value at E=0) which generally corresponds to a precautionary safe level was found to be 0.55. However, current exploitation rate is higher than the above three estimated yield indices used for management targets. The yield isopleths diagram indicates that eumetric fishing can be done at L_{C50}/L_∞ of 0.44 and exploitation rate of 0.6 (Fig.8).

The length based Thompson and Bell bio-economic model[35] was used to predict the value of yield, biomass, spawning stock biomass and value of yield as a function of fishing mortality factor which is considered as a percentage of the current fishing mortality. It showed that exploitation of the resource has already reached the maximum sustainable yield (2669.3t) at the current effort level where as maximum economic yield can be obtained at fishing level of 0.6 (Fig. 9).
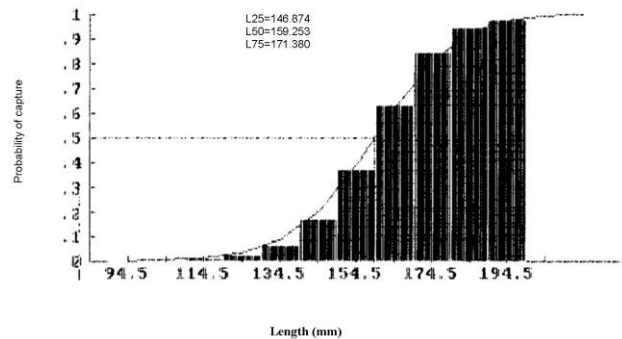

Fig. 4 — Length converted catch curve for estimation of Z

Fig.6 — Trawl net selection curve to determine length at First capture for *S. Undosquamis*
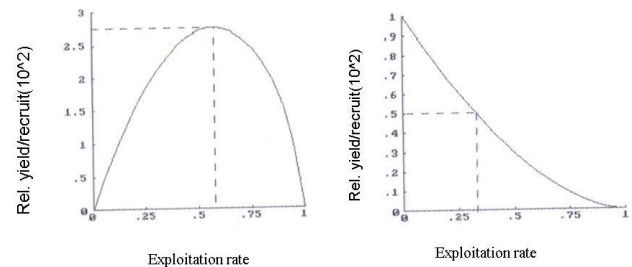

Fig.5 — Length structured VPA for *S.undosquamis*

Fig.7 — Relative yield per recruit and relative biomass per recruit using selection ogive
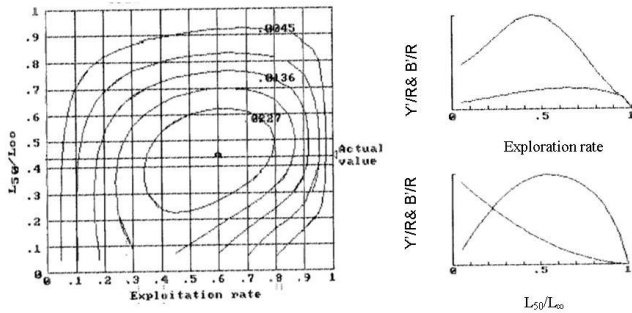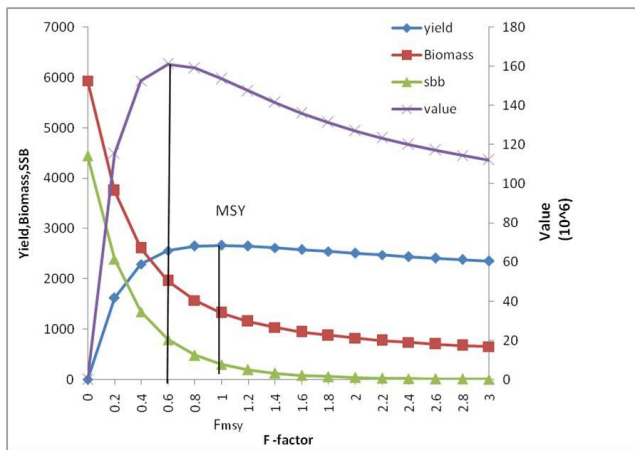
Fig. 8 — Yield isopleths diagram of *S.undosquamis*

Fig. 9— Length based Thompson and Bell analysis of *S. Undosquamis*

Discussion

The "b" value in length-weight relationship of *S. undosquamis* is expressed as $TW=0.0000018TL^{2.81}$, $TW=0.0000067TL^{3.04}$, $TW=0.0000097TL^{2.92}$ for male, female and pooled sexes, respectively. The value of "b" generally ranges between 2.5 to 3.5 and the relation is said to be isometric when b=3[36]. Growth is said to be positive allometric when b > 3 and negative allometric when b <3[37]. Present study indicates that females showed isometric growth (b = 3.04) while male and pooled sexes were characterized by slight negative allometric growth (b = 2.81 for male and 2.92 for -pooled sexes). Also, observed slight negative allometrc growth in *S. undosquamis* in the Egyptian Mediterranean coast[23]. Along Indian coast, length-weight relationship of *S. undosquamis* was studied by different authors[4,6]. They also observed different rate of increase in weight in relation to length for both the sexes.

The growth parameters of *S. undosquamis*, L∞ and K were estimated as 365mm and 0.75/yr, respectively. The values of L∞, K recorded by earlier studies were ranging from 305-518 mm and 0.13-0.8/yr for pooled sexes, respectively (Table 2)[4-23]. The current estimated value of "L∞" was found to be on lower side and "K" value on higher side than the most of the earlier studies in Indian water except Mumbai coast[6] and Karnataka coast[8]. Such variations may be due to variations in environmental conditions as well as the

Table no.2 — Stock parameters of *S. undosquamis* from earlier studies

Authors and area of study	K (yr-1)	L∞ (mm)	E	M (yr-1)	F (yr-1)	Z (yr-1)
Ingles and Pauly,1984, Philippines	0.80	305	0.62	1.54	2.53	4.07
Bingel,1987, Mersin Bay	-	-	-	0.26	0.81	1.07
Ts-Shiang et al.1987. Australia	0.121	889	-	-	-	-
Chakraborty *et al.* 1994, Maharashtra	0.51	420	0.56	1.10	1.42	2.52
Muthaiah, 1996, Karnataka	0.64	360	0.5	1.31	1.31	2.62
Yoneda et al., 2002Japan	0.16	518	-	-	-	-
Rajkumar et al., 2003, Visakhapatnam	0.31	395	0.58	1.05	0.76	1.81
Gookce et al., 2007 Turkey	0.51	42	-	-	-	-
Amin et al., 2007 Gulf of Suez	0.44	315.6	-	-	-	-
El-Halfawy et al., 2007Gulf of Suez	0.26	355.6	-	-	-	-
Metar et al., 2011,Mumbai	0.87	346	0.53	1.51	1.91	3.48
Manasirli et al. 2011 Turkey	0.118	415.7	0.47	0.40	0.363	0.766
Cicek and Avsar., 2011, Turkey	0.124	380.5	-	0.35	1.42	1.77
Raje et al ., 2012, Mumbai	0.57	392	-	-	-	-
Wang ehui et al., 2012 ,China	0.52	34	-	-	-	-
El-Etreby et al., 2013,Gulf of Suez	0.131	512.5	-	-	-	-
Mahmoud et al., 2014,Egyptian Medit	0.232	417.7	0.61	0.36	0.575	0.938
Present study	**0.75**	**365**	**0.67**	**1.47**	**3.23**	**4.70**

sampling limitation or biasness such as L_{max} in sample.

The average annual total mortality (Z), natural mortality (M), and fishing mortality (F) were estimated to be 4.7, 1.47, and 3.23 respectively. The mortality parameters estimated in previous studies were tabulated in Table 2. The current estimated value of average annual mortality is quite higher than the earlier reports[4,5,6,8,9,19,20,23]. The possible reason for this may be due to intensive fishing pressure to which these resources are subjected to at present. However, present estimated value of "Z" is found to be in agreement with the findings of Ingles and Pauly[8]. The estimated natural mortality can be compared with the earlier studies[4,5,6,8,9,19,20,23]. The variation in natural mortality within species in different areas may be due to density dependent factor (prey predation relationship in the ecosystem) as well as density independent factors such as disease, natural calamities. The M/K ratio for *S. undosquamis* falls within the range suggested by Breverton and Holt[38] which indicates the reasonable estimation of "M" in the present study. The current exploitation rate (E_{curr}) is significantly higher than optimum exploitation rate *i.e* 0.5 described by Gulland[39] for sustainable fisheries management which indicates that brushtooth lizard fish is in overexploitation phase in Mumbai water which calls for immediate management measures for betterment of stock. This species was also reported to be over exploited by earlier studies[5,7] along Indian coast.

The length at first maturity (Lm) is an important index in fisheries stock assessment. The length at which 50% of the population attain 1st sexual maturity was investigated to be 206 mm for females which is found to be in agreement with Muthiah[8] who estimated L_m=207 mm from Karnataka waters. However, the present estimated Lm value is lower than the L_m estimated from Visakhapatnam waters[5] and from Northwest of Bay of Bengal water[40]. The length at first maturity is used to determine minimum legal size which should be avoided in fishing net to maintain adequate spawning stock in the population. The length at 1st capture (L_c) corresponding to the length at which 50 % of the population are vulnerable to capture estimated for *S. undosquamis* was estimated to be 159.25 mm and the length of *S. undosquamis* which gives maximum possible yield i.e L_{opt} was calculated to be 220 mm. The present study indicates $L_c<L_m<L_{opt}$ for *S. undosquamis* in Mumbai waters. So, it is obvious to conclude that juveniles *of S. undosquamis* are caught before reaching their

length at 1st sexual maturity along Mumbai coast. As "L_c" is influenced by cod end mesh size of trawl net, it is recommended to increase the cod end mesh size of trawl net thereby giving at least one chance to all the individuals to mature and spawn.

In management context, biological reference points are the performance indicator of fish stock in question. It often takes various stock dynamics parameters i.e growth, recruitment and mortality, usually including fishing mortality into consideration and reflects into a single index. Analysis of the relative yield per recruit (Y^1/R) and relative biomass per recruit (B'/R) of *S. undosquamis* using selection ogive shows that present exploitation rate is higher than (0.67) than E_{max} (0.57), $E_{0.1}$ (0.55) and $E_{0.5}$ (0.33). Considering above yield indices, in any case the total exploitation rate of brushtooth lizard fish population should not exceed 0.57 as there after it shows declining trend. $E_{0.1}$ is generally preferred to E_{max} as biological reference point for long term fisheries management of any fish stock. The exploitation rate can be reduced up to 0.33 to maintain optimum yield and biomass per recruit current exploitation rate is higher than earlier reports[4,5,6,8].

The yield isopleths diagram shows that eumetric fishing can be done at L_{C50}/L_∞ of 0.44 and exploitation rate of 0.6. However, this value of L_{C50}/L_∞ cannot be recommended as it can cause recruitment overfishing ($L_c< L_m$). However, above yield indices are computed without regard to whether sufficient spawning stock biomass is conserved to maintain recruitment in the future[41].

Studies on spawning stock biomass per recruit are essential for effective fisheries management and it can be used as TRP for fisheries management. Taking spawning stock biomass as a biological reference point, it is always advisable to maintain the spawning stock biomass at 20 % and 30 % for well known stocks with average resilience and poorly understood species respectively[42]. However, when relation between SSB and recruitment cannot be statistically established, SSBR is maintained between 20-30 % of virgin stock to prevent recruitment overfishing[43]. Thompson and Bell Bioeconomic analysis shows that current fishing level F_{max} has already declined drastically the initial biomass to 26 % and spawning stock biomass to 11 % , putting population at risk (Fig. 10). Therefore, there is a need to maintain spawning stock biomass above 20 % since the relationship between stock and recruitment is not clearly established in present study. Considering this
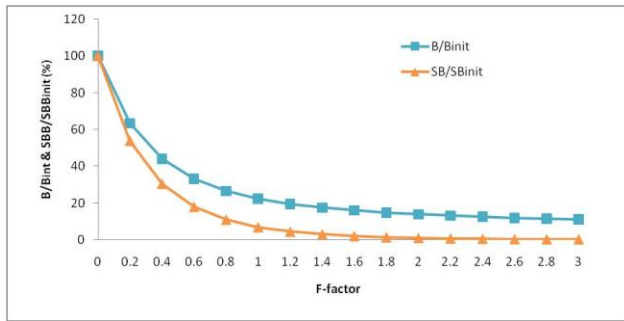
Fig.10 — Percentage of initial biomass and spawning stock biomass at different level of F

spawning stock biomass can be maintained by decreasing fishing effort by 40 %.

The basic purpose of fisheries management is to ensure sustainable production over time preferably through regulatory and enhancement action. Reducing fish stocks to biologically and ecologically detrimental levels will affect economic and social well being of fishermen, both immediately and in long term. The present study gives a clear information on status of brushtooth lizard fish along Mumbai coast. To improve the current stock status and sustain the stock of *S. undosquamis* in Mumbai waters, it is recommended to reduce fishing effort and to increase trawl cod end mesh size.

Acknowledgement

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