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RESEARCH ARTICLE

Stock dynamics of the brushtooth lizardfish *Saurida undosquamis* (Richardson, 1848) from a tropical multispecies fishery in the southeastern Arabian Sea

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Abstract – The brushtooth lizardfish *Saurida undosquamis* (Richardson, 1848) is a high trophic level benthic predator and is one among the most exploited demersal finfish species from eastern Arabian Sea by Indian trawlers. However, in recent years, the landings of many top predator fishes including *S. undosquamis* showed a declining trend resulting in a steady decline in the mean trophic levels of the fishes caught commercially in the region. We investigated the growth, mortality and stock dynamics of *S. undosquamis* harvested by mechanised trawls in the southeastern Arabian Sea, using length-based methods for the data collected during 2012–2016. Besides, Bayesian state-space implementation of the Schaefer model (BSM) and catch-based MSY (CMSY) estimation were also made using the data for the period 1985–2016. Total length of the fish ranged from 5.5 to 34.5 cm with average annual mean length of 22.0 cm during 2012–2016. The growth parameters L_∞ and K were 37.3 cm and 0.41 year^{-1}, respectively. The natural, fishing and total mortality coefficients were 0.92, 2.58 and 3.5, respectively and exploitation ratio was 0.82. The length at first maturity was estimated at 21.4 cm for females. The mean size in the catch is lower than the optimum length for exploitation. Fisheries reference points (MSY, F_{msy}, B_{msy}) as well as relative stock size (B/B_{msy}) and exploitation (F/F_{msy}) estimated from catch data and broad priors for resilience (r), implies an exploitation of 30% below B_{msy} level. Results from the length-based Thompson and Bell prediction model indicates that reducing the present level of fishing effort by 40% would lead to a harvest of the species at a sustainable level. As “fishing down food web” is reported in recent years from eastern Arabian Sea, the exploitation of top predators need to be maintained at sustainable levels to prevent ecosystem changes along the region.

Keywords: Bayesian Schaefer Model / exploitation / trophic level / lizardfish / population dynamics / southeastern Arabian Sea

1 Introduction

The tropical marine fishery in the southeastern Arabian Sea, bordered by coastal districts of the southwest coast of India, is characterised by the harvest of multi-species assemblages of finfish and shellfish groups employing multiple craft-gear combinations, with a dominance of mechanised multiday trawlnet operations (Vivekanandan et al., 2003). There is a notable shift in the target resources of trawlers in recent years from high value groups such as penaeid prawns to relatively low valued demersal finfish resources (Vivekanandan et al., 2005; Najmudeen et al., 2014). Among the four coastal zones of seas around India, viz., southeastern and northeastern Arabian Sea, southern and northern Bay of Bengal, the southeastern Arabian Sea in the west coast of India is one of the most productive regions in the world oceans due to several physical and chemical processes (Prasanna Kumar et al., 2002). The zonation is made based on the ecological assemblages appear in the commercial fish landings in each zone (Vivekanandan et al., 2005). The difference in trends of the fishery between the coastal zones is due to the innate differences in the productivity between the coastal zones.

Lizardfishes, belonging to the family Scopielidae, are one of the prospective demersal fishery resources of the southeastern Arabian Sea, harvested mainly by trawl nets

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throughout the year with the peak fishery during August–September. Vivekanandan et al. (2009) reported a mean trophic level of 4.30 for lizardfishes and grouped them as top predators. The average annual catch of lizardfishes from the region amounts to 33300 tonnes which forms 40% of the total lizardfish landings of the southwest coast of India. *Saurida undosquamis*, commonly known as the brushtooth lizardfish, distributed all along the Indian coastal waters and forms a major demersal fishery in all maritime regions of India except the northern Bay of Bengal. Nearly 45% of the lizardfish landings of eastern Arabian Sea comprised of *S. undosquamis*, which are landed either as juveniles or adults and fetches reasonable price in the local market. Though some aspects of the biology of this species have been studied and reported from the southeastern Arabian Sea (Sivakami, 1999; Nansimole et al., 2014), knowledge on the stock dynamics and recruitment pattern of *S. undosquamis* is scarce except that of the limited reports available from other tropical maritime regions (Ingles and Pauly, 1984; Rajkumar et al., 2003; Cicek and Avsar, 2011; Metar et al., 2011; Wang et al., 2012; Mahmoud et al., 2014).

One of the basic requirements for scientific fisheries management is availability of consistent and adequate data on the stock size of the resources and their dynamics. The length-based models for fish stock assessment existing today are basically those designed for the temperate stocks, nevertheless, these are invariably applied in tropical fish stock assessments as well (Vivekanandan, 2005). Froese et al. (2017) presented Bayesian state-space implementation of the Schaefer model (BSM) and catch-based MSY (CMSY) analysis for the estimation of relative stock size and exploitation in data poor situations, which is suggested to be a possible alternative for the assessment of tropical Indian fish stocks where adequate data is not available to apply micro-analytical models of stock assessment. However, proper validation is essential prior to attempting CMSY analysis for Indian stocks. Vivekanandan et al. (2005) noted that the southeastern Arabian Sea remains as a distinct entity with the lowest mean trophic value (3.14), compared to the other three regions of seas around the coast of India. The fishing down to food web resulted in ecosystem changes owing to intensive fishing pressure along the region, which led to the depletion of catches of many top predator species during the last decade, including *S. undosquamis*. As there was no published report on the stock status and fishery dynamics of the top predator species *S. undosquamis* in the southeastern Arabian Sea, the present study aimed to provide an insight into the growth and stock dynamics of *S. undosquamis* caught by trawlers. The study also aimed at exploring the suitability of the use of Bayesian Schaefer model and catch-based CMSY method in estimating relative stock size and exploitation of tropical Indian stocks by comparing the results of the stock assessment of *S. undosquamis* using length-based methods.

2 Materials and methods

2.1 Data sources

The catch in tonnes and the fishing effort data in hours of trawling for the harvest of *Saurida undosquamis* by mechanised trawlers operating in the southeastern Arabian Sea were collected from major fish landing centres along the state of Kerala bordering southeastern Arabian Sea for a period of five years from 2012–2016 following the stratified multistage random sampling design (Srinath et al., 2005). For applying micro analytical models for stock assessment, 5012 numbers of *S. undosquamis* in the size range of 55 to 345 mm in total length were collected during 2012–2016 by weekly random sampling from the fish landing centres and the total length in centimetres (cm) were measured to the nearest 0.01 cm and the weight (g) recorded for each individual specimen.

2.2 Growth models

The von Bertalanffy growth parameters viz., asymptotic length (L_∞), growth co-efficient (K) and age at zero length t_0, which are the most important inputs for modelling tropical fish stock dynamics, were estimated using the monthly data on length measurements of *S. undosquamis*. The total length (cm) were pooled and grouped into 1 cm class interval, and analysed using the ELEFAN I module of FiSAT software (Gayanilo et al., 1996). The length-based growth performance index (Ø) was calculated from the final estimates of L_∞ and K (Pauly and Munro, 1984). Length corresponding to the first value in the descending limb of the length converted catch curve was taken as the length at first capture (L_c). The age at zero length (t_0) was calculated from Pauly's (1979) empirical equation,

$\mathrm{Log}\ (-t_0) = -0.392 - 0.275\ \mathrm{Log}\ L_\infty - 1.038\,K.$

The growth and age were estimated using the von Bertalanffy growth equation,

$$L_t = L_\infty \left(1 - \mathrm{e}^{-k(t - t_0)}\right).$$

Natural mortality (M) was estimated using Pauly's empirical formula (Pauly, 1980), using 27 °C as the mean sea temperature. Total mortality (Z) and exploitation rate (E) were estimated from the length converted catch curve using FiSAT Software and exploitation rate (U) from the relation $U = F/Z \times (1 - e^{-Z})$; where, F is the fishing mortality (Pauly, 1983a), which was estimated by F = Z−M. The exploitation ratio (E) was estimated using the equation E = F/Z. The longevity t_{max} was estimated from the equation of Pauly (1983b). 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 (MSY) was calculated by the equation (Gulland, 1979) for exploited fish stocks, MSY = Z × 0.5 × B.

The size at first maturity (L_m), which is the size at which 50% of the population attains sexual maturity was determined from 750 female specimens by fitting sigmoid curves to the proportion mature by length applying logistic regression model using the software WinBUGS, for Byesian analysis using Markov Chain Monte Carlo (MCMC) (Sathianandan and Mohamed, 2014).

2.3 Stock dynamics and MSY estimates

The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F were estimated using LFSA package (Sparre, 1987) from Beverton and Holt yield per recruit model. The yield and biomass at different multiples of

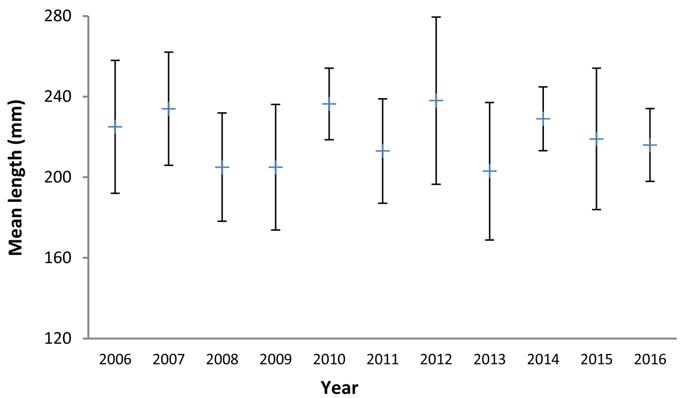

Fig. 1. Average annual mean length (mean ± SD) of *S. undosquamis* harvested by trawl nets along the southeastern Arabian Sea during 2006–2016.

F, MSY were also estimated using the Thompson Bell yield prediction models. Monthly and annual recruitment numbers and spawning stock biomass were estimated using length-based virtual population analysis (VPA).

Catch-MSY (CMSY) analysis and Bayesian state-space implementation of Schaefer model (BSM) (Froese et al., 2017) was applied to estimate fisheries reference points (MSY, F_{msy}, B_{msy}) as well as relative stock size (B/B_{msy}) and exploitation (F/F_{msy}), using catch and effort data of *S. undosquamis* harvested by trawlers for the period 1985–2016 from southeastern Arabian Sea. For this, catch and effort data were collected following the Stratified Multistage Random Sampling method (Srinath et al., 2005) to estimate the marine fish landings and available at the National Marine Fisheries Data Centre of CMFRI. CMSY/BSM analysis was run in R software module with a resilience value corresponding to "moderate resilience" adapted from FishBase (Froese and Pauly, 2018).

3 Results

The average annual harvest of *Saurida undosquamis* from the southeastern Arabian Sea during 2006–2016 was 5305 tonnes, which formed 43.8% of total lizardfish catches of the region. Fishery observed throughout the year and the most productive season was August–September period. The size range in the samples collected from trawl catches during 2012–2016 was 5.5–34.5 cm. The annual mean length of *S. undosquamis* in the fishery ranged from 20.3 cm in 2013 to 23.8 cm in 2012 (Fig. 1), with an average annual mean length of 22.0 cm in the catch by trawls. Monthly average mean length in the fishery ranged from 18.4 to 25.4 cm with the highest mean length recorded in August, immediately after ending the seasonal closure for mechanised fishing in the region. The length at first maturity, at which 50% of the animals are mature, was estimated at 21.4 cm for females (Fig. 2). However, gonadal development and sexual maturity in the individuals of the species was observed to commence from 15 cm onwards.

3.1 Population characteristics

The growth parameters L_∞ and K were 37.3 cm and 0.41 year^{-1}, respectively (Fig. 3) and the length attained at the end of 1,2,3,4 and 5 year/s were 12.5, 20.9, 26.4, 3.1 and 32.5 cm, respectively (Fig. 4). The growth performance index ($\acute{\varnothing}$) was 2.92 and the longevity was 7.3 years. The asymptotic weight (W_∞) estimated was 376 g and the length at first capture of the species (L_c) was 14.9 cm at an age (t_c) of 1.25 years.

The average instantaneous rate of natural mortality, fishing mortality and total mortality were 0.92, 2.88 and 3.5, respectively (Fig. 5). The exploitation rate (U) of *S. undosquamis* in southeastern Arabian Sea was 0.85 and exploitation ratio (E) was 0.82. The length at recruitment (L_r) was 8.5 cm at an age (t_r) of 0.63 years. The optimum size for exploitation (L_{opt}) is at 22.5 cm at the age (t_{opt}) of 2.3 years.

3.2 Estimation of stock, MSY and Yield-per-recruit using length-based models

The yield and biomass curves using Thompson and Bell prediction model showed that the maximum biomass and yield/recruit could be obtained at an *F* factor of 0.6 from the present fishing effort (Fig. 6). The yield-per-recruit of *S. undosquamis* increases rapidly with the increase in fishing mortality reaching a maximum value of 35.52 g at its optimum effort, after which the yield-per-recruit was more or less stable with further increase in fishing mortality. The maximum sustainable yield and yield per recruit obtained by reducing the present fishing effort is 5738 t and 35.52 g, whereas at the present level of fishing, it is 5342 t and 32.27 g, respectively. The effect on different rates of exploitation and L_c values on the yield per recruit is explored and presented as a contour map (Fig. 7). To get optimum yield and biomass per recruit, the present fishing effort has to be reduced by 40%. The increase in relative yield at the reduced effort would be 7.41%.

The MSY estimated using Thompson and Bell prediction model was 5738 t. The annual spawning stock biomass of *S. undosquamis* estimated using length-based virtual population analysis (VPA) was 3017 t, which is 55% of the standing stock biomass. The annual recruitment number estimated was 171.3 million year^{-1}. Monthly recruitment pattern indicates that the peak months of recruitment are May and August with the lowest numbers observed in December.

3.3 Estimation of MSY, B/B_{msy} and F/F_{msy} using CMSY/BSM analysis

The medium resilience range from 0.2 to 0.8 in the current analysis is found reasonable because fewer viable *r*–*k* combinations are found at the upper end of the *r* range. There is a good overlap of the best *r*–*k* estimate from CMSY using only catch and resilience and from BSM analysis using catch and CPUE data (Fig. 8). The catch relative to MSY and relative to stock size from CMSY and BSM overlap and cluster around the equilibrium curve, providing confidence in the assessment (Fig. 9). The MSY estimated using CMSY/BSM analysis was 4950 t with a lower confidence limit (95%) of 4510 t and upper confidence limit of 5440 t (Tab. 1). The biomass estimates indicate that the B/B_{msy} stood a level > 1 during 1986–1993 then substantially reduced to a level below 0.5 in 2007 (Fig. 10). However, there was a gradual increase in the values from 2008 onwards and the B/B_{msy} in the last year of analysis was 0.705. The B/B_{msy} was 1.78 with a confidence

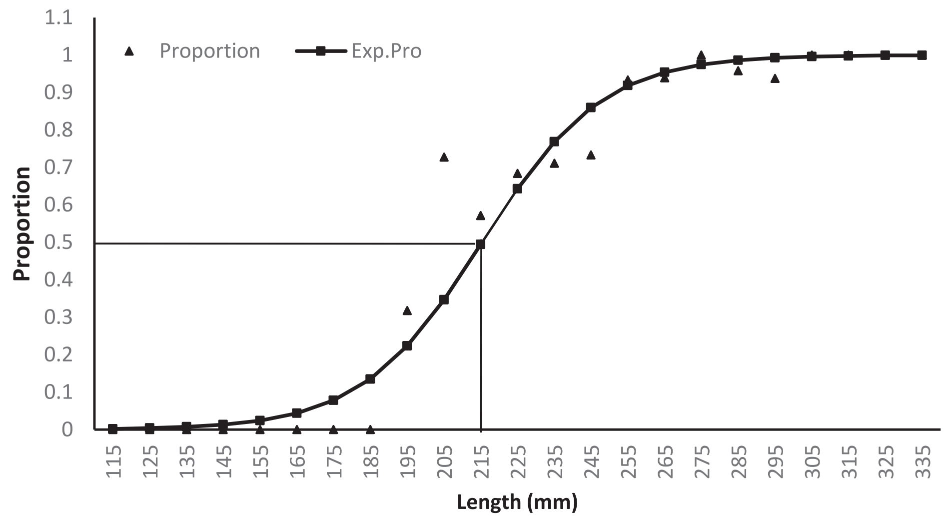

Fig. 2. Size at first maturity (L_m) among females of *S. undosquamis* from southeastern Arabian Sea.

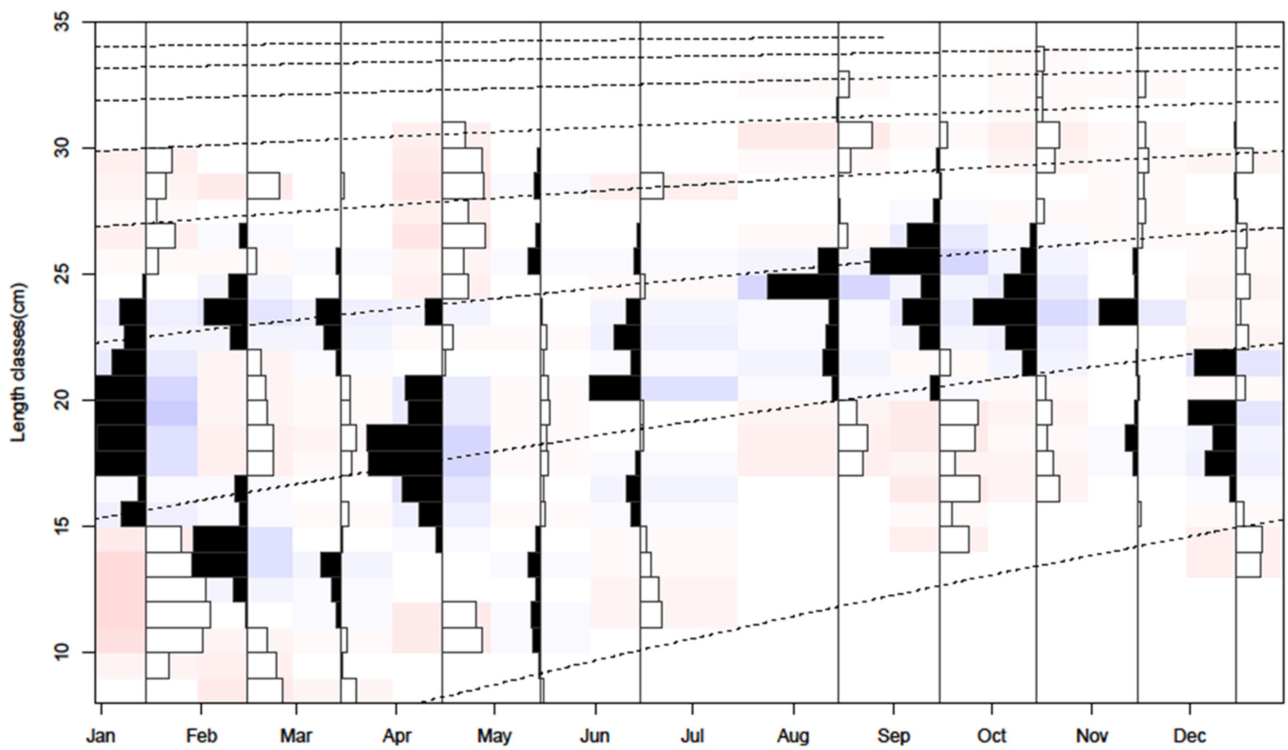

Fig. 3. von Bertalanffy growth curves estimated using restructured length-frequency data for *S. undosquamis* from southeastern Arabian Sea by ELEFAN I during 2012–2016.

limit of 1.26 to 2.62. The management-based BSM analysis indicates that the stock of *S. undosquamis* is either fully exploited or over-exploited in the southeastern Arabian Sea (Fig. 11).

4 Discussion

4.1 Growth parameters

Arabian Sea large marine ecosystem is considered as one among the highly productive ecosystems, in which the reported fish catch have remained relatively constant or shown increase over the past few decades (Desai and Bhargava, 1998; FAO, 2003). Lizardfishes form a potential demersal fishery in the southeastern Arabian Sea, for which good trawling grounds located north off Cochin along southwest coast of India (Bal and Rao, 1984). The expansion in vertical and horizontal fishing grounds of trawlers targeting demersal finfishes necessitates the appraisal of stock status of this important demersal finfish resource in the region. In the present study, age, growth and mortality parameters of *S. undosquamis* were estimated by employing length-based methods using the data

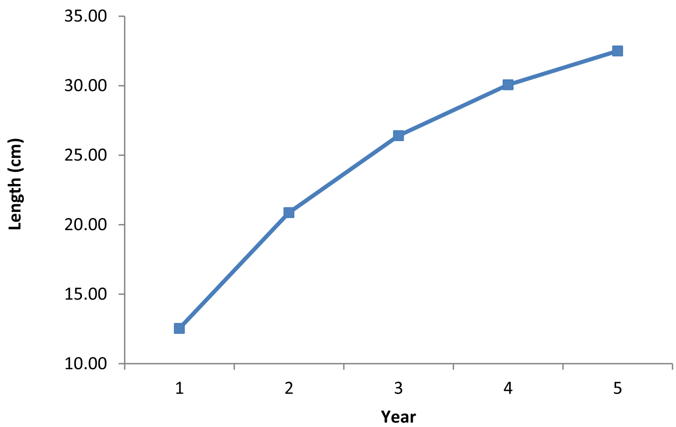

Fig. 4. Growth of *S. undosquamis* from southeastern Arabian Sea during different years.

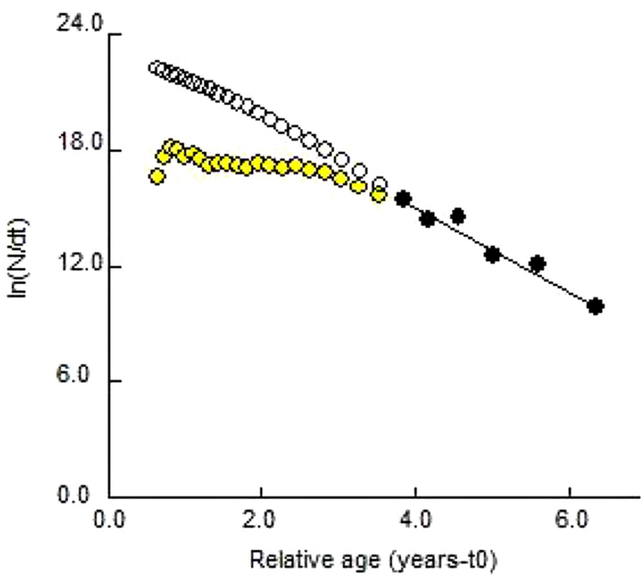

Fig. 5. Length converted catch curve for the estimation of mortality of *S. undosquamis* from southeastern Arabian Sea.

collected from commercial fisheries of the region. There are expected variations/differences in these parameters estimated using different methods and reported elsewhere. Most studies on growth and mortality parameters of *S. undosquamis* from different parts of the tropical oceans are based on the length frequency analyses (Chakraborty et al., 1997; Gokce et al., 2007; Wang et al., 2012; Mali et al., 2017). However, there are ample reports on age and growth determination based on the analysis of hard parts especially using otoliths (El Ganainy, 1992; Tureli and Erdem, 1997; Yoneda et al., 2002; Manasirli et al., 2011). The growth coefficient k for *S. undosquamis* determined by length-based methods ranged from 0.26 to 1.20 $year^{-1}$, on the other hand, the growth rate estimates using hard parts were lower compared to that obtained using length frequency data and ranged from 0.11 to 0.59 $year^{-1}$.

Previous findings on the growth rates of *S. undosquamis* along the coastal waters of India indicated that the specimens from the west coast, bordering northeastern Arabian Sea grow faster (Chakraborty et al., 1997; Mali et al., 2017), whereas in the northern Bay of Bengal, the species grows at a rate of 0.3 $year^{-1}$ (Rajkumar et al., 2003). It is likely that differences occur in growth rates and longevity among *Saurida* spp. with different geographical distributions (Yoneda et al., 2002). Monsoon upwelling resulting in constant replenishment of nutrients affect the plankton bloom giving better environment for high trophic productivity along southeastern Arabian sea (Ghosh et al., 2014) which may be the one of the reasons for increased growth rate of *S. undosquamis* in the region. This information on the growth rate of 0.41 $year^{-1}$ obtained for southeastern Arabian Sea stock of *S. undosquamis* is lower than that reported from other parts of Arabian Sea (Chakraborty et al., 1997; Mali et al., 2017). Similar range of K value estimates using length-based methods were also reported from other tropical seas including South China Sea (Wang et al., 2012), Gulf of Suez (Amin et al., 2007) eastern Mediterranean Sea (Gokce et al., 2007) and from Gulf of Thailand (Boonanich, 1991). Even though in most estimates of K values using hard parts of the species are much lower than that obtained using length-based methods, Tureli and Erdem (1997) reported a higher K value of 0.59 for *S. undosquamis* from eastern Mediterranean using otolith-based method.

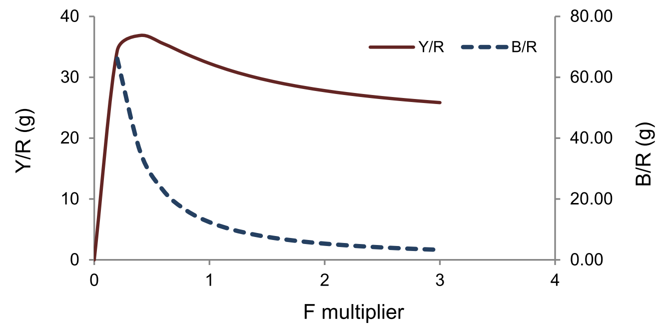

Fig. 6. Yield per recruit and biomass per recruit for *S. undosquamis* at different multiples of fishing mortality (F) using Thompson and Bell Prediction model.

Beverton and Holt (1957) pointed out that 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. Similar observations were made in the case of *S. undosquamis* which had a higher growth coefficient and higher mortality rates compared to that of the stocks from northern Bay of Bengal. The mortality rate of *S. undosquamis* obtained in the present study confirms that reported earlier from northern Arabian Sea (Kalharo et al., 2014) and differs from those reported earlier from northeastern Arabian Sea and Gulf of Suez (Chakraborty et al., 1997; Amin et al., 2007; Mali et al., 2017).

The growth performance index reported for *S. undosquamis* from other tropical regions varied from 2.65 to 5.29 (Kadharsha et al., 2014), and the value of 2.96 obtained in the present study lies well within this range. Mahmoud et al. (2014) reported a growth performance index of 2.61 from Mediterranean coast of Egypt. However, the values reported from Bay of Bengal by Rajkumar et al. (2003) and by Kadharsha et al. (2014) were 3.61 and 4.9, respectively, which are higher estimates compared to that reported in the present study.

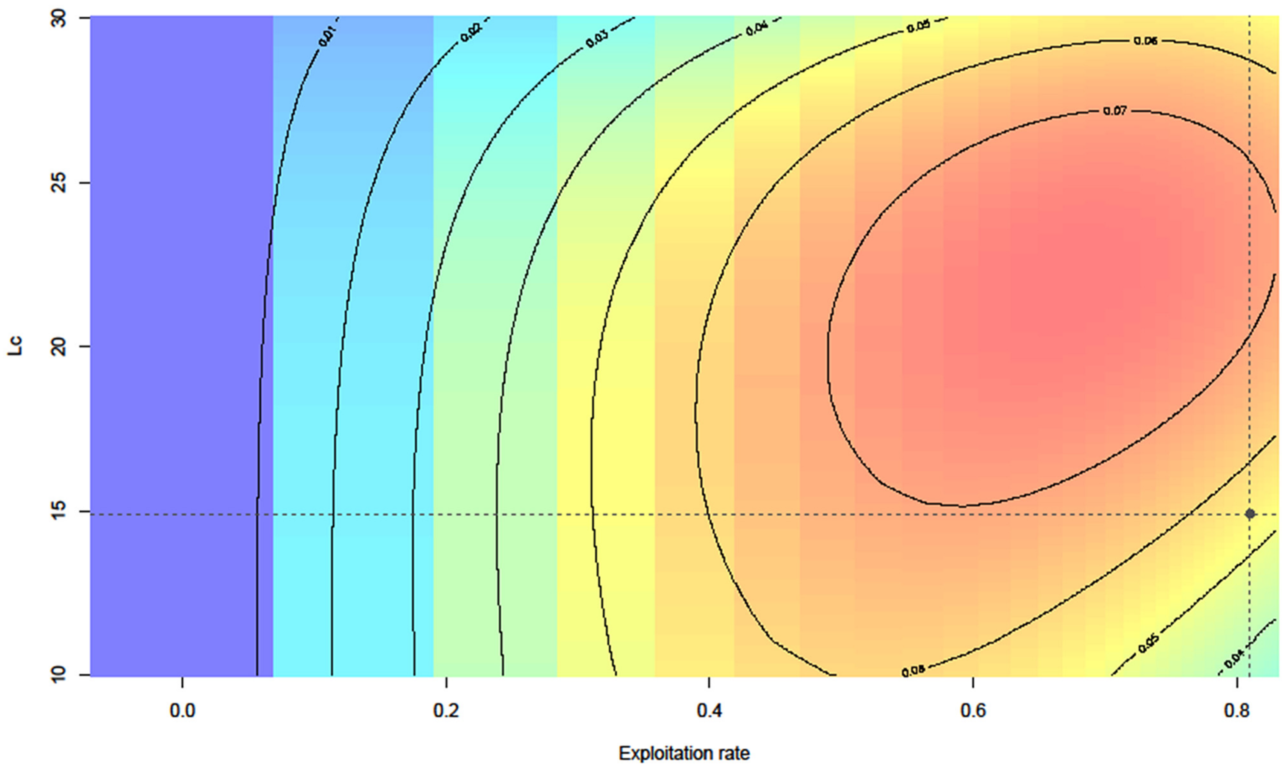

Fig. 7. Impact of different exploitation rates and L_c values on the yield per recruit of *S. undosquamis*. The x-axis displays the exploitation rate (F/Z) of the fully-exploited length class(es).

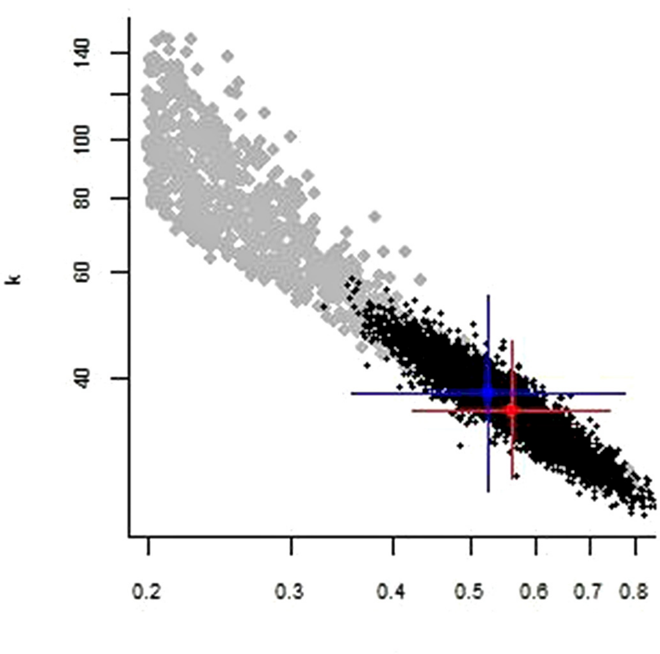

Fig. 8. Results of the CMSY/BSM analysis of *S. undosquamis* catch data from southeastern Arabian Sea for the period 1985–2016. The most probable *r–k* pair and its approximate 95% confidence limits are shown in dark (BSM) and grey (CMSY) points.

4.2 Exploitation and stock dynamics

The exploitation rate obtained in the present study was much higher than that of 0.62 reported from northeastern Arabian Sea by Mali et al. (2017), 0.56 by Chakraborty et al. (1997) and 0.56 from Bay of Bengal by Rajkumar et al. (2003). The Exploitation rate of *S.undosquamis* in southeastern Arabian Sea was 0.82, which indicates that the fishery is either fully exploited or overexploited. Therefore, there is a need for appropriate management interventions to curtail the fishing pressure to ensure sustainability of the resource in the region.

Maximum sustainable yield (MSY) estimated using the length-based Thompson and Bell model is 5738 t, which is corresponding to the fishing effort of 0.6 from the current effort. Hence to achieve the maximum sustainable yield the effort should be reduced by 40% from the current fishing effort expended for harvesting the resource to sustain the stocks of *S. undosquamis* in the region. Any increase in fishing effort could result in overfishing of the stock in the region and the other resources which are harvested by the same gear. Since the exploitation ratio for *S. undosquamis* is higher than $E_{0.5}$ and the value of MSY is lower than the annual average catch, the stock is under high fishing pressure than sustainable level in the region.

4.3 CMSY/BSM analysis

The estimation of fishery reference points using CMSY analysis heavily depends upon the catch and *r* values.

Table 1. Fisheries reference points based on Bayesian Schaefer model (BSM) analysis for the management of *S. undsquamis* stock in southeastern Arabian Sea.

Parameter	Value	Confidence limits
r	0.561	95% CL = 0.425–0.742
k	35300 t	95% CL = 27100–45900 t
Relative biomass in last year	0.353 k	2.5^{th} perc = 0.24; 97.5^{th} = 0.50
Exploitation (F/(r/2) in last year	1.78	–
F_{msy}	0.281	95% CL = 0.212–0.371
MSY	4950 t	95% CL = 4510–5440 t
B_{msy}	17600 t	95% CL = 13600–23000 t
Biomass in last year	12400 t	2.5^{th} perc = 8470 t; 97.5 perc = 17700 t
B/B_{msy} in last year	0.705	2.5^{th} perc = 0.48; 97.5 perc = 1.0
Fishing mortality in last year	0.5	2.5^{th} perc = 0.352; 97.5 perc = 0.735
F/F_{msy}	1.78	2.5^{th} perc = 1.26; 97.5 perc = 2.62

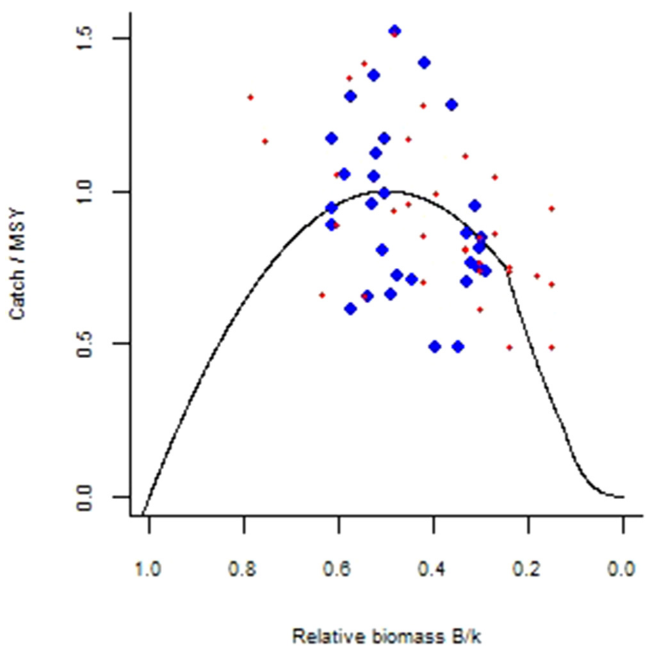

Fig. 9. Schaefer equilibrium curve of *S. undosquamis* catch/MSY relative to B/k. Points not falling on the equilibrium curve indicates overfishing and shrinking of biomass, if above the curve, and sustainable exploitation and growing of stock, if below the curve.

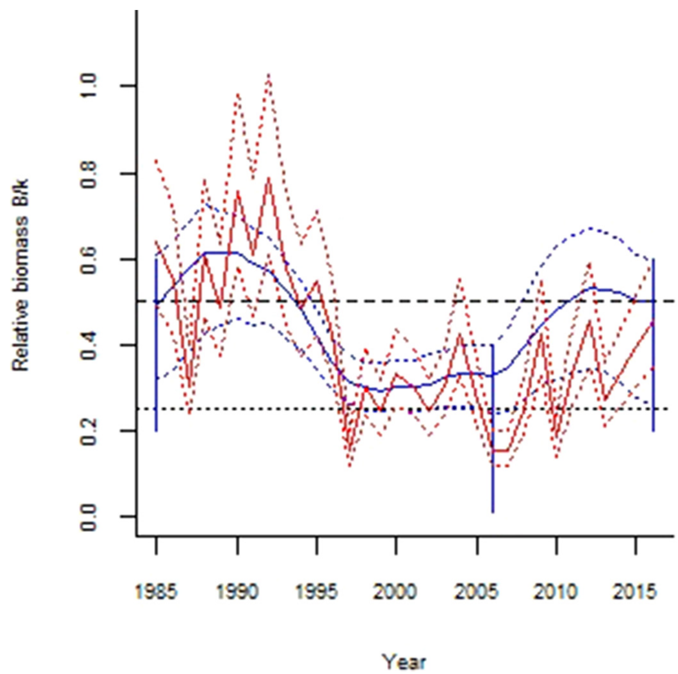

Fig. 10. CMSY predictions of relative biomass B/k (bold curve) with 2.5^{th} and 95^{th} percentiles (thin curves) compared to observed biomass (dashed curve) scaled by the respective BSM estimate for k, for *S. undosquamis* stock in southeastern Arabian Sea.

Uncertainties in these two values will substantially weaken the results and it is suggested to estimate the r value for the stock at the regional level based on the available biological information on the species (Palomares and Froese, 2017). The resilience categorisation from FishBase (Froese et al., 2000; Froese and Pauly, 2018) gave prior ranges of r that led to reasonable CMSY and BSM fits for *S. undosquamis*. In the present analysis, CPUE is used as proxy for biomass. Froese et al. (2017) noted that when CPUE instead of biomass was available for analysis, the results showed that BSM and CMSY estimates were not significantly different in 89% of the stocks. Nevertheless, the data on biomass, even if it is available for very short time period, may be given due importance as an input parameter to the analysis. In the fishery of *S. undosquamis* in the study area, the catch is contributed by many types of crafts and gears with greater part of the catch is by mechanised trawlers. In cases the species is harvested by multiple gears, Palomares and Froese (2017) suggest the use of CPUE from the most dominant gear type, i.e., that which catches more than 50% of the landings. Hence, the catch rates of mechanised multiday trawlers are considered for the present analysis.

The results of CMSY/BSM analysis using 25 years of catch data in the present study are in agreement with the results of stock assessment made using micro analytical models with five years length frequency and catch data with minor differences in MSY estimates. Both the analyses indicate that the stock of *S. undosquamis* in the region is either fully or over exploited

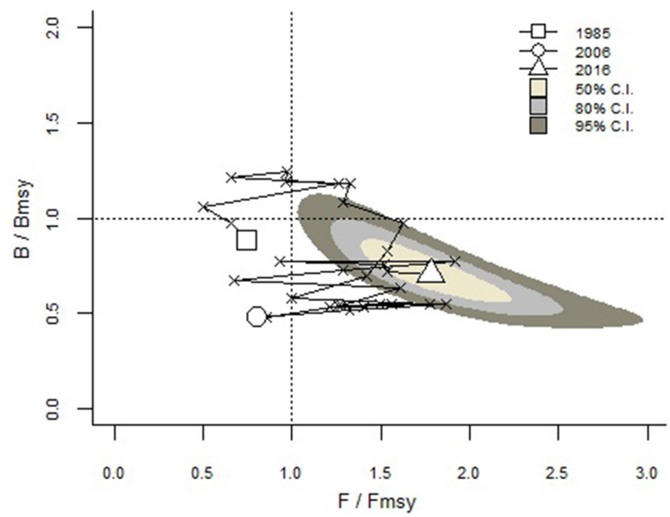

Fig. 11. Results of the BSM analyses relevant for management of *S. undosquamis* stock from the southeastern Arabain Sea. Figure shows the development of biomass and exploitation relative to B_{msy} (horizontal dashed line) and F_{msy} (vertical dashed line), respectively.

state. CMSY analysis points out an exploitation of 30% below B_{msy} level. However, Rosenberg et al. (2018) pointed out that stocks above 80% of B_{msy} are conventionally considered "fully exploited", and stocks staying at this level for many years, forego substantial yield. In order to achieve a stock recovery with better future yields of *S. undosquamis* from southeastern Arabian Sea, the management advice from CMSY analysis is to reduce the catches from the current level until both CMSY and BSM predict biomass above B_{msy} for two to three years in a row and then increase catches to the lower confidence limit of MSY. At that point, the lower 95% confidence limit of MSY is suggested as guidance for allowed catches (Froese et al., 2017).

The southwest coast of India is a classic example of upwelling driven fisheries, where the contribution of low trophic level fishes in the landings were high for most of the years, indicating the dominance of fish groups in low trophic categories. However, the contribution of other top predators, which were high during 1985–2000, sharply declined thereafter (Vivekanandan et al., 2005). They also report that the region remains as a distinct entity with the lowest mean trophic value (3.14), compared to the other three regions of seas around the coast of India, indicating fishing down to food web. Shifts from high-trophic-level predators to low-trophic-level invertebrates and plankton-feeders in the fishery were reported globally (Pauly and Palomares, 2005). Trends in decline of mean trophic level (MTL) in catches due to human impacts, i.e., when predators collapse ("fishing down marine food webs") and when low-trophic-level fisheries expand ("fishing through marine food webs") were also reported (Pauly et al., 1998). Catch MTL is considered as a measure of changes in ecosystem MTL and biodiversity (Pauly and Watson, 2005). The exploitation of top predators like *S. undosquamis* along southeastern Arabian Sea need to be maintained at sustainable level to prevent ecosystem changes along the region. As this resource is harvested by trawls which targets and harvests a multispecies assemblage, a multispecies stock management approach should also be addressed prior to implement any controlling measures for the sustainable exploitation of this species.

5 Conclusion

The length at first capture estimated for *S. undosquamis* in the fishery in southeastern Arabian Sea is 14.9 cm which is much lower than the estimated size at first maturity. Moreover, the average annual mean length observed in the fishery is lower than the estimated optimum length for exploitation. This implies that the juveniles are target of fishery. The high vulnerability of juvenile individuals by mechanised trawling and the indiscriminate harvest of juveniles by this major fishing gear would affect the future yield of this species. The results indicate that reducing the present level of fishing effort by 40% would lead to a harvest of the species at a sustainable level. The predictions of stock size and exploitation status of *S. undosquamis* using length-based Thompson and Bell model confirm the predictions of CMSY/BSM Analysis. This indicates that the CMSY/BSM method designed specifically for the use in data poor environment can be effectively applied for the assessment of tropical Indian stocks wherever data for micro analytical models are lacking.

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