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Growth and Mortality of Brushtooth Lizardfish, *Saurida undosquamis*, from Pakistani Waters

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Abstract.- Growth and mortality parameters of brushtooth lizardfish *Saurida undosquamis* (Richardson, 1848) were investigated using the length frequency data from five research trawl surveys from Pakistani waters during 2009 - 2010. The analysis was based on FiSAT computer software package. The pooled data of *S. undosquamis* consist of n = 870 pair of length weight data and n = 3607 length frequency data of both sexes combined with maximum length and weight of 38 cm (FL) and 492 g respectively. The length-weight relationship parameters from pooled data were a = 0.008, b = 3.000 and R^2 = 0.965. The von Bertalanffy growth function parameters were L_∞ = 39.90 cm, K = 0.270 $year^{-1}$ (using ELEFAN method) and age at zero length t_0 = - 0.572. Based on those growth parameters, the total mortality rate was calculated using length-converted catch curve analysis as 1.15 $year^{-1}$. The natural mortality (M) was 0.687 using Pauly's equation (the annual average sea surface temperature was 27°C) hence the fishing mortality (F) was estimated by F = Z – M = 0.463 $year^{-1}$. The yield per recruitment analysis indicated when t_c was assumed to be 2, F_{max} was estimated at 1.1 and F_{10} at 1; when t_c was assumed to be 1, F_{max} was estimated at 0.85 and F_{10} at 0.7. Currently age at first capture is about 1 year and $F_{current}$ was 0.463, therefore $F_{current}$ was smaller than F_{10} and F_{max}. This indicates that the current fishery is in a safe condition. Using Gulland (1971) biological reference point F_{opt} was equal 0.687. The current fishing mortality rate of 0.463 $year^{-1}$ was lower than biological reference point.

Keywords: *Saurida undosquamis*, brushtooth lizardfish.

INTRODUCTION

Fish is a valuable cheap source of animal protein for the increasing human population and fisheries represent one of the most important natural resources of Pakistan. Pakistan coastline extends 1100 km from the northwest Iranian and southwest Indian borders with an Exclusive Economic Zone (EEZ) of 240,000 km^2, from which Pakistan can explore their marine resources. About 57% landing of fish was from marine sector and export value of fishery products was about US $ 196 million in 2006 (FAO, 2009). Unlike the Baluchistan coast, the Sindh coast has the largest discharge of fresh water from Indus River which creates a favorable ecosystem to serve as nursery grounds for many finfish and shellfish (Snead, 1967; Ahmed *et al.*, 1999). The review of fisheries statistics shows a trend of increasing fishing efforts in the Pakistani waters during the last decades and there is an overall decreasing trend in fish stocks observed in marine captured fisheries since the year 1999 (FAO, 2009). Marine fisheries of Pakistan comprises of about 250 demersal fish species, 50 small pelagic, 20 large pelagic and 15 medium sized pelagic fish species (FAO, 2009).

Lizard fishes are demersal fishes belonging to the family Synodontidae comprising of four genera and about 57 species in the world (Nelson, 2006) and were reported from east coast of Africa, Madagascar and Red Sea coast, Pakistan, India, Srilanka, Maldives, Thailand, Philippines, China, Korea and Japan (Fisher and Bianchi, 1983). Two species of lizard fish commonly found in Pakistani waters are *Saurida tumbit* (Bloch, 1795) and *Saurida undosquamis* (Richardson, 1848). *S. undosquamis* is a demersal fish mostly found above

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100 m depth (Golani *et al.*, 2002), feeding habits of *S. undosquamis* is carnivorous mainly feeds on fishes, shrimps and molluscus (squids and cuttle fish) (Rajkumar *et al*., 2003; Kadharsha *et al*., 2013) Spawning season of *S. undosquamis* from Indian waters was found at August – November with the peak spawning in November (Annigeri, 1963; Kadharsha *et al.*, 2013). Rao (1983a) also found peak spawning season in November and December from the Bay of Bengal.

Because of the declined resources in Pakistani waters, the importance of the two species has increased. *S. undosquamis* is the second most commercially important fish species in the Synodontidae family after *S. tumbil* from the bottom trawl fishery of Pakistan.

The previous work on *S. undosquamis* was *e.g.* food and feeding habits of on Indian coast, from Bay of Bengal and Cochin (Rao, 1981; Sivakami, 1999), growth parameters from India (Chakraborty *et al*., 1997; Rajkumar *et al*., 2003; Metar *et al*., 2011), feeding and reproductive biology from India (Rao, 1983a, b; Kadharsha *et al*., 2013); growth, mortality and recruitment patterns from Indonesian waters (Dwipongo *et al*., 1986; Naamin, 2001), growth and mortality rate from Turkey (Gokce *et al*., 2007; Cicek and Avsar, 2011) and growth and mortality rate from Northern South China Sea (Shu and Qiu, 2004; Wang *et al*., 2012). But there is no work reported on stock assessment of *S. undosquamis* from Pakistani waters. Estimation of growth and mortality of exploitable species is important since the stock assessment and management rely on these population parameters (Fakhri *et al.*, 2011). This is the first record of growth and mortality parameters of *S. undosquamis* from which the researcher can get basic information and can be helpful for fishery managers for better management of this species from Pakistani waters.

Mostly the fish stock assessment were based on age-structured data but the length frequency data were frequently used where the age-structure data are limited (*e.g.* in tropical fisheries, Sparre and Venema, 1998) because the age-structure data are more difficult and more laborious to collect due to the bends on the otolith were indistinct and not easy to interpret (Morales-Nin and Panfili, 2005) and need high powered microscope to count the rings (Pauly, 1987). Those rings or circles were not visible due to changing of environmental factors and fish behavior especially from tropical fisheries (Morales-Nin, 2000). In this study the length frequency data were collected from five trawl surveys during 2009 - 2010 from Pakistani waters. The growth and mortality parameters of the *S. undosquamis* from Pakistani waters were also compared with previous studies conducted in different parts of the world.

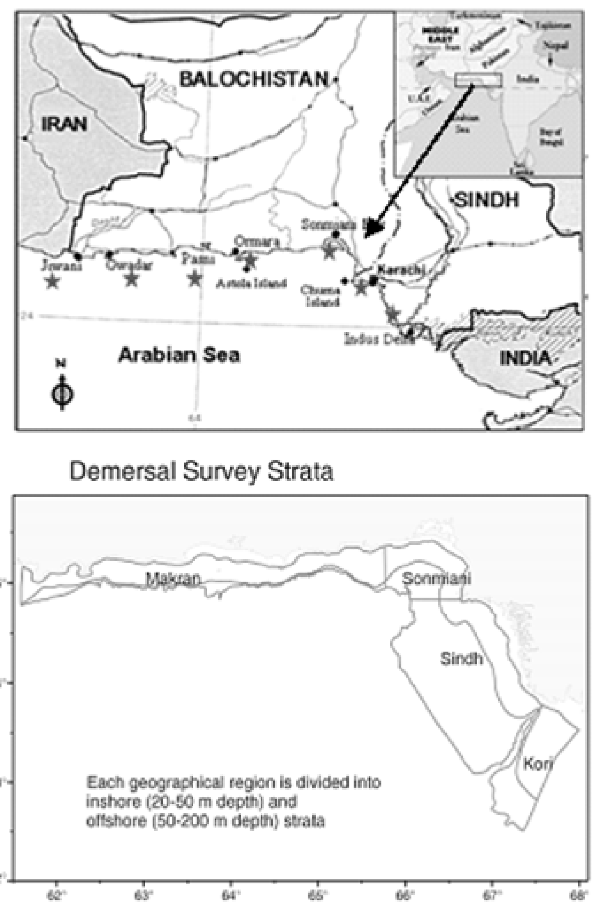

Fig. 1. Pakistan coast line. The sampling stations were randomly selected from surveys strata.

MATERIALS AND METHODS

Data

The five research trawl surveys during 2009 - 2010 were conducted to collect the length-weight and length frequency data from Pakistani waters for this study. Samples for length-weight and length frequency data were collected from five research trawl surveys from Pakistani waters (Fig. 1) during October to November 2009, May-June, August, October and November in 2010. The total of 870 pair of length-weight data of both sexes combined and 3607 of length frequency data of *S. undosquamis* were measured with 2487 in October - November 2009, 260 in May - June, 87 in August, 62 in October and 711 in November 2010. The individuals were measured in fork length to the nearest of 1.0 cm and the weight to the nearest 1.0 g. The present study was carried out by using FiSAT II computer software package (Gayanilo *et al*., 2003).

Analysis methods

Length weight relationship

The length-weight data for brushtooth lizardfish *S. undosquamis* was calculated by the power function of $W = aL^b$ where a was the condition factor and b was an allometric growth parameter or slope.

Growth parameters

The von Bertalanffy growth function (VBGF) was used to

$$L_t = L_\infty(1-\exp(-k(t-t_0)))$$

where L_t was the predicted length in cm at age t. L_∞ was the asymptotic length, K was the growth coefficient and t_0 was the hypothetical age at which length is equals to zero (usually negative) (Haddon, 2011) which can be estimated by using the empirical equation of Pauly (1983) as:

$$\log_{10}(-t_0) = -0.3922 - 0.275\log_{10} L_\infty - 1.038\log_{10} K$$

Mortality rate

The natural mortality rate (M) was calculated using Pauly's formula (Pauly, 1983)

$$\log_{10}(M) = -0.006 - 0.279\log_{10} L_\infty + 0.654\log_{10}(K) + 0.6434\log_{10}(T)$$

where L_∞ and K were the VBGF parameters and T the annual average sea surface temperature taken in the degree Celsius (27°C in Pakistani waters). The total mortality (Z) was estimated using length-converted catch curve analysis method (Pauly, 1983). The exploitation ratio (E) was calculated from equation: E = F / Z, where F was the fishing mortality which was calculated by F = Z - M.

The total mortality also estimated from Beverton and Holt method (1957) from equation:

$$Z = K(L_\infty - L_{mean})/(L_{mean} - L')$$

where L_∞ and K are VBGF parameters of asymptotic length and growth rate, L_{mean} is mean length and L' is the cut-off length.

Biological reference points

Biological reference points were calculated using Gulland (1969) method, the optimum fishing mortality is $F_{opt} = M$.

Yield per recruit analysis

Beverton-Holt model was used to estimate yield per recruit analysis by the following formula:

$$Y_w/R = FW_\infty e^{M(t_c-t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c-t_0)}}{F+M+nK}(1-e^{-(F+M+nK)(t_\lambda-t_c)})$$

where Y_w/R was yield per recruitment, t_c was the mean age of fish at first capture, t_r was the recruitment age, t_λ was the asymptotic age, Q was a constant value and equals to 1, -3, 3 and -1 when n was 0, 1, 2 and 3, respectively (Pitcher and Hart, 1982).

Growth performance index

The estimates of L_∞ and K were used to calculate the growth performance index (ϕ) of the species was calculation based on equation (Pauly and Munro, 1984):

$$\emptyset' = \log_{10} K + 2\log_{10} L_\infty$$

which is available in computer software package FiSAT.

RESULTS

Length-weight relationship

The total of 870 pairs both sexes combined of length and weight were examined in this study which were collected during the five research trawl surveys during 2009 - 2010, the lengths ranged from 6 to 38 cm (FL) and total weight ranged from 2 to 492 g and averaged length, weight were 17.36, (± 69.399) cm and 65.04, (± 5.348) g respectively. The dominant length range of *S. undosquamis* were from 11 to 19 cm (FL) (Fig. 2).

The length-weight relationship was calculated as $W = 0.008 * L^{3.000}$ ($R^2 = 0.965$) n = 870 (Fig. 3).

Growth parameters

A total of 3607 length frequency data were collected during trawl survey during 2009 – 2010 were used in ELEFAN method in FiSAT computer package. The von Bertalanffy growth parameters for *S. undosquamis* were $L_\infty = 39.90$ cm (FL) and 0.270 $year^{-1}$ (*K*) (Fig. 4). The value of t_0 was calculated by Pauly's equation as - 0.572 $year^{-1}$. The goodness of fit was $R_n = 0.297$.

Mortality rate

The annual total mortality rate (Z) was estimated using length-converted catch curve analysis with the input values of VBGF growth parameters ($L_\infty = 39.90$ cm (FL) and 0.270 $year^{-1}$ (*K*)), as Z = 1.15 $year^{-1}$ and its 95% confidence interval were estimated at (1.07 – 1.23) (Fig. 5). The value of natural mortality rate was calculated as M = 0.687 $year^{-1}$ using an annual average sea surface temperature 27°C in Pakistani waters. Hence the fishing mortality was calculated as F = Z - M = 0.463 $year^{-1}$ and the exploitation ratio (E) was obtained from F / Z = 0.402 $year^{-1}$. The total mortality rate from Beverton and Holt method the Z = 1.363 $year^{-1}$

Yield per recruit analysis

The yield per recruit contour map using the maximum age of *S. undosquamis* of 12 years is shown in Figure 6. When t_c was assumed to be 2, F_{max} was estimated at 1.1 and $F_{0.1}$ at 1; when t_c was assumed to be 1, F_{max} was estimated at 0.85 and $F_{0.1}$ at 0.7. Currently the age at first capture is about 1 year and $F_{current}$ was 0.463, therefore $F_{current}$ was smaller than $F_{0.1}$ and F_{max}. This indicates that the current fishery is in a safe condition. When using Gulland (1971) biological reference point, F_{opt} equal to 0.687, the current fishing mortality rate was 0.463 $year^{-1}$ was lower than the biological reference point.

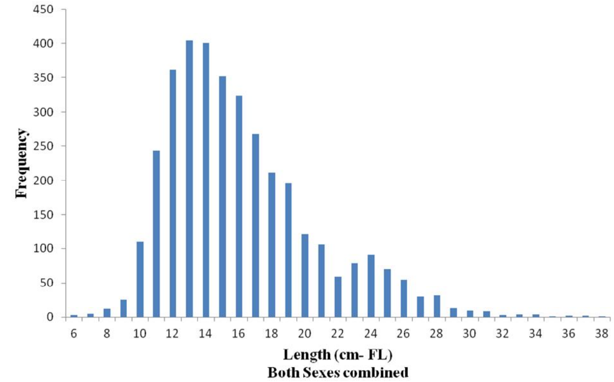

Fig 2. Length frequency distribution combined both sexes of *S. undosquamis* with total number of length frequency n = 3607 ranging from 6 to 38 cm (FL), the dominant length frequency range from 11 to 19 cm (FL) using the trawl survey data from Pakistani waters during 2009 - 2010.

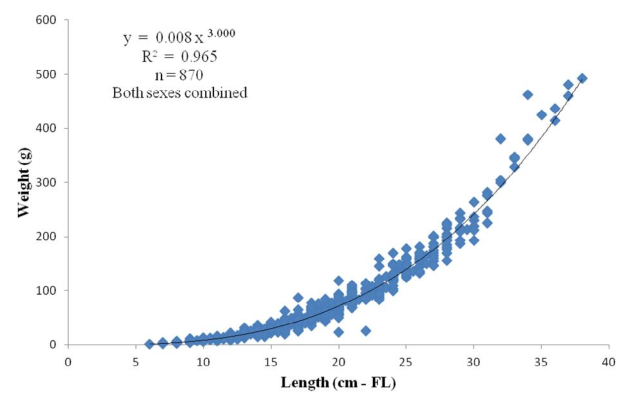

Fig 3. Length-weight relationship of both sexes combined of *S. undosquamis* length and weight ranging from 6 to 38 cm (FL), 2 to 492 g respectively and using trawl survey data from the Pakistani waters during 2009 – 2010.

Growth performance index

Growth performance index (ϕ) was estimated at 2.633 for *S. undosquamis* based on the length frequency data from five trawl surveys during 2009 - 2010.

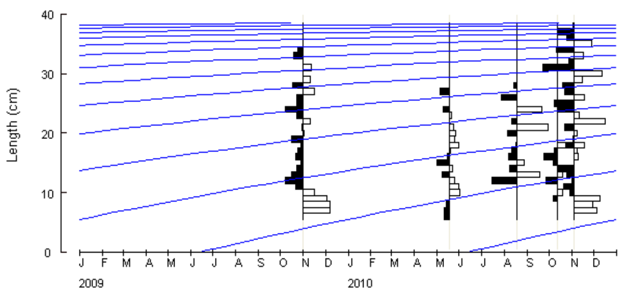

Fig. 4. Length frequency distribution data (n = 3607) and the growth estimated using ELEFAN for combined both sexes of *S. undosquamis* (L_∞ = 39.90 cm and K = 0.270 *year*$^{-1}$, t_0 = - 0.572^{-1}), (R_n = 0.297) using the trawl survey data from Pakistani waters during 2009 - 2010

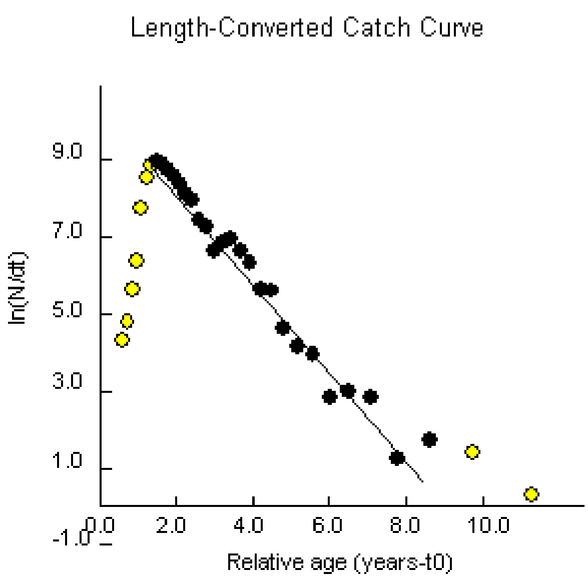

Fig. 5. Length converted catch curve analysis combined sexes of *S. undosquamis* using input value of VBGF growth parameters (the von Bertalanffy growth parameters were (L_∞ = 39.90 cm and K = 0.270 year^{-1}), only the black dots should be considered for estimating the total mortality, where (Z = 1.155 year^{-1}) and CI of Z (1.07 – 1.23) using the trawl survey data from Pakistani waters during 2009 - 2010.

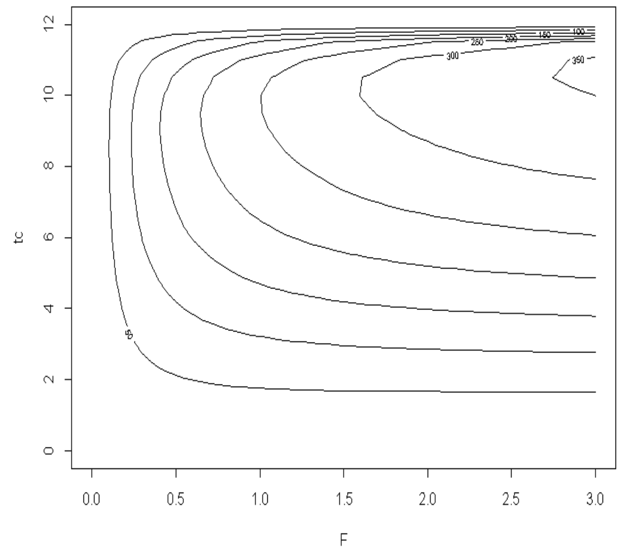

Fig. 6. Yield per recruit contour map of *S. undosquamis* from trawl survey from Pakistani waters during 2009 – 2010. Where F = fishing mortality, tc was the mean age of fish at first capture.

DISCUSSION

Length-weight relationship

The length-weight relationship is helpful in the estimation of metamorphosis, gonad maturity and rate of feeding of fish (Le Cren, 1951) and it is the basic parameter in fishery biology and stock assessment of fish (Abdurahiman *et al*., 2004). The values of slop *b* of *S. undosquamis* were estimated in present study at 3.00 (R^2 = 0.965) from Pakistani waters during 2009 – 2010, which show isometric growth of the species because the *b* value of 3 indicates an isometric growth otherwise it is allometric (Ricker, 1973; Gayanilo *et al*., 2003; Froese, 2006). The values of slope *b* were compared with the results obtained from different areas of same species (Table I). The *b* values were 2.879, 2.618 and 2.797 in Turkish waters (Cicek and Avsar, 2011; Mater and Torcu, 1996; Can *et al*., 2002) which were lower than present study. The *b* values were 3.030 in India (Rao, 1983b), 3.022 in Turkish waters (Tureli and Erdem, 1997), 3.043 in Northern South China Sea was (Wang *et al*., 2012) which were close to the present study. The *b* values were 3.306 in Karnataka, India (Muthiah, 1996) and

Table I.- Comparison of value *b* of *S. undosquamis* with previous studies from different areas of the world with present study from Pakistani waters during trawl surveys data during 2009-2010.

Area	*a*	*b*	Sources
Karatas coasts, Iskenderun Bay	0.0083	2.879	Cicek and Avsar (2011)
Turkish coasts	0.383	2.617	Mater and Torcu (1996)
Turkish coasts	0.127	3.022	Tureli and Erdem (1997)
Turkish coasts	0.004	3.086	Cicek *et al*. (2006)
Turkish coasts	0.0039	3.159	Sangun *et al*. (2007)
Gokova Bay, Turkey	0.0046	3.109	Tevfik Ceyhan *et al*. (2009)
Iskenderun Bay, Turkey	0.01	2.8	Gokce *et al.* (2010)
South coast of Iskenderun Bay	0.0117	2.797	Can *et al*. (2002)
India	0.0058	3.030	Rao (1983b)
Visakhapatnam, India	0.000003	3.102	Rajkumar *et al.* (2003)
Karnataka, India	-	3.306	Muthiah (1996)
Northern South China Sea	0.956	3.043	Wang *et al*. (2012)
South China Sea	0.0053	3.242	Ambak *et al*. (1986)
Beibu Gulf, NS China Sea	0.0097	3.05	Wang *et al.* (2011)
Alexandria, Egypt	0.003	3.3	Abdallah (2002)
Kenyan coast	0.0043	3.06	Christopher *et al.* (2011)
Pakistan	0.008	3.00	Present study

a = constant condition factor, *b* = slope

3.3 in Alexandria, Egypt (Abdallah, 2002) which were higher than the present study. However the overall *b* values from different areas were close to present study (*b* = 3.00) which may indicate that the samples in this research trawl surveys were fully representative for the length-weight relation of *S. undosquamis* from Pakistani waters during 2009 – 2010. The small differences of value slop *b* may be because of different regions, seasonal fluctuations, environmental parameters and physical conditions of the fish at the time of sample collection, sex gonad development and nutritive conditions, number of individuals examine in study, different observed length ranges during the study etc. (Biswas, 1993; Wootton, 1998; Froese, 2006).

Growth parameters

The length frequency data were used to estimate VBGF parameters *i.e.* asymptotic length (L_∞), growth rate (*K*) and the hypothetical age (t_0) which were compared with the results in previous studies from the different areas (Table II).

In this study the VBGF parameters were estimated using ELEFAN method. These results in Table II were estimated from different methods and different data. The asymptotic length (L_∞), growth rate (K) were estimated at 22.43, 0.597 from Turkish water (Otolith method) (Tureli and Erdem, 1997) and 28.9, 0.52 from Northern South China Sea (Wang *et al*., 2012), which were the lower L_∞ values and the higher K values than the present study. The L_∞ and *K* values were 49.25, 0.252 from South China Sea (Ford-Walford plot method) (Ambak *et al.*, 1986) and 51.8, 0.16 from Vietnam (Thuoc *et al*., 2000) which showed the higher. L_∞ and lower *K* values than present study. The L_∞ and *K* values were 40.6, 0.6 from Thailand (Boonvanich, 1991); 39.5, 0.31 from Visakhapatnam, India (Rajkumar *et al*., 2003); 40.0, 0.3 from Northern South China Sea (Shu and Qiu, 2004) were estimated by ELEFAN methods (Table II) and were close to the present study (39.90, 0.270). Because those parameters are correlated with each other (Pauly and Morgan, 1987), the higher *K* values are usually associated with the lower L_∞ values and vice versa. The differences of those values in Table II may be because of their sampling strategy, different data sets and differences of their life pattern and ecological characters (Adam, 1980). Table II also shows the methodology of estimating the growth parameters such as from otolith reading data or from length frequency analysis which may also affect the growth parameter results.

The t_0 values from Northern South China Sea by Shu and Qiu (2004) were t_0 = - 0.44 which were close to present study (t_0 = - 0.572). The t_0 values were calculated from the estimated growth parameters, the positive t_0 value indicate that the juveniles were grow more slowly and negative t_0 value indicated that the fish species grow faster during juvenile stage (King, 1995, 2007; Sparre and Venema, 1998).

Table II.- Comparison of growth parameters of *S. undosquamis* from present study with those from previous studies (The growth parameter estimation methods were given in brackets).

Area	$L\infty$	K	t_0	ϕ	Source
Karatas, Iskenderun Bay [a]	38.05	0.124	-1.68	-	Cicek and Avsar, 2011
N. Mediterranean, Turkey [b]	41.57	0.118	-1.895	-	Manasirli *et al*., 2011
Iskenderun Bay, Turkey (ELEFAN)	42.0	0.51	-0.29	-	Gokce *et al*., 2007
Turkish waters (Otolith)	22.43	0.597	-1.365	-	Tureli and Erdem, 1997
Northern South China Sea(ELEFAN)	28.9	0.52	-0.30	-	Wang *et al*., 2012
Northern South China Sea	40.0	0.3	-0.44	-	Shu and Qiu ., 2004
South China Sea (Ford-Walford plot)	49.25	0.252	-	-	Ambak *et al*., 1986
Visakhapatnam, India (ELEFAN)	39.5	0.31	-	-	Rajkumar *et al*., 2003
Maharashtra, India (ELEFAN)	42.0	0.51	-	-	Chakraborty *et al*., 1997
Mumbai coast, India (ELEFAN)	34.6	0.87	-	-	Metar *et al*., 2011
Karnataka, India (ELEFAN)	36.0	0.64	-	-	Muthaiah, 1996
Philippines (ELEFAN)	30.5	0.8	-	2.87	Ingles and Pauly, 1984
Philippines, Ragay Gulf (ELEFAN)	43.0	0.75	-	3.14	Corpuz *et al*., 1985
Australia (Male)	59.9	0.123	-	-	Wen *et al*., 1987
Australia (Female)	58.9	0.121	-	-	Wen *et al*., 1987
Indonesian waters (ELEFAN)	33.5	0.95	-	3.028	Dwipongo *et al*., 1986
Indonesian waters	33.6	1.00	-	3.053	Naamin, 2001
Malaysia West Sabah (ELEFAN)	42.00	1.20	-	3.325	Isa and Ahmed, 2001
Malaysia East Coast (ELEFAN)	40.50	0.98	-	-	Isa and Ahmed, 2001
Malaysia West Coast (ELEFAN)	34.0	1.20	-	3.142	Isa and Ahmed, 2001
Thailand	37.9	0.89	-	3.107	Kuhlmorgen-Hille, 1970
Thailand (ELEFAN)	40.6	0.6	-	3.00	Boonvanich, 1991
Vietnam (ELEFAN)	51.8	0.16	-	2.63	Thuoc *et al*., 2000
Pakistan (ELEFAN)	39.90	0.270	-0.572	2.633	Present study

L_∞, asymptotic length (cm - FL); K, growth rate $year^{-1}$; ϕ, growth performance index; t_0, hypothetical age at which length of the fish is equal to zero. - indicates that data not available in papers; a, least square method (Sparre and Venema, 1998); b, von Bertalanffy (1938) equation.

The R_n (goodness of fit) value in the ELEFAN-FiSAT package is different from R^2 (coefficient of determination) which is between 0 and 1with the values close to 1 indicating a better fit. R_n can be of any value for ELEFAN. For example, Gokce *et al*. (2007) reported that brushtooth lizardfish (*Saurida undosquamis*) in Iskenderun Bay (eastern Mediterranean Sea) had the growth parameters (L_∞, K) and goodness of fit (R_n) value at 42.0cm, 0.51 $year^{-1}$ and R_n = 0.190 from length frequency data (n = 4711) respectively. It is assumed that the R_n value in our results shows a better fit of the data. FiSAT can provide CI for estimated Z, but not for the growth parameters.

The studies from India proved that the spawning season of *S. undosquamis* were from August to December and the peak spawning seasons were at October – November (Annigeri, 1963; Kadharsha *et al*., 2013). The length at first maturity of *S. undosquamis* were from India at 19.5 cm (Kadharsha *et al*., 2013), 23 cm (Rao, 1983a; Rajkumar *et al*., 2003) and from Egypt 17.4 cm (Amin *et al*., 2007). Therefore, our data satisfy the assumption of ELEFAN method, overall the length frequency data which is collected from five different trawl surveys were satisfactory and we assume that the data in our sample may fully represent the length classes in the fish stock present in Pakistani waters. In this study the VBGF growth rate was estimated, using a non-parametric method commonly used in length frequency analysis of fish, which is basically *ad hoc* and does not depend on estimating the parameters of cohort distribution directly. So it makes only weak assumption about the distribution of sizes within the cohorts. The model lengths of each cohort are fixed to lie upon a curve described by growth models such as von Bertalanffy growth model, thus it makes a strong assumption about growth (Pitcher, 2002). However the little difference in the asymptotic length from different regions maybe because of physical, chemical factors to catching methodology.

Mortality rate

In this study the mortality rate of *S. undosquamis* were estimated using length-converted catch curve analysis and Beverton and Holt (1957) method using input values of VBGF growth parameters and were compared with previous studies from different areas of the world (Table III).

Generally the mortality values in Table III were higher than the present study especially the total (Z), natural (M) and fishing mortality (F) were 4.10, 1.19, 2.91 in Thailand (Boonvanich, 1991) and 5.05, 1.67, 3.38 in Malaysia east coast (Isa and Ahmed, 2001). The Z, M, F values were 1.11, 0.77, 0.34 in Philippines (Ahmed, 1999) and 0.766, 0.403, 0.363 in Turkey (Manasirli *et al.*, 2011) which were lower than the present study (Z = 1.15, M = 0.687, F = 0.463). These different values from different parts of the world may be due to higher commercial demand which increased fishing efforts in that region or unfavorable environmental conditions. The total mortality were estimated from only the dark circles in Figure 5. This is because the young fish were not fully vulnerable to the fishing gear due to the different distribution areas and because the older fish were scarce and not fully representative in the sample. Using Beverton and Holt method (1957) the total mortality were estimated at Z = 1.363 $year^{-1}$, which was slightly higher than length converted catch curve method at Z = 1.15 $year^{-1}$ for *S. undosquamis* in Pakistani waters.

The fish mortality are caused by different reasons such as fishing, pollution, diseases, predation and old age in the fish community (Nikolsky, 1969). The mortality rate estimates in the present study are from length converted catch curve analysis and Beverton and Holt (1957) method which require the input values of VGBF growth parameters and therefore the growth curve will directly affect on the mortality rates (Issac, 1990). Sparre (1990) and Pauly *et al*. (1995) also investigated the impact of growth curve on the estimating of total mortality. Biswas (1993) described that the growth parameters may vary from different regions due to different ecological, fishing, feeding and the sampling methods. Usually most of natural mortality are caused by predation (Brandt *et al*., 1987; Laevastu and Favorite, 1988) and predation mortality sometimes are much higher than the fishing mortality especially for juveniles (Christensen and Pauly, 1997). Natural mortality was not easy to estimate because the natural mortality was rarely observed (Quinn and Deriso, 1999). The natural mortality may be different due to the water temperature (27°C from Pakistani waters) and the fishing mortality is only influenced by increasing fishing efforts during the time period.

According to Gulland (1971) the exploitation rate should be lower than 0.5. He also suggested that the stock may be considered as over-exploitation if the exploitation rate is more than 0.5. According to Patterson (1992) the exploitation rate should be lower than 0.4 levels. Our results showed that the exploitation rate of 0.402 was lower than that biological reference points so that the *S. undosquamis* stock in Pakistani waters is in a safe condition.

Biological reference points

$F_{0.1}$ and F_{max} are the two biological reference points (BRP) commonly used for fisheries management in the world (Deriso, 1987; Hilborn and Walters, 1992) which were estimated from age-structure or length structure data to provide management guidance for better management (Caddy, 1998). $F_{0.1}$ is defined as the fishing mortality rate at which marginal increase in yield per recruit (YPR) is 10% of that at F of 0 and F_{max} is the fishing mortality rate which maximum YPR value is attained (Deriso, 1987; Hilborn and Walters, 1992). The yield per recruit analysis (YPR) (Fig. 6) indicated that when t_c was assumed to be 2, F_{max} was estimated at 1.1 and $F_{0.1}$ at 1; when t_c was assumed to be 1, F_{max} was estimated at 0.85 and $F_{0.1}$ at 0.7. Currently the age at first capture is about 1 year and $F_{current}$ was 0.463, therefore $F_{current}$ was smaller than $F_{0.1}$ and F_{max}. This indicated that the current fishery is in a safe condition. When using Gulland (1971) biological reference point, F_{opt} equal 0.687. The current fishing mortality rate of 0.463 $year^{-1}$ was lower than the biological reference point.

This study has been conducted based on the

Table III.- Mortality rates of *S. undosquamis* from Pakistani waters during trawl surveys during 2009 – 2010 were compared with the other studies from different areas. (The mortality estimation methods were given by superscripts a-e)

Area	*Z*	*M*	*F*	Source
Karatas Coast, Iskenderun Bay	1.77[c]	0.35[d]	1.42	Cicek and Avsar (2011)
Iskenderun Bay, Turkey	1.79a	0.87[b]	0.92	Gokce *et al*. (2007)
N. Mediterranean, Turkey	0.766[e]	0.403[d]	0.363	Manasirli *et al*. (2011)
Northern South China Sea	2.21[a]	1.02[b]	1.19	Wang *et al*. (2012)
Northern South China Sea	1.78	0.67	1.11	Shu and Qiu (2004)
Maharashtra, India	2.52[a]	1.1[b]	1.42	Chakraborty *et al*. (1997)
Karnataka, India	2.62[a]	1.31	1.31	Muthaiah (1996)
Visakhapatnam, India	1.81[a]	1.05[b]	0.76	Rajkumar *et al*. (2003)
Mumbai coast, India	3.48[a]	1.51[b]	1.97	Metar *et al*. (2011)
Philippines	4.07[a]	1.54[b]	2.53	Ingles and Pauly (1984)
Philippines	1.11	0.77	0.34	Ahmed (1999)
Indonesian waters	2.3[a]	1.69[b]	0.61	Dwipongo *et al*. (1986)
Indonesian waters	3.21	1.29	1.92	Naamin (2001)
Malaysia, East coast	5.05[a]	1.67[b]	3.38	Isa and Ahmed (2001)
Malaysia, Sabah	3.95[a]	1.89[b]	2.06	Isa and Ahmed (2001)
Thailand, Gulf of Thailand	4.10[a]	1.19[b]	2.91	Boonvanich (1991)
Pakistan	1.15[a]	0.687[b]	0.463	Present study

Z = total mortality, *M* = natural mortality, *F* = fishing mortality. [a:] Length converted catch curve; [b:] Pauly's empirical formula; [c:] Beverton and Holt method (1957); [d:] Ursin (1967) method ($M=W^{-(1/b)}$); [e:] Avsar (1998) method.

length frequency data collected during trawl surveys data from Pakistani waters during 2009 – 2010. From this data we cannot compare the life history parameters with those other studies, *i.e.* what biological and ecological and environmental factors and differences contributing with this process. Because the spatial and temporal differences can influences on the life history parameters of *S. undosquamis* and we don't have much data to compare those parameters but our work on this species may raise some concerns into this aspect from the fishery science community.

Growth performance index

Growth performance index (Pauly and Munro, 1984; Sparre and Venema, 1998) is estimated from the VBGF parameters (L_∞, K). The higher value of the growth performance index indicates that the fish can grow faster and larger. The growth performance index from the present study were 2.633, it was 3.00 in Thailand (Boonvanich, 1991), 3.053 in Indonesia (Naamin, 2001), 2.87 in Philippine (Ingles and Pauly, 1984), 2.63 in Vietnam (Thuoc *et al*., 2000). The overall values from different areas were close to the value from the present study. The differences may be because of some ecological and environmental conditions (Devaraj, 1981; Jayaprakash, 2002).

In conclusion with regard to the data collected from fish harbors where fishermen have selected their catch into different length class of fish species, the research trawl surveys can represent the full length class of fish species in the stock and provide the best measurement of the fish stock for the estimation of population dynamics. Length-frequency data give valuable information about growth, mortality and life history of fish species, the reliability depends much on the sampling strategy, environmental and ecological factors. Gulland (1987) suggested that the length frequency samples should be collected as much as possible and Pauly (1987, 1990) suggested that about more than 1000 – 1500 individuals are adequate for the study of growth and mortality of fish. The sampling size (n = 3607) collected from research trawl surveys from Pakistani waters during 2009 – 2010 may represent the fully length range of *S. undosquamis* and were adequate to meet these criteria.

The estimated length-weight relationship, VBGF growth parameters and growth performance index results were close to the previous studies (Tables I, II). Differences in the values may be due to geographical and ecological differences in to different water bodies, different analysis methods and different sampling strategies during those studies. The estimated mortality rate values from other parts of the world were frequently higher than the present study (Table III), but some values were similar and lower than present study. This may be because of the higher commercial demand of this fish species from that area and also the estimation methodologies as well as the selection of data.

This study showed that the stock of *S. undosquamis* fishery from Pakistani waters is below the biological reference points and in a safe condition. However in order to achieve a sustainable exploitation of the *S. undosquamis* fishery, further studies on age-structure analysis, growth, mortality and yield per recruit analysis are needed from different methods to understand the population dynamics for this fishery. The fisheries authorities and fisheries scientists need more scientific research to especially control on bycatch, discard of small fish into sea by fishermen, closing area, closing season, some Marine Protected Areas (MPAs), juvenile protections, completely prohibited fishing from estuaries because in that area have small sized fish, control mesh size, etc.

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