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Population Dynamics of Greater Lizardfish, *Saurida tumbil* From Pakistani Waters

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Abstract.- Growth and mortality parameters of greater lizardfish *Saurida tumbil* (Bloch, 1975) from the Pakistani waters were estimated using length frequency data which were collected from five research trawl surveys during 2009 - 2010. The pooled data of both sexes of *S. tumbil* consisted of 824 pair of length weight and 2320 length frequency data. The length-weight relationship were at a = 0.011, b = 2.931. The von Bertalanffy growth function parameters were L_∞ = 48.30 cm (FL) K = 0.320 $year^{-1}$ using ELEFAN method and t_0 = - 0.786. Based on the growth parameters the total, natural and fishing mortality were estimated at 1.160, 0.716 and 0.444 $year^{-1}$, respectively. The yield per recruit analysis indicates that, when t_c was assumed to be 2, F_{max} was estimated as 1.25 and $F_{0.1}$ at 1.15; when t_c was assumed to be 1, F_{max} was estimated as 1 and $F_{0.1}$ at 0.9. Currently we assume that the age at first capture was about 1 year and $F_{current}$ and was 0.444, therefore $F_{current}$ was smaller than $F_{0.1}$ and F_{max}. This indicated that the current fishery is in a sustainable condition. When using the Gulland formula biological reference point F_{opt} was equal to M (0.716). The current fishing mortality rate of 0.444 $year^{-1}$ was lower than the biological reference point. The exploitation ratio (E) was estimated at 0.382 $year^{-1}$. In the view of the above results we may assume that the stock of *S. tumbil* fishery from Pakistani waters is in a sustainable state.

Keywords: *Saurida tumbil*, stock assessment, growth parameters, mortality, yield per recruit.

INTRODUCTION

Pakistani waters are located at the Northern part of the Arabian Sea with the borders with India and Iran, The coastline and exclusive economic zone (EEZ) are about 1100 km and 240,000 km^2. The demersal fish resources are the major part of the marine fisheries of Pakistan with more than 250 demersal fishes (FAO, 2009). Marine fisheries provide 57% contribution to fishery products, however the marine fisheries resources are decreasing since 1999 (FAO, 2009).

Lizardfishes belonging to the family Synodontidae and comprise of 4 genera and 57 species in the world (Nelson, 2006). They are the common demersal fish species mostly found at sand bottom in shallow coastal waters and are widely distributed in the tropical and subtropical regions. These fishes mainly comprise two species of *Saurida tumbil* and *S. undosquamis* along the Sindh coast, and from Pakistan *S. tumbil* is the dominant fish species of genus *Saurida* spp. There is limited work done on Synodontidae fish family from Pakistani waters *i.e.* maximum sustainable yield of *Harpodon nehereus* (Kalhoro *et al*., 2013) and growth and mortality of *S. undosquamis* (Kalhoro *et al*., 2014) and from Pakistani waters.

Some studies have been done from the different parts of the world on different aspects of *S. tumbil* like stock assessment, age and growth , feeding habits from Indian waters and Arabian Sea, Persian Gulf and Oman Sea (Rao, 1983a, b, 1984; Muthaih, 1993; Gulati *et al*., 1994; Muthaih and Neelakantan, 1997; Jaiswar *et al*., 2003; Sivakami *et al*., 2003; Valinassab *et al*., 2006), reproductive biology of lizardfish (Muthiah, 1993; Bakhsh, 1994, 1996) from China (Okada and Kyushin, 1955; Yamada *et al*., 1965; Yamada, 1968; Shindo, 1972; Yoneda *et al*., 2002; Wang *et al*., 2012) from Kuwait (Euzen, 1989; Mathews and Samuel, 1989), but there is no report on stock assessment of *S.*

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tumbil from Pakistani waters. Therefore the aim of this investigation is to provide some basic information on the length-weight relationship, growth, mortality rate, and biological reference point of this commercial important fish species for its sustainable exploitation and better management of this species in future.

The exploitation history of *S. tumbil* fishery from Pakistani waters, according to the Kalhoro *et al.* (2015) the average catch of lizard fish from 1986 to 2009 were 49.29 mt (metric tons) the highest landing in 1993 was 96 mt and the lowest catch were 15 mt in 2009 (Kalhoro *et al.*, 2015) and during our present study most of the catches were from Sindh and Sonmiani bay (Balochistan) and mostly found from muddy bottom. It was observed that the Sindh and Sonmiani bays are good fishing ground of *S. tumbil*.

According to Kalhoro *et al.* (2015) the maximum sustainable yield of *S. tumbil* fishery from Pakistani waters was 60-70 mt and it was recommended that the stock of this fishery should be kept at current state.

The main objective of this study was to help taking appropriate measures for better management of *S. tumbil* fishery in Pakistani waters.

MATERIALS AND METHODS

Data collection

Five trawl surveys were conducted from Pakistani waters during 2009–2010. The pooled data of both sexes was 824 pair of length-weights and 2320 length frequency of *S. tumbil* were measured with 863 in October and 313 in November during 2009, 407 in May - June, 146 in August, 3 in October, and 588 in November during 2010. According to Pauly (1990) the minimum sample size and length frequency data collected is more than 1000 - 1500 and a period of at least six months is adequate for to analyze the growth and mortality. The fish individuals were measured into fork length (FL) to the nearest of 1.0 cm and the weight were measured to the nearest 1.0 g. The present study was carried out using the computer package FiSAT II (FAO-ICLARM stock assessment tool, Gayanilo *et al*. (2003) from which we calculated the growth and mortality parameters of *S. tumbil*.

Length-weight relationship

The pair of length-weight relationship of both sexes combined of *S. tumbil* was estimated by the power function of $W = aL^b$ where W is weight of fish (g), L is the length of fish (FL - cm) and a was the condition factor and b was the slope.

Growth parameters

The growth parameters were estimated by fitting length frequency data into the von Bertalanffy growth function (VBGF) was used to describe the fish growth;

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

where L_t was the predicted length in the cm at age t. $L\infty$ is the asymptotic length, K is the growth coefficient and t_0 was the hypothetical age at which length of the fish is equal to zero (usually negative), (Haddon, 2011) which can be estimated from the empirical equation of Pauly (1983) as:

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

Mortality parameters

The total mortality (Z) was calculated using length-converted catch curve analysis method (Pauly, 1983). The natural mortality rate (M) was estimated using Pauly's formula $\log_{10} (M) = -0.006\text{-}0.279 \log_{10} L_\infty + 0.654 \log_{10} (K) + 0.6434 \log_{10} (T)$ where L_∞ and K was the VBGF parameters and T was the annual average sea surface temperature (SST) (26°C from the Pakistani waters) (Panhwar and Liu, 2012). The exploitation ratio (E) was calculated from equation: $E = F / Z$ where F was the fishing mortality which was calculated by $F = Z - M$. To compare with the catch curve analysis results we also used Beverton-Holt (1957) method estimated from mean size from the catch: $Z = K (L_\infty - L_{mean}) / (L_{mean} - L')$ where L_∞ is asymptotic length, K is the growth curve, L_{mean} is mean length and L' is the cut-off length.

Biological reference points

Biological reference points (BRP) of *S. tumbil* were estimated by using Gulland (1969) method, the optimum fishing mortality is $F_{opt} = M$.

Yield per recruit analysis

Yield per recruit was analysis by Beverton-Holt model formula as below:

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

where Y_w / R was yield per recruitment, t_c was the mean age of fish at first capture, which was observed from catch-at age (*i.e.,* age composition) data, t_r was the recruitment age, which was also observed from catch-at age (*i.e.,* age composition) data, 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). The yield per recruit F_{max} and $F_{0.1}$ were estimation methods were used from Quinn and Deriso (1999).

Growth performance index

Growth performance index ($\acute{\varnothing}$) of the lizardfish was calculated from the equation given by Pauly and Munro (1984)

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

which is available in FiSAT II package by applying the VBGF growth parameters.

RESULTS

Length-weight relationship

A total of 824 pair of length-weight data of both sexes combined specimens of *S. tumbil* were ranging in size from 3 to 46 cm (FL), and the total weight ranged from 1 to 954 g and the average length are 24.73(7.142±S.D) FL - cm and average weight 179.84 (149.02±S.D) g The dominant length range of *S. tumbil* were from 22 to 29 cm (FL) (Fig.1).

The length-weight relationship for both sexes combined was calculated as $W = 0.011L^{2.931}$ (R^2 = 0.976) n = 824 (Fig. 2).

Growth parameters

ELEFAN method in FiSAT II has been used to estimate von Bertalanffy growth parameters of *S. tumbil* a $L\infty$ = 48.30 cm (FL) and 0.320 *year*$^{-1}$ *(K)* (Fig. 3). The third parameter t_0 was also calculated by Pauly equation as t_0 = - 0.786 *year*$^{-1}$. The goodness of fit or model of were estimation at R_n = 0.295.

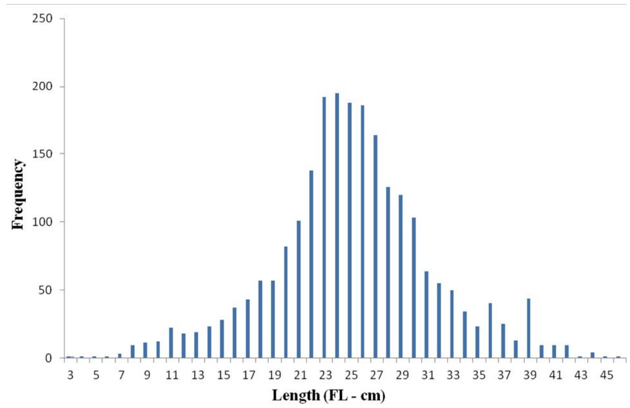

Fig. 1. Length frequency distribution of *S. tumbil* the dominant length frequency range from 22 to 29 cm (FL) using the trawl survey data from Pakistani waters during 2009 – 2010.

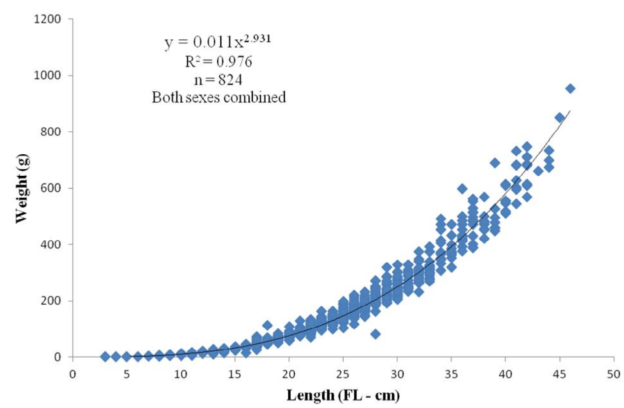

Fig. 2. Length-weight relationship of *S. tumbil,* using trawl survey data from the Pakistani waters during 2009 – 2010.

Mortality rate

The input values of the VBGF growth parameters ($L\infty$= 48.30, K = 0.320 *year*$^{-1}$) were used to convert the length data into age-based forms, the total mortality (Z) of *S. tumbil* from pooled data which were estimated was Z = 1.160 *year*$^{-1}$ with 95% confidential interval of Z were estimated at (CI = 1.05 – 1.27) (Fig. 4). The annual natural mortality was estimated using Pauly's empirical formula as M = 0.716 *year*$^{-1}$ at an average sea surface temperature

(SST) of 26°C, thus the fishing mortality was calculated as $F = Z - M = 0.444$ *year*$^{-1}$. The exploitation ratio (E) was obtained from $F / Z = 0.382$. The mortality rate from mean length in catch from Beverton and Holt method was estimated at $Z = 1.315$ *year*$^{-1}$.

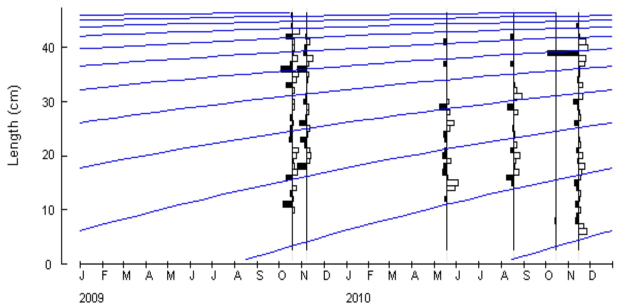

Fig. 3. Length frequency distribution data and growth curve parameters using ELEFAN for *S. tumbil* (the von Bertalanffy growth parameters were: $L\infty$ = 48.30 cm (FL), 0.320 *year*$^{-1}$ (K) t_0 = - 0.786 and (R_n = 0.295)) using the trawl surveys data from Pakistani waters during 2009 – 2010.

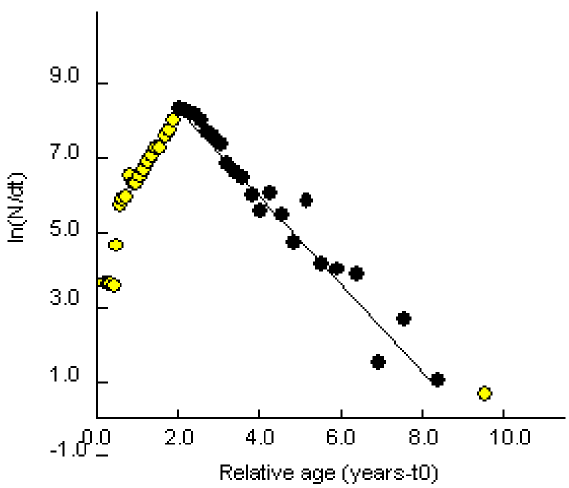

Fig. 4. Length converted catch curve of *S. tumbil* applying VBGF growth parameters (the von Bertalanffy growth parameters were $L\infty$ = 48.30 cm (FL) and K = 0.320 *year*$^{-1}$), only the black dots were selected to estimate the total mortality, where (Z = 1.160 *year*$^{-1}$ from Pakistani waters during 2009 – 2010.

Biological reference points

Figure 5 shows the yield per recruit contour map, when the maximum age was 12 years. When t_c was assumed to be 2, F_{max} was estimated as 1.25 and $F_{0.1}$ at 1.15, when t_c was assumed to be 1, F_{max} as estimated as 1 and $F_{0.1}$ at 0.9. Currently we assume that the age of fish t_c at first capture is about 1 year and $F_{current}$ was 0.444, therefore $F_{current}$ was smaller than $F_{0.1}$ and F_{max}. This indicated that the current fishery is in sustainable condition. When using the Gulland (1971) biological reference point F_{opt} was equal to M (0.716). The current fishing mortality rate is 0.444 *year*$^{-1}$ was lower than the biological reference point.

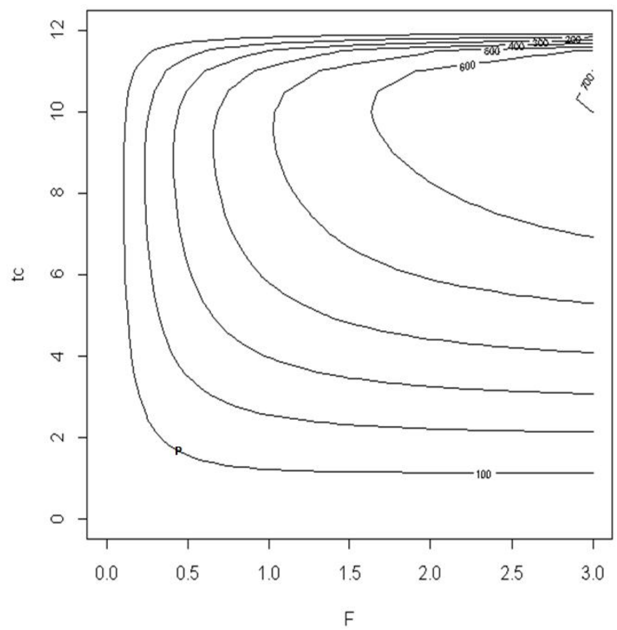

Fig. 5. Yield per recruit contour map of *S. tumbil* from Pakistani waters during 2009 – 2010. Where F = fishing mortality, *tc* was the mean age of fish at first capture and it was assumed from age composition data. P = When *tc*=1, F=0.44.

Growth performance index

The growth performance index (Ǿ) for *S. tumbil* was estimated at 2.873 from the five research survey data from Pakistani waters during 2009 – 2010.

DISCUSSION

Length-weight relationship

The length-weight relationship (LWR) is

among the basic parameters in biology and stock assessment of any fish species (Abdurahiman *et al*., 2004). LWR is useful to estimate the growth rates, length at age structure, and other components of population dynamics (Kolher *et al*., 1995) its variations indicate the growth and gonad development of the fish (Le Cren, 1951). The both sexes combined pair of LWR of *S. tumbil* from Pakistani waters was (b = 2.931) show the isomatric growth. The values from previous studies are shown in Table I and those values are close to the present study but the some values of slop b such as from Indian waters b = 3.29 (Rao, 1983); Kuwait waters b = 3.08 (Mathews and Samuel, 1989) and from China b = 3.04 (Wang *et al*., 2011) were greater than the present study. Few values are similar to the present study such as from South China Sea of 2.942 by Ambak *et al*. (1986), Persian Gulf of 2.921 by Rahimibashar *et al*. (2012) and 2.977 by Taghavi *et al*. (2012). The LWR parameters may be different due to some factors like availability of food climate, tropic state, temperature, salinity and the method in which samples were collected, Sex, season and stage of the fish maturity, habitat of fish (Begenal and Tesch, 1978; Biswas, 1993; Wootton, 1998; Taskavak and Bilecenoglu, 2001; Froese, 2006). Generally speaking the overall average values of LWR shown in Table I were close with the present study and showed the isometric growth of fish.

Growth parameters

The length frequency data were analyzed using FiSAT II to estimate the VBGF asymptotic length (L_∞) and growth parameters (K) and those can be compared with previous studies of the same species from different areas of the world shown in Table II.

The values of growth parameters from present studies of $L\infty$ = 48.30, K = 0.320 $year^{-1}$, were compared with previous studies from different parts of the world (Table II) The growth parameters from South Fujian and Taiwan $L\infty$ = 83.02, K = 0.11 $year^{-1}$ t_0 = - 0.427 (Xu and Zhang, 1988); Vietnam $L\infty$ = 79.5, 78.3, K = 0.1 $year^{-1}$, 0.08 $year^{-1}$ (Boonvanich, 1991); India $L\infty$= 57.5, K = 0.7 $year^{-1}$ (Manojkumar and Sivakami, 2005), $L\infty$= 57.5, K = 0.57 $year^{-1}$ (Muthiah, 1993), had shown that $L\infty$ values are higher than the present study but the K values were smaller than the present study, because of some ecological and biological factors effecting the growth of fish. Some ($L\infty$) asymptotic length parameters values are same or close to present study but the growth curve (K) values are higher than the present study such as from India $L\infty$ = 49.8, K = 0.96 $year^{-1}$ (Gulati *et al*., 1994); Vietnam $L\infty$ = 45.2, K = 0.36 $year^{-1}$ (Chu, 1999). Few values from previous studies are lower than the present study such as from China North South Beibu Gulf $L\infty$ = 31.0, K = 0.42 $year^{-1}$ (Wang *et al*., 2012); Bangladesh $L\infty$ = 41.8, K = 0.95 $year^{-1}$ (Mustafa, 1999); Bangladesh $L\infty$ = 39.0, K = 0.64 $year^{-1}$ (Mustafa and Khan, 1988); Bangladesh $L\infty$ = 40.70, K = 0.635 $year^{-1}$ (Khan *et al*., 2003) and from Malaysia West Sabah coast $L\infty$ = 36.0, K = 0.95 $year^{-1}$ (Isa and Ahmed, 2001). The difference in values maybe because of different localities and different factors effecting on the growth parameters and methods in which the sample has been collected, because those results were obtained from different data and different methods. Other factors affecting growth are some ecological characteristics, population size and life adaptation pattern of fish during their life within stock to stock and species to species (Adam, 1980; Sparre *et al*., 1992). Devaraj (1981) described that the differences in growth rate of fish indicates the stock separation. Table II also shows that difference different growth parameters analysis methods also affect on asymptotic length ($L\infty$) and growth curve (K) parameters. In this study the VBGF growth parameters were estimated by using the non-parametric method which is usually used in length frequency analysis of fish, which is basically ad hoc and does not depend on estimating the parameters of cohort directly.

Mortality rate

Causes of fish mortality are such as fish aging factor (King, 1991); fish predation (Otobo, 1993); environmental factor (Chapman and Van Well, 1978); Parasites and diseases (landau, 1979) and fishing activity (King, 1991). When age-structure data are not available then length converted catch curve method was frequently used to estimate the total mortality rate. The total, natural and fishing mortality rate of *S. tumbil* from Pakistani waters were (1.160, 0.716, 0.444 $year^{-1}$) respectively.

Table I.- **Comparison of length-weight relationship parameters of *S. tumbil* with previous studies from different parts of the world.**

Area	Sex	*a*	*b*	R^2	Sourlce
India	M	-	3.29	-	Rao, 1983
	F	-	3.20	-	Rao, 1983
Kuwait	F + M		3.08	-	Mathews and Samuel, 1989
Red Sea, Jizan Region	F	-	2.92	-	Bakhsh, 1994
	M	-	2.98	-	Bakhsh, 1994
India	F + M	3.43E-06	3.142	0.99	Muthiah, 1993
China	F + M	0.0096	3.04	0.999	Wang *et al*., 2011
China, NS, Beibu Gulf	F + M	-	3.047	0.994	Wang *et al*., 2012
China South Sea	F + M	0.014	2.942	-	Ambak *et al*., 1986
Persian Gulf	F + M	0.0096	2.921	0.937	Rahimibashar *et al*., 2012
Iran, Persian Gulf	F	0.022	2.977	0.958	Taghavi *et al*., 2012
Persian Gulf, Iran	F + M	0.0417	2.586	0.907	Raeisi *et al*., 2012
Pakistan, Arabian Sea	F + M	0.011	2.931	0.976	Present study

a, constant condition factor; *b*, slope; R^2, coefficient of determination; -, data not available in papers (F, Female; M, Male; F+M, both sexes).

Table II.- **Comparison of growth parameters of *S. tumbil* with present study from Pakistani waters during 2009–2010.**

Area	$L_{\infty (cm)}$	*K*	*Ǿ*	t_o	Source
Philippines Manila	43.6 (TL)	0.43	2.912	-	Tiews *et al*., 1972
Taiwan (Scale annuli)	68.7 (FL)	0.118	-	-1.40	Yeh *et al*., 1977
Taiwan (Scale annuli)	74.2 (FL)	0.104	-	-1.42	Yeh *et al*., 1977
India, Bay of Bengal***	63.7 (TL)	0.249	-	-0.334	Rao, 1984
Philippines, Manila Bay (ELEFAN)	37.5 (TL)	1.03	3.161	-	Ingles and Pauly, 1984
Philippines, Visayan Sea (ELEFAN)	41.0 (FL)	0.70	3.071	-	Ingles and Pauly, 1984
Philippines, Samar Sea (ELEFAN)	43.0 (FL)	0.64	3.073	-	Corpuz *et al*., 1985
Philippines, Ragay Gulf (ELEFAN)	53.0 (FL)	0.70	3.294	-	Corpuz *et al*., 1985
South China Sea (Ford-Walford plot)	55.06(SL)	0.197	-	-0.726	Ambak *et al*., 1986
South Fujian and Taiwan	83.02	0.111	-	-0.427	Xu and Zhang, 1988
Bangladesh	39.0	0.64	3.025	-	Mustafa and Khan, 1988
Vietnam	79.50	0.10	2.801	-	Boonvanich, 1991
Vietnam	78.30	0.08	2.691	-	Boonvanich, 1991
India, Karnataka coast	57.50	0.57	-	-0.216	Muthiah, 1993
India North west coast **	49.80	0.96	-	-0.141	Gulati *et al*., 1994
India, Maharashtra (ELEFAN)	60.0	0.51	-	-	Chakraborty, 1997
Bangladesh	41.80	0.95	3.22	-	Mustafa, 1999
Vietnam	45.20	0.36	2.867	-	Chu, 1999
Malaysia West Sabah (ELEFAN)	36.0	0.95	-	-	Isa and Ahmed, 2001
India, west coast Mumbai(ELEFAN)	60.0	0.76		-	Jaiswar *et al*., 2003
India, west coast Mumbai*	60.50	0.73	-	-	Jaiswar *et al*., 2003
Bangladesh (ELEFAN)	40.70	0.635	-	-	Khan *et al*., 2003
Brunei Darussalam (ELEFAN)	54.0 (TL)	0.65	3.29	-	Silvestre and Garces, 2004
India, Veraval (ELEFAN)	57.7 (TL)	0.70	-	-	Manojkumar and Sivakami, 2005
Southern Taiwan ***	56.3 (FL)	0.232	-	-0.558	Jianguo *et al*., 2011
China, Beibu Gulf (ELEFAN)	31.0 (SL)	0.42	-	-0.37	Wang *et al*., 2012
Pakistan, Arabian Sea (ELEFAN)	48.30(FL)	0.320	2.873	-0.786	Present study

$L\infty$ *(cm)* asymptotic length (cm); *K*, growth curve; (Ǿ), growth performance index; t_0, hypothetical age at which length of the fish is equal to zero length, (* Bhattacharya/Gulland Holt plot, ** Model Progression Analysis, *** von Bertalanffy, 1938) (TL = Total length, SL = Standard length, FL = Fork length), (- data not available in papers).

Table III.- Mortality rate of *S. tumbil* compared with previous studies and the present study from trawl surveys from Pakistani waters during 2009–2010.

Area	*Z*	*M*	*F*	Source
Philippines, Manila Bay	4.83[a]	1.71[b]	3.12	Ingles and Pauly, 1984
Philippines, Visayan Sea	2.22[a]	1.30[b]	0.92	Ingles and Pauly, 1984
Philippines, Ragay Gulf	5.31	1.17	4.14	Corpuz *et al*., 1985
Philippines, Samar Sea	1.68	1.18	0.50	Corpuz *et al*., 1985
Philippines, San Pedro Bay	2.79	1.52	1.27	Armada, 1996
Bangladesh	2.54	1.66	0.88	Mustafa and Khan, 1988
Bangladesh	2.99	1.57	1.42	Mustafa, 1999
Bangladesh	2.32	1.26	1.06	Khan, 1999
Bangladesh	1.93[a]	1.22[b]	0.71	Khan *et al*., 2003
Malaysia, west coast	3.40[a]	1.93[b]	1.47	Isa and Ahmed, 2001
Malaysia, Sarawak	2.75[a]	0.87[b]	1.88	Isa and Ahmed, 2001
Malaysia, Sabah	3.03[a]	1.69[b]	1.34	Isa and Ahmed, 2001
Malaysia, East coast	2.62[a]	1.54[b]	1.08	Isa and Ahmed, 2001
India, , Maharashtra	2.8[a]	1.0[b]	1.8	Chakraborty, 1997
India, west coast Mumbai	4.59[a]	1.20[b]	3.39	Jaiswar *et al*., 2003
Brunei Darussalam	1.19[a]	1.14[b]	0.05	Silvestre and Garces, 2004
India, Veraval	3.46[a]	1.16	2.30	Manojkumar and Sivakami, 2005
China,	2.55[a]	0.89[b]	1.66	Wang *et al*., 2012
Pakistan, Arabian Sea	1.160[a]	0.716[b]	0.444	Present study

Z, total mortality; *M*, natural mortality; *F*, fishing mortality, a, length converted catch curve method; b, Pauly's empirical formula.

Using Beverton-Holt method (1957) the total mortality were estimated at $Z = 1.315$ $year^{-1}$ which were close to the total mortality estimated from length converted catch curve where Z=1.160 $year^{-1}$. The total mortality estimate with the input value of growth parameters therefore the growth parameters can affect the total mortality (Isaac, 1990; Tserpes and Tsimenidis, 2001).

The mortality rates of the same species from different parts of the world are shown in Table III. The overall values from different areas are higher than the present study, *e.g.*, the total, natural and fishing mortality were such as 4.83, 1.71, 3.21 in Philippines Manila Bay (Ingles and Pauly, 1984); 2.99, 1.57, 1.42 in Bangladesh (Mustafa, 1999); 4.59, 1.2, 3.39 in India (Jaiswar *et al*., 2003); 2.55, 0.89, 1.66 in China (Wang *et al*., 2012), respectively (Table III). This maybe because of more commercial demand of this fish, the fishing mortality of this fish species were higher than those from the Pakistani waters during 2009 – 2010. The exploitation ratio of *S. tumbil* from Pakistani waters was $E = 0.382$. According to Gulland (1971, 1979) if exploitation ratio (E) is more than 0.5 it will be assumed that the fish stock is in a overexploitation state, and according to Patterson (1992) an exploitation ratio should be maintained at 0.4 level for sustainable level, therefore we may assume that the stock of *S. tumbil* from Pakistani waters are in sustainable condition. But according to Patterson (1992) the exploitation ratio is close to the present study ($E = 0.382$) so we may suggest that the fishery managers should take some actions to maintain the stock of this fish species at present state so as to in future the stockholder can get more benefits from the stock.

Biological reference points

In order to describe the long-term fishery management objectives we have to calculate the biological reference points using the length frequency data. In Figure 5, the yield per recruit analysis shows that when t_c was assumed to be 2, F_{max} was estimated as 1.25 and $F_{0.1}$ at 1.15; when t_c was assumed to be 1, F_{max} was estimated as 1 and $F_{0.1}$ at 0.9. Currently we assume the age of fish at first capture is about 1 year and $F_{current}$ was 0.444, therefore $F_{current}$ was smaller than $F_{0.1}$ and F_{max}. $F_{0.1}$ is considered more suitable to set management targets than F_{max} for several reasons (Deriso, 1987). This indicates that the fishing mortality at current stage is in a sustainable condition. Gulland (1971) suggested that F_{opt} was equals to M = 0.716. The current fishing mortality rate is 0.444 *year*$^{-1}$ and exploitation ration E = 0.382, were lower than the biological reference point and exploitation ratio of 0.5 and 0.4, respectively (Gulland, 1971; Patterson, 1992). Therefore we can assume that the stock of fish were in a safe condition, and recommend that the fishery manager can maintain the fishing efforts from Pakistani waters in the present level.

Growth performance index

Growth performance index is important in the fish stock assessment (Pauly and Munro, 1984) which is based on the two VBGF parameters of growth rate K and asymptotic length ($L\infty$). The present values (2.873) were compared to previous studies (Table II). The values were 3.161 in Philippines (Ingles and Pauly, 1984); 3.22 in Bangladesh (Mustafa, 1999) and 3.29 in Drunei Darussalam (Silvestre and Garces, 2004). Those were higher than present study but the same values were found from Vietnam were 2.867 (Chu, 1999); 2.801 (Boonvanich, 1991). The rest of the values are similar to the present study. The higher value of growth performance index indicates that fish can grow faster and larger according to our results it shows that the *S. tumbil* fish grow at good average from Pakistani waters.

In conclusion the research surveys data were frequently used for population dynamics and stock assessment for fisheries because the data collected from those research surveys were represent the all length classes of any fish species, the data collected from fish harbors were mostly selected length class species due to landing of larger size of fishes at harbor. Therefore our study may represent the all length class of *S. tumbil* from Pakistani waters.

According to our study the spatial and temporal distribution of *S. tumbil* during present study were found throughout all trawl survey at deferent levels from 20 to 60 m depth and most of the catches from Sindh coastline.

According to the mortality rate and exploitation rate from present study the stock of *S. tumbil* fishery from Pakistani waters is in sustainable state. Therefore we may suggest that the stock of this fishery should be kept at current fishing level and spawning grounds of this fishery should be protected to provide them better breeding opportunity and protect the breeding stock.

In this study length frequency data were used into length converted catch curve analysis by applying input of growth parameters and those parameters will affect on the total mortality of fish this may also may cause the different total mortality estimates (Issac, 1990). To maintain the stock of this commercial important fish species on sustainable state, the fishery managers should take some steps to maintain the stock of this fish species on current level and maintain the check and balance on fishing efforts especially during the closed season and during the spawning season especially during monsoon. Also efforts are needed to control on the fishing mesh size that can protect the small fish and allow each fish to produce eggs at least one time their life, protect the area during their breeding season and maintain the fishing efforts at current level.

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