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Full Length Article

Population Parameters of Siluroid Catfish (*Eutropiichthys vacha*) from Indus River, Pakistan

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Abstract

Population dynamics parameters and exploitation status of *Eutropiichthys vacha* (Hamilton, 1822) in the Indus River were evaluated (February 2011 to January 2012) collecting (*n*= 821) specimen with 459 males and 362 females. The total length was 10 to 34 cm with an average of 21±4.329 cm and weight ranged 15 to 210 g with an average of 71±39.911 g for both sexes. The pooled, male and female length weight relationship was estimated as $W= 0.016\ L^{2.692}$ (R^2= 0.913), $W= 0.014\ L^{2.750}$ (R^2= 0.909) and $W= 0.017\ L^{2.674}$ (R^2= 0.885) respectively. Length frequency distribution data was analyzed by using ELEFAN-I method in FiSAT-II software to estimate von Bertalanffy growth parameters. The L_∞, K, t_0, and R_n were estimated at 35.7 cm, 0.30/year, -0.358 year and 0.295 for pooled sex, 33.6 cm, 0.64/year, -0.610 year and 0.206 for males and 35.7 cm, 0.58/year, -0.573 year and 0.267 for females respectively. The annual total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated at 1.09/year, 0.762/year and 0.33/year for pooled sexes, 1.85/year, 1.129/year and 0.721/year for males and 1.51/years, 1.041/year and 0.469/year for females. For the pooled data the exploitation ratio was estimated 0.302, for male and female 0.389 and 0.31 respectively. Because the present fishing mortality 0.330/year was smaller than the limit biological reference points (F_{opt}= 0.762/year, F_{max}= 1.2/year and $F_{0.1}$= 1/year), indicating that the stock of *E. vacha* is not being over-fished.

Keywords: Population parameters; *Eutropiichthys vacha*; Indus river; FiSAT; Pakistan

Introduction

In Pakistan, there are about 193 freshwater fish species represented by 86 genera, 30 families, 13 orders, 6 suborders, 3 cohorts come under the class Actinopterygii and sub-class Teleoste (Rafique, 2007). Out of them 31 freshwater species of Pakistan have high economic importance (Rafique and Khan, 2012). According to the most recent and authentic information, the 326 marine water species of Pakistan are reported (Psomadakis *et al*., 2015).

Large and small lakes, reservoirs, ponds, irrigation canals, flood zones, waterlogged areas, streams, natural depressions, etc represent Pakistan's freshwater resources. In addition to these institutions, the Indus River and its tributaries are the major freshwater resources of Pakistan (Mirza, 1975). Freshwater resources of Sindh are Indus and Hub Rivers in connection with about 100 large and small lakes, a large number of ponds, depressions and flood areas in the recess of the Indus River. Indus River is the most important natural resources in Pakistan approximate length of about 3180 km, is one of the largest rivers in the world with drainage area of 11,65,000 sq km with 207 billion cubic meters annually flow (Nasir and Akbar, 2012; Waqas *et al*., 2012). It is derived from the northern mountains of the Himalayas enters in Pakistan from Gilgit-Baltistan and eventually drop to the Arabian Sea near Thatta District of Sindh, Pakistan (Bhatti, 1999). Kotri Barrage is the last dam on the Indus River about 0.575 miles to be measured (920 m) across the south of the Indus River near the city of Hyderabad, Pakistan. The Indus River runs about 100 km beneath the dam before expulsion into the Arabian Sea (Bhatti, 1999).

Fisheries play an important role in Pakistan's economy and are the source of livelihood for the coastal residents. In addition to marine fisheries, inland fisheries based on rivers, lakes, ponds, reservoirs are also very important activity all over the country. Fisheries account for 0.3% of GDP of Pakistan. Although the contribution is very small, it has greatly increased the national income through export earnings. A total of 84,498 tons of fish and fish products were exported during 2011–2012 (GoP, 2011–2012).

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The family Schilbeidae is represented by about 15 genera and 67 species of fish in freshwater bodies of the world (Eschmeyer and Fong, 2016). The schilbeid catfish is most important constituents of Ichthyofauna of many freshwater bodies, is heavily exploited and widely cultured (Etim *et al*., 1999). This family Schilbeidae is widely distributed in Asia and Africa (Mirza, 1975). In Pakistan this family is distributed by five species in three genera, genus *Ailia*, *Clupisoma* and *Eutropiichthys* (Mirza, 1975; Rafique and Khan, 2012; Rafique, 2007). The genus *Eutropiichthys* is represented in Pakistani waters by only one species *E. vacha* (Mirza, 1975; Rafique, 2007).

E. vacha (Hamilton, 1822) is a subtropical fresh and brackish water fish species commonly known as "River Catfish" (Rahman, 1989), locally known as "Challi" in Pakistan (Soomro *et al*., 2007). It is an economically important inland water bony fish, widely distributed in Asia, across the Indian subcontinent including Pakistan, Bangladesh, India, Nepal, Myanmar and Thailand (Talwar and Jhingran, 1991). This is a potamodromous freshwater fish typically migrate within freshwater from rivers to lakes, and vice versa for spawning and nursery purposes (Chandra *et al*., 2010). It inhabits in lentic and lotic waters, almost in rivers, lakes and streams. It is most important freshwater catfish found in all tropical freshwater of Pakistan. It has a high economic importance on US$ 1.2–1.5 per kg at the market and also exported to Middle East countries (Soomro *et al*., 2007).

The growth and mortality of schilbeid catfish has not been previously investigated in the Indus River. In this study, we examined the growth parameters, mortality rates, the biological reference points, growth performance indices and virtual population analysis of the *E. vacha* in the Indus River. In addition, we also calculated the rate of exploitation and relative yield per recruit. The purpose of this study was to understand the importance of stock position and population parameters of *E. vacha* in the Indus River.

Materials and Methods

Study Area and Sampling

Samples of *E. vacha* were collected during the second weekend of every month, from February 2011 to January 2012, from artisanal fishermen who use mostly nylon nets (gill nets and seine nets) in the Indus River and land their catches at Kotri Barrage lying at 25º 26'N 68º 22'E on the right bank of the Indus River (Fig. 1). Kotri is one of the most important fishing centers along the Sindh over the lower reaches of the river Indus (Bhatti, 1999). The total length and total weight of the fish samples was measured to the cm and g with an average of 21±4.329 cm TL and 71±39.911 g TW (*n*= 821) for combined sexes, while 21±4.274 cm and 67±37.703 g (*n*= 459) and 22.035±4.247 cm and 75.295±43.473 g (*n*= 362) for male and females respectively. The Provincial Government of Sindh

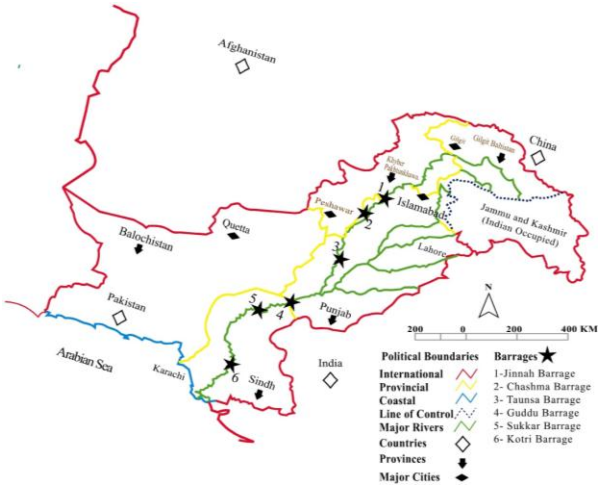

Fig. 1: Location of sampling points of the Kotri Barrage on the Indus River, Sindh, Pakistan

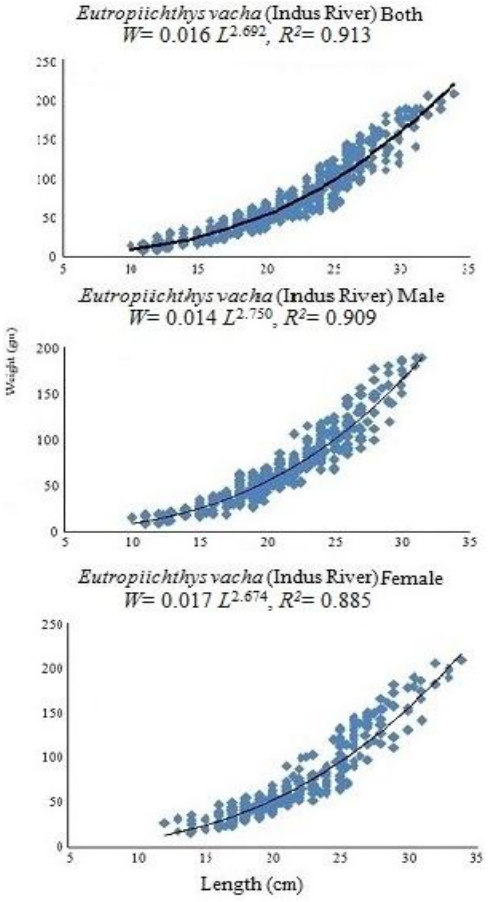

Fig. 2: Length-weight relationship of the *E. vacha* (Combined sexes, male and female) form Indus River

allows a minimum mesh size of 15 cm for the capture of adult fish but, unethically, this mesh size is ignored (Panhwar and Liu, 2013). For medium fish, the most effective mesh size is between 3–4 cm. This grid size

captures a fair amount of fish plus the maximum number of medium sized fish. We use a mesh size of 22–26 mm (2.20–2.60 cm) for *E. vacha* on the Indus River.

Length-weight Relationship Parameters

The length-weight relationship were estimated by the power equation as: $W= aL^b$, where weight of fish was represented by W in grams (g), constant condition factor was represented by intercept (a), L is total length in (cm) and allometric growth parameter was represented by exponent or slope (b).

Growth Parameters

Growth patterns of *E. vacha* were determined by using the method ELEFAN-I (Electronic Length Frequency Analysis) in this study, which make direct use of size distributions to prepare an estimate of the growth parameters. The von Bertalanffy growth function (VBGF) (Haddon, 2011) is: $L_t = L_\infty (1 – exp (- K (t – t_0)))$, where L_t was the length at time t, L_∞ was the asymptotic length, K was the growth coefficient and t_0 was the hypothetical age or time where length was equal to zero. Estimated value of t_0 was obtained by the empirical equation by Pauly (1983) as: $log_{10} (-t_0) = -0.3922 - 0.275 log_{10} L_\infty -1.038 log_{10} K$.

Estimation of Mortalities Rates

For the estimation of annual instantaneous total mortality (Z) a length converted catch curve method of Pauly (1983) was used: $ln(N_i / \Delta t_i) = a + b \cdot t_i$. N_i is the number of fish in length class i, Δt_i is the time required for development through length class i. While t_i is the age (or the relative age, computed with $t_0= 0$) corresponds to the intermediate length of class i. The slope b gives the estimated Z. Natural mortality (M) is estimated from $Log_{10} M = 0.0066 – 0.279 log_{10} L_\infty + 0.654 log_{10} K + 0.4634 log_{10} T$ (Pauly, 1980), where the average annual surface temperature of the water in the Indus River is 21°C in which the stock of *E. vacha* occurs. The F (Fishing mortality) was estimated by $F= Z-M$ (Sparre and Venema, 1992). The exploitation ratio (E) was obtained by $E = F/Z$ (Gulland, 1971a). The values of instantaneous total mortality for pooled sexes of *E. vacha* in Indus River Z= 1.09/year of $CI_{95\%}$ to 1.03–1.14 (r^2= 0.993), for male Z= 1.85/year of $CI_{95\%}$ to 1.76–1.94 (r^2= 0.994) and for female Z= 1.51/year of $CI_{95\%}$ to 1.41–1.61 (r^2= 0.987) were constructed from the input values of VBGF parameters (L_∞ and K) in the length converted catch curve model described by Pauly (1983).

Virtual Population Dynamics (VPA)

According to Sparre and Venema (1992) the length structured virtual population analysis (*VPA*) of *E. vacha* was carried out with the input values of length weight relationship, growth and mortality parameters to estimate the fishing mortalities per at length class. The t_0 value was taken as zero.

Biological Reference Points (BRPs)

According to Gulland (1969), the optimal fishing mortality rate $F_{opt}= M$ was used as biological reference points for *E. vacha* in the Indus River.

Beverton-Holt Yield per Recruit Model

Using the Beverton and Holt (1957) model in FiSAT-II program (Gayanilo *et al*., 2005) with the formula: $Y_w / R = FW_\infty e^{-M(t_c - t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c - t_0)}}{F + M + nK} (1 - e^{-(F+M+nK)(t_\lambda - t_c)})$ relative yield per recruit (Y/R) values of *E. vacha* was estimated. Where Y_W/R was yield per recruit, t_c was the average age of first capture, t_r was the age of recruitment, t_λ was the asymptotically ages, Q_n was the constant and equal to 1, -3, 3 and -1 when n was 0, 1, 2 and 3 correspondingly (Pitcher and Hart, 1982).

Growth Performances Indices (GPI, Phi prime Φ')

The estimated growth parameters values of L_∞ and K were used to compute the growth performance index (Phi prime Φ') (Pauly and Munro, 1984) $\Phi' = log_{10} K + 2 log_{10} L_\infty$.

Analysis of Data

The monthly length-frequency data of *E. vacha* was analyzed using the FISAT-II software as explained in detailed by Gayanilo *et al*. (2005). Time-series data were collected and size-frequency distributions at 5cm intervals were obtained for each month (Table 1).

Results

Length-weight Relationship Parameters

The total length and total weight of pooled sex, male and female ranged between 10 to 34 cm at average 21±4.329 cm and 15 to 210 g with an average 71±39.911 g (n= 821), 10 to 32 cm at average 21±4.274 cm and from 15 and 190 g with an average weight 67±37.703 g (n= 459) and 12 to 34 cm of average 22.035±4.247 cm and 27 to 210 g on weight average of 75.295±43.473 g (n= 362), respectively. The length-weight relationship for *E. vacha* was described by the power equation as: $W= 0.016 L^{2.692}$, $R^2= 0.913$ for pooled sexes, for males $W= 0.014 L^{2.750}$, $R^2= 0.909$ and $W= 0.017 L^{2.674}$, $R^2= 0.885$ for females respectively in Fig. 2. Dominant length ranges for both sexes, male and female were 18 to 26 cm, 18 to 22 cm and 18 to 22 cm respectively (Fig. 3). Dominant weight ranges for both sexes, male and female were between 40 and 65 g, 50 to 65 g and 40 to 50 g respectively.

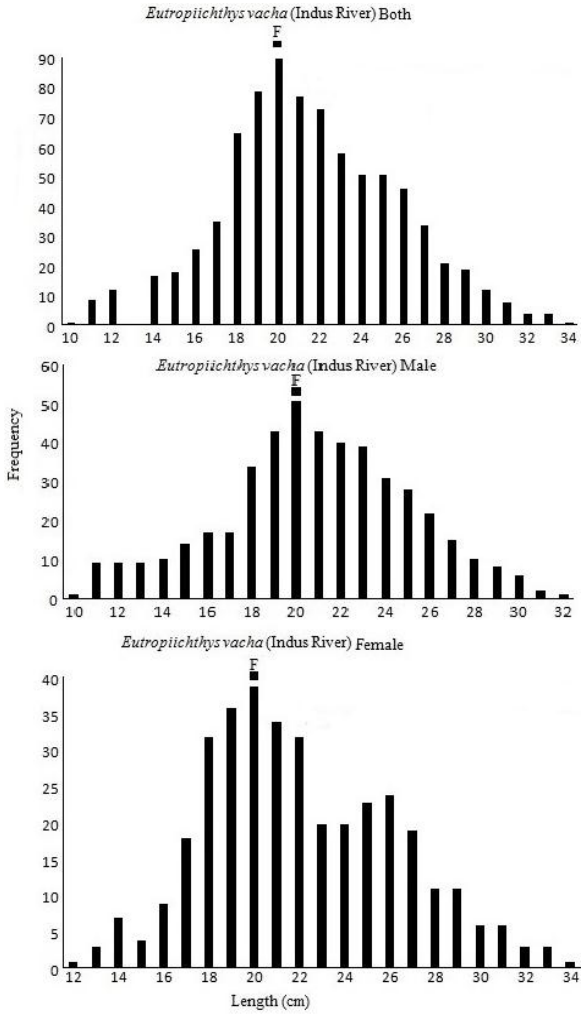

Fig. 3: Length frequency distribution of the *E. cacha* (Combined sexes, male and female) from Indus Revier of the Sindh Pakistan

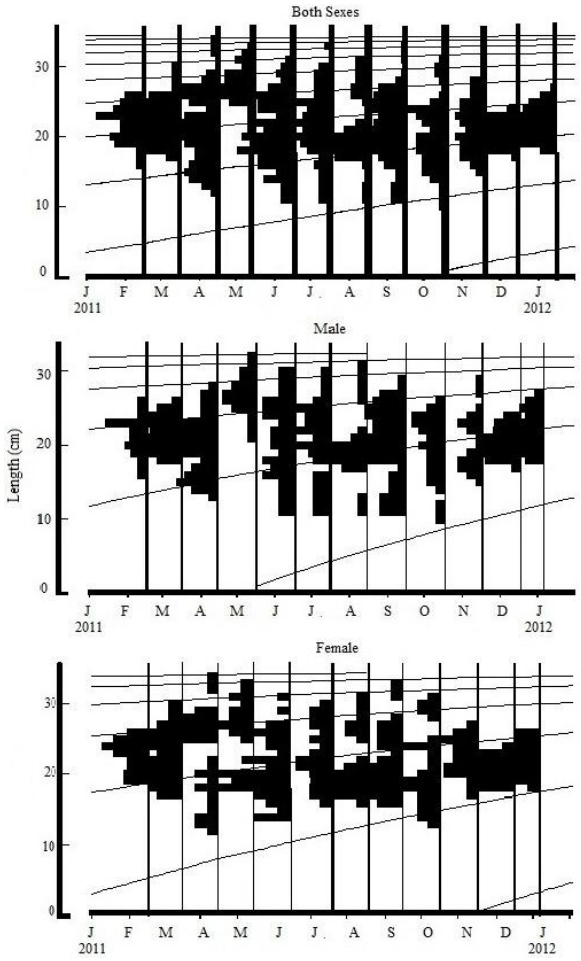

Fig. 4: Length frequency distribution and growth curves estimated using ELEFAN-I method for *E. vacha* (Combined sexes, male and female) from Indus River of Sindh, Pakistan

Estimations of Growth Parameters

The procedure of K-scan was computed to estimate the L_∞ (asymptotic length) and K (growth coefficient) through the method of ELEFAN-I for von Bertalanffy growth function of *E. vacha* in this study. Monthly length frequency size distribution of *E. vacha* was arranged at 5 cm interval shown in Table 1. The estimated values of L_∞ and K were obtained for pooled sexes as L_∞= 35.70 cm and K= 0.36/year, while L_∞= 33.60 cm and K= 0.64/year was acquired for male and L_∞= 35.70 cm and K= 0.58/year was achieved for female. The score or goodness of fit index of the ELEFAN-I routine R_n= 0.295 was constructed by the total sum of observation in this function. Whereas R_n= 0.206 and R_n= 0.267 were also separately computed for male and female. Output result of hypothetical age at zero length t_0= -0.358, t_0= -0.610 and t_0= -0.573 years were estimated for the pooled sexes, male and female respectively (Fig. 4).

Mortality and Exploitation Ratio

The value of natural mortalities M= 0.762/year for pooled sexes, M= 1.129/year for male and M= 1.041/year for female at the mean annual surface water temperature of Indus River of 21ºC were estimated. Fishing mortalities for pooled sexes, male and female of F= 0.330/year, F= 0.721/year and F= 0.469/year were obtained by the subtracting Z from M, respectively (Fig. 5). The exploitation ratio of E= 0.302 for pooled sexes, E= 0.389 for male and E= 0.310 for female were achieved (Table 2).

Virtual Population Analysis (VPA)

Input values of von Bertalanffy growth (L_∞= 35.7 cm and K= 0.36/year), mortality (M= 0.762/year and F= 0.33/year) and length weight relationship parameters (a= 0.016 and b= 2.692) were used to build the length structured virtual population analysis (LVPA) for the *E. vacha* in the Indus

Table 1: Combined, male and female number of individuals examined in various months and size classes in the population of *E. vacha* in 2011-2012

Size classes	11-Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	12-Jan	Total	%
							Both							
10-14.9	0	0	9	0	11	8	3	11	7	0	0	0	49	5.97
15-19.9	4	19	25	0	32	14	29	36	22	14	18	10	223	27.16
20-24.9	22	41	37	4	30	27	15	43	24	18	36	53	350	42.63
25-29.9	7	14	25	27	22	18	11	21	7	10	0	9	171	20.83
30-34.9	0	1	3	8	3	3	4	3	3	0	0	0	28	3.41
∑	33	75	99	39	98	70	62	114	63	42	54	72	821	100%
							Male							
10-15.9	0	0	9	0	10	10	3	13	6	1	0	0	52	11.33
16-21.9	5	20	31	1	19	12	23	29	13	12	19	21	205	44.66
22-27.9	10	16	22	14	19	17	3	25	14	9	8	18	175	38.13
28-32.9	0		1	9	6	3	4	2	0	2	0	0	27	5.88
∑	15	36	63	24	54	42	33	69	33	24	27	39	459	100%
							Female							
12-17.9	0	2	8	0	9	3	4	6	9	1	0	0	42	11.6
18-23.9	9	23	7	0	24	13	17	27	11	9	27	26	193	53.31
24-29.9	9	13	18	10	10	10	7	9	7	8	0	7	108	29.83
30-34.9	0	1	3	5	1	1	2	3	3	0	0	0	19	5.25
∑	18	39	36	15	44	27	30	45	30	18	27	33	362	100%

Table 2: Estimated key parameters of growth, mortality, exploitation and yield of *E. vacha* from the Indus River in 2011-2012

Population parameters	*Eutropiichthys vacha* (Indus River)		
	Both Sexes	Male	Female
Intercept (*a*)	0.016	0.014	0.017
Exponent (*b*)	2.692	2.75	2.674
Coefficient of determination (R^2)	0.913	0.909	0.885
Asymptotic length (L_∞)	35.7 cm	33.6 cm	35.7 cm
Growth coefficient (*K*)	0.36/year	0.64/year	0.58/year
Theoretical age (t) at zero length (t_0)	-0.358year	-0.61year	-0.573year
Goodness of fit (R_n)	0.295	0.206	0.267
Total mortality (*Z*)	1.09/year	1.85/year	1.51/year
Mean annual water temperature of Indus River	21ºC	21ºC	21ºC
Natural mortality (*M*)	0.762/year	1.129/year	1.041/year
Fishing mortality (*F*) $F= Z - M$	0.330/year	0.721/year	0.469/year
Exploitation rate (*E*) $E= F / Z$	0.302	0.389	0.31
GPI Φ' (L_∞)	2.662	2.859	2.869
GPI Φ (W_∞)	1.146	1.369	1.352
Length range (*cm*)	10-34 cm	10-32 cm	12-34 cm
Sample number (*n*)	821	459	362

River. Cohort analysis was used to output graphics for LVPA in FiSAT-II (Fig. 6). The length of the high fishing mortality was observed in 26.0 to 31.0 cm range for both sexes, while in male from 20.0 to 25.0 cm and 27.0 and 31.0 cm in females.

Biological Reference Points

The Beverton-Holt relative yield per recruit of *E. vacha* was analyzed assuming knife edge recruitment in FiSAT-II (Fig. 7). When t_c was to be at 1 the F_{max} was estimated at 1.2/year and $F_{0.1}$ to 1/year for combined sexes, 2.3/year and 1.9/year for male and 2.05/year and 1.5/year for females. As the current age at the first capture was approximately 1 year and $F_{current}$ was 0.330/year, 0.721/year and 0.469/year for combined sexes, male and female respectively, they are smaller than the limit fishing mortality. Apart from the above the $F_{current}$ (0.330/year) was smaller than the biological reference point, which is $F_{opt}= M$ = 0.762/year. This shows that stock of this species is not over-fished in Indus River.

Growth Performance Indices

Growth performances indices are Φ'= 2.662, Φ'= 2.859, Φ'= 2.869 for pooled sexes, male and females derived as results of the input values of von Bertalanffy growth parameters, respectively.

Discussion

The main objective of the fish population dynamics is to

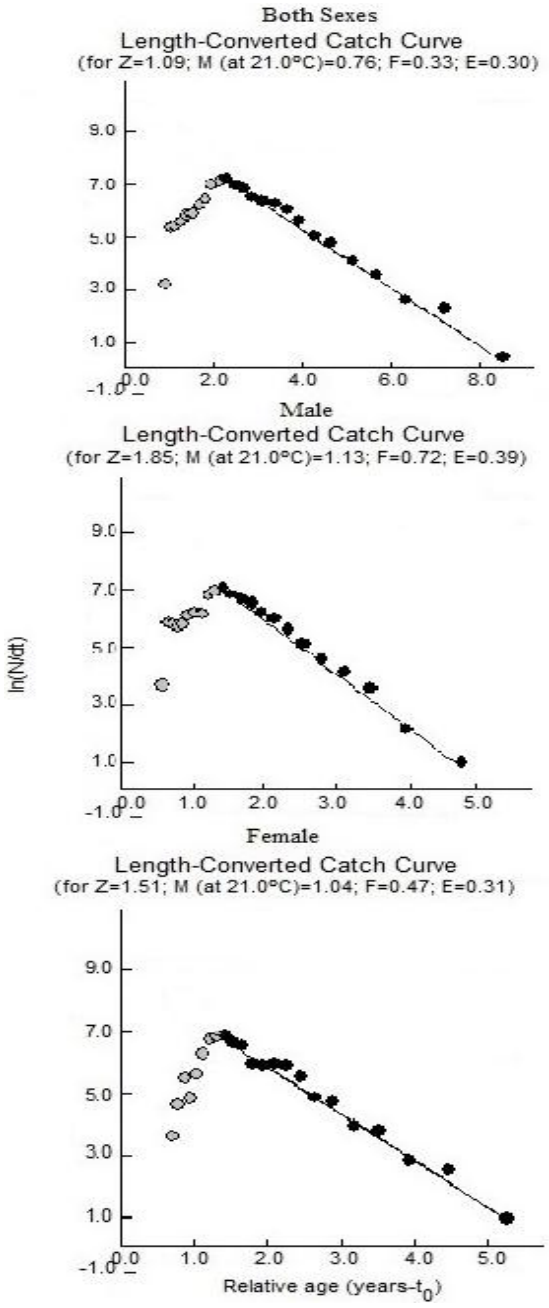

Fig. 5: Length converted catch curve analysis for *E. vacha* (Combined sexes, male and female) from Indus River of Sindh, Pakistan

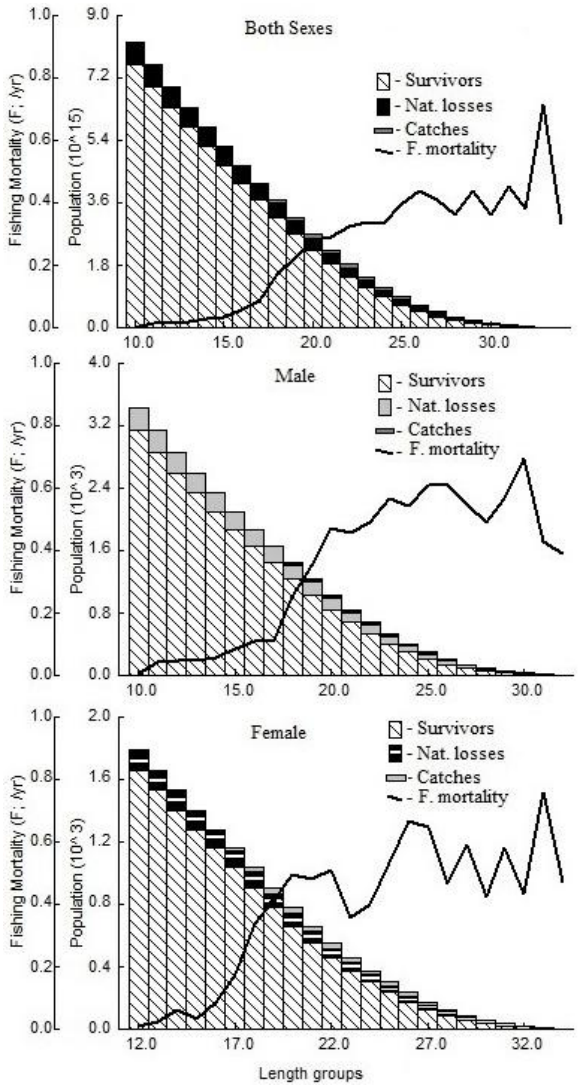

Fig. 6: Length structured cirtual population analysis (LVPA) was done in FiSAT-II for *E. vacha* for (Combined sexes, male and female) from Indus River of Sindh, Pakistan

estimate the population parameters such as growth of fish, mortality, exploitation ratio and biological reference points. There are a number of tools to evaluate exploitation level and the stock situation, of these FiSAT-II software (FAO-ICLARM Stock Assessment Tools) is the most often and widely used for the estimation of fish population parameters and requires only a length frequency data (Al-Barwani *et al*., 2007; Tah *et al*., 2010).

If *b* value is less than three the fishes will be light in growth, but the value of *b* is more than three the fishes might be heavy, wherein if the value of *b* is equal to three the growth of fishes would be isometric (Quinn and Deriso, 1999). Isometric growth represents a certain body shape of fish that would remain proportional throughout life in general (Pauly and Gayanilo, 1997). Information on the type of fish growth is provided by the value *b*. In the case $b = 3$ the growth is an isometric and when *b* value indicate $\neq 3$ the growth is allometric, the case of $b < 3$ means negative allometric growth and when $b > 3$ known as positive allometric growth. Growth coefficient factor *b* typically ranges from 2.5 to 3.5 (Pauly and Gayanilo, 1997). Overall our estimated *b* values of length weight relationship meet with this range in this study.

Table 3: The estimated length weight relationship parameters for the *E. vacha* from the different habitats in the world

Reference	Sex	n	Length (cm)		a	b	r^2	Location
		Type	Min	Max				
Hossain *et al*. (2013)	C	350	TL	8.01	16.95	0.007	2.292	0.914	Jammu River, Bangladesh
	M	160	TL	8.22	16.94	0.006	3.03	0.905	
	F	190	TL	8.01	16.95	0.009	2.81	0.901	
Sani *et al*. (2010)	C	23	TL	8.4	21.5	0.013	2.73	0.97	Gomti River, India
Soomro *et al*. (2007)	C	270	TL	12.3	34	0.005	3.05	0.964	Indus River, Pakistan
	M	142	TL	12.3	31.5	0.003	3.16	0.955	
	F	128	TL	13.9	34	0.007	2.96	0.976	
Hossain *et al.* (2010)	C	130	TL	7.45	21.3	0.107	2.988	0.984	Padma River, Bangladesh
Hossain *et al.* (2009)	C	136	TL	6	25.8	0.018	2.84	0.976	Ganges River, Bangladesh
Presesnt study	C	821	TL	10	34	0.016	2.692	0.913	River Indus, Pakistan
	M	459	TL	10	32	0.014	2.75	0.909	
	F	362	TL	12	34	0.017	2.674	0.885	

n = sample size, Min = minimum, Max = maximum, *a* = intercept, *b* = exponent, r^2 = coefficient of determination, *TL* = total length, *C* = combined sexes, *M* = male, *F* = female

Table 4: Computed growth parameters of *E. vacha* in the Indus River from the current study compared to the other of the estimated growth parameters of the different methods of Schilbeid catfish of different tropical regions

Reference	L_∞ (cm)	K/year	t_0	Φ'	Location
Cerny (1974)	47.04	0.07		2.21	Lake Kariba, Kenya
Frank (1974)	52.63	0.05		2.18	Lake Kariba, Kenya
Olatunde (1979)	33.13	0.19		2.32	Kainji Lake, Nigeria
Hecht (1980)	33.9	0.34		2.6	L. N. impound. S. Africa
Ramakrishnaiah (1984)	47.08	0.27		2.78	Nagarjunasagar res. India
Etim et al. (1999)	27.5	0.29		2.34	C. River, Obubra, Nigeria
Adedolapo (2007)	28.5	0.53	-0.31	2.62	Asejire lake, Nigeria
Adedolapo (2007)	28.7	0.39	-0.43	2.51	Oyan Lake, Nigeria
Presesnt study^B	35.7	0.36	-0.35	2.66	Indus River, Pakistan
Presesnt study^M	33.6	0.64	-0.61	2.85	Indus River, Pakistan
Presesnt study^F	35.7	0.58	-0.57	2.86	Indus River, Pakistan

B= both sexes, M= male, F= female

The regression coefficient parameter of *b* for the combined sexes, male and female was showing negative allometric growth for *E. vacha* in the Indus River for this study. 55.907% (*n*= 459) were from male, whereas 44.093% (*n*= 362) were contributed by female out of total sample (*n*= 821) by the artisanal fishermen. These fishes were mainly caught with the locally made nylon nets (seine gear locally known as "Katra" and gillnets locally called "Thukri") in the Indus River. Although, the regression parameter *b* for male 2.750 represents superior than female 2.674, showing the male got faster growth in body weight than the females. Similar results in Table 3 were reported for males in same species got bigger value of regression coefficient *b* than female in Indus River, Sindh, Pakistan (Soomro *et al*., 2007) and Jammu River, Bangladesh (Hossain *et al*., 2013). Estimated parameters of the LWR of *E. vacha* were compared with the previous studies from different population groups (Table 3). The difference in value *b* may be due to a combination of one or more factors including the environment, local zone, cyclical effects, the degree of fullness of the stomach, maturity, reproductive organs, health status, the methods and storage, and a length difference ranges observed in samples caught (Hossain, 2010).

Growth is a unique and one of the most common features of fish due to a good health indicator of the both individual samples and entire populations. The VBGF growth parameters L_∞ and *K* describing the fish populations in our study were estimated from length frequency data. Length data was grouped in 5 cm interval using ELEFAN-I method available in FiSAT-II. Data file of the length frequency is characterized by the limitations of the lower and upper class, the size of a certain class by the size of the variable class can be grouped by class interval. FiSAT-II is not required entering the input of the upper and lower class restriction, but the use of the size of the class or interval, the smallest in length, which makes it possible to calculate the length of the middle of the next class. In the size frequency distribution of *E. vacha* the maximum number of fishes 42.63% were belonging to the length category 20–24.9 cm in both sexes, followed by 44.66% was reflected in 16–21.9 cm of length category of male specimen. A majority (53.31%) were accompanying to the length category of 18–23.9 cm in female specimens (Table 1).

The most widely used model for explaining the growth of the fish is von Bertalanffy growth function according to Etim *et al*. (1999). However VBGF does not take into account the effects of seasonal variations. The exactness and reliability of L_∞ and *K* values are a function of several factors such as the source of biological information. Asymptotic length (L_∞) as the maximum theoretical length that average length species can achieve in its habitat ecological characteristics of that environment, and *K* is the rate of speed where it would grow in the direction of the final size. These estimated results were compared by various

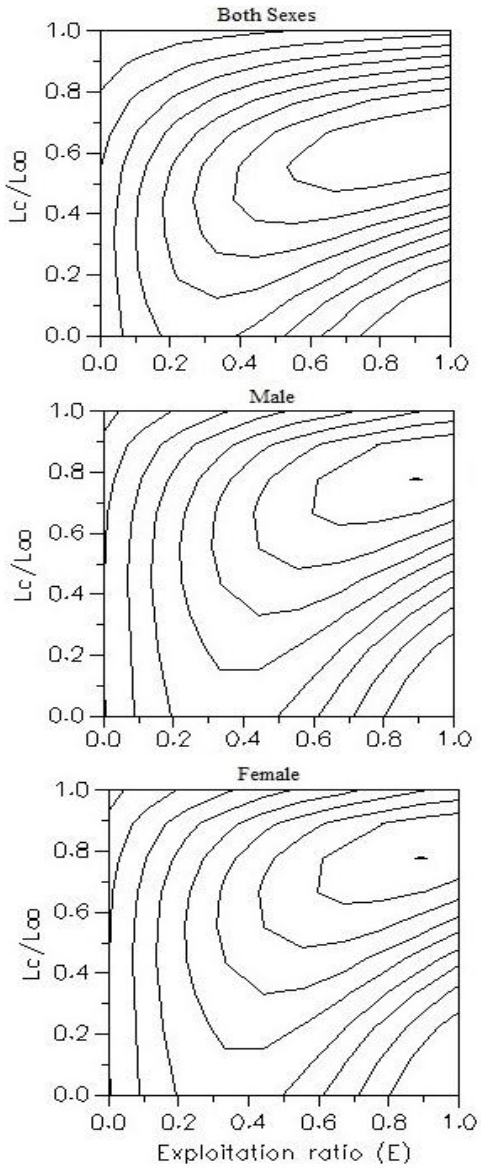

Fig. 7: Relative Beverton-Holt yield per recruit contour map with knife edge selection in FiSAT-II for *E. vacha* for (Combined sexes, male and female) from Indus River of Sindh, Pakistan

methods and from diverse data in Table 4. According to Pauly and Morgan (1987) higher values of the *K* are typically connected with lower values of L_∞ and vice versa, since these parameters are interrelated with each other. Reported reference values in this study (Table 4) have revealed considerable variability in growth between the various populations. The calculated t_0 value was close to our current study for *E. vacha* for combined sexes but high values were obtained in male and female from Indus River, Pakistan (Table 4). This may be due to onset of spawning during March–May when feeding intensities in adult *E. vacha* decreases towards the peak of spawning season, and after spawning in June–July the feeding intensities increased rapidly according to Soomro *et al.* (2012). According to King (1997) the value of t_0 is an indicator of growth rate in juveniles as well as adults. Negative value of t_0 indicated higher rate in juveniles than the expected growth curve for adults while the positive t_0 signified that the juveniles grow more slowly.

Mortality parameters are important indicators of the decomposition rate of the population, they do not need to assume constant and they may change from time to time with a slight instability of growth parameter in the calculation of mortality (Sparre and Venema, 1992). The coefficient of the total annual mortality rate *Z*=1.09/year of *E. vacha* was estimated from the pooling data of the both sexes by the linearized length converted catch curve method (Pauly, 1983). The estimated values of *Z* was lower than the present study from Asejire lake and Oyan Lake, Nigeria for *S. mystus Z*= 5.14/year and 1.83 by Adedolapo (2007) respectively, and Etim *et al*. (1999) from Cross River, Obubra, Nigeria for *S. intermidius* observed *Z*= 1.85/year. These differences may be due to the overfishing or may be due to the temperature or adverse ecological circumstances.

Under normal circumstances, to estimate direct natural mortality (*M*) in an exploited fish stock is generally very difficult (Beverton and Holt, 1957; Etim *et al*., 1999; Quinn and Deriso., 1999; Gayanilo *et al*., 2005). The ratio of $^{M}/_{K}$ 2.11 was obtained in the this study for *E. vacha* from Indus River showing reliability of the estimated natural mortality (*M*), because the $^{M}/_{K}$ ratio has been reported to be within the range of 1.12 to 2.50 for most of the fishes (Beverton and Holt, 1957). So obtained result of $^{M}/_{K}$ ratio 2.11 in this study has fallen in the reported range, we can suggest that our estimated natural mortality is reliable for this species. The calculated instantaneous fishing mortality was lower than the natural mortality and fishing mortality of fish populations is expected to be lower than natural mortality. Usually, the rate of exploitation (*E*) indicates the premise state of exploitation of a stock is being exploited. An estimated exploitation rate for the pooled data was lower than the Gulland (1971b) method, who suggested that the exploitation rate should be lower than 0.5 and greater than 0.5 is considered over-exploited.

Growth performance index is conducive in both movement (*K* and L_∞) between species and growth. To compare the growth, we used the phi prime (Φ') performance index of overall growth of Pauly and Munro (1984). Comparison of the growth rate is a multivariate problem that must take into account both considerations of growth rate (*K*) and the asymptotic size (L_∞) according to Etim *et al*. 1999. Since phi prime (Φ') meets with these criteria because it is easy to calculate and express the slightest variance when compared with the other alternative indices. The growth index (Φ) helps to explain the characteristics of the different ecosystems of the stock or housing of the different population of the environment (Baijot and Moreau, 1997). Phi prime (Φ') are usually

species specific and gross disparity parameters of phi prime values for distinct populations of the same species or family or related species is an indicator of the lack of reliability in the precision of anticipated growth parameters. In this way, the similarity of the phi prime with related species in different regions emphasizes the reliability of the calculated growth parameters. Regarding the overall growth performance indices (Table 4), this species exhibited slow growth in Indus River. According to Baijot and Moreau (1997) the average value of Φ' for some of the important fish species of Africa lie within the range between 2.65 to 3.32, specifying the growth rate of the *E. vacha* was lower because the computed Φ' values in this study were Φ'= 2.66, Φ'= 2.85 and Φ'= 2.86 for combined sexes, male and female respectively.

Biological reference points are usually a combination of the various elements such as the stock dynamic, growth, recruitment and mortality. They can give a basic philosophy about the status of the fish stock due to meaningful and significant character. The biological reference points (BRPs) in our study were estimated as designed by Patterson (1992) F_{opt}= 0.5 M (0.381, F_{opt}) and F_{limit}= 2/3 M (0.508 F_{limit}), these values were lower than estimated method of Gulland (1969) M= 0.762/year. $F_{0.1}$ in biological reference point with respect of F_{max}, is considered a target of biological safety measure. These BRPs $F_{0.1}$ and F_{max} indicate only excessive growth rather than excessive recruitment. The output graph of yield per recruit contour map (Fig. 7) showed that when t_c was at 1, the F_{max} (1.2/year) and $F_{0.1}$ (1/year) indicating the stock of *E. vacha* for combined sexes in the Indus River was in accordance with the situation of the holding exploitation state. Because the current age at the first capture was about 1 year, the current fishing mortality rate of 0.330/year was below the biological reference point (F_{opt}= 0.762/year) target benchmark following Gulland (1971b) method. Our result of exploitation rate 0.302 was also lower than the Fcurrent = 0.330/year, which means we should seek further support to strengthen our fishing effort.

Conclusion

The population dynamics of *E. vacha* in Indus River indicated that the stock is not damaged and has perspective economic values in Pakistan. The current fishing mortality rate is 0.330/year, 0.721/year and 0.469/year for combined, male and female, respectively is lower than the biological reference points F_{opt}= 0.762 using the Gulland criterion. Apart from this, from the revealed exploitation ratio (E) it is also confirmed that *E. vacha* species is in safe condition as E= 0.302, E= 0.389 and E = 0.310 for pooled sexes, male and female correspondingly.

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