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ESTIMATION OF MAXIMUM SUSTAINABLE HARVEST LEVELS OF SEA CATFISHES IN SINDH, PAKISTAN

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ABSTRACT

It is necessary to access fishery stock status before harvesting due to continued overexploitation of fishery resources. The aim of this study is to estimate maximum sustainable yield (MSY) of sea catfishes (Family: Ariidae) in Pakistani marine waters from Sindh coastline. Research method used is the statistical analysis of fishery output (FO) and fishery input (FI) data by using non-equilibrium surplus production models (SPMs). In Catch and Effort Data Analysis (CEDA) software, three SPMs viz. Fox model (F-M), Schaefer model (S-M) and Pella-Tomlinson model (PT-M) were used along with three error assumptions (EAs) viz. log (L-EA), log normal (LN-EA) and gamma (G-EA). Whereas, in A Stock Production Model Incorporating Covariates (ASPIC) computer package two SPMs viz. Fox (F-M) and Logistic (L-M) were employed for data analysis. For initial proportion (IP) 0.9, CEDA software computed MSY in range 12,000 – 16,000 t (metric ton). F-M showed the highest goodness of fit (R^2= 0.928) value. For the same IP value, ASPIC computer package estimated MSY in a range 14,000 – 20,000 t. Here, F-M again showed higher R^2 (0.926), value. Estimated results suggest that, MSY range at Sindh coast is around 12,000 – 200,000 t. However, FO statistics indicate that this resource has consistently been overexploited. The conclusion of this study is that this fishery resource is overharvested and demand some concrete fishery management steps for its conservation in Pakistani marine waters.

Keywords: Sea catfishes, MSY, CEDA, ASPIC, Sindh, Pakistan.

INTRODUCTION

Exploitation of marine fishes demands studies focused on understanding the population of the exploited stock at a particular place and at a particular time (Sawant *et. al*., 2013). Therefore, the main objective of stock assessment of exploited commercially important fisheries stocks is to forecast that what is going to happen in terms of the value of the fishery output (FO), biomass levels i.e. sustainability and FO (Kilduff *et. al*., 2009). Stock assessments deliver significant scientific evidence essential for the conservation and management of fish stocks (NOAA, 2013). It also involves the use of different mathematical and statistical computations in order to make right forecast related to the reaction of the fish population to alternative management choice (Hilborn and Walters, 1992).

Various models of fish populations are required to assess the stock status of important fisheries resources. These models are based on three basic categories of information viz. FO, abundance, and biology. Therefore, the data employed for the stock assessment must be correct and appropriate to ensure the highest quality of assessment (NOAA, 2013). However, surplus production models i.e. SPMs (also known as biomass dynamic models) are extensively used in fisheries stock assessment and fisheries management because of their lesser data requirement than age-structured models (Schaefer, 1954; Pella and Tomlinson, 1969; Fox, 1970; Prager, 1994). Therefore, they are widely used to manage tropical fisheries where age estimation is difficult or almost impossible. They are also preferred because of their single production function to estimate all the crucial parameters such as growth, recruitment and mortality (Haddon, 2011).

Sea catfishes are demersal in habitat and extensively distributed in the Indo-Pacific region. They are distributed more preciously on the west and east coast of India to Bangladesh, Myanmar, Singapore, Malacca, Indonesia, Brunei Darussalam, Malaysia Bangladesh and Pakistan (Anderson and Gutreuter, 1983; Petrakis and Stergiou, 1995). They are bottom dwellers and generally found over inshore areas in depths up to 30 – 80 m. This bottom dwelling habit makes them a best target for bottom trawling. However, their population is considered to be under great threat due to their low fecundity and excessive destruction of eggs, juveniles and incubating males with the use of purse seines (Acero, 2002; Sawant *et. al*., 2013).

Landings of sea catfishes follow ebb and tide pattern with some species ebbing and totally disappearing from the fishery catches at certain times, followed by resurfacing of the same, after a period. These observations calls for update studies to assess the population dynamics and recruitment of sea catfishes on regular basis. It is very important to induce effective assumption related to revitalization of their fishery

(Sawant *et. al*., 2013). This aspect is significant in the perspective of the multispecies fishery in Pakistani marine waters. Because here the impact of fishing is not only on particular target groups but also on associated species/groups caught a by catch.

Maximum sustainable yield (MSY) and maximum economic yield (MEY) are the two reference points which are used to manage fishery resources around the world. Though, according to economists the concept of MEY sounds great (Gordon, 1954; Grafton *et. al*., 2007). However, the benefits of this reference point are not witnessed till now. It has been found that MSY reference point is the better reference point at which maximum economic utility of the fishery resources is generated (Christensen, 2010).

Previously, even though the biology and population dynamics of sea catfishes have been studied extensively worldwide (Conand *et. al*., 1995; Chakraborty *et. al*., 1997; Raje, 2003, 2006; Mazlan *et. al*., 2008; Sawant and Raje, 2009; Chu *et. al*., 2011; Farooq *et. al*., 2016) but there are no previous studies available to examine the stock status of sea catfishes in Pakistani marine waters. The present study is the first attempt to assess the maximum sustainable yield of sea catfishes in Pakistani marine waters.

MATERIALS AND METHODS

Data Procurement: The stock status of sea catfishes was evaluated by using available CE data (1997-2012) for this fishery resource from marine waters of Sindh, Pakistan. The published data was obtained from Marine Fisheries Department (MFD). FO and FI are in the form of tons (t) and the number of fishermen correspondingly.

Data Analysis: In this study, three SPMs i.e. F-M, S-M, and PT-M were used to evaluate the procured time series data of 16 years (1997-2012) of sea catfishes. These SPMs were explained by the three scientists named Fox, Schaefer and Pella-Tomlinson. S-M is the most commonly used model in stock assessment and is based on a logistic growth model.

$$\frac{dB}{dt} = rB(B_\infty - B)$$ (Schaefer, 1954)

While F-M and PT-M are based on Gompertz growth equation and common production equation, correspondingly.

$$\frac{dB}{dt} = rB(1nB_\infty - 1nB)$$ (Fox, 1970)

$$\frac{dB}{dt} = rB(B_\infty^{n-1} - B^{n-1})$$ (Pella and Tomlinson, 1969)

Where, B is for fish stock biomass, n reveals shape parameter, t donates for the time (year), B ∞ represents carrying capacity (*K*) and r is the intrinsic rate of population growth.

However, data was analyzed through the specified computer packages such as Catch and Effort Data Analysis (CEDA) and A Stock Production Model Incorporating Covariates (ASPIC) downloaded from MRAG website and NOAA Fisheries Toolbox respectively. The catch per unit effort (CPUE) is a significant RP to evaluate the stock status of commercially important fishery resources (Hoggarth *et. al*., 2006). Hence, the nominal CPUE is used here in this study to evaluate the stock status of sea catfishes.

CEDA (version 3.0.1): CEDA computer software is menu driven data fitting tool and has the ability to estimate customized parameters. CEDA employs a confidence interval (CI) of 95% through bootstrapping method for all the SPMs models i.e. F-M, S-M and PT-M with three EAs viz. L-EA, LN-EA and G-EA. It requires an input of IP (B_1/K) which is a key indicator used to access fishery stock. For example, when the input value is one then it does assume that data is acquired from fully developed fishery stock. On the other hand, if the input value of IP is zero or close to zero then its mean that data is obtained from virgin fishery stock. Occasionally, initial biomass is fixed as $B1 = C1/(qE1)$. In this mathematical equation, C is catch; q and E denote catch and catch ability respectively. Some programmers also use $B1$ equal to K. The coefficient of variation (CV) is predicted by using CIs. Other key parameters expected by using CEDA are MSY (maximum sustainable yield), K (carrying capacity), q (catchability coefficient), r (intrinsic growth rate), R_{yield} (replacement yield) and final biomass.

ASPIC (version 5.0): ASPIC computer package also needs an input of IP. Nevertheless, in contrast to CEDA, it needs individual input files for each IP value. Two SPMs i.e. F-M (a special case of GENFIT) and L-M (also called Schaefer model) were employed by using this fishery software. FIT and BOT files, for both of the SPMs, were prepared to compute CV (coefficient of variation) for all IP values. FIT and BOT represent the program modes used in ASPIC and there exists a technical difference between them. The managerial parameters are estimated by ASPIC software during FIT mode while during BOT program mode, it uses bootstrapped CIs with many trials for the calculation of parameters. Therefore, the finishing time of BOT mode is much higher than FIT mode. 500 trails were done in order to calculate maximum sustainable yield (MSY). Different Important parameters approximated by using this computer package include MSY, K, q, B_1/K (starting biomass over carrying capacity), R^2 (coefficient of determination), F_{MSY} (fishing mortality rate at MSY), B_{MSY} (stock biomass giving MSY).

Sensitivity analysis were done for constant recruitment model. However, due to unpredictable results obtained we switched to non-equilibrium SPMs evaluation i.e. three production models. Within these models again sensitivity analysis was performed by using IP values. The results obtained for different parameters were further considered along with R^2 values and visual inspection of the graphs for model selection and evaluation for depicting reliable results.

RESULTS

During the study period, the total capture production of sea catfishes form Pakistani marine waters at Sindh coastline was 370,149 t. The average FO remained 23,134 t year^{-1} while maximum and minimum FO quantity was examined in 1998 (44,272 t) and 2010 (13,100 t) respectively (Figure 1). Similarly, the average CPUE during the study period remained 0.247 year^{-1} while highest and lowest values of CPUE were observed during 2010 (0.122) and 1998 (0.522) i.e. second and fourteenth study years in that order (Figure 2). Recorded results by using CEDA and ASPIC were further calculated by considering four factors viz. maximum sustainable yield (MSY), the goodness of fit (R^2), graphs between observed and expected FO and coefficient of variation (CV). Estimated MSY values were compared with data figures and very large or small MSY values were not treated. Models were compared by keeping in view R^2 values and visual examination of residual plots. The higher is the value of R^2 the better is the fitting of the model. Results with appropriate CV values were acknowledged.

CEDA Estimates: CEDA exhibited sensitivity towards the input IP values as it created various output MSY figures for various IP inputs (Table 1). L-EA for CV values produced minimization failure (MF) for IP values of 0.2 and 0.4 which were obtained by using a special method called bootstrapping confidence limit method for both S-M and PT-M. Besides this, G-EA sometimes showed MF in all the SPMs used. Except for IP 0.9, for all the SPMs used along with their error assumptions either MSY or R^2 value did not produce rational results.

Evaluated parameters for IP 0.9 are given in Table 2. Computed values of MSY and their CV for F-M with L-EA were 12,042 t and 0.139, respectively. For LN-EA their values remained 13,315 t and 0.111 in that order while for G-EA showed MF. Estimated MSY values for N-EA and LN-EA used in S-M and PT-M remained same as 14,515 t and 16,401 t respectively while calculated CV values for both of these models for both error assumptions were 0.214, 0.103 and 0.218, 0.109 correspondingly. The G-EA showed MF for both viz. S-M and PT-M. Calculated B_{MSY} values are same for the both S-M and PT-M. This may be due to the convergence of PT-M at 0.5 of B_{MSY}/K which implies the results of this model may not be considerable. However, for model evaluation full criteria used has already been described.

For IP 0.9, R^2 values computed by using L-EA and LN-EA F-M were 0.907, 0.928 respectively while G-EA produced MF (Table 2). R^2 values for both the models i.e. S-M and PT-M with L-EA and LN-EA were same as 0.892 and 0.912 in that order while G-EA produced MF. R^2 (the goodness of fit) values are very important to consider as they tell us about the fitting of the model.

Figure 2 shows the graphical demonstration of experiential and predicted annual FO values. From visual examination it can be acknowledged that for all the error assumptions used in F-M, observed and expected FO values are close to each other, however in detail, they change from each other. CEDA computed higher MSY values with lower IP values and vice versa.

ASPIC Estimates: In ASPIC, computed parameters for IP 0.9 are listed in Table 3. F-M showed better fit as its R^2 value (0.926) was higher than the computed R^2 value (0.908) for L-M. MSY along with their CV values for both i.e. F-M and L-M used in ASPIC were estimated at 14,040 t (0.076) and 19,670 t (0.139) in that order. For F-M, computed K, B_{MSY} (fishing mortality rate at MSY) and F_{MSY} (stock biomass giving MSY) remained 236,200 t, 86,900 t and 0.1615, respectively. Similarly, the K, B_{MSY}, and F_{MSY} values were remained 167500 t, 83740 and 0.2349 in that order for Logistic models.

Table 4 reveals various factors estimated for IP 0.3 – 0.9. Like CEDA, ASPIC also showed sensitivity to IP values as it evaluated different output parameter values for different IP input. ASPIC computed smaller MSY for larger IP value and vice versa. However, parameters calculated by this software did not exhibit higher differences as compared to CEDA. Computed MSY by ASPIC, for instance, ranged in 500,000 t – 2,550,000 t while for CEDA its most of estimated range was 14,000 t – 44,000 t. It means even though ASPIC is sensitive to IP values but its sensitivity is less than CEDA. In contrast to CEDA, ASPIC models showed lower R^2 values indicating that less good fitting of the data.

Estimated fishing mortality (F) and biomass (B) values of sea catfishes by using ASPIC are highlighted in Table 5. Calculated figures indicate that F has shown rising trend with the passage of time whereas B is decreasing. F/F_{MSY} is increased and B/B_{MSY} is decreased during the course of the study period. Both, F/F_{MSY} and B/B_{MSY} indicate overexploitation of the fishery stock.

Table 1. CEDA estimates of various parameters for sea catfishes from Sindh, Pakistan (IP = 0.1-0.9).

IP	Model								
	F-M			S-M			PT-M		
	L-EA	LN-EA	G-EA	L-EA	LN-EA	G-EA	L-EA	LN-EA	G-EA
0.1	1.25E+11	44,528	MF	352,807	108,327	MF	358,207	108,327	MF
	0.424	0.000	0.000	0.042	0.000	0.000	0.035	0.000	0.000
0.2	32,659	27,133	MF	MF	52,813	52,813	MF	52,813	52,813
	0.055	0.036	0.000	0.000	0.000	0.000	0.00	0.000	0.000
0.3	24,374	20,180	MF	203,505	38,076	38,072	203,505	38,076	38,072
	0.097	0.072	0.00	0.703	0.000	0.000	0.342	0.000	0.000
0.4	19,995	19,597	MF	MF	30,937	108,510	MF	30,937	108,510
	0.096	0.047	0.000	0.000	0.000	814.65	0.00	0.000	515.88
0.5	17,241	18,176	MF	26,827	27,127	26,835	26,827	27,127	26,835
	0.115	0.069	0.000	0.056	0.003	0.000	0.057	0.003	0.000
0.6	15,345	16,126	MF	23,306	23,608	25,373	23,306	23,608	25,373
	0.128	0.086	0.000	0.092	0.007	0.000	0.095	0.007	0.000
0.7	13,953	15,448	MF	19,463	22,381	MF	19,463	22,381	MF
	0.131	0.092	0.000	0.173	0.013	0.000	0.162	0.011	0.000
0.8	12,886	14,827	13,799	16,656	20,554	18,510	16,656	20,554	18,510
	0.142	0.106	0.113	0.184	0.024	0.174	0.211	0.021	0.179
0.9	12,042	13,315	MF	14,515	16,401	MF	14,515	16,401	MF
	0.139	0.111	0.000	0.214	0.103	0.00	0.218	0.109	0.000

Note: CV: coefficient of variation is written below MSY values; MF: represents minimization failure.

Table 2. CEDA estimates of various parameters for sea catfishes from Sindh, Pakistan (IP = 0.9).

Model	MSY	CV	R^2	K	q	r	R_{Yield}	B
F-M (L-EA)	120,42	0.139	0.907	279,256	2.36E-06	0.117	9,924	48,187
F-M (LN-EA)	13,315	0.111	0.928	256,145	2.64E-06	0.141	11,102	45,420
F-M (G-EA)	MF	MF	MF	MF	MF	MF	MF	MF
S-M (L-EA)	14,515	0.214	0.892	248,047	2.36E-06	0.234	7,640	38,668
S-M (LN-EA)	16,401	0.103	0.912	219,982	2.36E-06	0.298	9,017	36,191
S-M (G-EA)	MF	MF	MF	MF	MF	MF	MF	MF
PT-M (L-EA)	14,515	0.218	0.892	248,047	2.36E-06	0.234	7,640	38,668
PT-M (LN-EA)	16,401	0.109	0.912	219,982	2.36E-06	0.298	9,017	36,191
PT-M (G-EA)	MF	MF	MF	MF	MF	MF	MF	MF

Note: MSY: indicates maximum sustainable yield; CV: coefficient of variation; R^2: coefficient of determination; *K:* carrying capacity; *q:* catchability coefficient; *r:* intrinsic population growth rate; R_{Yield}: replacement yield; *B:* current biomass; MF: minimization failure

Table 3. ASPIC estimates of various parameters for sea catfishes from Sindh, Pakistan (IP = 0.9).

Model	IP	MSY	CV	R^2	K	B_{MSY}	F_{MSY}	q
F-M	0.9	14,040	0.076	0.926	236,200	86,900	0.162	2.92E-06
L-M	0.9	19,670	0.139	0.908	167,500	83,740	0.235	4.24E-06

Table 4. ASPIC estimates for sea catfishes from Sindh, Pakistan (IP = 0.3-0.9).

Model	**IP**	**MSY**	**CV**	R^2	K	B_{MSY}	F_{MSY}	q
	0.3	27,630	0.066	0.921	345,800	127,200	0.217	6.02E-06
	0.4	22,600	0.079	0.923	314,400	115,700	0.195	4.93E-06
	0.5	19,730	0.089	0.923	285,800	105,100	0.188	4.36E-06
	0.6	17,640	0.078	0.924	268,200	98,650	0.179	3.87E-06
F-M	0.7	16,090	0.071	0.925	255,300	93,910	0.171	3.48E-06
	0.8	14,950	0.085	0.925	244,500	89,940	0.166	3.18E-06

	0.9	14,040	0.076	0.926	236,200	86,900	0.162	2.92E-06
	0.3	43,580	0.017	0.907	225,000	112,500	0.388	7.85E-06
	0.4	36,350	0.018	0.914	172,400	86,210	0.422	8.18E-06
	0.5	32,390	0.026	0.912	142,200	71,110	0.456	8.49E-06
	0.6	28,520	0.044	0.907	141,000	70,500	0.405	7.41E-06
L-M	0.7	25,010	0.078	0.905	148,700	74,340	0.337	6.11E-06
	0.8	22,150	0.105	0.906	157,300	78,630	0.282	5.09E-06
	0.9	19,670	0.139	0.908	167,500	83,740	0.235	4.24E-06

Table 5. ASPIC software estimates of fishing mortality (*F*) and biomass (*B*) (IP = 0.9) (1997-2012).

Year	Model							
	F-M				L-M			
	F	*B*	F/F_{MSY}	B/B_{MSY}	*F*	*B*	F/F_{MSY}	B/B_{MSY}
1997	0.212	212,700	1.311	2.447	0.305	150,700	1.299	1.799
1998	0.278	177,600	1.720	2.043	0.412	121,700	1.756	1.454
1999	0.303	143,300	1.873	1.649	0.461	95,390	1.962	1.139
2000	0.248	116,700	1.533	1.343	0.379	75,860	1.612	0.906
2001	0.267	103,200	1.653	1.187	0.403	67,970	1.717	0.812
2002	0.243	91,220	1.506	1.050	0.361	60,680	1.536	0.725
2003	0.278	83,970	1.722	0.966	0.404	57,360	1.721	0.685
2004	0.304	75,780	1.884	0.872	0.438	52,510	1.866	0.627
2005	0.262	67,790	1.622	0.780	0.372	47,140	1.585	0.563
2006	0.299	64,120	1.854	0.738	0.418	45,640	1.782	0.545
2007	0.300	59,070	1.858	0.680	0.416	42,470	1.769	0.507
2008	0.369	55,050	2.287	0.634	0.515	39,950	2.194	0.477
2009	0.295	48,640	1.829	0.560	0.419	34,410	1.783	0.411
2010	0.282	46,870	1.748	0.539	0.402	32,950	1.713	0.394
2011	0.305	45,970	1.888	0.529	0.440	32,180	1.874	0.384
2012	0.340	44,270	2.104	0.510	0.509	30,370	2.168	0.363

Note: *F*: fishing mortality; *B:* biomass; F/F_{MSY}: ratio of fishing mortality to fishing mortality rate at MSY; B/B_{MSY}: ratio of biomass to biomass giving MSY.

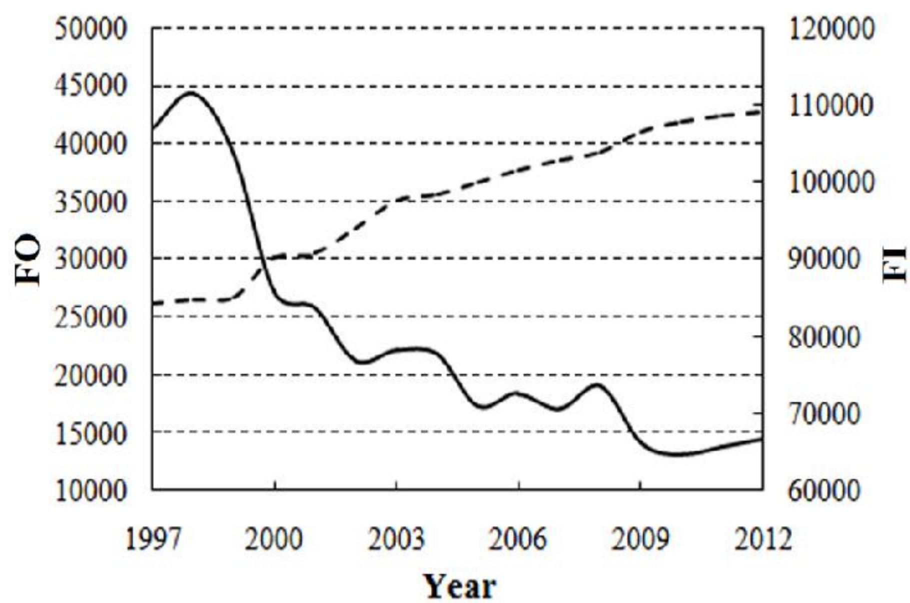

Fig. 1. FO (catch in t; represented by solid line) and FI (effort in number of fishermen; represented by dotted line) statistics of sea catfishes from Sindh, Pakistan.

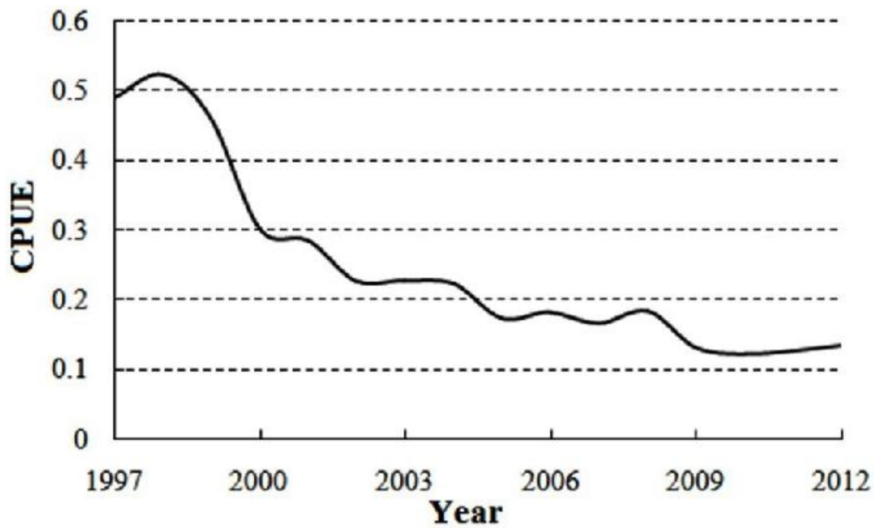

Fig. 2. Computed CPUE for sea catfishes from Sindh, Pakistan.

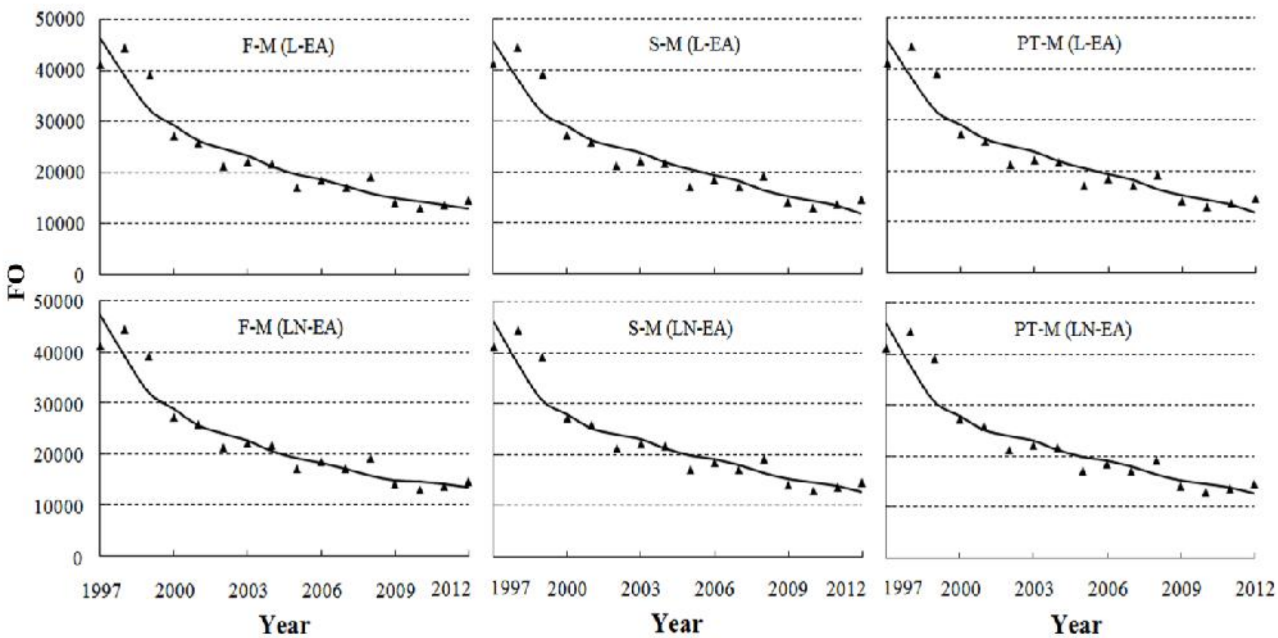

Fig. 3. Annual observed (Marks) and Expected (solid line) fishery output (quantity in t on y-axis) of sea catfishes from Sindh, Pakistan.

DISCUSSION

This study reveals that sea catfishes are overexploited in Pakistani marine waters. This overharvesting of fishery resources confers many disadvantages to the society such as it results in the competitive harvesting of the fishery resources. Moreover, private owner tries to maximize their profits without considering the damage caused by overfishing. In order to increase profit more and more FO is done which may lead fishery stock to the depletion stage. Thus, it is of utmost importance to access the commercial fishery stock regularly to ensure the sustainable economic contribution of fishery resources (Clark, 1973).

As aforementioned, overexploitation may lead to fishery stock depletion. This depletion is actually an outcome of an attempt to increase profit gain beyond the capacity of the fishery stock (Clark, 1973). In the beginning of fishery, fishermen get more profit with lower FI. The incentives created by fishery at this stage attracts more and more fishermen to join fishery however a stage comes when profit goes negative. At this stage, B_{CUR} becomes lower than B_{MSY} and for more FI lesser FO is obtained. Thus, fishing does not remain economic. In order to make fishing beneficial again, fishery stock building is usually recommended. But, there is a problem associated with fishery stock rebuilding. Actually, for slow growing fish species fishery stock rebuilding can take dozens of years. Therefore, usually fishers oppose the idea of fishery stock rebuilding (Grafton *et. al*., 2007).Moreover, during the process of rebuilding, fishers have to pay the transition costs for fishery stock rebuilding. However, if these transition costs are compensated for fishers then they may be agreed upon the idea of rebuilding. Transition costs may be supplemented by some incentives which may include harvesting rights given individually or at community level (Hilborn, 2007).Such incentives may motivate fishers for fishery stock rebuilding (Grafton, 1995).

Overcapacity management also proves very effective for fishery stock rebuilding. If fishery stock is harvested at sustainable level it would automatically start to rebuild itself. In Pakistan, overcapacity management has received very little attention in the past. First national fisheries policy in Pakistan was announced in 2007 viz. "The National Policy and Strategy for Fisheries and Aquaculture Development in Pakistan". This policy legislatively monitors FO and FI matters in Pakistan (GoP, 2007). Though, this policy has some framework to monitor these FO and FI matters however ground reality proves that outcome of this policy is not witnessed. It has been found that the number of trawlers operating in Sindh is more than double than the recommended ones (Schmidt, 2014). Thus, this ineffective control on overcapacity has led to overexploitation of fishery resources as this study shows.

This study uses famous fishery SPMs which have already been used for the stock status of fishery resources in Pakistan. (Memon *et. al*., 2015; Siyal *et. al*., 2013; Kalhoro *et. al*., 2013; Panhwar *et. al*., 2012; Kalhoro *et. al*., 2014; Panhwar and Liu, 2013). Actually, these SPMs possess many advantages over the other routine used in the science of fishery management. Such as, these models use simple data related to FI and FO. In addition to this, these models estimated simultaneously exclusive parameters of the fishery stock. Besides, the computed parameter such as q indicate the fishery stock status. Other main computed fishery parameters include F, F_{MSY}, B and B_{MSY}. It is necessary to mention that these SPMs rely on some assumption which may not be met in nature. These assumptions include non-existence of immigration or emigration in the fishery stock, age composition of the fishery stock has no relation with r, q does not change with the passage of time, there exists single fishery stock and natural with fishing mortality occur at the same time (Ewald and Wang, 2010; Hoggarth *et. al*., 2006). Moreover, these models do not use data related to the age-structure of the population and confer the risk of uncertainty in their estimation. Nevertheless, these models are frequently used in the science of fishery management and are very effective tools which tell us about the status of the fishery stock upon which fishery management advice is made (Musick and Bonfil, 2005).

Conclusion: The computed value of MSY for IP 0.9, ranged from 12,000 t – 16,000 t and 14,000 t – 20,000 t for CEDA and ASPIC correspondingly. Thus, CEDA remained more conservative in terms of MSY calculation as compared to ASPIC. Higher values of R^2 for ASPIC reveal that its results are more reliable. Since the computed MSY range by F-M and L-M overlaps thus by considering the results of both the software and applying pulse fishing rule we recommend that the MSY target reference pint (TRP) range of sea catfishes is as 14,000 t – 16,000 t in Pakistani marine waters. Capture production of 16500 t or more must be considered as a limiting reference point (LRP). By comparing computed MSY values with recorded data (Table 1) and considering F/F_{MSY} and B/B_{MSY}, it can be concluded that in the past, this fishery resource has constantly been overexploited. The stock of sea catfishes is declining with the passage of time due to overfishing. Thus, instantaneous steps with appropriate forecast with rightful execution are direly required to conserve this fishery resource for future.

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REFERENCES

Acero, A. (2002). Ariidae: sea catfishes. pp. 831-852. In: The living marine resources of the Western Central Atlantic. Volume 2. Bony fishes part 1 (Acipenseridae to Grammatidae), K.E. Carpenter, editor. FAO Species Identification Guide for Fisheries Purposes, American Society of Ichthyologists and Herpetologists Special Publication 5. Rome.

Anderson, R., S.J. Gutreuter (1983). Length-weight, and associated structural indices. In: Fisheries Techniques. L. Nielsen and D. Jhonson (Eds.) American fisheries society, Bethesda, Maryland.

Chakraborty, S.K., V.D. Deshmukh, M.Z. Khan, K. Vidyasagar, S.G. Raje (1997). Estimates of growth, mortality, recruitment pattern and maximum sustainable yield of important fishery resources of Maharashtra coast. Indian J.Geo-Mar. Sci. 26: 53-56.

Christensen, V. 2010. MEY = MSY. Fish Fish. 11: 105-110.

Chu, W.S., Y.Y. Hou, Y.T. Ueng, J.P. Wang, H.C. Chen (2011). Estimates of age, growth and mortality of spotted catfish, *Arius maculatus* (Thunberg, 1792), off the Coast of Yunlin, Southwestern

Taiwan. African J. Biotech. 10(66): 15416-15421.
Clark, C.W. (1973). The economics of overexploitation. Science. 181(4100): 630-634.
Conand, F., S.B. Camara, F. Domain (1995). Age and growth of three species of Ariidae (Siluriformes) in coastal waters of Guinea. Bull. Mar. Sci., 56(1): 58-67.
Ewald, C.O., W.K. Wang (2010). Sustainable yields in fisheries: uncertainty, risk-aversion, and mean-variance analysis. Nat. Resour. Model. 23(3): 303-323.
Farooq, N., N. Qamar, S. Rashid, S.K. Panhwar (2016). Length-weight relationship of eleven species of marine catfishes from the northern Arabian Sea coast of Pakistan. Chinese J. Ocaenol. Limnol. (Accepted)
Fox, W.W.Jr. (1970). An exponential surplus-yield model for optimizing exploited fish populations. Tam. Fish Soc. 99(1): 80–88.
GoP. (2007). National policy and strategy for fisheries and aquaculture development in Pakistan. Ministry of Food, Agriculture and Livestock, Islamabad. Government of Pakistan. pp. 1-13. Retrieved from: http:// faolex.fao.org/docs/pdf/pak150786.pdf.
Gordon, H.S. (1954). The economic theory of a common-property resource: the fishery. J. Polit. Econ., 62(2): 124-142.
Grafton, R.Q., T. Kompas, R.W. Hilborn (2007). Economics of overexploitation revisited. Science, 318(5856): 1601-1601.
Grafton, R.Q. (1995). Rent Capture in a Rights-Based Fishery. J. Environ. Econ. Manage. 28(1): 48-67.
Haddon, M. (2011). Modelling and Quantitative Methods in Fisheries. 2nd Ed. Chapman & Hall /CRC, New York, London. 285-300.
Hilborn, R. (2007). Defining success in fisheries and conflicts in objectives. Mar. Pol. 31(2): 153-158.
Hilborn, R., C.J. Walters (1992). Quantitative fisheries stock assessment and management. Chapman-Hall: New York.
Hoggarth, D.D., S. Abeyasekera, R.I. Arthur, J.R. Beddington, R.W. Burn,A.S. Halls, G.P. Kirkwood, M. McAllister, P. Medley, C.C. Mees, G.B. Parkes, G.M. Pilling, R.C. Wakeford, R.L. Welcomme (2006). Stock Assessment for Fishery Management-A Framework Guide to the Stock Assessment Tools of the Fisheries Management Science Programme. FAO Fisheries Technical Paper 487. FAO, Rome, Italy. 261p. CEDA download page: https://www.mrag.co.uk/resources/fisheries-assessment-software.
Kalhoro, M.A, Q. Liu, K.H. Memon, M.S. Chang, A.N. Jatt (2013). Estimation of maximum sustainable yield of Bombay Duck, *Harpodon nehereus* fishery in Pakistan using the CEDA and ASPIC packages. Pakistan J. Zool. 45(6): 1 757-1 764.
Kalhoro, M.A., Q. Liu, B. Waryani, S.K. Panhwar, K. Hussain (2014). Growth and mortality of Brushtooth lizardfish, *Saurida undosquamis*, from Pakistani Waters. Pakistan J. Zool. 46(1): 139-151.
Kilduff, P., J. Carmichael, R. Latou (2009). Guide to Fisheries Science and Stock Assessments. Washington, DC: Atlantic States Marine Fisheries Commission.
Mazlan, A.G., S. Abdullah, M.G. Shariman, A. Arshad (2008). On the biology and bioacoustic characteristic of spotted catfish *Arius maculates* (Thunberg 1792) from the Malaysian estuary. Res. J. Fish. Hydrobiol.3: 63-70.
Memon, A.M, Q. Liu, K.H. Memon, W.A. Baloch, A. Memon, A. Baset (2015). Evaluation of the fishery status for King Soldier Bream *Argyrops spinifer* in Pakistan using the software CEDA and ASPIC. Chin. J. Oceanol. Limnol. 33(4): 966-973.
MRAG. 2016. CEDA Version 3. 0. http://www.mrag.co.uk/ resources/fi sheries-assessment-software. Accessed on 20-01-2017.
Musick, J.A., R. Bonfil (2005). Management techniques for elasmobranch fisheries. FAO Fisheries Technical Paper 474. FAO, Rome, Italy. 251p.
NOAA (2013). Fish stock assessment 101. Retrieved from: http://www.nmfs.noaa.gov/stories/2013/06/science_stock_assessments.html.
NOAA. 2016. NOAA Fisheries Toolbox, A Stock Production Model Incorporating Covariates (ASPIC), http://nft.nefsc. noaa.gov/ASPIC.html. Accessed on 20-01-2017.
Panhwar, S.K, Q. Liu (2013). Population statistics of the migratory hilsa shad, *Tenualosa ilisha*, in Sindh, Pakistan. J. Appl. Ichthyol. 29(5): 1 091-1 096.
Panhwar, S.K., Q. Liu,F. Khan, P.J.A. Siddiqui (2012). Maximum sustainable yield estimates of Ladypees, *Sillago sihama* (Forsskål), fishery in Pakistan using the ASPIC and CEDA packages. J. Ocean Univ. China, 11(1): 93-98.
Pella, J.J., P.K. Tomlinson (1969). A generalized stock production model. Inter-American Tropical Tuna C. 13(3): 416–497.
Petrakis, G., K.I. Stergiou (1995). Length-weight relationships for 33 species in Greek waters. Fish. Res. 21: 465-469.
Prager, M.H. (1994). A suite of extensions to a non-equilibrium surplus-production model. Fishery Bulletin. 92: 374–389.

Raje, S.G (2006). Some aspects of biology of catfishes *Tachysaurus caelatus* (Valenciennes) and *Osteogeneiosus militaris* (Linn.) from Mumbai. Indian J. Fish. 53(3): 333-340.

Rajie, S.G. (2003). Some aspects of the biology of *Tachysurus tenuispinis* Day from Veradale. J. Indian Fish. Assoc. 30: 97-103.

Sawant, B.T., S.K. Chakraborty, A.K. Jaiswar, D. Panda, S.K. Bhagabati, P.B. Sawant (2013). Population parameters of the catfishes, *Arius caelatus* (Valenciennes, 1830) and *Arius tenuispinis* (Day, 1877) from Mumbai waters. Indian J. Geo-Mar. Sci. 42(6): 775-780.

Sawant, P.B., S.G. Raje (2009). Morphometry and length weight relationship of the Catfishes *Arius caelatus* (Valenciennes, 1840) and *Arius thalassinus* (Ruppell, 1837) off Mumbai, Veradale and Vishakhapatnam coasts. Asian Fish. Sci. 22 (1): 215-228.

Schaefer, M.B. (1954). Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Inter-American Trop. Tuna C. 1(2): 23–56.

Schmidt, U.W. (2014). Fisheries policy report and recommendations for Sindh. USAID Firms Project. Final Report. USAID, pp. 1–66.

Siyal, F.K., Y. Li, T.X. Gao, Q. Liu (2013). Maximum sustainable yield estimates of silver pomfret, *Pampus argenteus* (Family: Strometidae) fishery in Pakistan. Pakistan J. Zool. 45(2): 447-452.