Indian Journal of Geo Marine Sciences
Vol. 47 (03), March 2018, pp. 522-528

Research News

Maximum sustainable yield appraisal for Indian Oil Sardine *Sardinella longiceps* in Pakistani marine waters: An update

Muhammad Mohsin, Yong Tong Mu*, Ana Mehak & Aamir Mahmood Memon

College of Fisheries, Ocean University of China, Qingdao, 266003, China

*[E-mail: ytmu@ouc.edu.cn]

Received 13 January 2016 ; revised 24 February 2016

The highest and the lowest catch quantity of *S. longiceps* was observed in 1993, 92704 Mg, and 2010, 20127 Mg respectively, whereas average catch quantity of this fishery resource remained 44265 Mg year^{-1} during the study period (1990-2010). To estimate MSY we applied IP (B_1/K) of 0.7 because the initial catch was about 70% of the maximum catch. For Fox model computed values of MSY, CV and R^2 by using log and log-normal assumption were 21734 Mg, 0.2180, 0.841 and 27477 Mg, 0.1033 and 0.815 in that order. Calculated figures of same parameters for Schaefer model were 27609 Mg, 0.1925, 0.838 and 32665 Mg, 0.1217, 0.815 respectively, while for Pella-Tomlinson model their values were 27609 Mg, 0.2062, 0.838 and 32665 Mg, 0.1173, 0.815 correspondingly. Gamma error assumption did not produce rational results in all the three models used. Fox model appeared to be more conservative as compared to other models in terms of MSY calculation and produced higher R^2 values. Obtained results suggest that fishery stock of this aquatic resource is in safe condition and therefore harvest should be kept at the current level.

[**Keywords:** Fishery management, Fish stock assessment, *Sardinella longiceps*, Maximum sustainable yield, CEDA, Surplus production models, Pakistan]

Introduction

Fishes belonging to genus sardine are considered very important and their contribution in total pelagic catch is 30%[1]. Amid marine production, *S. longiceps* is listed amongst the important commercial fishes of Pakistan. It is not only consumed locally but also a large volume of revenue is earned by its export. *S. longiceps* belongs to the family Clupeidae. This fish is commonly known as Lee-gur in Pakistan[2]. Among small pelagic fishes *S. longiceps* is the main targeted fish. It is used in multiple ways. Its fresh consumption is preferred or it is sundried to be used as fertilizer or cattle feed.

In order to hunt larger fish species *S. longiceps* is also used as bait. This fish is marketed in various forms such as smoked, canned, dried, fresh etc.[3]. It forms schools and show migratory behavior. It breeds once in a year during monsoon months with a peak spawning in August and September. It prefers to live at 22 – 28 ^{O}C. Breeding grounds are near western coasts of India[4]. Its average catch from Pakistan marine waters is 44265 Mg year^{-1}. The maximum and minimum catches of *S. longiceps* were recorded in 1993 and 2010 having catch quantity of 92704 Mg and 20127 Mg respectively. Unfortunately, catch quantity of this fish is continuously decreasing with the passage of time.

For maximum utilization and conservation of fishery resources it is necessary to evaluate them. Surplus production models (SPMs, sometimes are referred as biomass dynamic models) are the statistical tools based on certain assumptions and are used to access fishery resources. Obviously, they are the most popular models used in fisheries management and plethora of literature is available related to them[5-12]. Their popularity stems into their ease of use. They require simple data of catch and effort or catch per unit effort (CPUE). Generally they involve two to four parameters; however seven parameters were also presented for the analysis of catch and effort data[13]. The interpretation of data by SPMs is easy to understand and less problematic. The main parameters computed by the use of SPMs include maximum sustainable yield (MSY) and optimum fishing effort (E_{msy}). Classical production models were based on assumption that fishery stocks are at equilibrium state and employed linear regression technique. But with the advent of modern fishery science non linear regression models are used now which are based on non equilibrium state of the fishery stock. The software CEDA[14] assumes non-equilibrium state and relatively difficult to interpret.

Many researchers have evaluated stock status of many fishes[15-19] dwelling Pakistani marine waters. Stock assessment of *S. longiceps* is also conducted before[20]. The need of this fishery stock reevaluation of this marine resource relies on three reasons. First, data source is different and length of data series is longer used in this study as compared to the pervious study. Second, the reliability of the data used in the previous study is debateable[21-22] which compels to conduct this study. Third, recent available data should be used and frequent stock assessment analysis should be done for effective fishery management[23]. In the light of these cited reasons this research project is conducted.

Materials and Methods

Fishery statistics on catch and effort, 1990-2010, of Indian Oil Sardine *S. longiceps*, were obtained from Food and Agriculture Organization of the United States (FAO) website by using specialized software for fisheries data procurement viz. FishStatJ – FAO Global Fishery and Aquaculture Statistics Software[24] and by contacting FAO. Catch is in the form of megagrams (Mg) whereas effort is in number of fishermen. The highest catch was observed in 1993 with a capture biomass of 92704 Mg. The maximum CPUE, 0.185, was also observed in the same year.

Data was analyzed through biomass surplus productions models or biomass dynamics models (SPMs or BDMs). Three SPMs of Fox, Schaefer and Pella-Tomlinson were used through CEDA (Catch and effort data analysis)[14]. Among these three models, the Schaefer model is frequently used and based on logistic population growth:

$$\frac{dB}{dt} = rB(B_\infty - B) \quad {}_{25}$$

While Fox model is relied on Gompertz growth equation:

$$\frac{dB}{dt} = rB(1nB_\infty - 1nB) \quad {}_{26}$$

Pella-Tomlinson model is based on generalized production equation.

$$\frac{dB}{dt} = rB(B_\infty^{n-1} - B^{n-1}) \quad {}_{27}$$

Where B is fish stock biomass; t, time (year); B, carrying capacity; and r, intrinsic rate of population increase.

CEDA has the ability to calculate MSY through non-equilibrium Fox, Schaefer and Pella-Tomlinson models by assuming three error estimates i.e. log, log-normal and gamma. MSY estimation further requires confidence interval input. Estimated key parameters by using CEDA are K (carrying capacity), MSY (maximum sustainable yield), q (catchability coefficient), r (intrinsic growth rate), *R*yield (replacement yield), R^2 (coefficient of determination), final biomass and CV (coefficient of variation) of the estimated MSY. SPMs used in fishery management are based on certain assumptions. CEDA software also assumes some supposition. Among these assumptions one is that there exists no inter species interaction. In addition to this several other assumptions are also made. These are that no environmental factor affects population, r is independent of age composition, there exists a single stock unit i.e. no multi stocks exist, *q* (catchability coefficient is constant), fishing mortality and natural mortality take place simultaneously and finally catch statistics are reliable an accurate.

Results

Major landing sites in Pakistan are shown in Figure 1. Overall, there is a decreasing trend in catch. Staring with, in 1990, the catch quantity of 63743 Mg ended up, in 2010, with 20127 Mg. The catch quantity has decreased, 1990 – 2010, more than 50% of the initial catch. The calculated difference between first and last catch was 43616 Mg. The maximum recorded catch, 92704 Mg, was observed in 1993. The lowest catch was recorded in 2010 i.e. 20127 Mg, while average catch value remained 44265 Mg. Computed CPUE is graphically presented in Figure 2. CPUE, average value is 0.111, also showed declining trend. It's maximum and minimum values, 0.186 and 0.060, were observed in 1993 and 2010 in that order.

Graphical representation of estimated and observed catches computed by using CEDA software showed no visual difference between log and log-normal error assumptions anticipated for all the three SPMs that were used. However, gamma estimation graph gave different picture.

It indicated greater value of expected catch against observed catch in contrast to log and log-normal assumption values (Figure 3).

Estimated MSY along with coefficient of variation (CV) values by using CEDA software are listed in Table 1. This software requires an input of initial proportion. It can be noted that CEDA package shows sensitivity towards input value of initial proportion, IP (B_1/K, starting biomass over carrying capacity). With different IP inputs, diverse estimated values for various parameters were obtained. Estimation of MSY with gamma error assumption in all the three Fox, Schaefer and Pella-Tomlinson models sometimes resulted in unreliable output values or showed minimization failure. On the other hand, log and log-normal estimation of MSY and other parameters, for all the SPMs used, gave more rational results.

An IP of 0.7 was used because the initial catch was about 70% of the maximum catch. Concluded results of CEDA for IP 0.7 are presented in Table 2. It can be noted that gamma assumption in terms of MSY, CV or R^2 calculation did not computed reliable results.

Table 1— MSY values for all the three SPMs along with error assumptions computed by using CEDA (IP 0.1 – 0.9)

IP	Fox			Schaefer			Pella-Tomlinson		
	Log	Log-normal	Gamma	Log	Log-normal	Gamma	Log	Log-normal	Gamma
0.1	78973	90723	MF	655378	183291	676174	655378	183291	676174
	0.0894	0.0005	MF	4359.0230	0.0000	0.4885	8962.6130	0.0000	0.2779
0.2	47883	54530	734186	100339	101098	MF	100339	101098	MF
	0.1186	0.0478	1383.6050	0.0099	0.0000	MF	0.0089	0.0000	MF
0.3	36331	40889	734186	68008	74538	316798	68008	74538	316798
	0.1307	0.0711	1924.2000	0.0488	0.0000	482.4796	0.0478	0.0001	1287.5700
0.4	30173	35326	34101	51126	61665	MF	51126	61665	MF
	0.1477	0.0838	0.1221	0.0979	0.0007	MF	0.0978	0.0006	MF
0.5	26307	31728	MF	40468	38408	44225	40468	38408	44225
	0.1894	0.1014	MF	0.1376	0.0854	0.0919	0.1432	0.0997	0.0966
0.6	23655	29031	250793	33050	34567	37651	33050	34567	37651
	0.2091	0.1111	3176.1468	0.1609	0.1111	0.1296	0.1618	0.1006	0.1199
0.7	21734	27477	609242	27609	32665	225727	27609	32665	225727
	0.2180	0.1033	2774.8540	0.1925	0.1217	3023.4450	0.2062	0.1173	4268.0570
0.8	20286	26612	MF	23493	31848	MF	23493	31848	MF
	0.2503	0.1004	MF	0.2511	0.1186	MF	0.2507	0.1064	MF
0.9	19155	25401	253874	20305	28427	26353	20305	28427	26326
	0.2835	0.1163	0.1711	0.2992	0.1462	0.1588	0.3018	0.1459	0.1755

Models

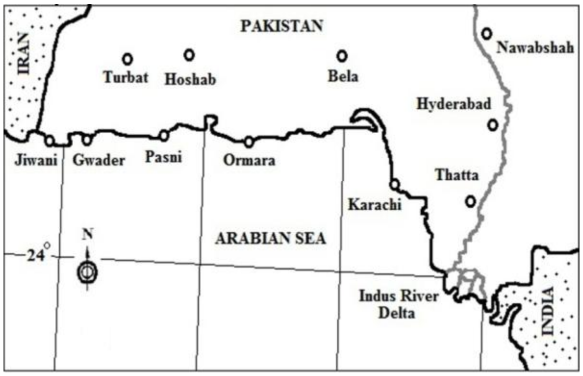

Fig. 1— Major landing sites (circles) along the coastline of Pakistan.

For gamma, MSY and CV values are too high while coefficient of determination of goodness of fit R^2 is very low. Log and log-normal assumptions for all the SPMs produced good results. Estimated MSY values by Fox model for log and log-normal assumptions were 21734 Mg and 27477 Mg respectively. Schaefer and Pella-Tomlinson models computed same MSY for both the assumptions i.e. log and log-normal. Fox model remained a bit more conservative in MSY calculation as compared to other models. R^2 value calculated for log and log-normal assumption for all the three SPMs remained same, except Fox (log) value. CV values remained 0.2180, 0.1033 and 0.1925, 0.1217 and 0.2062, 0.1173 for log and log-normal assumptions used in Fox, Schaefer and Pella-Tomlinson models.

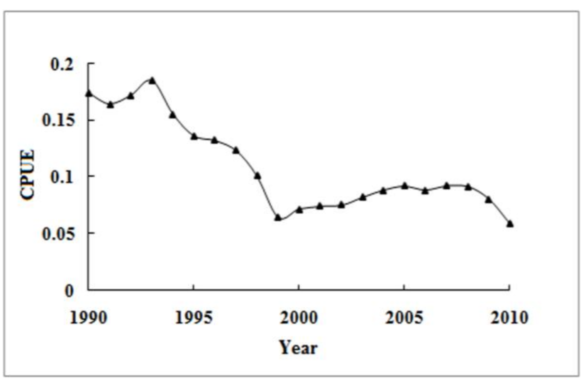

Fig. 2— Graphical representation of CPUE of *S. longiceps* fishery from 1990-2010 in Pakistan.

Discussion

In fishery management science the concept of MSY is crucial. Sometimes MSY is regarded as biological reference point (BRP). BRPs play central role in long term fishery management objectives. By considering this point maximum capture production or sustainable yield is predicted[7]. BRPs tell about fishing mortality or of biomass and predict sustainable catch by indicating best possible catch values[28].

Surplus production models just need catch and effort data, other data such as of age structure etc. is not required, and are used for fishery resource administration[29]. They give us the output in the form of estimated MSY. Thus, surplus production models forecast about the fate of the fishery stock. Commonly, when computed output value of surplus production model is higher than catch figure we say fishery stock is flourishing. However, when both values are equal the stock is at constant or equilibrium state. But, if calculated surplus production figure is lower than catch then the stock is overexploited.

To meet the demands of domestic consumption and fulfill export orders in the pursuit of earning extra money more and more effort is done to increase catch. Pakistani fishery is rich in biotic diversity and has tremendous export potential[30]. Mechanized fishing vessels with bigger nets having small mesh size are used without considering ecological harms. Overexploitation of fishery resources causes irreparable loss due to genetic drift.

Removal of large number of genes from gene pool leaves few to manipulate in the next generation. Future generations suffer from bottle neck effect and face low disease resistance and less biomass production. On the other hand if the stock is underexploited we suffer from economic loss and do not get full benefit of natural blessing. Thus it is of utmost importance to evaluate fishery resource status.

In a nut shell, we can say that the best fishery management practice must involve what type of data to be collected, which statistical technique is used to analyze the data and finally what management proposals are followed. In SPMs, MSY or BRP gives us the direction for further fishery management[31-32].

CEDA software is menu driven and can guess customized parameters. It estimates parameters by using confidence intervals, 95%, through bootstrapping and has useful analytic tools such as residual plots and goodness of fit. It is not only limited to just three SPMs i.e. Fox, Schaefer and Pella-Tomlinson but each of these models further have three error assumptions i.e. log, log-normal and gamma.

It requires simple data and calculates MSY for different error assumptions and does not assume that the fishery stock is at a stable state. As temporal and spatial distribution of fish stocks does not remain constant rather it fluctuates under the effect of biotic or abiotic factors. MSY, 21734 Mg, calculated through Fox with log assumption was the most conservative. Fox, Schaefer and Pella-Tomlinson models with log-normal assumption produced almost same estimated MSY such as 27477 Mg, 32665 Mg and 32665 Mg in that order.

The concept of MSY implies the resource exploitation under the sustainable level. That is why MSY is also called as target biological reference point (BRP). SPMs are also referred to as Biomass Dynamic Models and are considered as basic fishery management models[14].

In common, when catch quantity is higher than estimated MSY value then the population size of the stock is decreasing. When, it equals to the MSY value, the stock is at sustainable state so the catch should neither be increased nor decreased rather maintained at computed MSY level. When, the catch quantity is smaller than the computed MSY value then the stock population is flourishing and more exploitation is possible. Hence, MSY is crucial in making fishery management decision, in the light of which sustainable exploitation can be decided[32-33], however caution is required in decision making otherwise modelling approach may go wrong[34].

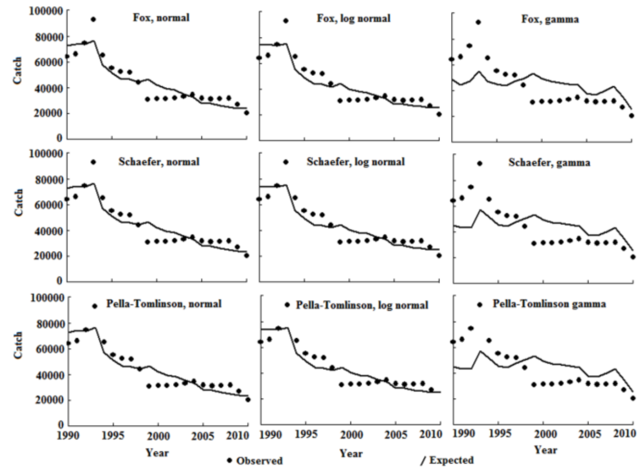

Fig. 3— Comparison of observed and estimated catches computed for all the SPMs used along with their error assumptions by using CEDA package for *S. longiceps* fishery in Pakistan.

Conclusion

For IP = 0.7, CEDA computed MSY of *S. longiceps* in a range between 21000 to 33000 Mg. Log error assumption remained conservative as compared to log-normal error assumption but showed higher R^2 values. Thus, by considering estimates of log error assumption, MSY of *S. longiceps* is 21000 – 27000 Mg in Pakistani marine waters. In order to conserve this fishery resource it must not be harvest beyond this range rather harvest should be kept at current level.

Table 2— Various parameters estimated for IP = 0.7 because the initial catch was about 70% by using CEDA

Model	*K*	*q*	*r*	MSY	R_{yield}	CV	R^2	Biomass
Fox (log)	1085259	2.69E-07	5.44E-02	21734	20180	0.2180	0.841	258125
Fox (log-normal)	878059	3.42E-07	8.51E-02	27477	26145	0.1033	0.815	227800
Fox (gamma)	621543	2.18E-07	2.66E+00	609242	81726	2774.8	0.295	590059
Schaefer (log)	914258	3.20E-07	1.21E-01	27609	19996	0.1925	0.838	217086
Schaefer (log-normal)	754015	3.94E-07	1.73E-01	32665	24856	0.1217	0.815	192665
Schaefer (gamma)	298623	4.52E-07	3.02E+00	225727	127389	3023.4	0.276	247863
Pella-Tomlinson (log)	914258	3.20E-07	1.21E-01	27609	19996	0.2062	0.838	217086
Pella-Tomlinson (log-normal)	754015	3.94E-07	1.73E-01	32665	24856	0.1173	0.815	192665
Pella-Tomlinson (gamma)	298623	4.52E-07	3.02E+00	225727	127389	4268.0	0.276	247863

Note: *K*: carrying capacity; *q*: catchability coefficient; *r*: intrinsic growth rate; MSY: maximum sustainable yield; R_{yield}: replacement yield; CV: coefficient of variation; R^2: goodness of fit.

Acknowledgements

The first author is thankful to China Scholarship Council (CSC) for funding his PhD. Degree. This work was supported by the special research fund of Ocean University of China (201022001) and China Agriculture Research System (CARS-49).

References

1 Mohamed, K.S., Vinod, K., Radhakrishnan, E.V. (editors), *CMFRI Annual Report 2007-2008*. Central marine research institute, (2008) 135 pp.

2 Misra, K.S., *Pisces*. Vol. 2. Manager of Publications. Dehli, India. Vol. 2, (1976) 417 pp.

3 Frimodt, C., *Multiligual illustrated guide to the world's commercial warm water fish*. Fishing News Books, Osney Mead, oxford, England, (1995) 215pp.

4 Deshmukh, A.V., Kovale, S.R., Sawant, M.S., Shirdhankar, M.M., Funde, A.B., Reproductive biology of *Sardinella longiceps* along Ratnagiri coast of Maharashtra. *Indian J. Mar. Sci.*, 39(2010): 274-279.

5 Ricker, W.E., Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd. Canada*, 191(1975): 1-382.

6 Pitcher, T.J., Hart, P.J.B., *Fisheries ecology*. Kluwer Academic Publishers, the Netherlands, (1982) 47pp.

7 Hilborn, R., Walters, C.J., Quantitative fisheries stock assessment, choices, dynamics and uncertainty, (1992) Chapman and Hall, New York, London.

8 Prager, M.H., A suite of extensions to a nonequilibrium surplus productionmodel. *Fish. Bull.*, 92(1994): 374-389.

9 Laloe, F., Should surplus production models be fishery description tools rather than biological models? *Aquat. Living Resour.*, 8(1994): 1-16.

10 Walters, C.J., Perma, A., Fixed exploitation rate strategies for copying with effects of climate change. *Can. J. Fish. aquatic. Sci*., 53(1996): 148-158.

11 Quinn II, T. J., Deriso, R. B., *Quantitative Fish Dynamics*. Oxford University Press, New York, USA, (1999) 542pp.

12 Maunder, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., Harley, S. J., Interpreting catch per unit effort data to assess the status of individual stocks and communities. *ICES J. Mar. Sci.*, 63(2006): 1373-1385.

13 Schnute, J., A general theory for the analysis of catch and effort data. *Can. J. Fish. Aquat. Sci.*, 42(1985): 414-429.

14 MRAG. 2016. CEDA Version 3.0. http://www.mrag.co.uk/resources/fisheries-assessment-software. Accessed on 2016-06-29.

15 Mohsin, M., Mu, Y., Zhu, Y., Memon A.M., Akhter, N., Shafqat, M.M., Kalhoro, M.T., Hussain, N., Noman, M., The status of molluscan fisheries in Pakistan evaluated by using CEDA and ASPIC computer packages. *Ind. J. Mar. Sci*., (2015). Accepted.

16 Memon, A.M., Liu ,Q., Memon, K.H., Baloch, W.A., Memon, A., Baset, A., Evaluation of the fishery status for King Soldier Bream *Argyrops spinifer* in Pakistan using the software CEDA and ASPIC. *Chin. J. Oceanol. Limn*., 33(2015): 966-973.

17 Siyal, F.K., Li, Y., Gao, T., Liu, Q., Maximum Sustainable Yield Estimates of Silver Pomfret, *Pampus argenteus* (Family: Strometidae) Fishery in Pakistan. *Pak. J. Zool.*, 45(2013): 447-452.

18 Panhwar, S.K., Liu, Q., Khan, F., Siddiqui, P.J.A., Maximum sustainable yield estimates of Ladypees, *Sillago sihama* (Forsskål), fishery in Pakistan using the ASPIC and CEDA packages. *J. Ocean Univ. China*, 11(2012): 93-98.

19 Kalhoro, M.A., Liu, Q., Memon, K.H., Chang, M.S., Jatt, A.N., Estimation of maximum sustainable yield of Bombay duck, *Harpodon nehereus* fishery in Pakistan using the CEDA and ASPIC packages. *Pak. J. Zool*., 45(2013): 1757-1764.

20 Abdul Baset, Qun Liu, Muhammad Tariq Hanif, Baochao Liao, Aamir Mahmood Memon, Muhammad Mohsin. Estimation of Maximum Sustainable Yield Using Production Modeling: A Stock Appraisal of Indian Oil Sardine (*Sardinella longiceps*) from Pakistani Waters. Pakistan Journal of Zoology 49(2017):485-492.

21 Zeller D, Booth A and Pauly D (2006) Fisheries contri butions to GDP: understanding small- scale fisheries i n the Pacific. Marine Resource Economics 21: 21.

22 Claire Hornby, M. Moazzam Khan, Kyrstn Zylich, Dirk Zeller. 2014. Reconstruction of Pakistan's marine fisheries catches 1950-2010. Working Paper #2014 – 28. Working Paper Series. Fisheries Centre. The University of British Columbia.

23 Clark, C. W. (1973). The economics of overexploitation. *Science*, *181*(4100), 630-634.

24 FAO, FishStat Plus (Version 2.31). FAO Fisheries Department, Fishery Information, Data, and Statistics Unit. (2008) Retrieved from: *www.fao.org/fishery/statistics/software/fishstat/en*.

25 Schaefer, M.B., Some aspects of the dynamics of populations important to the management of commercial marine fisheries. *Bull. Inter-Am. trop. Tuna Commiss.*, 1(1954): 25-56.

26 Fox, W.W., An Exponential yield model for optimizing exploited fish populations. *Trans. Am. Fish. Soc.*, 99 (1970): 80-88.

27 Pella, T. J., Tomlinson, P. K., A generalized stock production model. *Bull. Inter-Am. Trop. Tuna Comm.*, 13(1969): 419 – 496.

28 Cadima, E. L., Fish Stock Assessment Manual. FAO, Fisheries Department, Rome, Italy, (2003) Technical Paper 393.

29 Mehanna, S.F., El-gammal, F.I., Gulf of Suez fisheries: current status, assessment and management. *JKAU*: *Mar. Sci*., 18(2007): 3-18.

30 Mohsin, M., Mu, Y., Memon, A.M., Akhter, N., Shafqat, M.M., Nazir, K., Shah, S.B.H., Hussain, N., Noman, M., Molluscan fisheries in Pakistan: production, consumption and trade trends, *Ind. J. Mar. Sci*. (2017). 46 (5): 929-935.

31 Prager, M.H., Comparison of logistic and generalized surplus production models applied to swordfish *Xiphias gladius*, in North Atlantic Ocean. *Fish. Res.*, 58(2002): 41-57.

32 Musick, J. A., and Bonfil, R., Elasmobranch Fisheries Management Techniques. Asia-Pacific Economic Cooperation (APEC) Fisheries Working Group, Singapore, (2004), 133-164.