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Accessing the risk of overfishing faced by mullet fisheries and its ongoing economics in Pakistan

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In this study, catch statistics of mullets are first time evaluated to know their exploitation status and ongoing economic implications. Catch and effort (CE) figures of mullets acquired from Sindh, Pakistan was statistically evaluated by employing surplus production models (SPMs), non-equilibrium versions, through two famous fishery related software, *viz*., catch and effort data analysis (CEDA) and a stock production model incorporating covariates (ASPIC). In total three SPMs, i.e., Fox, Schaefer and Pella-Tomlinson were used to investigate CE statistics, 1995 to 2012. Obtained results reveal that catch per unit effort (CPUE) has considerably dropped from 0.206 (1995) to 0.055 (2012). CEDA estimates of maximum sustainable yield (MSY) remained conservative as they were calculated between 5100 to 6500 t against ASPIC for which estimates of this parameter remained between 5800 and 7600 t. Considering the results, it can be concluded that mullet fishery is experiencing overexploitation (OE). This OE is an indicator of economic losses by increasing costs and decreasing profits. Thus, mullet resource conservation is necessary for its long-term economic utilization. Therefore, it is suggested that the target reference point (TRP) with respect to harvest should be between 5100 to 5500 t. However, this study is a preliminary study, hence; further in-depth studies are suggested before making and implementing any management plan for mullet fishery in Sindh, Pakistan.

[**Keywords**: Economics, Management, Mullet fishery, Overexploitation risk, Pakistan]

Introduction

Mullet fishery is an important commercial marine fishery resource in Pakistan. It is caught from the two coastal provinces of Pakistan, *viz*., Sindh and Baluchistan and is landed at each landing centre (Fig. 1). Mullets belong to the family Mugilidae. In this family around 30 genera and 78 species are included from all over the world[1]. In Pakistan, mullets comprise *Lisa* spp. and *Mugil* spp. Locally, mullets are known as “Boi” in Sindhi language, whereas, in Balochi language they are called as “Murbo”[2]. It is reported that twelve mullet species dwell in Pakistan, *viz*., *Chelon klunzingeri*, *C. macrolepis*, *C. melinopterus*, *C. parsia*, *C. tade*, *Ellochelon vaigiensis*, *Liza subviridis*, *Moolgarda cunnesius*, *M. perusii*, *M. seheli*, *M. speigleri* and *Mugil cephalus*[3]. These fishes are mainly distributed in marine coastal and brackish waters. However, some are also found in fresh water such as *Liza abu*. These fishes can attain a maximum length of 90 cm[4]. All of the mullets are fished through gillnets, bottom trawls, bag nets and beach seines[3].

Export of fish form Pakistan is getting pace with the passage of time[5]. In order to meet market demand and earn more profits, fishermen try to catch more and more fish. This thirst has resulted in an enormous increase in the number of trawlers. Thus, their number has increased from 3 (1958) to 1631 (1985)[6]. According to a recent report, recent number of trawlers operating in Pakistan is about 2400[(ref. 7)]. This happening has seriously threatened commercially important fish species in Pakistan. Several studies

Fig. 1 — Map showing landing sites in Pakistan

confirm that commercially important fishery resources of Pakistan are a victim of overexploitation (OE). As aforementioned, mullet fishery resource is an important commercial fishery resource of Pakistan, hence, it becomes essential to assess its exploitation status and discuss its ongoing economics.

Surplus production models (SPMs) are the best commonly used statistical tools to access the stock status of a fishery resource. They are famous fishery models because they need simple statistics of catch figures and have the ability to estimate important fishery parameters[8]. In addition to SPMs, statistical routines of age structure are also used, but, they are less popular because the data required for them is difficult to collect. In order to access fishery stock status, a simple estimate of CPUE can also be used[9]. In a nutshell, SPMs have been very popular and several published fishery stock assessment studies employ them[10,11]. SPMs are usually classified into two types based on their assumptions. Their classical versions, commonly known as equilibrium SPMs, assumed fish stock in a stable state, which means fish stock does not change which is obviously not possible[12]. In contrast to them, modern versions, commonly known as non-equilibrium SPMs, assume the dynamic state of the fish stock and are more realistic versions as compared to equilibrium versions of SPMs[8,13]. Considering these advantages of SPMs, in this study these models are used.

Fisheries management literature usually employs idea of maximum sustainable yield (MSY) and maximum economic yield (MEY) which are mostly used for biological as well as economic management of fishery resource, respectively[14]. Several studies suggest that operating fisheries at MEY can bring more profit as compared to MSY reference point[15,16]. Following this thought, many countries around the world adopted the MEY approach to manage the fishery resources[17]. Practically speaking, the expected benefits of MEY are not witnessed in the real world[18]. Basically, the concept of MEY focuses on increasing profits by considering individual fishing vessels. Fisheries not just only comprises fishing fleets rather several other parts are also included in this sector such as marketing, processing etc.[19]. On the other hand, technically speaking, fish yield at MEY is lower than MSY[20], which means less production, less processing, less marketing and so on. That’s why, recent studies now suggest that MSY is a better reference point which is not only better with respect to conserve fish stock but also to maximize overall fisheries industry efficiency[19]. In this paper, this logic is followed and the MSY reference point is taken as that reference point at which maximum economic effectiveness of fishery resource is created.

The published literature does not depict stock assessment studies related to mullets for their economic and biological management in Pakistan. Thus, this is the first attempt in this regard. The aim of this study is to perform a stock assessment study of mullet fishery resource and describe its bioeconomic implications. It is hoped that the findings of this preliminary study will give direction to the policy makers for further in-depth studies and better management practices.

Material and Methods

In this study, the catch statistics, 1995-2012, of mullets caught from Sindh, Pakistan (Fig. 1) were statistically analyzed by using non-equilibrium SPMs. The catch statistics of mullets from Baluchistan are not included in this analysis because of two reasons. First, catch is mainly from Sindh. Second, the statistical results are more reliable when the catch statistics obtained from the small geographical area are used. Numerical data to draw results was acquired from the published Handbook of Fisheries Statistics of Pakistan[2]. Moreover, catch of all the twelve reported mullet species in Pakistan is reported collectively by Marine Fisheries Department (MFD) of Pakistan. Hence, catch statistics used in this study are collective catch figures of all the mullet fish species. It means for Sindh and Baluchistan, MFD publishes mullet catch statistics separately, however, that reported catch represents all the caught species collectively. CE data was taken in tons (t) and number of fishermen, correspondingly. In total, three SPMs, viz., Fox Model (FM), Schaefer Model (SM) and Pella-Tomlinson Model (PTM) were employed. FM relies on growth equation (Gompertz) and is represented as follows:

$$\frac{dB}{dt} = rB(1nB_{\infty} - 1nB)$$ [21]

Whereas, SM and PTM use logistic population growth concept and generalized production equation, in that order. There models are represented as follows:

$$\frac{dB}{dt} = rB(B_\infty - B)^{22}$$

$$\frac{dB}{dt} = rB(B_\infty^{n-1} - B^{n-1})^{23}$$

Where, r, n, B and B_∞ represent growth rate, shape parameter, biomass and carrying capacity (K), in that order.

SPMs were applied to the data through famous fishery routines, i.e., catch and data analysis (CEDA)[8] and a stock production model incorporating covariates (ASPIC)[24]. In CEDA, we used three kinds of error assumptions (EA) for each of CEDA models. The names of these EA are normal error assumption, log-normal error assumption and gamma error assumption, i.e., NEA, LNEA and GEA, respectively. CEDA is a menu driven statistical routine. First, .txt (text) file was prepared containing catch statistics and then uploaded into the software to compute fishery parameters. Initial proportion (IP) was estimated by dividing first catch value with the maximum catch value reported in the data series. For this IP value, separate table is presented. Besides, results were also obtained for some other supposed IP values to get more clear idea about the state of the fishery. In order to get the results, models and EA were selected one by one. Output parameters were recorded in the form of tables.

In ASPIC, only two models were used, i.e., FM and SM without assuming any further EA. Separate files were prepared for different IP values to estimate fishery parameters. 500 trials were done to compute fishery parameters by using bootstrapping confidence interval method. Furthermore, for each IP value, BOT and FIT files were prepared. Parameters computed by using CEDA and ASPIC included carrying capacity (K), catch ability coefficient (q), growth rate (r), MSY, coefficient of variation (CV), goodness of fit (R^2), biomass (B), fishing mortality at MSY (F_{MSY}) and biomass at MSY (B_{MSY}). The models used in this study were compared to judge their fitting to data on the basis of three factors. First, MSY estimates having reasonable CV values were considered only. Second, too small or large estimated values of MSY were not considered. Third, models with higher R^2 values were used to draw a conclusion.

Results

Obtained results show that effort, i.e., number of fishermen, has increased from 80383 (1995) to 109143 (2012), whereas, catch has declined from 16567 t (1995) to 6015 t (2012) (Fig. 2). Consequently, the computed CPUE has considerably decreased from 0.206 (1995) to 0.055 (2012) (Fig. 3).

CEDA Results

In Table 1, MSY estimates by using IP from 0.6 to 1 through CEDA software are presented. Most of the time, GEA produced minimization failure (MF) because for this assumption data pattern did not suit to get results. For lower IP values, higher MSY was estimated, while, for higher IP values, lower MSY was obtained. For instance, for IP 0.6, computed MSY was 6508 t, while, for IP 1, estimated MSY was 4812 t. Table 2 lists various fishery parameters estimated by CEDA by using IP 0.9. For FM by using all EA, *viz*., NEA, LNEA and GEA, MSY and CV was calculated as 5102 t (0.186), 5822 t (0.120) and 5514 t (0.130), respectively. The R^2 values for these EA remained 0.874, 0.905 and 0.890, respectively. For SM and PTM, MSY and R^2 estimates remained same for NEA and LNEA, i.e., 5819 t, 6432 t and 0.862, 0.896, correspondingly. CEDA graphs between

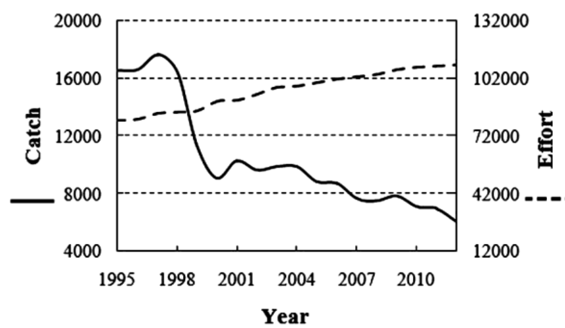

Fig. 2 — Catch and effort statistics of mullet fishery in Sindh, Pakistan

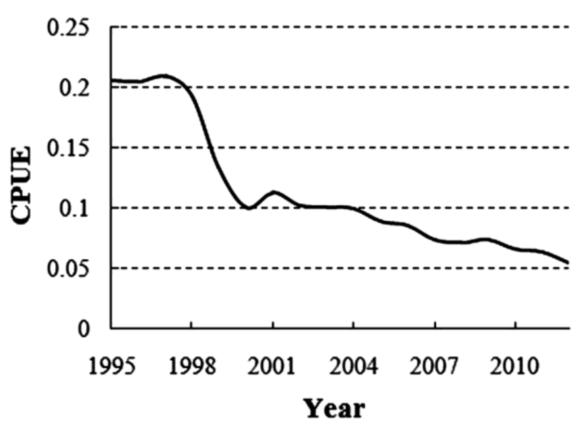

Fig. 3 — Computed CPUE of mullet fishery in Sindh, Pakistan

Table 1 — MSY estimates of mullet fishery resource in Sindh, Pakistan obtained through CEDA (IP = 0.6-1)

IP	Model								
	FM			SM			PTM		
	NEA	LNEA	GEA	NEA	LNEA	GEA	NEA	LNEA	GEA
0.6	6508	6683	MF	9413	10761	10377	9413	6432	MF
	0.156	0.102	-	0.127	0.003	0.072	0.124	0.143	-
0.7	5915	6390	6343	7819	10101	MF	7819	10101	MF
	0.153	0.112	0.122	0.182	0.007	-	0.194	0.006	-
0.8	5461	6255	MF	6685	6372	MF	6685	6372	MF
	0.153	0.108	-	0.241	0.126	-	0.188	0.145	-
0.9	5102	5822	5514	5819	6432	MF	5819	6432	MF
	0.186	0.120	0.130	0.256	0.141	-	0.255	0.134	-
1	4812	5440	611362	5130	6819	287020	5130	6819	287020
	0.189	0.137	0.003	0.266	0.103	0.411	0.264	0.119	0.062

CV- coefficient of variation (mentioned underneath MSY estimates); MF- it represents minimization failure

Table 2 — Various parameters estimated through CEDA for mullet fishery resource in Sindh, Pakistan (IP = 0.9)

Model	K	q	*r*	MSY	R_{yield}	CV	R^2	B
FM (NEA)	156684	1.71E-06	0.088	5102	4535	0.186	0.874	32712
FM (LNEA)	140326	1.96E-06	0.110	5822	5216	0.120	0.905	29949
FM (GEA)	148062	1.83E-06	0.101	5514	4953	0.130	0.890	31835
SM (NEA)	142304	1.86E-06	0.163	5819	3653	0.256	0.862	27751
SM (LNEA)	130756	2.02E-06	0.196	6432	4221	0.141	0.896	27048
SM (GEA)	MF	-	-	-	-	-	-	-
PTM (NEA)	142304	1.86E-06	0.163	5819	3653	0.255	0.862	27751
PTM (LNEA)	130756	2.02E-06	0.196	6432	4221	0.134	0.896	27048
PTM (GEA)	MF	-	-	-	-	-	-	-

MF- Minimization failure; K- carrying capacity; q- Catchability coefficient; *r*- intrinsic growth rate; MSY- Maximum sustainable yield; CV- coefficient of variation; R^2- coefficient of determination; B- current biomass; B_{MSY}- biomass giving MSY

observed and expected catches are presented in Figure 4. GEA produced MF in SM and PTM so only seven graphs are given in this Figure. Here, graphs appear the same, though with minor differences they are different from each other.

ASPIC Results

Table 3 presents the results obtained using various IP values from 0.5 to 1 through ASPIC. Higher MSY estimates were obtained when we used lower IP values. Lower MSY values were obtained when we used higher IP values. For instance, in FM for IP 0.5, computed MSY was 8182 t, whereas, for IP 1, computed MSY value was 5532 t. Both the models, *viz*., FM and LM show the same trend. Table 4 lists the various fishery parameters computed using IP 0.9 through ASPIC. For FM and LM, estimated MSY and CV values for this software are 5831 t (0.098) and 7539 t (0.161), respectively. The calculated R^2 values for these models remained 0.912 and 0.900, respectively. Figure 5 illustrates the estimates of F and B computed through ASPIC. It clearly indicates that F has increased and B has decreased considerably. For FM, F has risen from 0.142 (1995) to 0.202 (2012) and B has declined from 123800 t (1995) to 30180 t (2012). The same increase and decrease trend was observed for these parameters in the LM.

Discussion

SPMs are used frequently in fisheries management science. Several studies conducted by various researchers regarding the fisheries management in Pakistan employ this statistical routines[25-27]. The popularity of these models is based on the fact that these are very convenient to use and compute very important fishery parameters. Thus, these models are usually preferred over the others. Simple catch statistics can be analyzed through them to estimate the fishery stock status. Another, advantage of these models is that these models give output representing unified biomass by considering various aspects of the fish population such as recruitment, mortality and growth. Moreover, these models can estimate fishing mortality by using current fish population size.

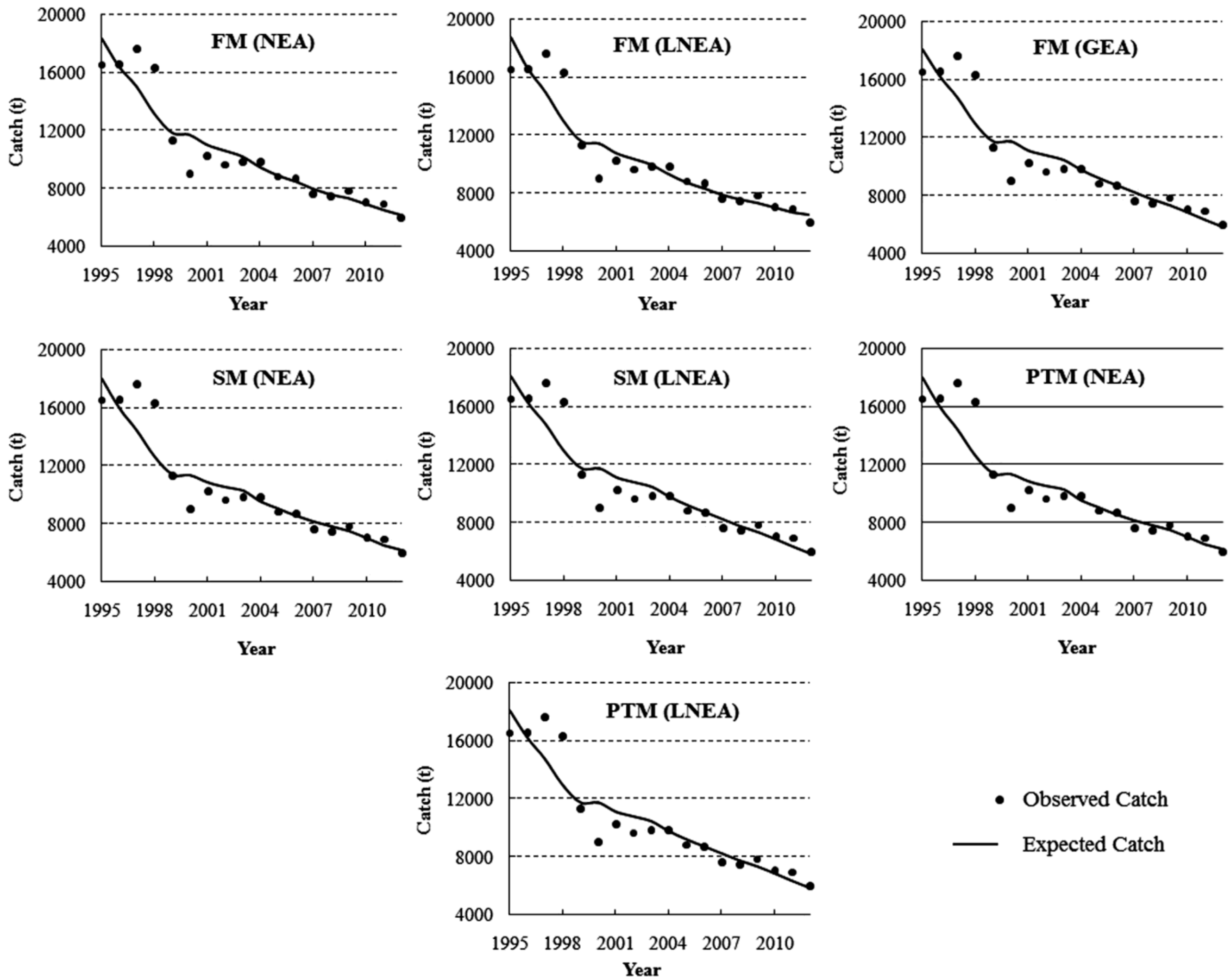

Fig. 4 — CEDA graphs obtained for mullet fishery in Sindh, Pakistan

Table 3 — ASPIC estimates for mullet fishery resource in Sindh, Pakistan (IP = 0.6-1)

Model	IP	MSY	K	*q*	F_{MSY}	B_{MSY}	R^2	CV
	0.5	8182	159700	3.092E-06	0.139	58760	0.909	0.091
	0.6	7301	152600	2.689E-06	0.130	56140	0.910	0.102
FM	0.7	6684	146200	2.408E-06	0.124	53770	0.911	0.099
	0.8	6204	141500	2.176E-06	0.119	52040	0.912	0.106
	0.9	5831	137500	1.990E-06	0.115	50600	0.912	0.098
	1	5532	134400	1.832E-06	0.111	49450	0.913	0.107
	0.5	13610	66470	7.482E-06	0.409	33240	0.894	0.022
	0.6	11420	79220	5.264E-06	0.288	39610	0.892	0.064
LM	0.7	9711	91050	3.910E-06	0.213	45520	0.895	0.120
	0.8	8482	99150	3.143E-06	0.171	49570	0.897	0.119
	0.9	7539	105300	2.636E-06	0.143	52630	0.900	0.161
	1	6787	110100	2.274E-06	0.123	55040	0.901	0.158

Table 4 — Various parameters estimated through ASPIC software for mullet fishery resource in Sindh, Pakistan (IP = 0.9)

Model	IP	MSY	K	q	F_{MSY}	B_{MSY}	R^2	CV
FM	0.9	5831	137500	1.990E-06	0.115	50600	0.912	0.098
LM	0.9	7539	105300	2.636E-06	0.143	52630	0.900	0.161

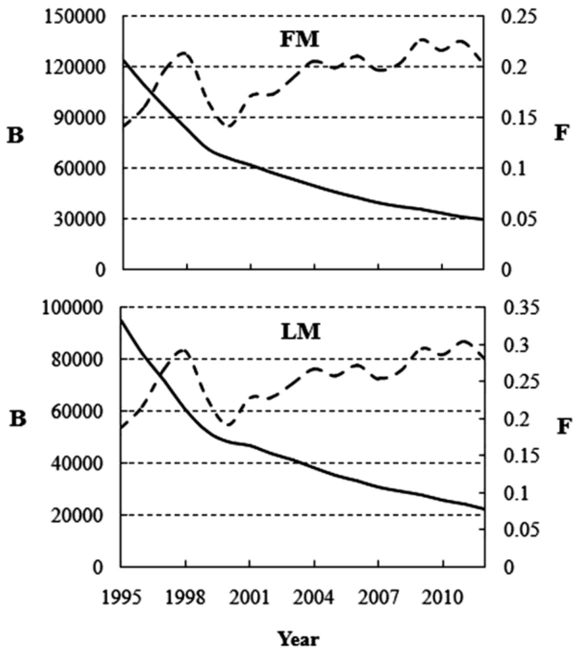

Fig. 5 — F and B statistics obtained for mullet fishery in Sindh, Pakistan

Besides, estimated catchability coefficient (q) represents straightly the fish stock status. Like other statistical routines, SPMs use certain assumptions for their estimation. For instance, these models assume that *r* is independent of age composition. q remain same over time. The data used for analysis belong to single fishing stock. In the fish stock natural and artificial mortality occur simultaneously. The catch statistics are true and performance of the fishing vessels does not change over the time[28]. SPMs also assume that no fish leave or new fish enter into the fish stock[8]. In nature, some assumptions of SPMs may not be met, however, the scientific method is not rejected rather these models are very famous and strong tool used for fishery assessment studies all over the world[29].

The type of SPM which should be used for the analysis of data depends upon the objective and nature of available data. Production models can be fitted for annul catch statistics. Usually, many production models are used for the analysis of the data. Later on, by comparing the obtained results, the best fit is sought. Different results are obtained because of different assumptions of the different models. Sometimes, different models compute similar results which indicate that the obtained results are independent of some assumptions[8]. Comparing the various models based on the obtained results and selecting the best fit is very important and crucial step of analysis. For obtaining the best fit, models were compared on the basis of four factors. First, very large or very small MSY with respect to the catch statistics was not considered. Second, Results with suitable CV value were considered only. Third, results with higher R^2 values were considered more reliable because it represents more goodness of fit. Fourth, obtained graphs between observed and expected catch were also considered to get best fit. According to various researchers R^2 values should be considered along with inspection of graphs[8], thus, in this study this approach is followed.

The pattern of catch, effort and CPUE statistics also represent the status of the fishery stock. If CE shows rising trend and CPUE does not significantly change, it indicates that the fishery is not harming fish stock. But, if efforts increase and catch decrease, it may represent that stock of fish is experiencing OE. This situation is witnessed in this study. Hence, this situation is alarming. On the other hand, if efforts remain same but catch fluctuates significantly, it may indicate quantitative changes in the fish stock[8].

Fishery management is not a simple process; rather, it involves various stages such as data gathering, data analysis, result interpretation, consultation and finally decision making[30]. For managing fishery resources, reference points (RPs) are frequently used worldwide[8]. In 1992, the idea of RPs was introduced for the first time. Now they are very popular for giving management advice[31]. Broadly speaking, RPs are usually categorized into two types: target reference points (TRPs) and limit reference points (LRPs). TRPs are those fishing levels which are tried to achieve for fishery management. On the other hand, LRPs are those fishing levels which are avoided because at these fishery start to suffer. Thus, RPs are basically parameter estimates in the form of specific values which serve as a guide for making management strategy[32,33]. RPs are not fixed quantities and urge constant yield rather these are OE alarms[34]. Three RPs *viz*., MSY, F_{MSY} and B_{MSY} are used frequently for managing fishery resources. Among these three RPs, MSY has received more attention. The concept of this RP was first introduced in 1992. MSY indicates the status of the fishery when computed MSY is compared to the observed catch statistic of the fishery resource. There are three possible situations in this regard. First, estimated MSY is higher than the observed catch statistics which means there is still more potential to increase catch up to the estimated MSY level. Second, estimated MSY is almost equal to the observed catch statistics which indicates that fishing is not harming fish stock and catch levels can be kept at the same level[8]. However, it is better to keep catch levels below the computed MSY[35]. Third, estimated MSY is lower than the observed catch statistics which represents fishery resource is experiencing OE and there is a dire need to lower the catch[8].

This study indicates that mullet fishery resource is experiencing OE. It is reported that OE of fishery resource result into economic losses. OE leads to the social disorders by encouraging private owners to maximize profits. In order to gain more profits, they put more and more effort to exploit fishery resources. In severe cases, OE can result in the extinction of fishery resources. Thus, it is of utmost importance to conduct fishery resource analysis frequently[36]. When fishery starts somewhere, with less effort more fish is caught which generate sufficient revenue. This attracts more fishermen to join fishery. However, when the number of fishermen rise, i.e., effort the catch starts to decline. If the effort continues to increase uncontrolled it may deplete fishery resources[16]. Rebuilding OE fish stock is an economic activity but sometimes the fishermen do not comply with the idea of rebuilding[37]. For rebuilding, fishermen may be attracted by inter-temporal transfers through quota rental charge[38].

Pakistan is a member of FAO. According to the article 2.A of Code of Conduct of Responsible Fisheries of FAO, it is state's responsibility to address and control the issues of OE and increase in uncontrolled fishing effort[31]. In the past, fisheries related issues have been addressed through the Agriculture Enquiry Committee and National Agriculture Commission. In Pakistan, first comprehensive fishery policy was announced in 2007. Strategy axis, 2A.2 and 2A.3, of this policy, i.e., The National Policy and Strategy for Fisheries and Aquaculture Development in Pakistan insist to control OE and encourage sustainable development of fishery resources in Pakistan[39]. Despite having national fisheries policy, there is continued OE of fishery resources and increase in fishing effort. This study also finds mullets fishery resource OE hence their catch should be lowered. The fishery managers should play their crucial role in managing this resource. The government should also further enhance their efforts for the proper implantation of fishery policies. Implementation of fishing ban during spawning season and use of only recommended mesh size should be properly checked. In order to relieve pressure on capture fisheries, aquaculture should be promoted even on larger scale. Moreover, it is suggested to evaluate stock status of other commercially important fishery resource too.

Conclusion

Results have shown that mullet fishery resource is OE in Sindh, Pakistan. This study has shown that effort is increasing and catch is decreasing. Consequently, CPUE is declining. CEDA computed MSY in a range between 5100 to 6500 t. Whereas, ASPIC, estimated MSY in a range between 5800 to 7500 t. Thus, CEDA remained conservative in its MSY estimates in terms of range and values as compared to ASPIC. By considering these results, the suggested TRP for mullet fishery in Sindh, Pakistan is between 5100 to 5500 t. However, harvest below 4800 t and harvest above 6000 t should be considered as LRP. If OE of this fishery resource is not controlled it will result into increased fishing costs and less revenue. Thus, it is of utmost importance to formulate, revise and implement such policies which not only biologically safeguard mullet fishery resource but also ensure its long-term economic contribution.

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Conflict of Interest

Authors declare no conflict of interest.

Author Contributions

MM initiated this work and wrote the article. YH designed, supervised, collected data, and edited this

article. UN revised several parts and constructed tables and figures.

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