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Maximum Sustainable Yield of Dolphinfish, *Coryphaena hippurus* (Linnaeus, 1758) Fishery in Pakistan

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Abstract

The maximum sustainable yield (MSY) of Dolphinfish *Coryphaena hippurus* (Linnaeus, 1758) fishery in Pakistan was estimated from 20 (Twenty) years catch and effort data during 1990-2009. The average landing of dolphinfish fishery was 2418.55t. The highest catch was 4053t in the year 2002 and the lowest catch was 1297t in the year 1990. The CEDA (Catch and Effort Data Analysis) computer software package was used for the MSY estimation of dolphinfish fishery in Pakistan. In this study we used the initial proportion (IP) value of 0.3 because the starting catch was approximately 30% of the maximum catch. The estimated values of MSY from Fox model with two error assumptions normal and log-normal were 2792.125t (R^2=0.454) and 2920.592t (R^2=0.565) respectively. The MSY values from Schaefer and Pella Tomlinson models with two error assumptions normal and log-normal were 2781.02t (R^2=0.474) and 2863.3t (R^2=0.572) respectively. The values of Schaefer and Pella Tomlinson were the same. The gamma error assumption showed minimization failures for all three models. We may say the estimated MSY were lower than the current catch, therefore we suggest reducing the fishing effort for dolphinfish fishery.

Keywords: Stock assessment; *Coryphaena hippurus*; Maximum Sustainable Yield; CEDA; Pakistan

Introduction

The world's fisheries sectors have more developed in the last 60 years. In 1950, the total world fish production was 19.3 million tones and reached 163 million tons in 2009 [1]. In 2009 marine fisheries produced 80 million tons of fishes and 34 million employers were operating the fishing in 2008 [2]. More than 3 billion people received fish in which at least 15% of their average animal protein produced [2].

Fishery resources have a big role in economics development of Pakistan [3,4]. In 1996 Pakistan received amount of Rs. 196 million from its export, in which 70% obtain from marine sector [5]. In 2007 total production of fishes was 750300 t including 60% from marine [6]. That's why marine fisheries sector has a central role in Pakistan national economy and fish is a good source of protein for the public [7]. The Pakistanis provinces of Sindh and Baluchistan occupy coastal areas and about 90% of their population related to fishing and fishing related activities [8]. But the catch of fish is reducing day by day due to illegal, increased fishing efforts, unreported and unregulated fishing nets and the great problem of water pollution [9].

The dolphinfish *Coryphaena hippurus* (Linnaeus, 1758) belong to the family Coryphaenidae (Öktener, 2008) [10]. It is epipelagic and sophisticated fish, which found in tropical and subtropical waters mostly in warmer months [11]. Dolphinfish found in the depth from 0 to 85m. It is found in Western Mediterranean when the surface temperature reaches >16-18°C [12]. Mostly the adults of *Coryphaena hippurus* found in open sea but also found some time near the coast [13].

On economic point of view, the *Coryphaena hippurus* has great importance commercially as well as sport fisheries in all over the world [14-16]. Currently, there is no work presenting the estimation of Maximum Sustainable Yield (MSY) for dolphinfish from Pakistani waters. So, the present work has done on catch and effort data of *Coryphaena hippurus* from Pakistan, which have estimated maximum sustainable yield [17].

Materials and Methods

Data source

The catch and effort data of dolphinfish in the period from 1990 to 2009 were taken from the handbook of Fisheries Statistics of Pakistan

compiled by Marine Fisheries Department (MFD), Karachi, Pakistan (Table 1). Fishing effort is represented by the number of powered fishing boats, and the annual total catch is presented in the form of weight in metric tons (mt).

Surplus production models

The dolphinfish catch and effort data from 1990-2009 were analyzed by CEDA computer software package. There are three surplus production models (SPMs) used in CEDA package, Schaefer, Fox and Pella-Tomlinson. The most commonly used model is Schaefer MB, et al. [18] which is based on the logistic growth model:

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

After then the work of Fox (1970) put a Gompertz growth equation and a generalized production equation has reported by Pella and Tomlinson (1969).

$$\frac{dB}{dt} = rB(1nB_{\infty} - 1nB) \text{ [19]}$$

$$\frac{dB}{dt} = rB(B_{\infty}^{n-1} - B^{n-1}) \text{ [20]}$$

Where: B is fish stock biomass; t is time (year); $B\infty$ is carrying capacity; and r is intrinsic rate of population increase, n is the shape parameter.

Catch and Effort Data Analysis-CEDA

Catch and Effort Data Analysis (CEDA version 3.0.1) is a computer software package which is made of three non-equilibrium production models which are Schaefer (1954), Fox (1970) and Pella JJ, et al. [20] with three error assumption (normal, log-normal and gamma). By CEDA computer software package we calculate the following parameters MSY (maximum sustainable yield), q (catchability coefficient), K (carrying capacity), r (intrinsic growth rate), replacement yield and final biomass.

The initial proportion (IP, ratio of starting biomass over carrying capacity) is needed for CEDA from the user. When the IP is close to zero, it means that the data is from a virgin population and if the IP is close to 1 it indicates the data starts from a fully developed area. IP is an indicator that shows from which place the data has collected, starts from virgin population or from the serious exploitation population.

Table 1: The catch and effort data of dolphinfish fishery in Pakistani waters from 1990-2009.

Year	Catch	Effort	CPUE
1990	1297	8522	0.152
1991	1300	8619	0.151
1992	1577	8831	0.179
1993	1875	9604	0.195
1994	2054	10296	0.199
1995	2570	11066	0.232
1996	1841	11061	0.166
1997	1658	10983	0.151
1998	1892	11444	0.165
1999	3109	11768	0.264
2000	1954	12114	0.161
2001	3850	12618	0.305
2002	4053	12695	0.319
2003	3742	12838	0.291
2004	2949	13002	0.227
2005	2705	13145	0.206
2006	2453	13308	0.184
2007	2536	13426	0.189
2008	2839	13522	0.21
2009	2072	13879	0.149

Note: Catch is in the form of metric ton.

Results

The CEDA package results are showed with IP values 0.1 to 0.9 in table 2. There are mostly minimization failures for gamma error assumption. The estimated MSY is different from 0.1 to 0.9, sometime higher than the maximum catch and sometime lower than, but, the table 3 showed the CEDA results with initial proportions IP of 0.3 in which the estimated MSY is lower from the maximum catch from all of three models Fox, Schaefer and Pella-Tomlinson. The estimated values of MSY for Fox model were 2792.125t and 2920.592t for normal and log normal error assumptions respectively [21].

The estimated values of MSY for Schaefer and Pella Tomlinson with two error assumptions, normal and log normal were 2781.02 and 2896.3 metric tons respectively. The values of MSY were same for both Schaefer and Pella Tomlinson. Gamma error assumption showed minimization failure here from all models. There was a little difference among the estimated values of MSY for all of three models Fox, Schaefer and Pella Tomlinson. The figure 1 showed the estimated and observed catches, if using IP value 0.3, the observed catches by Fox and Schaefer were approximately near to the estimated catch.

Discussion and Conclusion

The average catch of *Coryphaena hippurus* from Pakistani waters was 2418.55t. For CEDA [22] computer software package needs catch and effort data which made of three surplus production models Fox, Schaefer and Pella Tomlinson. Each model has three error assumptions normal, log normal and gamma [23]. We can estimate MSY and some other related population parameters by surplus production models but do not contain age-structured models and related environmental factors.

Generally, when surplus production is greater than catch it means the population size increase when surplus production and catch are equal to one another its shows that population size remains constant, while when the catch is greater than the surplus production means the decline of population size. In surplus production models the MSY is measured as a biological indication point by which we can get sustainable exploitation [24-26]. The optimum fishing effort and MSY can be determined by surplus production model, which require the CPUE (catch per unit effort) and landed catch [27,28] without the need of age structure data [29].

CEDA is a helpful implement to estimate the MSY from different error assumptions. Table 3 showed initial proportion (IP) ranging from 0.1-0.9 in which the MSY values are different. From IP 0.1 and 0.2 from model Fox, the estimated SMY were higher than the maximum catch, Especially the values of Fox with assumption error normal is more high as compared to log normal and gamma error assumptions. But IP value 0.1 the estimated MSY from models Schaefer and Pella Tomlinson with all error assumptions normal, lognormal and gamma are nearly high than the maximum catch and IP value 0.2

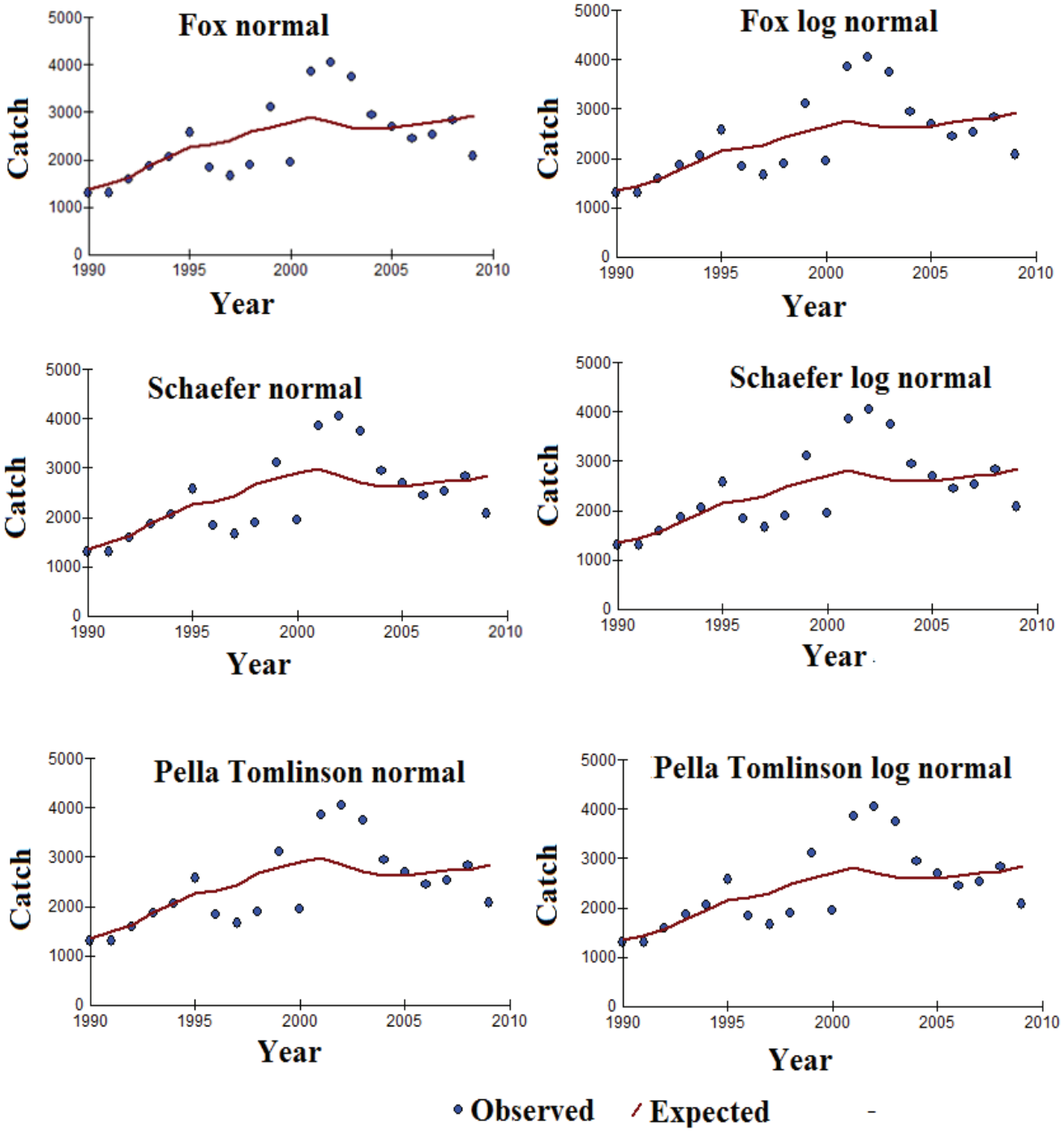

Figure 1: Annual expected (lines) and observed (points) catch (mt) of *Coryphaena hippurus* fishery in Pakistan using CEDA. Gamma error assumption showed minimization failure for Fox, Schaefer and Pella-Tomlinson models.

Table 2: Applying CEDA (Catch and Effort Data Analysis) Computer software package for *Coryphaena hippururs* in Pakistan for estimation of MSY with initial proportion ranging from 0.1 to 0.9.

IP					MODELS				
		FOX			SCHAEFER			PELLATOMLINSON	
	Normal	log-normal	Gamma	normal	Log-normal	Gamma	Normal	Log-normal	Gamma
0.1	2.06E+07	3583.544	105258.6	MF	4648.458	4834.89	MF	4648.458	4834.89
0.2	252534.9	2875.534	MF	3139.889	3344.583	MF	3139.889	3344.583	MF
0.3	2792.125	2920.592	MF	2781.02	2896.3	MF	2781.02	2896.3	MF
0.4	3135.516	3361.771	MF	2775.479	2936.091	MF	2775.479	2936.091	MF
0.5	IPV	4788.347	57866.7	1.13E+09	3616.933	MF	1.13E+09	3616.933	MF
0.6	69622.14	68392.27	5.94E+07	1.30E+09	26443.56	MF	1.30E+09	26443.56	MF
0.7	2.45E+09	802399.6	MF	4.50E+08	370788.9	MF	4.50E+08	370788.9	MF
0.8	3.87E+09	485038.8	MF	1.09E+09	294272.9	MF	1.09E+09	294272.9	MF
0.9	1.49E+09	318078.2	MF	IPV	439866.6	MF	IPV	439866.6	MF

IPV=Invalid property value, MF=Showing minimization failures

Table 3: Applying CEDA (Catch and Effort Data Analysis) Computer software package for *Coryphaena hippururs* in Pakistan for estimation of MSY used initial proportion 0.3 because the initial catch was approximately 30% of the maximum catch.

Models	IP	K	q	r	MSY	R_{yield}	R^2
Fox Normal	0.3	62693.63	8.31E-06	1.21E-01	2792.125	2771.76	0.454
Fox Log normal		79866.97	6.36E-06	9.94E-02	2920.592	2890.824	0.565
Fox Gamma		MF	MF	MF	MF	MF	MF
Schaefer Normal		44456.97	1.15E-05	0.250	2781.02	2681.629	0.474
Schaefer Log normal		58193.68	8.73E-06	0.199	2896.3	2805.809	0.572
Schaefer Gamma		MF	MF	MF	MF	MF	MF
Pella-Tomlinson Normal		44456.97	1.16E-05	0.250	2781.02	2681.629	0.474
Pella-Tomlinson Log normal		58193.68	8.73E-06	0.199	2896.3	2805.809	0.572
Pella-Tomlinson Gamma		MF	MF	MF	MF	MF	MF

Note: The sign of hyphen–showing minimization failure
The parameters are: *K*=carrying capacity, *r*=intrinsic population growth rate, MSY=Maximum Sustainable Yield, R_{yield}=Replacement Yield, q=catchability coefficient, R^2=coefficient of determination

the estimated values of MSY from Schaefer and Pella Tomlinson with all error assumptions are lower than the maximum catch. With IP values 0.3 and 0.4 the estimated values from all three models are lower than the maximum catch. When applying IP 0.5 from Fox with error assumption normal and IP 0.9 From Schaefer and Pella Tomlinson with error assumption normal showed Invalid Property Value (IPV). From IP value 0.5 to 0.9 the estimated values of MSY were high as compared with maximum catch (Table 3). The R^2 from Fox model with error assumptions normal and log-normal were 0.454 and 0.565, respectively while from Schaefer and Pella Tomlinson with normal and log-normal were 0.474 and 0.572, respectively.

The estimated MSY results from CEDA were lower than the recent catch (Table 2). Therefore, we may say that the *Coryphaena hippurus* fishery in Pakistani waters over exploited. In Pakistan there is not any successful development to manage the dolphinfish stock. We may suggest that Pakistan fisheries managers will take some steps to reduce the catch to MSY level because by this way we can control fishing efforts trawl mesh size as way to protect the growth of the juvenile dolphinfish. We should to provide the time to bread once in their lifespan.

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