Pakistan J. Zool., vol. 45(2), pp. 447-452, 2013.

Maximum Sustainable Yield Estimates of Silver Pomfret, *Pampus argenteus* (Family: Strometidae) Fishery in Pakistan

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Abstract.- In this paper we present Maximum Sustainable Yield (MSY) estimates of the silver pomfret, *Pampus argenteus* fishery based on the time series catch and effort data from 1989 to 2009 in Pakistan. Three surplus production models (SPMs) and three model error assumptions estimated by CEDA computer programme and two SPMs were estimated with ASPIC package. Estimated biological reference point (*e.g.* MSY) with ASPIC are Fox model 5525 mt and fishing mortality at maximum sustainable yield F_{MSY} = 1619, the coefficient of variation of estimated MSY was 1.0 and coefficient of determination R^2 = 0.58 and the catchability coefficient q = 0.00077 were estimated. The logistic model out puts are MSY = 94940 mt and fishing mortality at maximum sustainable yield F_{MSY} = 6290, estimated CV (1.0) of the MSY and coefficient of determination R^2 = 0.55. Three surplus production models of Schaefer, Fox and Pella-Tomlinson and model error assumption of normal, log normal and gamma were also estimated using CEDA package are Fox model MSY = 3841 (R^2 = 0.63) and Schaefer and Pella-Tomlinson estimates were 3800 (R^2 = 0.61) both the models produced similar MSY results. It seems that MSY estimated from the Schaefer and Pella-Tomlinson model were conservative than the Fox model which indicates a better fit. Moreover, values of coefficient of determination R^2 showed appropriation of the model. From the CEDA analysis some outliers were identified and these were in 1986, 2002 and 2009. On the basis of the outputs estimated with the ASPIC package appeared higher than the annual landings and seems non-conservative than the parameters estimated with CEDA software. In view of the estimations from CEDA package it seems that the stock are over fished and require some effective management and should maintain sustainable exploitation of the stocks by reducing fishing effort in the area and also implement conservation of an excellent food fish is required.

Key word: *Pampus argenteus*; surplus-production models; stock assessment; fishery.

INTRODUCTION

Fish is a source of valuable animal protein and makes a major contribution to the economy of Pakistan by earning foreign exchange. Pakistan has earned an amount of Rs. 196 million in 1996 from its export (FAO, 2009).

Silver pomfret is the most sought after fish, in Pakistan. Two species of silver pomfret *Pampus argenteus* and *P. chinesis* are known (FAO, 1985), which are widely distributed throughout the Indo-Western Pacific region. It is distributed along the coast of Pakistan and extends from western Asia to the Arabian Gulf (Kagwade, 1988; Pati, 1982; Al-Hussaini, 2003). It is also found in the eastern part of China and the Korean Peninsula (Chao *et al*., 1989). Most catches of *P. argenteus* in Zobaidy, East China Sea and Yellow Sea come from areas where oceanic fronts occur due to mixing of warm and cold currents (Chao *et al*., 1989).

Year-wise catch trends of *P. argenteus* showed fluctuations: the catch was 3273mt in 1981, 6339 mt in 2002 and 2799 mt in 1996. However, a continuous decreasing trend was recorded in 2009, when the catch was 3471mt.

To study the harvested population, biomass dynamic models or surplus production models are frequently used which require limited data of catch, effort or CPUE. Earlier work is well documented on the various production models (Schaefer, 1954; Fox, 1970; Pella and Tomlinson, 1969; Ricker, 1975; Pitcher and Hart, 1982; Hilborn and Walters, 1992; Laloe, 1994; Prager, 1994, 2005; Walter and Perma, 1996; Quinn and Deriso, 1999; Maunder *et al*., 2006). Ricker (1975) opined that the production of a fish or other aquatic animals is often sought as a means of establishing an upper limit to the annual harvest. Since the fish stocks remain unstable or at non-equilibrium state because of natural fish mortality or environmental fluctuations, equilibrium modeling has failed (Hilborn and Walters, 1992).

Sissenwine and Shepherd (1987)

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0030-9923/2013/0002-0447 $ 8.00/0

demonstrated that there are two traditional approaches for estimating surplus-production models and maximum sustainable yield or reference point *a*) surplus production models or biomass dynamics models *b*) biomass-per-recruit, spawner-per-recruit and yield-per-recruit estimators. However, MSY parameters estimations from the surplus production model can be directly estimated from the catch and effort or CPUE data (Polacheck *et al*., 1993).

Understanding the population biology of the fish is essential to meet the objectives of maximizing yield while safeguarding the long term viability of populations and ecosystems. A number of renowned researchers have contributed to the population dynamics worldwide (Hilborn and Walters, 1992; Polacheck *et al*. 1993; Quinn and Deriso, 1999). Panhwar *et al.* (2012a, b) described the maximum sustainable yield of lobster (*Panulirus* spp.) and ladypees (*Silago sihama*) fishery in Pakistan and described the assumption that CPUE data can reliably quantify temporal variability in population abundance. The modeling results would however, be wrong if such an assumption is not met. Recently Panhwar and Liu (2013) comprehensively presented the current status and stock estimates of the migratory fish, *Tenualosa ilisha*, and suggested that better and effective management is required to rescue the stocks by reducing fishing pressure and strict ban should be imposed during the period of migration in the River Indus.

Despite a huge commercial demand of silver pomfret, no published information is available on the stock assessment of *P. argenteus* in Pakistan. In view of the above, the scope of this paper was to provide new perspective of surplus production models and fishery of *P. argenteus* in Pakistan using no-equilibrium stock assessment package of Catch Effort Data Analysis (CEDA) and A Stock assessment model incorporating Covariates (ASPIC).

MATERIALS AND METHODS

Data source

The time series (catch and effort data) of silver pomfret, *P. argenteus* fishery were taken from Marine Fisheries Department's fisheries statistics book. The data catch is in the form of weight in metric tons (mt) and effort is in the form of number of fishermen.

Biomass dynamic models

Three surplus production models of Schaefer, Fox and Pella-Tomlinson model were estimated with CEDA. Earlier work of Graham (1935) Schaefer formulated that model and is widely used biomass dynamic model based on the logistic population growth model:

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

Later work of Fox (1970) is based on the Gompertz growth equation, and another work from Pella-Tomlinson (1969) is on a generalized production equation:

$$\frac{dB}{dt} = rB(\ln B_{\infty} - \ln B) \text{ (Fox, 1970)}$$

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

where B is fish stock biomass; t, time (year); B_{∞}, carrying capacity; and r, intrinsic rate of population increase.

ASPIC computer package (Prager, 1994)

A stock production model incorporating covariates (ASPIC, ver. 5.0) is a computer programme based on the non-equilibrium assumption state of the stocks. The package computes parameters of maximums sustainable yield (*MSY*), initial biomass over carrying capacity (*B1/K*), intrinsic growth (*r*), and carrying capacity (*k*).

CEDA computer package (FAO, 2006)

In this study we used catch effort data analysis (CEDA, ver. 3.0) package which is capable and allows fitting three production models of Schaefer (1954), Fox (1970) and Pella and Tomlinson (1969). Basically this package is based on the no-equilibrium assumption of the stocks. Additionally CEDA has ability to estimate three model error assumptions (normal, log-normal and gamma) error distributions.

Key parameters which can be estimated by CEDA package are: *MSY* (maximum sustainable yield), *q* (catchability coefficient), *K* (carrying capacity), *r* (intrinsic growth rate), replacement yield, final biomass, whereas *CV* (coefficient of variation) of estimated MSY values were computed separately.

Package requires an initial proportion (IP)

CEDA package requires an input of initial proportion or ratio of starting biomass (B_1) over carrying capacity (K) by the user. When the initial proportion has set as or near zero which indicates that the fishery started from a virgin population and when it set as or near 1, that mean fishery started from a heavily exploited population. However, in some cases starting biomass is fixed at $B_1 = C_1/ (qE_1)$ (*C*, catch; *q*, catchability; *E*, fishing effort), or $B_1 = K$ by some programmers.

RESULTS

Data source and analysis

Figure 1 shows annual landing record of silver pomfret. The yield has been steadily declining year by year from 1989 – 2009. Figure 2 shows the catch and abundance index trends.

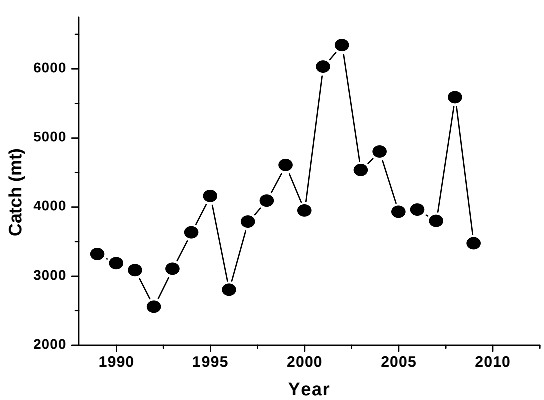

Fig.1. Fluctuations in annual landing of silver pomfret at Karachi fish harbour from 1989-2009.

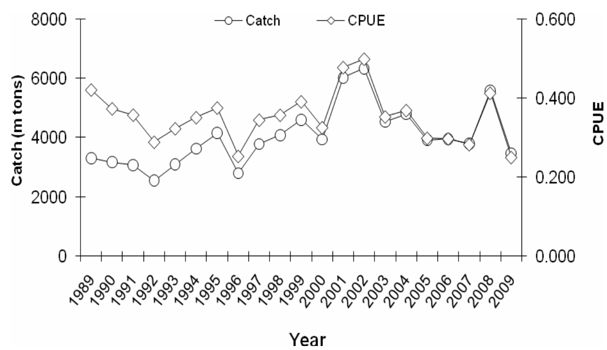

Fig. 2. Catch and abundance index of silver pomfret from 1989 to 2009 in Pakistan.

Estimated key parameters with ASPIC software

The parameters estimated by ASPIC are presented in Table I and observed and estimated abundance index and the biological reference point (MSY) outputs of Fox model are 5525 mt and fishing mortality at maximum sustainable yield (F_{MSY}) was 1619. The coefficient of variation of estimated MSY was 1.0 and coefficient of determination (R^2) was 0.58. The logistic model estimated parameters with the ASPIC package (MSY) was 94940 mt and fishing mortality at maximum sustainable yield (F_{MSY}) was 6290. The estimated CV (1.0) of the MSY was similar for both Fox and logistic models and R^2 was 0.55 (Table I).

Table I.- Estimated parameters for silver pomfret *P. argenteus* using ASPIC (at 0.5 initial proportion) computer programme.

Model parameters	Fox model	Logistic model
B1/k	0.533	0.668
K	11970	28320
q	0.00077	0.000010
MSY	5525	94940
F_{MSY}	1619	62900
CV	1.0	1.0
R^2	0.58	0.55

Estimated key management parameters with CEDA software

Three surplus production models of Schaefer, Fox and Pella-Tomlinson were analyzed and three model error assumption of normal, log normal and gamma were also estimated using CEDA package. The MSY estimates of Fox model 3841 (R^2=0.63) and Schaefer and Pella-Tomlinson estimates were 3800 (R^2=0.61) both of them appeared with similar MSY results. It seems MSY estimated from the Schaefer and Pella-Tomlinson model were conservative than the Fox model. This indicates a better fit of the model. Moreover, values of coefficient of determination R^2 showed fitting of the model (Table II). Using CEDA package we observed few outliers (Fig. 3) in 1986, 2002 and 2009.

Table II.- Estimated parameters for silver pomfret *Pampus argenteus* using catch per unit effort package CEDA (initial proportion was set at 0.5).

Model parameters	Fox model	Schaefer model	Pella-Tomlinson model
k	242772	168472	168472
q	0.0000029	0.0000041	0.0000041
r	0.043	0.090	0.090
MSY	3841	3800	3800
CV	0.9	0.9	0.9
R^2	0.63	0.61	0.61

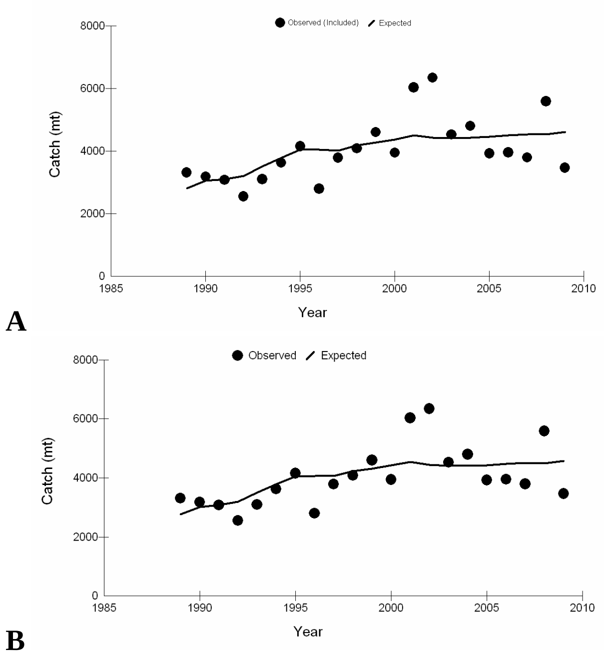

Fig. 3. Annual expected and observed catch (mt) of the silver pomfret in Pakistan Fox model (A) and Schaefer and Pella-Tomlinson model (B).

DISCUSSION

In this study using CEDA computer programmes we have analyzed five surplus production models of Fox, Schaefer and Pella-Tomlinson, whereas catch effort data of *P. argenteus* were also applied on the Fox and logistic surplus production models using ASPIC software. Therefore maximum sustainable yield has great importance for the conservation of any fish stock.

Haddon (2011) stated that in the risk assessment and to obtain management advice from the surplus production models (SPMs) now have surprising flexibility and can be used than the traditional assessment of MSY and E_{MSY}.

Moreover, recently SPMs have now been reached at a more complex and realistic models and developed to a point where even more information is available and more complex and realistic model can be implemented, it would be sensible to implement a simpler model if only to act as contrast (Haddon, 2011). Generally when surplus production of any stock is greater than catch which indicate increasing trends in population size; when catch equals surplus production tells that catch is sustainable and population size remains constant. However, if catch is greater than surplus production shows decline of population size. In surplus production models *MSY* is considered as a biological reference point by which sustainable exploitation goal can be achieved (Hilborn and Walters, 1992; Prager, 2002; Musick and Bonfil, 2004).

The results estimated from CEDA software were more reasonable and appeared close to the annual landing records of the *P. argenteus* in Pakistan (Table II).

The outputs estimated from the ASPIC package appeared higher than the annual landings and seems weaker results than the parameters estimation of CEDA software.

Moreover, in view of the estimations from CEDA package seems that the stock are over fished and require some effective management and should maintain sustainable exploitation of the stocks by reduce fishing effort in the area and to implement conservation of an excellent food fish.

In this paper, we did not accommodate uncertainty in the MSY estimate and also do not consider the case of risk adverse fisheries, which balance expected sustainable yield with risk. Therefore, the caution is required when the results are used in any management strategy.

ACKNOWLEDGEMENT

The first author gratefully acknowledges the financial support of CSC for her Ph. D degree. The support of the Ocean University of China is also acknowledged during the course of this study.

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(Received 1 December 2012, revised 10 January 2013)