

# An Assessment of Overexploitation Risk Faced by *Penaeus* Shrimps in Pakistan by using SPMs: Management Perspectives and Economic Consequences

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## ABSTRACT

Most of the published scientific literature declares Pakistani marine fisheries a victim of open access phenomenon. Under the influence of this ongoing regime, it becomes necessary to estimate overexploitation risk and understand ongoing economic implications of particularly important fishery resources. Thus, this study is the first-time attempt to evaluate very important fishery resource, i.e., *Penaeus* shrimps of Pakistan by considering these aspects. A long catch and effort (CE) data series, 1971-2009, were used in this study. CE data was statistically analyzed by using non-equilibrium surplus production models (NE-SPMs), viz., Fox Model (FM), Schaefer Model (SM), and Pella-Tomlinson Model (PTM) through two specialized fishery software, viz., catch and effort data analysis (CEDA) and a stock production model incorporating covariates (ASPIC). In CEDA, FM showed highest value of  $R^2$  (0.897) and computed maximum sustainable yield (MSY) as 2471 t. On the other hand, in ASPIC, FM also produced highest  $R^2$  value (0.931) and estimated MSY as 2867 t. Obtained results indicate that fishing mortality (F) and biomass (B) showed increasing and declining trend from 2000 to 2009, in that order. Thus, results indicate overexploitation of *Penaeus* shrimps in Pakistan. By considering results, recommended MSY target reference point (TRP) for *Penaeus* shrimps is between 2600 t – 3000 t. Moreover, harvest below 2300 t and over 3200 t may be considered as limit reference point (LRP). To conserve *Penaeus* shrimps biologically and to keep their economic contribution continuously, it is suggested to conduct further in-depth studies in this regard.

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## Authors' Contribution

MM and YH initiated this project, performed statistical analysis and wrote the manuscript. QC gave suggestions and provided necessary materials for this study. BK constructed tables and figures and revised several parts of the manuscript.

## Key words

*Penaeus* shrimps, Overexploitation risk, Management, CEDA, ASPIC, Pakistan

## INTRODUCTION

In Pakistan, significant quantity of caught fish biomass is comprised of shrimps. That's why, they are landed on every coastal dock station (Mohsin *et al.*, 2017). Pakistani marine waters are rich in shrimp biodiversity especially the delta of Indus River. Studies indicate that more than 30 shrimp species live in this region (Hayat, 2003). Commercially caught shrimps in Pakistan are usually sorted into three local types, viz., Kalri (pink-brown shrimp; *metapenaeus* shrimps), Kiddi (*parapenaeopsis* shrimps), and Jaira (white shrimp; *Penaeus* shrimps). These categories are based on the size of caught shrimps.

With respect of their size, *Metapenaeus*, *Parapenaeopsis*, and *Penaeus* shrimps are medium, small-sized, and large shrimps in that order (Kazmi and Sultana, 2008). *Penaeus* shrimps belong to the family Penaeidae in which 48 genera are included worldwide (De Grave *et al.*, 2009). Overall, 27 penaeid shrimps are reported from Pakistani marine waters (Tirmizi and Bashir, 1973). This family has great commercial and economic importance. Most of the commercially hunted shrimps belong to this family. In total, seven penaeid shrimps are collectively known as Jaira in Pakistan. These *penaeus* shrimps species include *Penaeus indicus*, *P. merguensis*, *P. penicillatus*, *P. pulchricaudatus*, *P. canaliculatus*, *P. monodon*, and *P. semisulcatus*. These Jaira shrimps are known as Saana, Bili Tiger, and Green Tiger in Sindhi language, whereas, in Balochi language they are called Patas, Madak, Kala Tiger, and Patapati depending upon the species. They are mostly fished through bottom trawls, cast nets, bag nets,

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beach seines, and gillnets (Kazmi, 2003; FAO, 2015).

Shrimps are expensive fishery products and preferred seafood as well. They usually fetch higher profits as compared to other seafood products in the market. Their popularity and demand is increasing in many countries such as Japan, USA, West Europe, etc. To meet with this demand and earn more profit, it is tried to commercially hunt more and more shrimps. This lust has resulted in uncontrolled fishing effort in the past which is evidenced by published literature (Memon *et al.*, 2015). According to FAO, number of trawlers operating in Pakistan has significantly increased during the course of time from 1958 (3) to 1985 (1631) (FAO, 2011). Currently, the number of operational trawlers in Pakistan is around 2400. Although, fishing effort has increased but the catch statistics indicate that catch is declining. Some studies blame overexploitation for this happening (FAO, 2009). Many fishery resources of Pakistan are a victim of overexploitation due to continuing open access phenomena in Pakistan (Memon *et al.*, 2015). Hardin (1968) described this regime for fisheries as “tragedy of the commons”. Such an uncontrolled and unmanaged exploitation of fishery resources is not only ruining aquatic environment but also resulting in economic losses. In order to get continued economic benefit from fishery resources their proper management is direly needed (Mohsin *et al.*, 2017).

There are several statistical routines such as age-structured models, surplus production models (SPMs) etc. which are used to manage fishery resources. Fishery resources are frequently managed by employing SPMs. The reason for this preference is that these models are easy to execute and use simple data. These models rely on depletion concept of fish stock. This concept means that removal of fish stock is reflected through fall in its abundance (Hoggarth *et al.*, 2006). These models estimate important fishery parameters upon which management advice can be given. On the other hand, data collection for age-structured models is problematic (Jensen, 2002). Moreover, recent SPMs estimate parameters by considering fish stock in a non-equilibrium state. That is why these models are known as non-equilibrium SPMs, i.e., NE-SPMs. This assumption makes these statistical routines more reliable as compared to older versions of SPMs, which assumed equilibrium state of fish stock (Hoggarth *et al.*, 2006; Medley and Ninnes, 1997). By considering these advantages of NE-SPMs, we have employed these statistical routine for this study.

Several researchers have published numerous studies related to penaeid shrimps of Pakistan. For instance, Qureshi and Amanat (2014) described reproductive biology of *P. merguensis*. Likewise, Korai *et al.* (2008) examined biodiversity of Keenjhar Lake with respect of their

physicochemical qualities. In the same way, Sultana and Mustaqim (2006) studied features of juvenile population of penaeid shrimps. Therefore, most of the published literature undertakes research related to reproductive or ecological aspects of shrimps. No published study evaluates stock status of commercially important penaeid shrimps of Pakistan and strives to access its economic implications. Thus, this study is the first attempt to fill this gap.

## MATERIALS AND METHODS

### Data collection

This study employs a long data series, 1971-2009, representing catch statistics of *Penaeus* shrimps from Pakistani marine waters. This data was obtained from the published statistics by Marine Fisheries Department, Pakistan. NE-SPMs were used to statistically evaluate the data. It is necessary to mention that catch of *Penaeus* shrimps is reported in tons (t) and effort in number of trawlers in actual operation.

### Data analysis

For statistical analysis of the data, three NE-SPMs were used, viz., Fox Model (FM), Schaefer Model (SM), and Pella-Tomlinson Model (PTM). Among these models, the most frequently employed model in fishery sciences is SM. SM model is based on the logistic fish population increase and can be expressed mathematically as follows:

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

Where,  $B$ ,  $r$ ,  $t$ , and  $B_{\infty}$  represent biomass of fish stock, growth rate of fish stock, time, and carrying capacity of fish stock, respectively. On the other hand, FM is based on the growth formula suggested by Gompertz while PTM is based on generalized production. The mathematical expression of these two models is as follows:

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

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

Where,  $n$  denotes shape parameter. NE-SPMs were employed through specialized fishery software, viz., CEDA (catch and data analysis) and ASPIC (a stock production model incorporating covariates) (Prager, 2005; Hoggarth *et al.*, 2006). In CEDA, three error assumptions (EA), viz., normal error assumption (NEA), log-normal error assumption (LNEA) and, gamma error assumption (GEA) were used. Besides, in ASPIC, two models were employed, viz., FM and SM or sometimes also called as logistic model (LM). The main purpose of

using many models was to ensure the dependability of results. Models used in this study were compared by using certain criteria. Such as, results with  $R^2$  values higher than 0.5 were considered only. Moreover, results having only suitable coefficient of variation (CV) value were accepted. In addition to this, obtained CEDA graphs for different models were compared to find the best fit model.

#### CEDA (version 3.0.1)

This software is a computer based statistical routine frequently employed in fishery sciences to compute important parameters. The special method used in this program is known as bootstrapping method. During these method fishery parameters are estimated by using 95% confidence interval. The first step in parameter estimation is the computation of initial proportion (IP). IP was obtained by dividing the initial catch with the highest catch. For this study, calculated IP value was 1 because the initial catch is also the highest catch. Afterwards, other supposed IP values, 0.6-0.9, are also used to comprehensively understand the fishery dynamics of *Penaeus* shrimps in Pakistani marine waters. The use of different IP values for estimating fishery stock is generally referred to as sensitivity analysis. The reason why different IP values are used in this study is that IP values indicate the state of the fishery. For virgin fishery population IP is considered to be 0, whereas, for fully exploited fishery populations IP value is 1. Since, calculated IP is 1, therefore, we employed other IP values from 0.6-0.9. Because, in this condition there is no chance of fishery to start for virgin state. Key fishery parameters computed by CEDA are maximum sustainable yield (MSY), catchability coefficient (q), carrying capacity (K), growth rate (r), current biomass (B), and goodness of fit ( $R^2$ ).

#### ASPIC (Version 5.0)

ASPIC software computes important fishery parameters. That's why this routine is frequently used in fishery management studies. ASPIC also requires IP values for the estimation of parameters. Technically speaking, this software runs two different types of files, viz., FIT and BOT. FIT and BOT actually represent different program modes of ASPIC. During FIT mode, ASPIC estimates management parameters, whereas, during BOT mode bootstrapping method by using confidence interval is used. BOT file takes more time to compute fishery parameters as compared to FIT file. It is important to mention that 250 trials were set for the computation of parameters. Alike CEDA, in order to compute MSY with ASPIC separate files for each IP value, i.e., 0.6-1 was prepared. Fishery parameters estimated by using ASPIC routine are MSY, q, K,  $R^2$ , fishing mortality at MSY ( $F_{MSY}$ ), fishing mortality

(F), biomass at MSY ( $B_{MSY}$ ), ratio of fishing mortality to fishing mortality at MSY ( $F/F_{MSY}$ ) and ratio of biomass to biomass at MSY ( $B/B_{MSY}$ ).

## RESULTS

Study results are presented in this section. Analysis of catch statistics reveal that overall catch of *Penaeus* shrimps from Pakistani marine waters has considerably decreased from 1971 (10000 t) to 2009 (3425 t). However, this decrease showed many fluctuations. Sudden decrease in catch can be observed between the years 1987 (9718 t) and 1989 (3472 t). In contrast to catch, effort has increased almost consistently during the study period, i.e., from 1971 (668) to 2009 (3044) (Fig. 1). CPUE has shown decreasing trend. In 1971, estimated CPUE is 14.97 which decreased significantly and reached at 1.25 during 2009 (Fig. 2). Figure 3 graphically demonstrates residual plots obtained for all the three NE-SPMs by using IP 1 during CEDA analysis. These graphs compare reported and expected catch statistics. These graphs visually look similar but in fact they are different from each other in details.

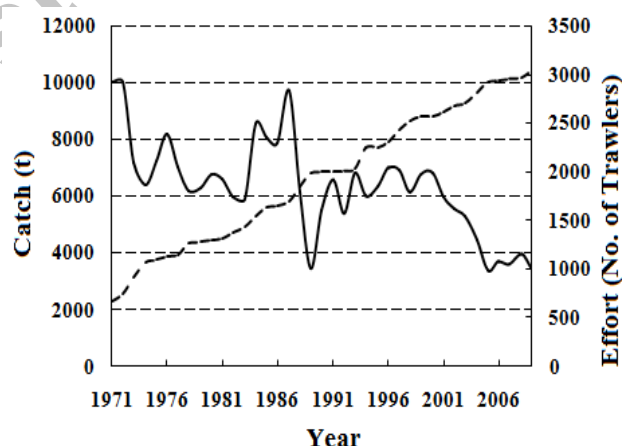


Fig. 1. Catch and effort statistics of *Penaeus* Shrimps in Pakistan.

#### CEDA estimates

CEDA estimates for various parameters by using IP 1 for all the three NE-SPMs are presented in Table I. FM estimated MSY by using NEA and LNEA as 2471 t and 2776 t, correspondingly. The computed values of  $R^2$ , CV, and B by using NEA remained 0.897, 0.163, and 15632 t. Whereas, the values of these parameters estimated by using LNEA remained 0.860, 0.113, and 13880 t, in that order. For GEA, FM did not produced results rather it showed minimization failure (MF). MF represents that condition in which software does not compute parameter values.

**Table I. Various parameters computed by using CEDA for *Penaeus* shrimps in Pakistani marine waters (IP = 1).**

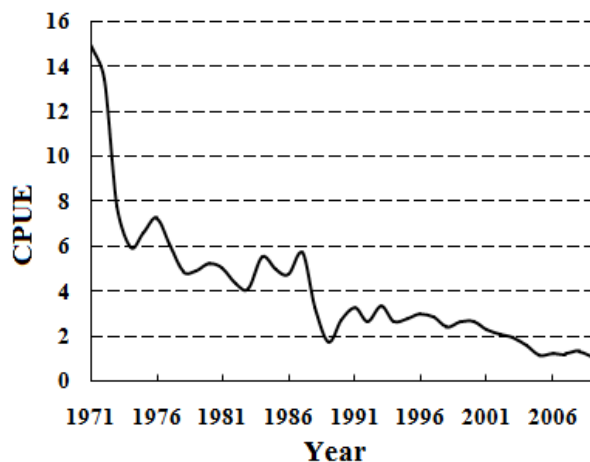
| Model      | K     | q        | r     | MSY  | CV    | R <sup>2</sup> | B     |
|------------|-------|----------|-------|------|-------|----------------|-------|
| FM (NEA)   | 43106 | 6.80E-05 | 0.155 | 2471 | 0.163 | 0.897          | 15632 |
| FM (LNEA)  | 38469 | 7.87E-05 | 0.196 | 2776 | 0.113 | 0.860          | 13880 |
| FM (GEA)   | MF    |          |       |      |       |                |       |
| SM (NEA)   | 40694 | 7.23E-05 | 0.238 | 2424 | 0.180 | 0.889          | 14378 |
| SM (LNEA)  | 35443 | 8.59E-05 | 0.314 | 2782 | 0.181 | 0.849          | 12404 |
| SM (GEA)   | MF    |          |       |      |       |                |       |
| PTM (NEA)  | 40694 | 7.23E-05 | 0.238 | 2424 | 0.201 | 0.889          | 14378 |
| PTM (LNEA) | 35443 | 8.59E-05 | 0.314 | 2782 | 0.178 | 0.849          | 12404 |
| PTM (GEA)  | MF    |          |       |      |       |                |       |

MF, Minimization failure; K, carrying capacity; q, Catchability coefficient; r, intrinsic population growth rate; MSY, Maximum sustainable yield; CV, coefficient of variation; R<sup>2</sup>, coefficient of determination; B, current biomass.

**Table II. Estimated MSY values for *Penaeus* Shrimps in Pakistani marine waters by using CEDA (IP = 0.6-1).**

| IP  | Model |       |       |       |       |       |       |       |       |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|     | FM    |       |       | SM    |       |       | PTM   |       |       |
|     | NEA   | LNEA  | GEA   | NEA   | LNEA  | GEA   | NEA   | LNEA  | GEA   |
| 0.6 | 3008  | 3316  | 3183  | 4057  | 4579  | 4345  | 4057  | 4579  | 4345  |
|     | 0.112 | 0.090 | 0.112 | 0.100 | 0.030 | 0.077 | 0.106 | 0.026 | 0.083 |
| 0.7 | 2804  | 3102  | MF    | 3446  | 3609  | 3700  | 3446  | 3609  | 3700  |
|     | 0.132 | 0.102 |       | 0.137 | 0.109 | 0.118 | 0.124 | 0.105 | 0.131 |
| 0.8 | 2657  | 2977  | 2833  | 3010  | 3317  | 3247  | 3010  | 3317  | 3247  |
|     | 0.142 | 0.104 | 0.116 | 0.159 | 0.134 | 0.141 | 0.150 | 0.133 | 0.142 |
| 0.9 | 2550  | 2854  | 2730  | 2682  | 3057  | MF    | 2682  | 3057  | MF    |
|     | 0.164 | 0.118 | 0.125 | 0.165 | 0.166 |       | 0.156 | 0.159 |       |
| 1   | 2471  | 2776  | MF    | 2424  | 2782  | MF    | 2424  | 2782  | MF    |
|     | 0.163 | 0.113 |       | 0.180 | 0.181 |       | 0.201 | 0.178 |       |

CV, coefficient of variation (written below MSY values); MF, it represents minimization failure.

Fig. 2. Computed CPUE for *Penaeus* shrimps in Pakistan.

This happens because data pattern does not fit to some assumptions. SM and PTM showed same MSY estimates for NEA and LNEA, i.e., 2424 t and 2782 t, respectively. For NEA, estimates of R<sup>2</sup> and B also remained same by using these error assumptions through these two models, i.e., 0.889 and 14378 t, correspondingly. However, estimated CV values varied for each of error assumptions used in SM and PTM. For SM, calculated CV values remained 0.180 (NEA) and 0.181 (LNEA), respectively. On the other hand, for PTM, computed CV values remained 0.201 (NEA) and 0.178 (LNEA), correspondingly. GEA showed MF in both the models, i.e., SM and PTM. Table II presents CEDA estimates of IP values 0.6-1. Obtained results indicate that for lower IP values higher MSY was estimated and vice versa. For example, for IP 0.6, estimated MSY remained 3008 t by using NEA, whereas, for IP 1, computed MSY value was 2471 t by using NEA in FM.

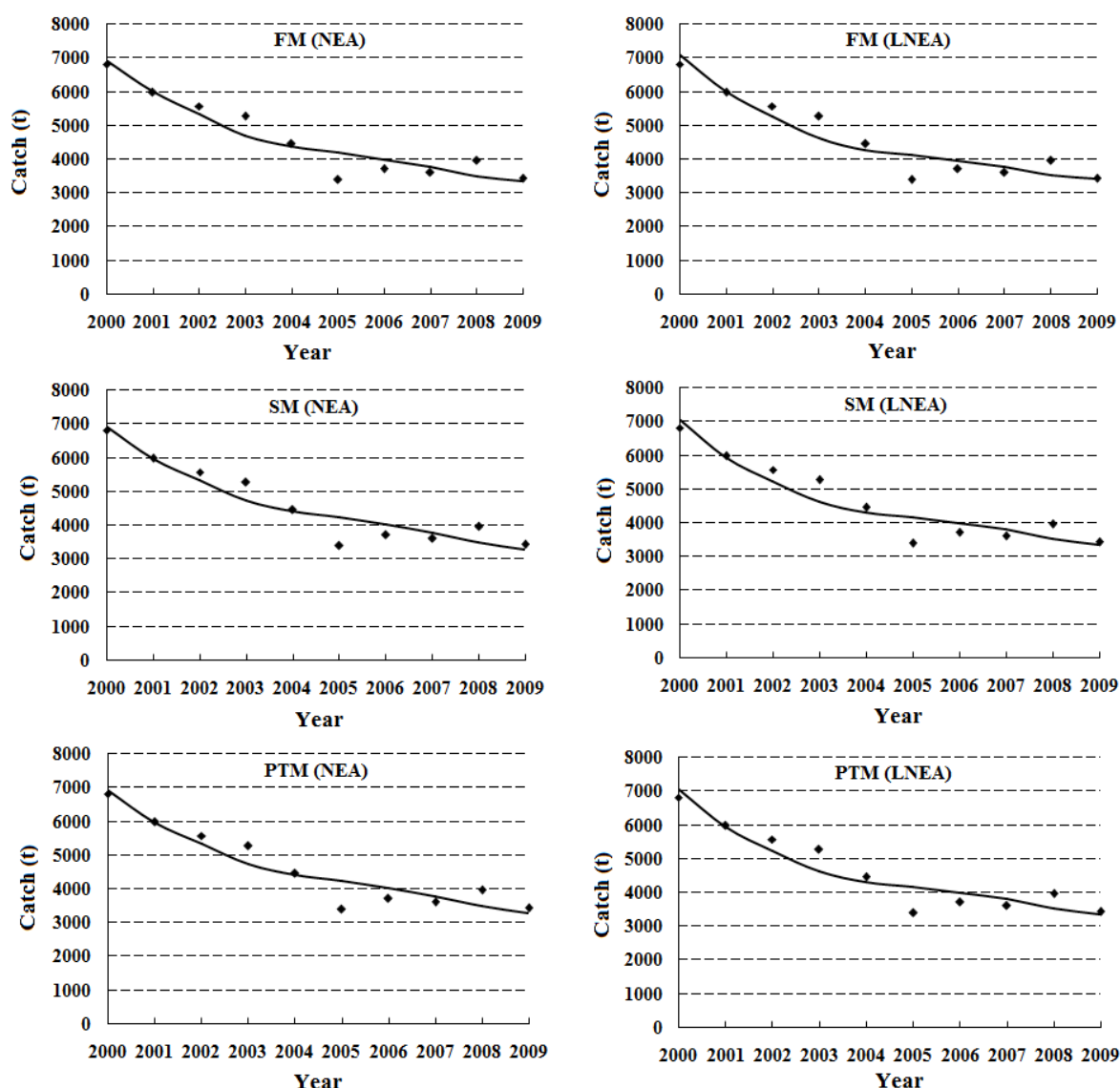


Fig. 3. CEDA graphs obtained for IP 1.

Dots represent observed catch (t) whereas straight line indicates expected catch (t).

#### ASPIC estimates

Table III presents calculated ASPIC parameters for IP 1. The two models, viz., FM and LM used in ASPIC estimated MSY as 2867 t and 3030 t, correspondingly. Other parameters such as  $R^2$ , CV, and  $K$  for FM were calculated as 0.931, 0.107, and 34850 t in that order. On the other hand, LM estimated same parameters as 0.926, 0.115, and 29720 t, correspondingly. Estimated values of  $F_{MSY}$  and  $B_{MSY}$  by FM and LM as 0.223, 12820 t and 0.203, 14860 t, respectively. Fishery parameters computed for IP from 0.6 to 1 are listed in Table IV. There is a general trend of computed parameters. For instance, lower IP

produced higher MSY estimates and vice versa in FM. Other parameters such as  $K$ ,  $q$ ,  $F_{MSY}$ , and  $F_{MSY}$  followed the same parameter estimates. For LM parameter estimates of MSY,  $K$ ,  $q$ ,  $F_{MSY}$ , and  $F_{MSY}$  showed the same pattern of estimates like FM. ASPIC estimates of  $F$  and  $B$  by using IP 1 are listed in Table V. For FM, results indicate that  $F$  has noticeably increased from 2000 (0.216) to 2009 (0.268). Besides,  $B$  has declined from 2000 (34850 t) to 2009 (13090 t). Same parameter estimate trends, i.e., increase in  $F$  and decrease in  $B$  are observed for LM. Obtained results obviously indicate that fishery stock of *Penaeus* shrimps is decreasing quickly as a result of overexploitation.



**Table III. Various parameters estimated by using ASPIC for *Penaeus* shrimps in Pakistani marine waters (IP = 1).**

| Model | IP | MSY  | K     | q         | F <sub>MSY</sub> | B <sub>MSY</sub> | R <sup>2</sup> | CV    |
|-------|----|------|-------|-----------|------------------|------------------|----------------|-------|
| FM    | 1  | 2867 | 34850 | 8.754E-05 | 0.223            | 12820            | 0.931          | 0.107 |
| LM    | 1  | 3030 | 29720 | 1.039E-04 | 0.203            | 14860            | 0.926          | 0.115 |

**Table IV. ASPIC results for *Penaeus* shrimps by using ASPIC in Pakistani marine waters (IP = 0.5-1).**

| Model | IP  | MSY  | K     | q         | F <sub>MSY</sub> | B <sub>MSY</sub> | R <sup>2</sup> | CV    |
|-------|-----|------|-------|-----------|------------------|------------------|----------------|-------|
| FM    | 0.6 | 3370 | 36490 | 1.394E-04 | 0.251            | 13430            | 0.929          | 0.078 |
|       | 0.7 | 3172 | 35560 | 1.227E-04 | 0.242            | 13080            | 0.930          | 0.087 |
|       | 0.8 | 3029 | 35080 | 1.087E-04 | 0.234            | 12910            | 0.930          | 0.065 |
|       | 0.9 | 2932 | 34850 | 9.726E-05 | 0.228            | 12820            | 0.930          | 0.093 |
|       | 1   | 2867 | 34850 | 8.754E-05 | 0.223            | 12820            | 0.931          | 0.107 |
| LM    | 0.6 | 4868 | 16650 | 3.233E-04 | 0.584            | 8323             | 0.918          | 0.045 |
|       | 0.7 | 4156 | 21290 | 2.123E-04 | 0.390            | 10640            | 0.920          | 0.089 |
|       | 0.8 | 3650 | 24900 | 1.564E-04 | 0.293            | 12450            | 0.923          | 0.083 |
|       | 0.9 | 3297 | 27520 | 1.250E-04 | 0.239            | 13760            | 0.925          | 0.118 |
|       | 1   | 3030 | 29720 | 1.039E-04 | 0.203            | 14860            | 0.926          | 0.115 |

**Table V. ASPIC estimates of fishing mortality (F) and biomass (B) (IP = 1).**

| Year | Model |       |                    |                    |       |       |                    |                    |
|------|-------|-------|--------------------|--------------------|-------|-------|--------------------|--------------------|
|      | FM    |       |                    |                    | LM    |       |                    |                    |
|      | F     | B     | F/F <sub>MSY</sub> | B/B <sub>MSY</sub> | F     | B     | F/F <sub>MSY</sub> | B/B <sub>MSY</sub> |
| 2000 | 0.216 | 34850 | 0.966              | 2.718              | 0.257 | 29710 | 1.258              | 2.000              |
| 2001 | 0.227 | 28690 | 1.014              | 2.238              | 0.271 | 24000 | 1.331              | 1.615              |
| 2002 | 0.247 | 24340 | 1.106              | 1.898              | 0.296 | 20330 | 1.449              | 1.369              |
| 2003 | 0.270 | 20950 | 1.209              | 1.634              | 0.322 | 17560 | 1.580              | 1.182              |
| 2004 | 0.258 | 18200 | 1.154              | 1.420              | 0.307 | 15290 | 1.505              | 1.029              |
| 2005 | 0.210 | 16450 | 0.938              | 1.283              | 0.248 | 13850 | 1.216              | 0.932              |
| 2006 | 0.241 | 15840 | 1.077              | 1.235              | 0.282 | 13480 | 1.385              | 0.907              |
| 2007 | 0.247 | 14950 | 1.105              | 1.166              | 0.289 | 12760 | 1.419              | 0.859              |
| 2008 | 0.291 | 14200 | 1.302              | 1.107              | 0.343 | 12110 | 1.683              | 0.815              |
| 2009 | 0.268 | 13090 | 1.196              | 1.021              | 0.320 | 11030 | 1.569              | 0.742              |

## DISCUSSION

Several indicators such as CPUE, MSY etc. can be used to predict status of fishery. Among these indicators, CPUE is the simplest and the straightway to forecast fishery status. Different CPUE trends represent different states of fishery. For instance, when CPUE remains stable, it indicates that fishing operations are not affecting fish population. Conversely, if CPUE is increasing or decreasing, it may reflect some quantitative variations in the fish stock. Moreover, when CPUE is decreasing and effort

is increasing, it may indicate overexploitation (Hoggarth *et al.*, 2006). This study finds that CPUE of *Penaeus* shrimps has considerably decreased from 1971 (14.97) to 2009 (1.25) which indicates overexploitation. In addition to CPUE, MSY estimates also speaks about the fate of the fishery. The concept of MSY was introduced in 1992. MSY is the commonly used indicator to manage fisheries all over the world (Hoggarth *et al.*, 2006). However, MSY does not permit fixed catch quantity rather it only serves as an alarm to overfishing. Therefore, MSY should be estimated with great care. If MSY is underestimated, in this condition

economic loss will happen due to the less catch of fish. On the other hand, if MSY is overestimated, in this condition fisheries stock will be overexploited (Rosenberg *et al.*, 1993). MSY estimates represent the status of fisheries stock. If MSY estimates are almost equal to current catch in this condition fishing can be continued with current effort. However, if MSY estimates are lower than recent catch statistics it means that fishery resource is experiencing overexploitation. On the contrary, if MSY estimates are higher than reported current catch this indicates that there is a potential to increase fish catch (Hoggarth *et al.*, 2006). Obtained results reveal that current catch of Jaira Shrimp from Pakistani marine water is higher than calculated MSY which means that this fishery resource is experiencing overexploitation.

The process of fisheries management involves many stages from data collection to rational decision making (FAO, 1997). Practically fisheries management is done through some scientifically estimated points known as reference points. These reference points guide and form the basis of fisheries management (Hoggarth *et al.*, 2006). They started to appear in fisheries management literature in 1992 (FAO, 1995). Two types of reference points are usually recognized, i.e., target reference point (TRP) and limit reference point (LRP). TRP and LRP differ from each other in this sense that TRP are targeted whereas LRP are avoided for fisheries management. Reference points are actually represent scientifically estimated values on which fishery managers make management policies (Caddy and Mahon, 1995; Cochrane, 2002).

A plethora of published literature uses the same statistical routines used in this study (Memon *et al.*, 2015). The models, i.e., NE-SPMs employed through these routines are based on some assumptions. For instance, they assume that there is neither intra or inter fish species competition. Likewise,  $r$  is independent of fish age composition. The sample catch statistics belong to single fish stock. Natural and artificial fish mortality occur simultaneously. Catch statistics are true and vessels efficiency remain same (Ewald and Wang, 2010). Thus, these models are very popular in fisheries management studies because they have numerous advantages over the other methods. For instance, simple catch statistics can be employed by these models. These models have tendency to use unified biomass and compute diverse parameters such as recruitment, growth and mortality. Moreover, these models estimate catchability coefficient which shows fish stock. Important fishery parameters estimated through these models include  $B_{MSY}$ ,  $B_{current}$ ,  $F_{MSY}$  and  $F_{current}$  (Ewald and Wang, 2010). Nevertheless, it does not mean that these models are error free rather these models also confer some disadvantages. Such as, these model don't use age-structure

data. Furthermore, these models don't employ time delay mechanism in between reproduction and recruitment. Therefore, these models are accompanied by uncertainty (Ewald and Wang, 2010). However, regardless of these ambiguities these models are available famous fishery tools to access initial stock for scientific management (Musick and Bonfil, 2005).

Usually more than one production model is applied to catch and effort data. This is done to increase the reliability of the results. In some cases, the output values of some parameters even with different models may be same as our conducted study indicates. This may happen due to the untestable assumptions of the models. When the best fitting model is found, various parameter reference points can be extracted for giving advice on management (Hoggarth *et al.*, 2006).

This study finds that *Penaeus* shrimps are overexploited in Pakistan. This overexploitation has diverse types of bad consequences in terms of biological, social and economic aspects. Economic effects of overexploitation were first studies by Clark (1973). He stated that overexploitation results in social chaos through fishery resource exploitation competition and profit maximization phenomenon. The urge to catch maximum quantity of fish may result in the extinction of this resource (Clark, 1973). Published literature advocates that greater economic gains can be achieved through the rebuilding of overexploited fishery stock. When fishery starts somewhere, with low effort more catch is obtained. However, if effort continue to increase a stage is reached at which catch starts to decline and profits become negative (Grafton *et al.*, 2007). In other words, fishery resource decline is an outcome of an attempt to increase economic gain (Clark, 1973). If some fishery resource is found to be overexploited, rebuilding this resource is the best idea. However, most of the time this idea is opposed by the fishermen. Their conflict with this plan is usually primarily based on the transition costs and recovery time. In contrast to fast growing fishes, slow growing fishes would take long time to rebuild stock. In such cases, fishermen can be given some suitable incentives such as impermanent employment or harvesting rights etc. to attract them towards rebuilding (Grafton *et al.*, 2007). In this way fishermen can feel satisfied with the idea of fishery stock rebuilding (Grafton, 1995).

This study finds overexploitation of *Penaeus* shrimps in Pakistan. However, national fisheries policy of Pakistan emphasizes to control overexploitation of fisheries resources through its strategy axis 2A.2. Despite having this policy to control overexploitation, scientific studies declare rise in fishing effort and witness overharvesting of fishery resources (Schmidt, 2014; Memon *et al.*, 2015). Pakistan is a follower of FAO's Code of Conduct

for Responsible Fisheries. According to article 2. A section of this code, Pakistan must effectively control the issues of overexploitation (FAO, 1995). Since, many public and private organizations are striving to control overexploitation, however, to effectively control overexploitation increased inter departmental coordination is very important. Fishery managers should also play their role in this regard by observing illegal fishing particularly through small size mesh gears used during close seasons. Moreover, policy revision with its proper implementation is direly needed. It is also suggested to investigate stock status of other important fishery resources as well.

## CONCLUSIONS

CPUE has considerably decreased from 1971 (14.97) to 2009 (1.25). Estimated MSY values are significantly lower than reported catch statistics. Although, MSY estimation range, 2400 t–2800 t, of CEDA overlaps ASPIC range, 2800 t–3100 t, but former software remained conservation in MSY estimation. Obtained results indicate that F and B showed increasing and declining trend from 2000 to 2009, in that order. Thus, results indicate overexploitation of *Penaeus* shrimps in Pakistan. By considering results, recommended MSY target reference point (TRP) for *Penaeus* shrimps is between 2600 t–3000 t. Moreover, harvest below 2300 t and over 3200 t may be considered as limit reference point (LRP). To conserve *Penaeus* shrimps biologically and to keep their economic contribution continuously, it is suggested to conduct further in-depth studies in this regard.

### Conflict of interest statement

The authors have declared no conflict of interest.

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