



# Dynamics and Potential of Commercially Harvested Shrimps by Estuarine Set Bagnet in the Indus River Estuary, Sindh, Pakistan

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## ABSTRACT

In this study, periodic changes of population dynamics of high valued shrimp species *Exopalaemon styliferus* (112), *Metapenaeus monoceros* (265), *Parapenaeopsis styliifera* (688) collected from September 2017 to April 2018 by Estuarine Set Bagnet are discussed. High linearity (>0.8) among parameters was estimated by fitting a liner model and a negative allometric growth pattern in *E. styliferus*, *P. styliifera* and slight positive growth was calculated for *M. monoceros*. A moderate growth rate for *E. styliferus* whereas fast growth rate for *M. monoceros* and *P. styliifera* was calculated by applying von Bertalanffy model. Higher natural mortalities (M) for *E. styliferus* and *M. monoceros* and fishing mortalities for *P. styliifera* was estimated. Biological reference points or Fishing limitations ( $F_{\text{limitation}}$ ) for three species was beyond proposed limit of exploitation rate of 0.5 indicates that resource have been reached maximum sustainable yield. A persistent recruitment pattern for three species recorded with prominent peaks (82% in June-July) for *E. styliferus*, (70% June-October for *M. Monoceros* and (47% April-May) estimated for *P. styliifera*. Based on the data it is recommended that use of Estuarine Set Bagnet ESNB should be banned especially in the Indus River Estuary IRE and it is hoped that data can be used for shrimp fishery management in Pakistan.

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## Authors' Contribution

NQ collected and analysis the data and wrote first draft of the manuscript. SKP guided the research and helped in manuscript write-up. PW helped in manuscript preparation.

## Key words

Estuarine set bagnet, Population dynamics, Commercially valued shrimps, Indus River Estuary-Sindh

## INTRODUCTION

Penaeid shrimps inhabiting in tropical and sub-tropical waters (Fischer and Bianchi, 1984) are highly valued marine stuff with size varying from 2.5–35 TL<sub>cm</sub> (Carpenter and Niem, 1998). Indus River Estuary a versatile ecosystem provide seems vulnerable owing to use of Estuarine Set Bagnet (ESBN) in the river mouth that ultimately harm stock and that does not allow recruits to attain size of maturity and play role in reproduction and expansion. Along with a number of fish and shellfish species of high commercial importance for instance *Exopalaemon styliferus*, *Parapenaeopsis styliifera* and *Metapenaeus monoceros* have been caught. The frequent use of ESNB at the mouth of the Rive has snarled-up entrance of marine and freshwater animals vice versa that has collectively damaged estuarine biodiversity and ecosystem. These shrimps are also catch with cast net, gill net and beach seines at the depth of 50–60 meters depth (Fischer and Bianchi, 1984). Hence *E. styliferus* (Roshna prawn) is uncommon species inhabits in shallow coastal

water and occasionally found in fresh water.

The population abundance of fisheries resources depends on the rate of natality and mortality whereas total biomass depends on fish growth. Population dynamics supposed to be the best management strategies which conveniently predicting future yields and stock biomass at different fishing levels. Length weight relationships of these species was reported from other part of the world (Rao, 1990; Nandakumar, 1997; Safaie, 2017; Sarda, 2002) but information on growth, mortality, exploitation and age of these species is scarce in literature. According to ten year statistics data compiled by Marine Fisheries Department, Government of Pakistan *M. monoceros* and *P. styliifera* composed 17-29% and 50-65% of the total shrimp landing catches from the coastal waters of northern Arabian Sea. Present study was aimed to discuss population dynamics of three highly commercially important shrimps species sampled from Indus River Estuary for the sake of conservation and management of most important fishery resource.

## MATERIALS AND METHODS

### Sampling method and data analysis

Data of three shrimp species *Exopalaemon styliferus*, *Metapenaeus monoceros*, *Parapenaeopsis styliifera* were

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collected from Indus River Estuary IRE from September 2017 to April 2018 using Estuarine Set Bagnet ESNB. The net was fixed for the period of at least six hours (one high and one low tide) during day time. A total of 1065 individuals (*E. styliferus*, 112, *M. monoceros*, 265, *P. styliifera*, 688) were sampled and kept in deep freezer for further analyses. Species was clearly identified by using FAO field guide (Fischer and Bianchi, 1984). Each individual shrimp was measured in centimeter and weighed in grams. The entire data were pooled as one-year and analyzed from FAO-ICLARM stock Assessment Tools (FiSAT).

#### Length weight relationship

Length and weight relationship was used for estimating the weight corresponding to a given length. It is the building block of stock assessment. The length weight relationship was estimated with the equation,  $W=aL^b$ ,  $W$ = weight,  $L$ = length,  $a$  and  $b$  are intercept and slope, the data were converted on natural log to fit linear straight line of log length and log weight. The equation can be demonstrated logarithmically  $\log w = \log a + b \log L$ . The linear regression LW relationship estimated using Microsoft excel (Data analysis tool).

#### Estimation of growth parameters

The von Bertalanffy growth equation (VBGF) was used to describe the growth.

$$L_t = L_\infty(1 - \exp(-K(t - t_0)))$$

Where  $L_t$ = predicated length at age  $t$ ,  $L_\infty$ = asymptotic length,  $K$ = growth coefficient,  $t_0$ = the age when the fish at zero length. Using input data from length frequencies and ELEFAN 1 program, asymptotic length ( $L_\infty$ ) and growth coefficient ( $K$ ) were estimated. Growth performance index GPI was applied to compare growth of similar species from different geographical distributions (Pauly and Munro, 1980).

$$GPI = \text{Log } K + 2 \times \text{Log } L_\infty$$

From the estimate of growth parameters ( $K$ ,  $L_\infty$ ), the instantaneous rate of annual total mortality ( $Z$ ) was estimated using the length converted catch equation (Pauly, 1983). The instantaneous rate of natural mortality ( $M$ ) was obtained using Pauly's empirical formula (1980):

$$\ln M = -0.0152 - 0.279 \times \ln L_\infty + 0.6543 \times K + 0.463 \times \ln T$$

where  $L_\infty$  is an asymptotic length,  $K$  is the growth coefficient ( $\text{Yr}^{-1}$ ) and  $T$  is the annual average of water temperature ( $^\circ\text{C}$ ); in the distribution area these species, it was  $26.5^\circ\text{C}$ . From estimate of the growth parameters ( $K$ ,  $L_\infty$ ), the instantaneous rate of total mortality ( $Z$ ) was estimated using a length converted catch equation (Pauly, 1983), subtracting the estimate of  $M$  and  $Z$ , the

instantaneous rate of fishing mortality ( $F$ ) is given by  $F=Z-M$ . The exploitation rate  $E=F/Z$  is obtained with the formula:  $U= F(1-\exp(-Z))/Z$  (Beaverton and Holt, 1957).

## RESULTS

#### Catch composition and size structure

The declining trends of shrimp catches have been identified from annual catch records documented from (1999–2009) by M.F.D for *Penaeus* spp. whereas *Metapenaeus* spp. catch composition recorded 17–24% among overall shrimp catches. *Parapenaeopsis styliifera* found to be most abundant (65–68%) being landed at Karachi Harbour (MFD, 2012) (Fig. 1).

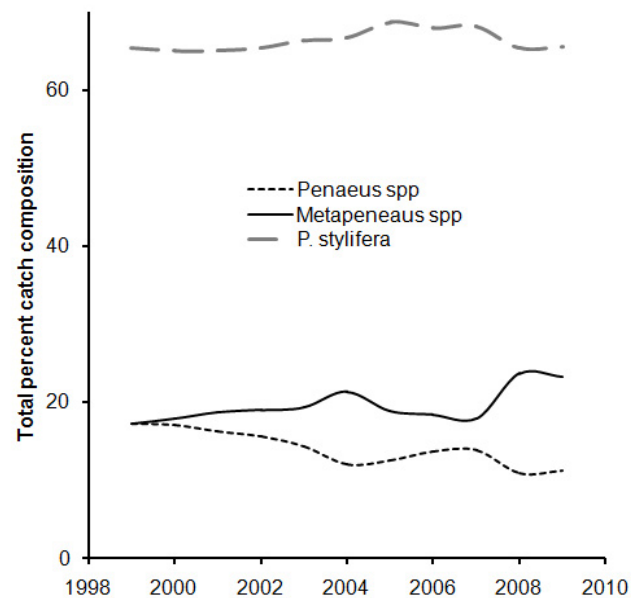


Fig. 1. The total landing record of the *Penaeus* spp. *Metapenaeus* spp, *Parapenopsis styliifera*, total catch (metric catch) and effort is in the form of number of fishermen, time series data from 1999- 2009 in Pakistan. (The data obtained from the Fisheries Statistics Book of MFD, West Warf, fish harbor Karachi, Govt of Pakistan).

About 74% of the *E. styliferus* was sampled between 5.5–7.4 cm TL. This size is below marketable size and landing recorded only in October 2017. Most of the individual of *Metapenaeus monoceros* (43.7%) lies within the size class of (9–10.9 cm) TL. For *P. styliifera* (90.2%) of the individual were in the size class 6–9.9cm TL. The highest individual was caught in September with marketable size 6–9.9cm TL (Fig. 2).

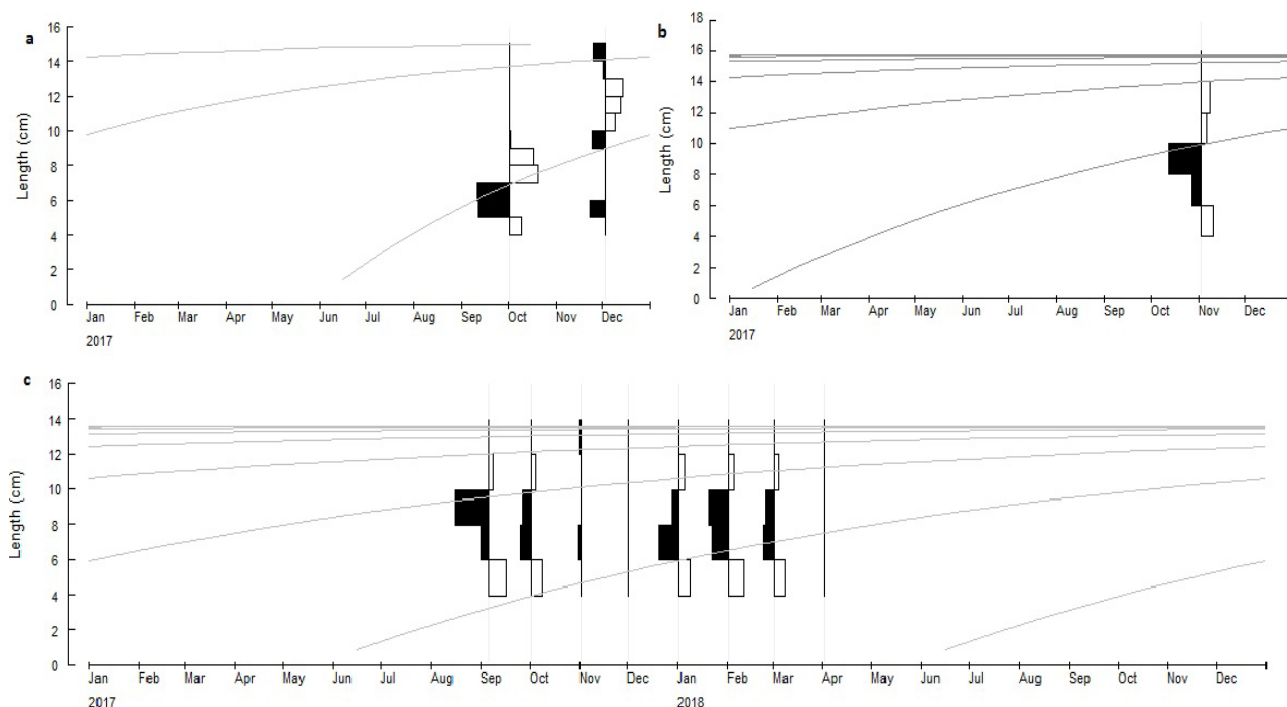


Fig. 2. Growth curve derived by the ELEFAN 1 computer program for three species, *Exopalaemon styliferus* (a), *Metapenaeus monoceros* (b), *Parapenaeopsis styliifera* (c).

**Table I. Summary of linear model parameters estimated for *Exopalaemon styliferus*, *Metapenaeus monoceros*, *Parapenaeopsis styliifera* sampled from Indus Estuary.**

Species name	TL		BW		a	b	r <sup>2</sup>	CI (a)	CI(b)	SE(a)	SE(b)
	Min-max	Mean±SD	Min-max	Mean±SD							
<i>E. styliferus</i>	4.8-15	6.83±2.05	0.48-18.4	2.93±3.30	0.015	2.69	0.93	-1.93_-1.72	2.51-2.76	0.053	0.064
<i>M. monoceros</i>	5.2-16.2	9.20±1.70	0.72-30.3	5.34±3.89	0.004	3.15	0.96	-2.45_-2.30	3.08-3.23	0.036	0.037
<i>P. styliifera</i>	4.6-13	8.02±1.25	1.11-12.5	3.09±1.66	0.007	2.86	0.87	-2.21_-2.07	2.77-2.94	0.037	0.041

**Table II. Population parameter estimated for *Exopalaemon styliferus*, *Metapenaeus Monoceros* and *Parapenaeopsis styliifera* [number pf individuals (n), asymptotic length ( $L_{\infty}$ ), growth coefficient (K), natural (M), fishing (F), total (Z) mortalities, Fishing limitations ( $F_{limit}$ ), optimum fishing ( $F_{opt}$ ), age at length zero ( $t_0$ ), growth performance index / phi ( $\phi$ ), exploitation ratio (U) and exploitation rate (E)].**

Species name	n	$L_{\infty}$	K	M	F	Z	$F_{limits}$	$F_{opt}$	$t_0$	$\phi$	U	E	$L_c/L_{inf}$
<i>E. styliferus</i>	112	13.65	0.72	1.75	1.27	2.23	0.85	0.63	-0.09	2.12	0.53	0.57	0.34
<i>M. monoceros</i>	265	15.75	1.20	2.34	1.43	3.35	0.95	0.75	-0.14	2.47	0.20	0.43	0.33
<i>P. styliifera</i>	698	18.90	1.10	2.10	4.05	8.52	2.69	2.02	-0.28	2.60	0.40	0.48	0.24

*Length–weight relationships*

The size and weight ranges of each species are given in in [Table I](#). The coefficient of determination  $R^2$  values (0.87–0.96), slopes were lower than 3.0 ( $p < 0.05$ ) defines negative allometric growth pattern ([Table I](#)).

The growth parameters obtained from the maximum length by ELEFAN1 in the FiSAT which was superimposed on structure of length frequency data ([Fig. 2](#)). The values obtained for  $L_{\infty}$  and K showed that *P. styliifera* attain less asymptotic length and slow growth than *M. monoceros*

and *E. styliferus*. The growth performance parameters were obtained from ELEFAN 1. The growth performance index ( $\phi$ ) during the present investigations showed low value in *P. stylifera* and highest in *E. styliferus*.

#### Growth, Mortalities, Recruitment and Age assessment

Total mortalities (Z), natural (M) and Fishing (F) and exploitation rate (E) was low in *M. monoceros* (Table II). The growth parameters obtained from ELEFAN 1 ( $L_{\infty}$ , K,  $t_0$ ) were used as input values to estimate the instantaneous rate of total mortality from the length converted curve method (Fig. 3). The total mortality coefficients from length-converted catch curves indicate an annual estimate for 1 year.

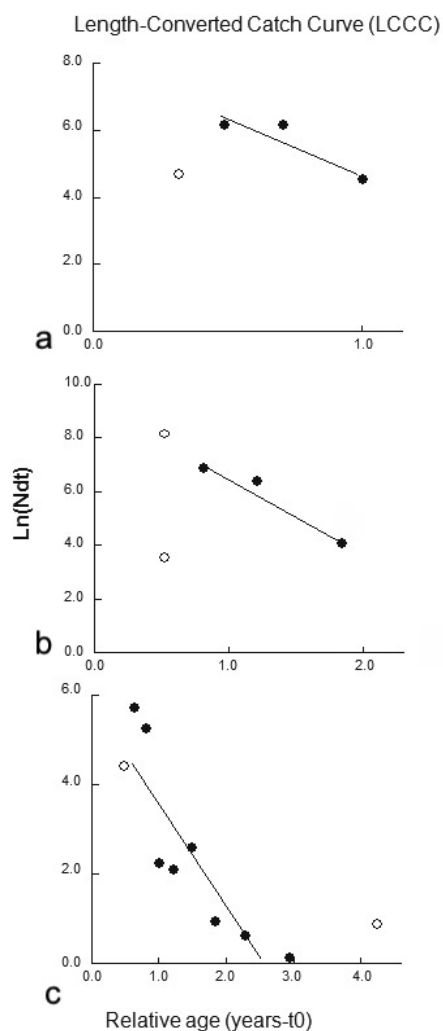


Fig. 3. Length converted catch curve of three shrimps *Exopalaemon Styliferus* (a), *Metapenaeus monoceros* (b), *Parapenaeopsis stylifera* (c) inhabiting along Indus Delta.

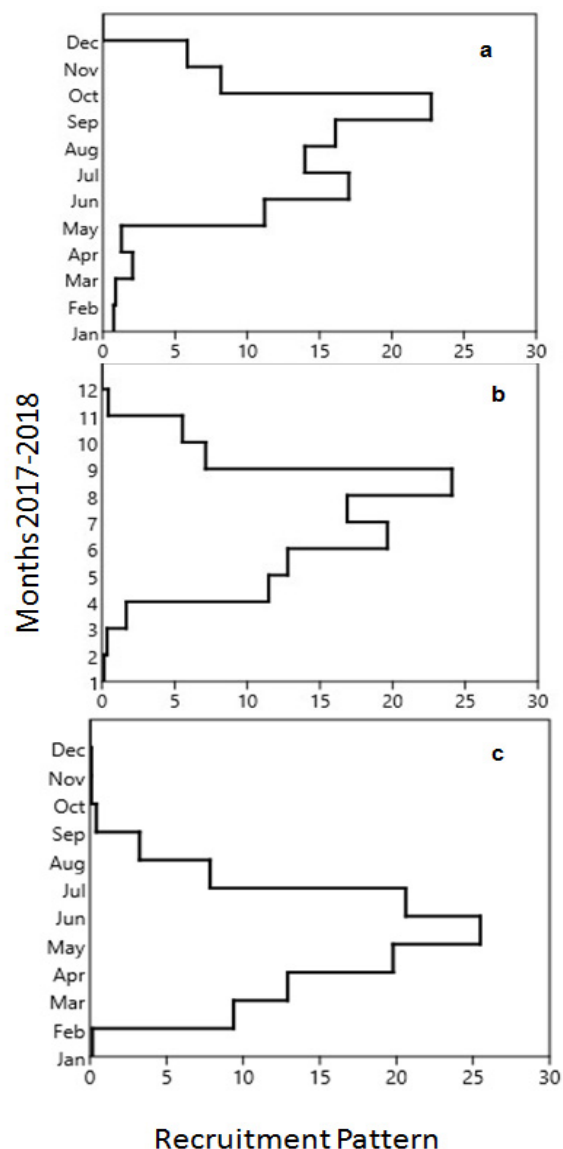


Fig. 4. Seasonal recruitment pattern of three shrimps *Exopalaemon styliferus* (a), *Metapenaeus monoceros* (b), *Parapenaeopsis stylifera* (c) inhabiting along Indus Delta.

The recruitment pattern was continued throughout the year with one major peak, about (82.4%) in June to July in *E. styliferus* (69.84%) from June to October in *M. monoceros* and (46.68) % in April–May in *P. stylifera* (Fig. 4). The dynamics of the stock influenced by the number of survivors and portion of population subjected to natural mortality and fishing mortality are very much reflected in (Fig. 5). In *E. styliferus*, fishing mortality is more than 1 with the size class (5.5–6.5)  $TL_{cm}$  and highest for the larger group greater than the length of 12.5  $TL_{cm}$ . In *M. monoceros* the fishing mortality rises when the shrimps

attain  $5.0 TL_{cm}$  and shrimps remain susceptible till the attain  $13.0 TL_{cm}$ . In *P. stylifera*, only small individual less than  $6.9 TL_{cm}$  have can survive, others are susceptible to fishing mortality. Here, fishing mortality increases towards higher length group as it followed fishing down the size, that's why. Larger size group in the population were subsequently from the stock by the fishing gears. Initial terminal fishing mortality was kept as one for estimation and terminal fishing mortality one lies to removal of all adults from the population. The number of individual in the population reduces towards the higher classes but biomass values were more in higher length groups. This is mainly due to growth and resultant increases in weight of individuals. The results of Relative yield and biomass per recruit analysis of three species with current  $L_c$  is shown in (Fig. 5). The  $L_c/L_\infty$  plotted against exploitation rate. Fitting von Bertalanffy growth curve age of each species was estimated using length frequency cohort data. The growth curves are depicted (Fig. 6).

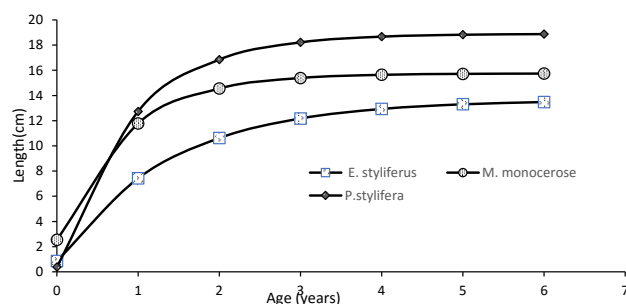


Fig. 6. Growth curves on growth parameters estimated by model progression *Exopalaemon styliferus*, *Metapenaeus monoceros*, *Parapenaeopsis stylifera*.

### DISCUSSION

Lack of organized fishery is fundamentally deteriorating coastal, estuarine and oceanic ecosystems. In this study we highlight use of ESMB can vastly damage shrimp industry is further remained unmanaged. Marine Fisheries Department document separate landing data including data of *Monoceros* spp. *P. stylifera* (kiddy shrimps). Most of the shrimps have been exported due to high export earning and lest local consumption. Total length is a common biometry to detect morphometric traits and to be used to determine functional relationship between size and weight of animals. A negative slope value determines that length increase inversely increases but weight does not. Similarly, a negative slope value for *P. stylifera* was calculated by Safaie (2017) from Persian Gulf. Agreeing with Dineshbabu (2006), Nandakumar and Srinath (1999) and Lalithedevi (1987) slopes for *M. monoceros* this study reconfirms isometric growth of the species in Pakistan.

A quick, reliable and frequently method of estimating growth, mortality and asymptotic length ELEFAN-1 approach was adopted to understand dynamics of single and multi species (Pauly, 1980, 1982). Previously, no information regarding asymptotic length ( $L_\infty$ ) and growth coefficient (K) of *E. styliferus* was seen in published form. However, annual estimation of  $L_\infty$  and K of *M. monoceros* was found lower than previously reported (Nandakumar, 2000; Dineshbabu, 2006) from India. Similar results obtained from the comparison of above parameters of *P. stylifera* stated by Safaie (2017). The lifespan of shrimps is very short (Etim and Sankare, 1998) and they attain their asymptotic length in the first or second year and are measured by a high K-value (Beverton and Holt, 1957; Garcia and Le Reste, 1981). For growth mortality and exploitation pooled data was used therefore male and female comparison is not possible although value found to

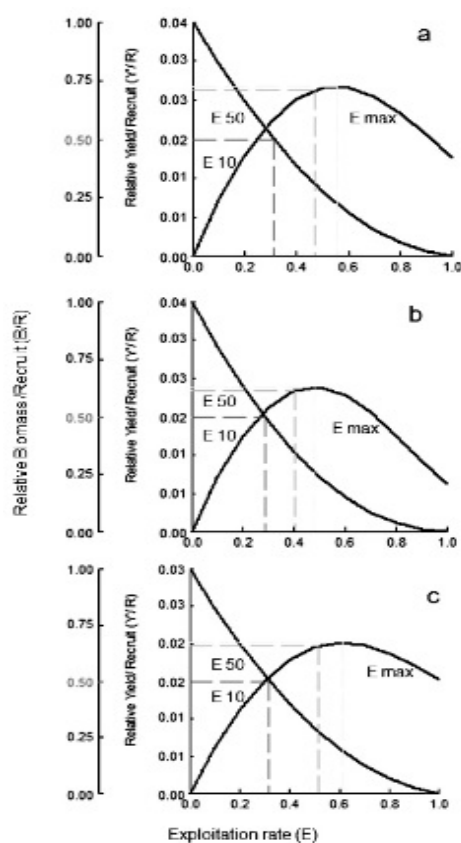


Fig. 5. Relative yield and biomass per recruit analysis of three shrimps *Exopalaemon styliferus* (a), *Metapenaeus monoceros* (b), *Parapenaeopsis stylifera* (c) exploited from Indus delta with current  $L_c$ .



be in range (Safaie, 2017).

A comparison of growth performance index GPI (Munro and Pauly, 1983) is suitable for computation of overall growth performance of similar species from geographically distributed regions. Lower GPI was estimated for *P. stylifera* than reported (Methews *et al.*, 1987; Suseelen and Rajan, 1989; Sarada, 2002; Dineshbabu, 2005; Safaie, 2017). However, GPI values can vary within the related taxa and have narrow normal distributions (Spare and Venema, 1992).

Short life span and high mortality rate can easily damage shrimp stocks and bad ecosystem health of Indus River Estuary might be another factor. We observed relatively fast growth in *E. styliferus* followed by *M. monoceros* than *P. stylifera*. Moreover, higher natural mortalities than fishing was found in two species except in *E. stylifera*. These results are in agreement with our result. Our results also agreed with those of Beverton and Holt (1959) who observed that fast growing species have high K-value and high natural mortality rate. For *P. stylifera*, our values also lie within the range as described by Safaie (2017) from Persian Gulf of Iran. It might be due to short lived species who are exposed to strong fluctuation in growth due to variability in environmental condition (Sparre, 1990). Low fishing mortality may be subjected to younger age groups of shrimps because they are either not recruited fully and are more vulnerable to the fishing gear used (King, 1995). Values estimated in this study are consistent with those reported earlier within the range for other penaeids (Garcia and Von Zalinge, 1982; Safaie, 2015; Niamaimandi *et al.*, 2007).

The fishing limitations ( $F_{lim}$ ) and optimum fishing ( $F_{opt}$ ) level demonstrates that stock have been exploited beyond the optimum fishing level of  $0.5 / \text{year}^{-1}$  Gulland (1971). Estimates of relative yield and biomass per recruit demonstrates that constant increase of fishing effort will ruin stock over 90% of the biomass and reduction yield by 25 percentage.

Recruitment pattern in these three species showed consistent recruitment with marked peaks round the year. In this context Garcia (1984) added that shrimp annual recruitments loosely related to the parental stock size and only depends on environmental factors and restrictions caused by anthropogenic activities rather than fishing pressure (Garcia and Le Raste, 1981). According to their prediction, recruitment based on environmental factor such as rainfall, temperature, river outflow, estuarine hydrology etc. It is concluded that due to high commercial value of these shrimps management measurement are unavoidable. Therefore, strict ban must be imposed on the ESNB especially in the Indus River Estuary and creek areas. Moreover, these short lived and fast growth of aquatic

animals is more susceptible to environmental degradation and low freshwater flow into estuarine area.

#### Statement of conflict of interest

The authors declare that there is no conflict of interest.

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