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Population structure of banana shrimp, *Penaeus merguiensis* De Man, 1888 in the Strait of Hormoz, Persian Gulf

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Abstract

Monthly length frequency data of banana shrimp, *Penaeus merguiensis* were collected from the coastal waters of the north east of the Persian Gulf, from January 2012 to January 2013. Software package FiSAT was used to analyze the length frequency data. Growth parameters, mortalities, exploitation rate and recruitment pattern were estimated from the carapace length in the area. Based on length – weight relationships, the estimated parameter *a* was 0.0015 for males and females and *b* was 2.8015 for males and 2.7852 for females. The estimated growth parameters: L_∞=39.5 mm, K=1.8 year^{-1} and t_0=-0.08 year^{-1} for males and L_∞=50 mm, K=1.5 year^{-1} and t_0=-0.09 year^{-1} for females. Longevity was estimated 1.67 and 2.00 years for males and females, respectively. The estimated mortality coefficients, were Z=5.9 (4.89 – 6.92) year^{-1} (α=0.05), M=2.9 year^{-1} and F=3.0 year^{-1} for males and Z=5.7 (4.94–6.37) year^{-1} (α=0.05), M=2.5 year^{-1} and F=3.2 year^{-1} for females. The length at first capture, L_c estimated from the probability of capture routine was 23.3 mm for males and 24.2 mm for females. Sex ratio (M:F=1.1:1) was significantly different to 1:1. The exploitation rates of shrimp were 0.49 and 0.56 for males and females, respectively which could get higher because the survival of spawning stock after the fishing season is related to environmental factors and has less effect on the next year's biomass. Recruitment was continued throughout the year but with one major peak in July to November.

Keywords: *Penaeus merguiensis*, Population dynamics, Persian Gulf.

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Introduction

Banana shrimp, *Penaeus merguiensis* De Man, 1888 is distributed along the northern and eastern coasts of the Arabian Sea, from the Persian Gulf and Strait of Hormoz to south India and Sri Lanka. This species which extends as far as south China, the Philippines, Australia , New Caledonia and the Gulf of Carpentaria inhabits in shallow waters of less than 20 m depth, on mud or sandy-mud (Fischer and Bianchi, 1984; Carpenter and Niem, 1998). This species is one of the most abundant shrimp in the Persian Gulf and Oman Sea. The juveniles spend their life in creeks of mangroves (Momeni *et al.*, 2009). Banana shrimp constitutes about 60 to 70% of the total annual shrimp landings in the area. 30-40% of total shrimp catch belong to *P. semisulcatus*, *P. indicus*, *Metapenaeus affinis*, *M. stebbingi* and *Parapenaeopsis stylifera* (Momeni *et al.*, 2014).

Because of expanding the trawl fleet, catches in late 1970s dropped, resulting in the introduction of fisheries management in early 1980s. These included closed season, protected areas (some important Mangrove habitats as nursery grounds of juvenile shrimps) and effort limitation to optimize shrimp productivity (Unpublished data from Iranian Fisheries Organization). The shrimp opening season is determined by growth conditions and recruitment patterns and it is closed by decreasing trends observed in studies of catch per unit effort (CPUE) of shrimp fleet. Before the catch season the growth of juvenile shrimp and standing stock biomass is estimated by trawler research vessels of Iranian Fisheries Science Research Institute (IFSRI) to determine the starting time of harvest and total allowable catch. Shrimp are caught mainly by artisanal trawl boats, set nets, and seine nets in the region. In recent years total catch of shrimp has decreased from 1900 tons in 2009 to 1100 tons in 2014 (Momeni *et al.*, 2013, 2014).

Population dynamics is the quantitative description of the changes in population number and form of population growth or decline for a particular organism (Juliano, 2007). Studies on population dynamics estimates the growth and mortality parameters by providing biological data from marine stocks (Mathews *et al.*, 1987). Several mathematical models predict stock biomass and yields at different levels of fishing mortalities which were used for defining management strategies. The knowledge about growth and mortality of the populations is an essential prerequisite for derivation of these models. Information on rates of growth and mortality and probability of capture relative to fish size, age composition data and abundance of population, can be estimated from length frequency data which have the advantage from research surveys or landing sites and fish markets (Pilling *et al.*, 2008).

Shrimp molt in their life and estimation of age and growth parameters with the help of hard body

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parts is not possible (Kurata, 1962). Length-frequency methods have been developed for the estimation of those population parameters in crustaceans (Pauly and Caddy, 1985). In tropical and sub-tropical waters, despite the difficulty in determining growth in shrimp stocks with length-based stock assessment methodologies, it is possible to investigate population dynamics to provide estimates of growth and mortality parameters and a dynamic pool model of the shrimp and other aquatic resources (Mathews *et al.*, 1987). Shrimp have a short lifespan and stock parameters vary greatly from season to season, and studies on dynamics of their populations usually refer to monthly time intervals (sometimes weekly) (Garcia, 1988). Also the annual recruitment of shrimp was changed due to environmental fluctuations and this changes the annual catch of shrimp. The recruitment affected not only the biomass, but also the spawning biomass for next year's generation in short-lived species such as shrimp (Garcia, 1984).

Studies on population dynamics and stock assessment of shrimp have greatly developed in Latin America, West Africa, South East Asia, Persian Gulf, eastern Indian Ocean and Australia (Garcia, 1985). Many scientists carried out different studies on population dynamics, feeding, lifecycle, behavior and management purposes of penaeid shrimp in the Persian Gulf (Mathews *et al.*, 1987; Khorshidian, 1993; Kamrani and Zarshenas, 1997; Kamrani and Behzadi, 1999; Safaei *et al.*, 2002; Safaei and Kamrani, 2003; Safaei, 2005; Niameimandi *et al.*, 2007; Gerami *et al.*, 2010).

The aim of this paper is to contribute to the biological and fishery information pool. Growth parameters, mortality, probability of capture and recruitment patterns can be used as input values in the mathematic models such as yield per recruit and age structure model to contribute to the stock and harvest management scenarios.

Materials and methods

Sampling was carried out in a stratified random design which was conducted monthly during 2012-2013 in the fishing grounds of *P. merguiensis* from latitude 26°25′ N to 27°09′ N and from longitude 56°02′ E to 57°04′ E in the north of the Strait of Hormoz in the Persian Gulf (Fig. 1). Data were collected from the research cruises by fiberglass boats with 8.5m wide, 26m length and 450hp engine. Bottom trawl net was used with 41m head rope; 40mm mesh size (stretched) in panel and 25mm in cod-end. Average speed of towing was 2.7knots; each haul lasted one hour and was carried out in coastal waters at 5 to 35m depths. Sampling was done on 4 days in the fourth week of each month. The collected data included position, depth and time at start and end of each tow.

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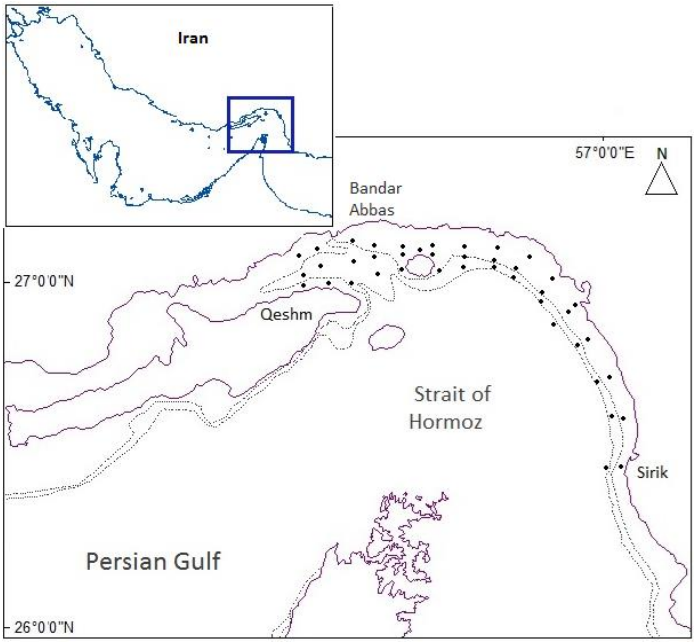


Figure 1: Location of study area and sampling positions in the Strait of Hormoz.

In the laboratory, carapace and total length of each individual was measured to the nearest 1 mm for length and total weight to the nearest 1 g. All parameters were measured and estimated separately for males and females.

Sex ratio was estimated as M (male): F (Female) for each month. Chi-squared test (χ^2) was used to compare between original calculated ratio and 1:1 (df=1, α=0.05):

$$\chi^2 = \frac{\sum(Observed - Expected)^2}{Expected}$$

Length-weight relationship for male and female was studied by formula, $W = aL^b$ (Quinn and Deriso, 1989), Where W is the total weight (g), L is the carapace length (mm), a is intercept and b is slope.

Parameters a and b could be estimated by least squares on natural log data transform to linear regression $Ln\,W = ln\,a + bLn\,L$. The coefficient of determination (r^2) was used as an indicator of the quality of fit in the regression. Additionally, the confidence intervals at specific probability for each parameter a and b were estimated (Chatterjee and Hadi, 2006):

$$a \pm Exp(t_{(n-2,\ \propto/2)}\, S.E\ (Ln\,a))$$

$$b \pm t_{(n-2,\ \propto/2)}\, S.E\ (b)$$

Where t is t-student table with n-2 degree of freedom, n is number of observations, α is one minus the specific probability and $S.E\ (x)$ is the Standard error that as follow (Chatterjee and Hadi, 2006):

$$SE(Ln\,a) = \sqrt{\sum(y_i - \hat{y}_i)^2/(n-2)} \times \sqrt{(1/n) + (\bar{x}^2/\sum(x_i - \bar{x})^2)}$$

$$SE\ (b) = \sqrt{\sum(y_i - \hat{y}_i)^2/n-2}/\sqrt{\sum(x_i - \bar{x})^2}$$

Where y_i is $Ln\,W$ for each individual, $\hat{y}_i$ is the mean value of estimated $Ln\,W$, n is the total number of observations, x_i is the $Ln\,L$ for the each individuals, $\bar{x}$ is the mean value of $Ln\,L$.

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To demonstrate the difference of *b* from isometric growth index (b=3) used the function Pauly (1984):

$$\hat{t} = \frac{S.D(Ln\,L)}{S.D(Ln\,W)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where $S.D(Ln\,L)$ and $S.D(Ln\,W)$ are standard deviation of natural logarithm of length and weight respectively, b is the parameter in length-weight relationship, r^2 is coefficient of determination and n is the number of observations.

Monthly length frequency data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained by Gayanilo *et al.* (2003). Fit the growth curve was based on the ELEFAN 1 (Electronic Length Frequency Analysis) (Pauly and David, 1981), which passed through the maximum number of peaks from length- frequency data to get the goodness-of-fit by assessing the ratio of ESP/ASP (R_n). With the fixed value of asymptotic length (L_∞) from L_{max} as suggested by Beverton (1963) and R_n, we can use the response surface method of ELEFAN 1 to estimate best curvature parameters of growth (K) (Kleiber and Pauly, 1991). With the aid of the best growth curve, the growth constant (K) was estimated for each sex by the Von Bertalanffy growth equation (Sparre and Venema, 1998):

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

Where, L_t is the carapace length at time *t*, K is the growth coefficient and L_∞ is the asymptotic length, which according to Beverton (1963) is equal to $L_{max}/0.95$. Where L_{max} is the largest fish in the samples?

t_0 is the hypothetical age when the size of shrimp is zero that used briefly as "Age at zero length". The t_0 value estimated using the empirical equation (Pauly, 1983a):

$$Log_{10}(-t_0) = -0.3922 - 0.2752Log_{10}L_\infty - 1.038Log_{10}K$$

That L_∞ is total length in cm.

To comparison K and L_∞ with those from other studies used phi-prime index (φ') (Pauly and Munro, 1984):

$$\varphi' = 2Log_{10}\,L\infty + Log_{10}K$$

Longevity of shrimp (T_{max}) was calculated as follow (Pauly, 1983a):

$$T_{max} = 3/K$$

The instantaneous rate of total mortality (Z) was estimated using the length converted catch curve method in Fisat II package from the estimated growth parameters (K and L_∞) (Pauly, 1983b).

The instantaneous rate of natural mortality (M) was obtained using empirical relationship of Pauly (1980):

$$Log_{10}M = -0.0066 - 0.279Log_{10}L_\infty + 0.6543Log_{10} + 0.4634Log_{10}T$$

Where M is the natural mortality, K and L_∞(total length in centimeter) are population parameters and T is the main annual water habitat temperature (26.5°C).

To calculate the instantaneous rates of fishing mortality (F) and exploitation rate (E) using (Sparre and Venema, 1998):

$$F = Z - M$$

$$E = F/Z$$

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The length at first capture (L_c) was obtained from the probability of capture equal to 0.5 which in each length class of fish could be estimated from the left ascending part of the length convert catch-curve. The ratio of the expected numbers of fish caught to those that are actually caught have being used to estimate the probability of capture in the FiSAT program (Gayanilo *et al.*, 1997).

Recruitment pattern of shrimp is estimated from the length frequency data in each month. According to Tuma (1967), recruitment of banana shrimp occurred at carapace length of 26 and 28 mm for males and females, respectively in the southern part of the Gulf of Carpentaria. So the ratio of numbers of individual equal or less than that length to total number of shrimp in each month was used to estimate the recruitment pattern.

Results

Size frequency distribution

A total number of 5410 individuals were collected of which 2828 were male and 2582 were female. Minimum carapace length was 14 mm for both sexes and maximum were 43 and 51 mm for males and females, respectively. Mean carapace length was estimated as 26.5±4.2 mm and 30.7±7.0 mm for males and females, respectively (p-value<0.05) (Fig. 2).

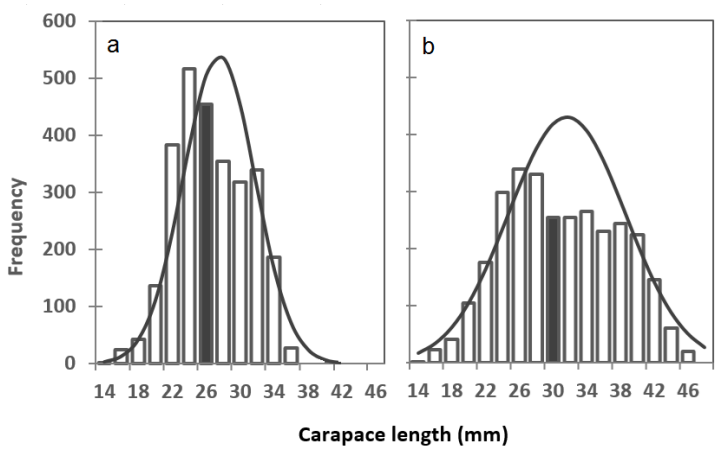


Figure 2: Length frequency of male (a) and female (b) of *Penaeus merguiensis* in the Persian Gulf. Mean carapace length and standard deviation for male were 26.5 and 4.2 mm and for female were 30.7 and 7.0 mm, respectively.

Sex ratio

Chi-square test for sex ratio was not significantly different to 1:1 in Jan, Feb, Apr, Jun and Jul. But sex ratio in Mar, May, Aug 2012 to Jan 2013 were significantly different (α=0.05). The annual single sex ratio was significantly different to 1:1 (Table 1).

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Table 1: Sex ratio of *Penaeus merguiensis*, Strait of Hormoz.

	Number				
Month	**Male**	**Female**	**M:F ratio**	χ^2	***p*-value**
January	138	113	1.22 : 1	2.49	0.1146
February	111	109	1.02 : 1	0.02	0.8927
March	178	129	1.38 : 1	7.82*	0.0052
April	63	61	1.03 : 1	0.03	0.8575
May	125	206	0.61 : 1	19.82*	0.0000
Jun	138	141	0.98 : 1	0.03	0.8575
July	190	170	1.12 : 1	1.11	0.2918
August	536	622	0.86 : 1	6.39*	0.0115
September	341	290	1.18 : 1	4.12*	0.0423
October	75	31	2.42 : 1	18.26*	0.0000
November	170	127	1.34 : 1	6.23*	0.0126
December	763	583	1.31 : 1	24.07*	0.0000
January	341	282	1.21 : 1	5.59*	0.0181
All months	3469	2864	1.10 : 1	15.42*	0.0001

Significantly different from 1:1 at probability of 0.95[*].

Length – weight relationships:

Length and corresponding weight of individuals were used to estimate the length-weight relationships. Range of length and weight were 13-37 mm and 2.6-38 g for males and 13-47 mm and 2-68.5 g for females. Length-weight relationship equations were estimated as:

$T.W = 0.0015 \times C.L^{2.8015} (Ln\, T.W = -6.6153 + 2.8015 \times Ln\, C.L)$ (Male)

$T.W = 0.0015 \times C.L^{2.7852} (Ln\, T.W = -6.5220 + 2.7852 \times Ln\, C.L)$ (Female)

The value of parameter *a* for males and females was 0.0015. The values of *b* for males was 2.8015 and for females was 2.7852 which were significantly different from 3 in males (p<0.01, n=705) and females (p<0.01, n=633) that indicated growth is not isometric in both sexes. Confidence intervals for both parameters *a* and *b* and coefficient of determination (r^2) are in Table 2 and Fig. 3.

Growth parameters

The growth parameters obtained from the maximum length by ELEFAN1 in FiSAT which is superimposed on structure of length frequency data for male and female (Fig. 4). The best estimates of growth parameter obtained are given in Table 2. Maximum length, $L_{\max}$ and then asymptotic length, L_∞, Growth constant, *K*, phi-prime, φ' and age at zero length, t_0 for males were 37.5 mm, 39.5 mm, 1.8 year^{-1}, 3.45 and -0.08 year^{-1}, respectively and 47.5 mm, 50 mm, 1.5 year^{-1}, 3.57 and -0.09 year^{-1}, respectively for females. Longevity of shrimp in each sex based the growth constant parameters were 1.67 and 2.00 years for males and females, respectively (Table 2).

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Table 2: Population parameters of *Penaeus merguiensis*, Persian Gulf.

Population parameters	Male	Female
Length-weight parameter (a)	0.0015	0.0015
C.I of a at α=0.05	0.0012-0.0019	0.0013-0.0018
Length-weight parameter (b)	2.8015	2.7852
C.I of b at α=0.05	2.7195-2.8832	2.7373-2.8331
length weight coefficient of determination (R^2)	0.8821	0.9357
Maximum length (L_{max})		
Asymptotic length (L_∞)	37.5 mm	47.5 mm
Growth coefficient (K)	39.5 mm	50.0 mm
Age at zero length (t_0)	1.8 y^{-1}	1.5 y^{-1}
phi-prime (φ')	-0.08 y	-0.09 y
Longevity (T_{max})	3.45	3.57
Length of capture (L_c)	1.67 y	2.00 y
Natural mortality (M)	23.3 mm	24.2 mm
Fishing mortality (F)	2.9 y^{-1}	2.5 y^{-1}
Total mortality (Z)	3.0 y^{-1}	3.2 y^{-1}
C.I of Z at α=0.05	5.9 y^{-1}	5.7 y^{-1}
Exploitation rate (E)	4.89 – 6.92 y^{-1}	4.94 – 6.37 y^{-1}
	0.49	0.56

C.I= Confidence intervals.

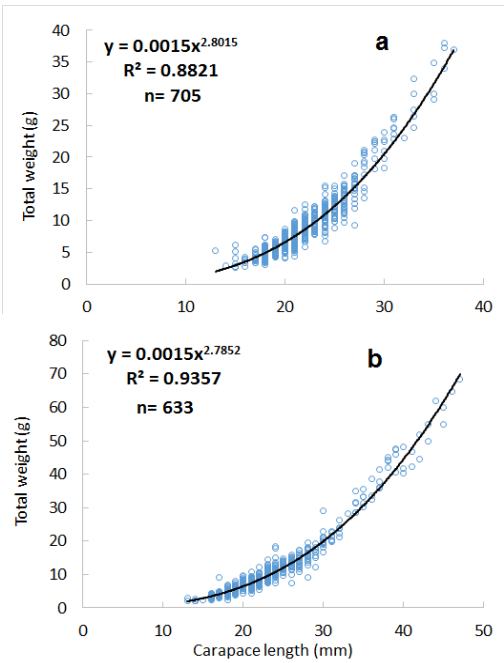


Figure 3: Length-weight relationship of *Penaeus merguiensis*, Strait of Hormoz (a: male; b: female).

Mortality parameters

The growth parameters obtained from ELEFAN1 (L_∞=39.5 mm, K=1.8 $year^{-1}$ and t_0=-0.08 $year^{-1}$ for males and L_∞= 50 mm, K=1.5 $year^{-1}$ and t_0=-0.09 $year^{-1}$ for females), were used as input values to estimate the instantaneous rates of total mortality from the length converted catch curve method (Fig. 5).

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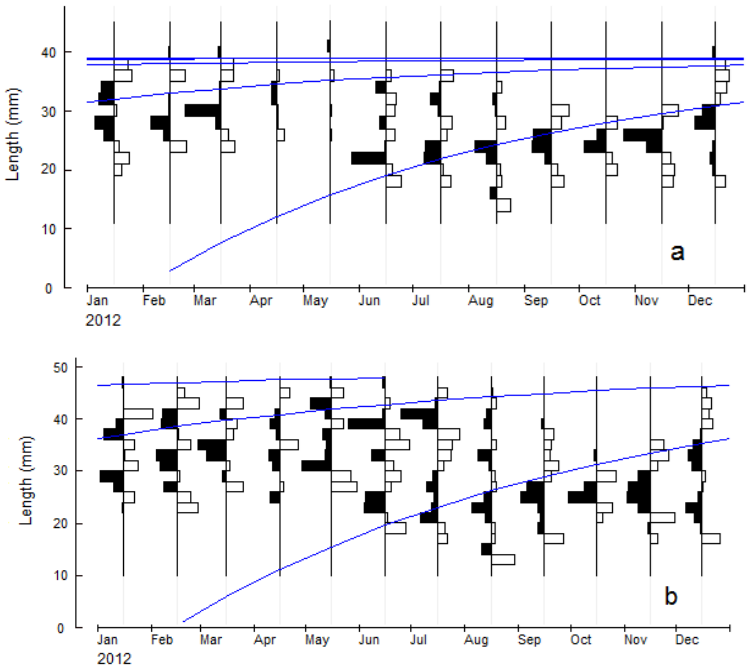


Figure 4: Length frequency of *Penaeus merguiensis* (a: male; b: female).

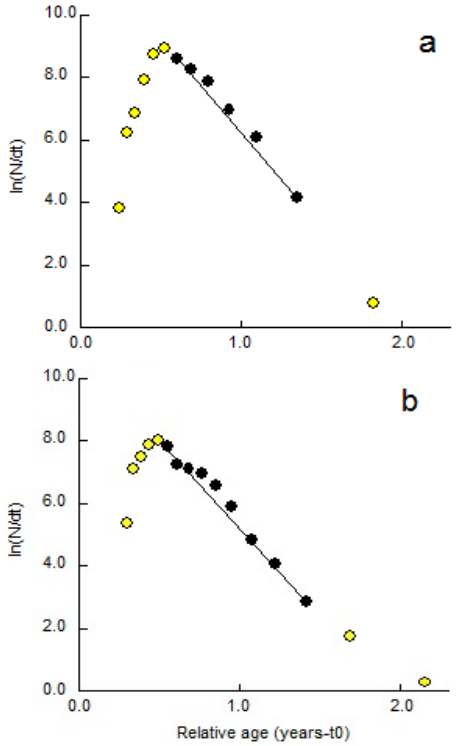


Figure 5: Length converted catch curve of *Penaeus merguiensis* (a: male; b: female).

The estimated values and confidence intervals (α=0.05) obtained were:

Z = 5.9 (4.89 – 6.92) year^{-1} Males

Z = 5.7 (4.94 – 6.37) year^{-1} Females

The values of the instantaneous rates of natural mortality (M) estimated for

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males and females were 2.9 year^{-1} and 2.5 year^{-1} by Pauly's formula respectively. Also the value of instantaneous rate of fishing mortality (F) for male and female were 3.0 and 3.2 year^{-1} respectively. Exploitation rate of shrimp were 0.49 and 0.56 for male and female, respectively.

The values of length of capture ($L_{0.25}$, $L_{0.50}$ and $L_{0.75}$) for male were estimated 21.4, 23.3 and 25.2 mm and for female were 22.3, 24.2 and 26.3 mm (Fig. 6).

Recruitment pattern

The recruitment pattern of *P. merguiensis* was continued throughout the year with one major peak. About 63% of total recruitment for both sexes occurs within 5 months from Jul to Nov (Fig. 7).

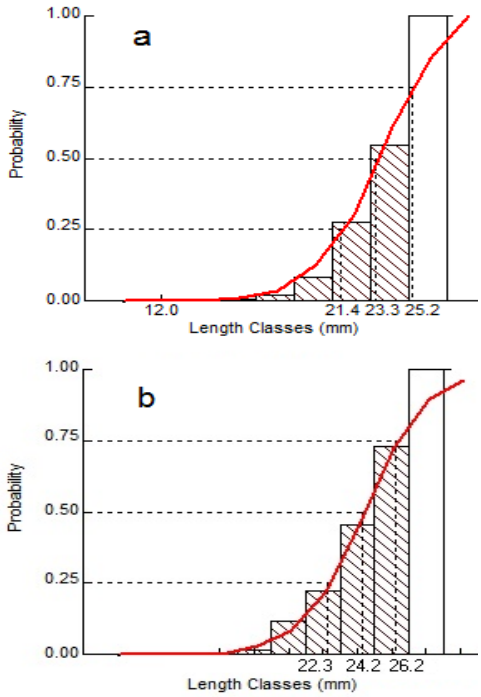


Figure 6: Probability of capture of *Penaeus merguiensis* (a: male; b: female).

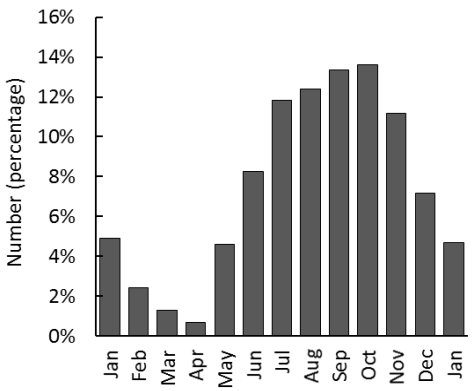


Figure 7: Recruitment pattern of *Penaeus merguiensis* in the Strait of Hormoz (mixed genders). Carapace length used was less than 26 mm for males and 28 mm for females.

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Discussion

Monthly length distribution of Banana shrimp was used to estimate some population parameters. Pauly (1984) developed a method for assessing the length frequency data for population dynamics, based on the number of individuals' biometry that are well distributed over time.

In population dynamics one of the main features is the ELEFAN 1 method that uses response surface matrix to scores from the different K and L_∞ values which are tested in the process of finding the best fit curve. This method is reliable and highly recommended for single species dynamics studies (Pauly, 1982).

The estimated values of L_∞ and K for *P. merguiensis* (39.5 mm and 1.8 year^{-1} for males, and 50.0 mm and 1.5 year^{-1} for females) in the present study were different from estimates by Mane and Deshmukh (2011) from Maharashtra, Bhadra and Biradar (2000) from Mumbai coast (India) and Lucas *et al.*, (1979) from Queensland (Australia). But these parameters are almost near to others suggested from the Persian Gulf (Momeni *et al.*, 2013) (Table 3).

Table 3: Population parameters of *Penaeus merguiensis* in other investigations.

K	L_∞	φ'	M	F	Z	E	Gender	Area	Source
1.6	35.5	3.30	2.3	1.6	3.9	0.4	Male	Persian Gulf (Iran)	Safaei, 2005
1.8	45.5	3.57	2.3	2.2	4.5	0.5	Female	Persian Gulf (Iran)	Safaei, 2015
1.6	48	3.57	2.10	6.17	8.27	0.8	Male		
1.8	54	3.72	2.19	4.78	6.97	0.7	Female	Persian Gulf (Iran)	Momeni *et al.*, 2013
1.9	38	3.44	3.1	1.4	4.5	0.3	Male		
1.6	49	3.58	2.6	1	3.6	0.3	Female	Maharashtra (India)	Mane and Deshmukh, 2011
2.1	44.7	3.62	2.8	6.7	9.8	0.7	Male		
1.9	61.5	3.86	2.6	4.8	7.4	0.7	Female	Mumbai (India)	Bhadra and Biradar, 2000
1.8	48.5	3.63					Male		
1.7	68.1	3.90					Female	Goa (India)	Achuthankutty and Parulekar, 1986
1.2	40	3.28	2.8	5.3	8.1	0.7	Male		Lucas *et al.*, 1979
0.6	63.4	3.38	2.4	1	3.4	0.3	Female	Gulf of Carpentaria (Australia)	
4.2	38	3.78					Mixed		

L_∞ is based on Carapace length (mm), all parameters are based on year^{-1}.

Similar to the estimated best fit of K and L_∞, the growth performance index or phi prime is the basis of comparison between populations (Munro and Pauly, 1983). The K and L_∞ values are not evaluated alone, but are used together in some stock assessment models as input values. In this study phi prime for males and females were 3.45 and 3.57, respectively which are in the acceptable range of values from other studies in the region and out of the region. Safaei (2005) estimated the K , L_∞ and phi-prime index (φ') as 1.6 year^{-1} , 35.5 mm and 3.30, respectively for males, and 1.8 year^{-1} , 45.5 mm and 3.57, respectively for females. Safaei (2015) recently estimated those parameters as 1.6 year^{-1}, 48 mm and 3.57 for males and 1.8 year^{-1}, 54 mm and 3.72 for

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females. Another study in the region in 2010 and 2011 denoted that the K , L_∞ and φ' were equal to 1.9 year^{-1} , 38 mm and 3.44 for males and 1.6 year^{-1} , 49 mm and 3.58 for females (Momeni *et al.,* 2013). Mane and Deshmukh (2011) reported that the results from Maharashtra, India that K , L_∞ and φ' were estimated as 2.1 year^{-1}, 44.7 mm and 3.62 for males and 1.9 year^{-1}, 61.5 mm and 3.86 for females that are higher than values in the present study and other results from the Persian Gulf region (Table 3).

Some changes in the phi-prime index and subsequent in growth parameters can be related to characteristics of size structure of the samples during the survey. According to this, in the absence of large specimens, the size-structure of samples produces an overestimate of K and under estimate of the asymptotic length (L_∞). Information generated by the smallest and largest specimens is important to estimate the growth parameters. The absence of largest sizes brings over-representation of the smallest organisms and increasing the slope of the growth curve with no defined limits for the asymptotic length causing an overestimating of K. In contrast, when the smallest sizes are not represented, the curve becomes flat and the curve reaches the asymptotic length slowly and underestimating of K occurred (Lopez-Martınez *et al.,* 2005). The length distribution showed that, like other studies from other authors from this species and other Penaeid species, females attained larger sizes than males and also had a higher growth rate than males but the growth coefficient (K) in males was higher than females (Garcia and Le Reste, 1981; Bhadra and Biradar, 2000; Niamaimandi *et al*., 2007; Gerami, 2012; Abdul-Wahab, 2014).

Natural mortality (M) of adult fish is not typically controlled by fisheries management actions, but the level of natural mortality is very important for establishing harvest criteria (Allen and Hightower, 2010). Natural mortality is related to life history pattern and longevity in the approach of stock assessment (Sparre and Venema, 1998; King, 2007) and many environmental factors such as predation, disease, parasitism, and any other natural causes act on the survival of marine individuals during their life spam (Allen and Hightower, 2010). Pauly (1980) analyzed data from a large number of fish species to obtain a relationship to predict natural mortality from the von Bertalanffy growth parameters, K (per year) and L_∞ (cm), and mean annual surface temperature, T (°C). Pauly *et al.* (1984) noted that the formula can be used for invertebrates, because these marine organisms generally have the same habitats, resources and predators, and they are not likely to differ widely in their vital parameters. The value of natural mortality at about the time of recruitment is important in stock assessment (Gulland, 1987). But the M almost is different in length or age of

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individuals in each stock. In lengths less than that at maturity, it is higher than adult's *M* (Brodziak *et al.*, 2011).

The *M* from the present study was 2.9 year^{-1} and 2.5 year^{-1} for males and females, respectively. These results were similar to Suman and Rijal (1994) who reported it as 2.75 year^{-1}. The results from the Gulf of Papua represented that natural mortality of Banana shrimp (mixed genders) was equal to 0.21 per month (2.5 year^{-1}) (Frusher *et al.*, 1985). Also a survey on *P. merguiensis* in the Gulf of Carpentaria, Australia reported that *M* was equal to 0.05 per week (2.6 year^{-1}) (Lucas *et al.*, 1979). However they were higher than the results from Safaie (2005) that were 2.3 year^{-1} for males and females and higher than those from Safaie (2015) that were 2.10 year^{-1} and 2.19 year^{-1} for males and females, respectively. A report on banana shrimp in East Borneo indicated that total mortality (*Z*), natural mortality (*M*) and fishing mortality (*F*) were 4.85 year^{-1}, 1.76 year^{-1} and 3.1 year^{-1} respectively (Kembaren and Suman, 2013). Niamaimandi *et al.* (2007) reported that calculated values of the *Z*, *F* and *M* for *P. semisulcatus* in the Persian Gulf were 6.4 year^{-1}, 4.3 year^{-1} and 2.1 year^{-1} for males and 8.2 year^{-1}, 5.8 year^{-1} and 2.4 year^{-1} for females. Also Gerami *et al.* (2010) reported that values of the *Z*, *F* and *M* for *Metapenaeus affinis* in the same region were 4.0 year^{-1}, 2.1 year^{-1} and 2.0 year^{-1} for males and 4.9 year^{-1}, 3.2 year^{-1} and 1.8 year^{-1} for females. Most of the Penaeid fisheries around the world have high fishing mortalities and thus show high *Z* values. Distribution of length frequency in catches will be affected, ultimately, by mortality rates. Thus, fewer individuals will reach large sizes when mortality from fishing or/and natural causes is high (Jayawardane *et al.*, 2003). The values of natural mortality in the present study are in the acceptable range given by Mathews *et al.* (1987) and Pauly *et al.* (1984). Fishing mortality (*F*) is affected by fishing effort and catchability coefficient that are used in specific regions by fishermen (Sparre and Venema, 1998). So *F* may be different between fishing areas or between the different times in the same fishing area. But the values of natural mortality may be changed to the varying levels of water temperature, predation, salinity and any other natural cause (Allen and Hightower, 2010).

The length convert catch curve analysis was used to estimate the total mortality (*Z*). The initial ascending data points represent younger age groups of shrimp that are not included in the regression (Fig. 5). Because they are either not fully vulnerable to the fishing gear or not fully recruited to the fishing ground (King, 2007). Perhaps either only a proportion of the younger age groups have moved from nursery ground or juveniles that have reached the fishing grounds, but were small enough to escape through the meshes of the trawl net used.

Exploitation rate (*E*) in the present study is near 0.5 which states suitable

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harvesting of shrimp stocks in the region. Of course the use of suitable level of E is important in fisheries stock assessment but it is not enough for the survival of spawning stock to the generation of the next cohort (Garcia, 1989). On the other hand, the spawning stock – recruitment relationship will have little impact on shrimp stocks, but the environment factors have more effect on the number of the next cohort (Garcia, 1985). Garcia (1989) recommended using some models such as yield per recruit or Thompson and Bell to manage the shrimp stock harvest instead of using only the exploitation rate.

Recruitment of young banana prawn in the present study occurred in all months, but about 63% of them were in July, August, September, October and November (Fig. 7). Shrimp fishing season in the area occurred after the recruitment time and the duration is about 6 weeks (from early of October to mid of November).

Tuma (1967) reported that in the Gulf of Carpentaria the size of recruitment of the *P. merguiensis* is 26 mm (C.l) for males and 28 mm (C.l) for females. Also Mane and Deshmukh (2011) explained that recruitment of banana shrimp occurs at 113.8 – 121 mm (T.L) (about 28mm C.l) in Indian waters.

During the study, very high amounts of biomass of *P. merguiensis* were observed in the cruise of September in which the mean carapace length was about 25 mm for males and 27 mm for females, but the size of recruitment or spawning stock – recruitment relationship of shrimp was not estimated. So the number of individuals less than the length that was introduced by Tuma (1967) was used to plot the recruitment pattern of banana shrimp in the region.

In a strongly variable environment the shrimp annual recruitment should therefore be only loosely related to the parental stock size (Garcia, 1984). As a result of this lack of clear spawning stock – recruitment relationship for penaeids, management of these fisheries has generally proceeded on the premise that recruitment overfishing will not occur and that for practical purposes annual recruitment levels can be considered to depend only on environmental factors or environmental constraints caused by human activity without fishing pressures. This widely held view has been supported by a large number of studies (reviewed by Garcia and Le Reste, 1981) which have produced models for predicting recruitment based only on a variety of environmental parameters such as rainfall, temperature, river outflow, estuarine hydrology, etc.

Sex ratio of banana shrimp was 1.1:1 (male: female). Our study is consistent with Safaie (2005) who found that there was a significant difference between sex ratio in *P. merguiensis* in the Hormozgan Province. Such deviation has been reported in other studies. For example, studies on the sex ratio of banana shrimp by Kamrani and Behzadi

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(1999) and Nurjana and Won (1976). In the Gulf of Carpentaria, the Tuma (1967) reported that sex ratio was 1.3:1 while Kirkegaard *et al.* (1970) explained that it was 1:1. Kim (2005) suggested that differences in sex ratio may be due to differences in mortality rates between the two sexes or because of differences in behavioral characteristics such as migration. Da Costa *et al.* (2010) suggested that the sex ratio in the shrimp *Artemesia longinaris* from the southern coast of Brazil may be related to differential migration pattern of sexes during the reproductive cycle that caused the principal reason for the larger catch of females in the samples.

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References

Abdol-Wahab, M.M., 2014. Population dynamics of the shrimp *Penaeus semisulcatus* in the Yemeni Red Sea waters. *Iranian Journal of Fisheries Sciences*, 13(**3**), 585-596.

Allen, M.S. and Hightower, J.E., 2010. Fish population dynamics: Mortality, growth, and recruitment, pp. 43-79 in W.A. Hubert and M.C. Quist, editors. Inland Fisheries Management in North America, 3rd Edition. American Fisheries Society.

Beverton, R.J.H., 1963. Maturation, growth and mortality of clupeid and engraulid stock in relation to fishing. Rapports et procès-verbaux des réunions CIEM, 154, 44-67.

Bhadra, S. and Biradar, R.S., 2000. Population dynamics of penaeid prawn *Penaeus merguiensis* off Mumbai coast. *Indian Journal of Fish Assessment, 27, 65-77.*

Brodziak, J., Ianelli, I., Lorenzen, K. and Methot Jr, R.D., 2011. Estimating natural mortality in stock assessment applications. U.S. Dep. Commer, NOAA Technical Memorandum NMFS-F/SPO-119, 38P.

Carpenter, K.E. and Niem, V.H., (eds), 1998. FAO species identification guide for fishery purposes, The living marine resources of the Western Central Pacific. Vol. 2. Cephalopods, crustaceans, holothurians and sharks. Rome, FAO. pp. 687-1396.

Chatterjee, S. and Hadi, A.S., 2006. Regression analysis by example, Fourth Edition, John Wiley and Sons, Inc., Chapter 2. pp. 21-45.

Da Costa, R.C., Branco, J.O., Machado, I.F., Campos, B.R. and Avila, M.G., 2010. Population biology of shrimp *Artemesia*

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[DOR: 20.1001.1.15622916.2018.17.1.5.3]

longinaris (Crustacea: Decapoda: Penaeidae) from the southern coast of Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 90, pp. 663-669.

Fischer, W. and Bianchi, G., (eds), 1984. FAO species identification sheets for fishery purposes. Western Indian Ocean; (Fishing Area 51). Prepared and printed with the support of the Danish International Development Agency (DANIDA). Rome, Food and Agricultural Organization of the United Nations, Vols. 1-6. pag. var. *Fishbyte, Newsletter of the Network of Tropical Fisheries Scientists*, 9(**2**), 45-49.

Frusher, S.D., Gwyther, D. and Lindholm, R., 1985. Growth of the banana prawn, *Penaeus merguiensis* De Man, as estimated from tagging studies in the Gulf of Papua. *Australian Journal of Marine Freshwater Research*, 36(**6**), 793–796.

Garcia, S. and Le Reste, L., 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fisheries Technical Paper, 203, 215P.

Garcia, S., Gulland, J.A. and Rothschild, B.J. (ed.), 1984. A note on environmental aspects of penaeid shrimp biology and dynamics, In: Workshop on the scientific basis for the management of Penaeid shrimp, Fishing News Books Ltd, pp. 268-271.

Garcia, S., 1985. Reproduction, stock assessment models and populations parameters in exploited penaeid shrimp population. pp. 362-367, In: Rothlisberg, P.e., B.J. Hill and D.J. Staples (eds.), Second Australian National Prawn Seminar, NSP2, Cleveland, Australia.

Garcia, S., 1988. Tropical penaeid prawns, pp. 219-249. In: J.A. Gulland (ed.) Fish population dynamics: the implications for management, Chichester, John Wiley and Sons Ltd., 422P.

Garcia, S., 1989. The management of coastal penaeid shrimp fisheries in marine invertebrate fisheries their assessment and management, Ed, J.F. Caddy, J. Wiley, New York. pp. 281-306.

Gayanilo, F.C. Jr., and Pauly, D. (eds.), 1997. FAO-ICLARM stock assessment tools. (FiSAT) Reference manual, FAO Computerized Information Series (Fisheries). No. 8. Rome, FAO. 262P.

Gayanilo, F.C. Jr., Sparre, P. and Pauly, D., 2003. FAO-ICLARM Stock assessment tools (FiSAT) user's guide, FAO Computerized Information Series (Fisheries), No. 8, Rome, FAO, 266P.

Gerami, M.H., Paighambari, S.Y., Ghorbani, R. and Momeni, M., 2010. Population structure, growth and mortality rates of Jinga shrimp, *Metapenaeus affinis* in fishing grounds of Hormozgan Province, Iran. *Caspian Journal of Applied Sciences Research*, 1, 29-35.

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[DOR: 20.1001.1.15622916.2018.17.1.5.3]

Gulland, J.A., 1987. Natural mortality and age. *Marine Ecology Progress Series*, 39, 197-199.

Jayawardane, P.A.A., Maclucy, D.S. and Tytler, P., 2003. Population dynamic of *Metapenaeus dobsoni* from the western coastal waters of Sri Lanka. *Fisheries Management and Ecology*, 10, 179-189.

Juliano, S.A., 2007. Population Dynamics. *Journal of the American Mosquito Control Association,* 23(**2 Suppl**), 265–275.

Kamrani, A. and Behzadi, S., 1999. Biological reproduction with emphasis on the fecundity of (*Penaeus merguiensis*) banana shrimp, in Hormozgan waters. *Iranian Journal of Fisheries Sciences*, 8, 24-53 (In Persian).

Kamrani, E. and Zarshenas, G.A., 1997. Analysis of population structure and catch situation of main shrimp species in Hormozgan waters, Persian Gulf, Iranian Fisheries Research Organization Publications, 45P. (In Persian).

Kembaren, D.D. and Suman, A., 2013. Biology and population dynamics of Banana shrimp (*Penaeus merguiensis*) in the Tarakan waters, East Borneo. *Indian Journal of Fisheries Research,* 19(**2**), 99-105

Khorshidian, K., 1993. Stock assessment of banana shrimp in Hormozgan Province, Persian Gulf, Iranian Fisheries Research Organization publications, 38P. (In Persian).

Kim, S., 2005. Population structure, growth, mortality and size at sexual maturity of *Palaemon gravieri* (Decapoda: Caridea: Palaemonidae). *Journal of Crustacean Biology*, 25, 226-232.

King, M., 2007. Fisheries biology, assessment and management, Black well, 2nd edition. 382P.

Kirkegaard, I., Tuma, D.J. and Walker, R.H., 1970. Synopsis of biological data on the Banana prawn *Penaeus merguiensis* de Man 1888, Melbourne Common Wealth Scientific and Industrial Research Organization, 39P.

Kleiber, P. and Pauly, D., 1991. Graphical representations of ELEFAN I response surfaces. *Fishbyte*, 9(**2**), 45-49.

Kurata, H., 1962. Studies on the age and growth of Crustacea. *Bulletin of the Hokkaido Regional Fisheries Research Laboratory*, 24, 1–15.

Lopez-Martınez, J., Rabago-Quiroz, C., Nevarez-Martınez, M.O., Garcıa-Juarez, A.R., Rivera-Parra, G. and Chavez-Villalba, J., 2005. Growth, reproduction, and size at first maturity of blue shrimp, *Litopenaeus stylirostris* (Stimpson, 1874) along the east coast of the Gulf of California, Mexico. *Fisheries Research,* 71, 93–102.

Lucas, C., Kirkwood, G. and Somers, I., 1979. An assessment of the stocks of the banana prawn *Penaeus merguiensis* in the Gulf of Carpentaria. *Australian Journal of*

[Downloaded from jifro.ir on 2026-11-05]

[DOR: 20.1001.1.15622916.2018.17.1.5.3]

Marine and Freshwater Research, 30, 639-652.

Mane, S.J. and Deshmukh, V.D., 2011. Age and growth studies of banana prawn, *Penaeus merguiensis* de Man from Maharashtra waters. *Journal of the Marine Biological Association of India*, 53(**2**), 184–188.

Mathews, C.P., Al-Hossaini, M.A., Abdul Ghaffar, R. and Al-Shoushani, M., 1987. Assessment of short-lived stocks with special reference to Kuwait's shrimp fisheries: a contrast of the results obtained from traditional and recent size-based techniques, pp. 147-166. In D. Pauly and G.R. Morgan (eds.) Length-based methods in fisheries research. ICLARM Conference Proceedings 13, 468P. International Center for Living Aquatic Resources Management, Manila, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait.

Momeni, M., Daghooghi, B., Darvishi, M., Pehpouri, A., Khajehnouri, K., Sadeghi, M., Gharibnia, M., Karami, N., Barani, M., Maghsudi, A. and Ghaeini, I., 2009. A survey on Movement and estimation of growth rate in Banana shrimp (*Penaeus merguiensis*) released to the Persian Gulf and Oman Sea waters (Hormozgan Province). Iranian Fisheries Research Organization, 108P.

Momeni, M., Salarpouri, A., Behzadi, S., Darvishi, M., Khajehnouri, K., Daghooghi, B. and Safaei, M., 2013. Stock assessment of banana shrimp (*Penaeus merguiensis*, De Man) in coastal water of Hormozgan Province in 2010 and 2011. Iranian Fisheries Research Organization, 59P. (In Persian).

Momeni, M., Salarpouri, A., Behzadi, S., Darvishi, M., Khajehnouri, K., Mohebbi, S.P., Karami, N. and Barani, M., 2014. A review on status of shrimp stocks in Hormozgan Province waters, Persian Gulf. Iranian Fisheries Research Organization publications, 58P. (In Persian).

Munro J.L. and Pauly D., 1983. A simple method for comparing the growth of fishes and invertebrates. *Fishbyte*, 1(**1**), 5-6.

Niamaimandi, N., Arshad, A.B., Khalijah Daud, S., Saed, R.C. and Kiabi, B., 2007. Population dynamic of green tiger prawn, *Penaeus semisulcatus* (De Haan*)* in Bushehr coastal waters, Persian Gulf. *Fisheries Research*, 86, 105–112.

Nurjana, M.L. and Won, T.Y., 1976. Induced gonad maturation, spawning and post larval production of *Penaeus merguiensis* de Man. *Bulletin of the Shrimp Culture Research Center*, 2, 177-186.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil / Conseil Permanent International*

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[DOR: 20.1001.1.15622916.2018.17.1.5.3]

pour l'Exploration de la Mer, 39(**2**), 175–192.

Pauly, D. and David, N., 1981. ELEFAN-1 Basic program for the objective extraction of growth parameter from length frequency data. Meeresforsch. *Report Marine Research*, 28(**4**), 205-211.

Pauly, D., 1982. Studying single - species dynamics in a tropical multispecies context, pp. 33-70. In: D. Pauly, and Murphy G.I. (eds.) Theory and management of tropical fisheries. ICLARM Conference Proceedings 9.

Pauly, D., 1983a. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries and Aquaculture Technical Paper, 234, FAO, 52P.

Pauly D., 1983b. Length-converted catch curves: A powerful tool for fisheries research in the tropics (Part 1). *FishByte* 1(**2**), 9–13.

Pauly, D., 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM*, 143, 1-325.

Pauly, D. and Munro, J.L., 1984. Once more on the growth comparison in fish and invertebrates. *Fishbyte*, 2, 21.

Pauly, D., Ingles, J. and Neal, R., 1984. Application to shrimp stocks of objective methods for the estimation of vital statistics from length data (ELEFAN I and II), p. 220-234. In: J.A. Gulland and B.I. Rothschild (eds) Penaeid shrimp - their biology and management, Fishing News Books Limited Farnham, Surrey, England.

Pauly, D. and Caddy, J.F., 1985. Modification of bhattacharya's method for the analysis of mixtures of normal distributions. *FAO Fisheries and Aquaculture - CIRCULARS*, 781, 16P.

Pilling, G.M., Apostolaki, P., Failler, P., Floros, C., Large, P.A., Morales-Nin, B., Reglero, P., Stergiou. K.I. and Tsikliras, A.C., 2008. Assessment and management of data-poor fisheries. In: advances in fisheries science: 50 years on from Beverton and Holt, Payne, A., L. Cotter and T. Potter (Eds.). Blackwell Publishing, New York, pp. 280-305.

Quinn II, T. and Deriso, R.B., 1989. Quantitative fish dynamics. Oxford University Press, New York. 542P.

Safaei, M., Kamrani, E., Zarshenas, G. A., Momeni, M., Ejlali, K., Salarpour, A. and Behzadi, S., 2002. Management of important commercial shrimp stock with emphasis on meteorological parameters, Iranian Fisheries Research Organization Publications, 75P. (In Persian).

Safaie M. and Kamrani, E., 2003. Population dynamic of Jinga shrimp (*Metapenaeus affinis*) in coastal waters of Hormozgan Province. *Iranian Journal of Marine Science and Technology*, 2, 39-50.

Safaei, M., 2005. Population dynamics banana shrimp (*Penaeus merguiensis*) in coastal water of

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[DOR: 20.1001.1.15622916.2018.17.1.5.3]

Hormozgan Province. *Pajouhesh and Sazandegi*, 67, 50-61. (In Persian).

Safaie, M., 2015. Population dynamics for banana prawns, *Penaeus merguiensis* de Man, 1888 in coastal waters off the northern part of the Persian Gulf, Iran. *Tropical Zoology*, 28(**1**), 1-14.

Sparre, P. and Venema, S.C., 1998. Introduction to tropical fish stock assessment, Part 1. Manual. FAO Fisheries Technical Paper, No. 306.1, Rev. 2. Rome, FAO. 407P.

Suman, A. and Rijal, M., 1994. Biology and population dynamics of banana prawn (*Penaeus merguiensis* De Man) in Demak waters, central Java Indonesia. *Journal Penelitian Perikanan Laut.* (In Indonesian, with abstract in English), 87, 10-23

Tuma, D.J., 1967. A description of the development of primary and secondart sexual characters in the banana prawn, *Penaeus merguiensis* de Man (Crustacea: Decapoda: Penaeinae), *Australian Journal of Marine and Freshwater Research*, 18, 73-88.

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