



Population dynamics and stock assessment of deep water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) from the Mediterranean Coast of Morocco

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ABSTRACT

The population dynamics and stock parameters of the deep water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) was investigated from the Mediterranean coast of Morocco. Length-frequency data were collected from landings of coastal trawlers at M'diq Port on the Moroccan Mediterranean coast over a period of 13 months from April 2017 to April 2018. The estimated growth parameters were $CL_{\infty} = 52.87$ mm, $K = 0.39$ yr⁻¹ and $t_0 = -0.35$. Total mortality coefficient (Z) was estimated as 3.49 yr⁻¹ while the natural mortality estimated using two different methods was 1.89 yr⁻¹ and 1.36 yr⁻¹ and correspondingly the fishing mortality was calculated as 1.51 yr⁻¹ and 2.13 yr⁻¹. Yield per recruit and relative biomass per recruit analysis showed that the value of current exploitation rate (E) is 0.68 which is higher than the exploitation rate $E_{0.5} = 0.36$. Hence it is advised to decrease the present exploitation rate to $E_{0.5}$ which will maintain the spawning stock biomass at 50%.

Keywords: Exploitation, Mediterranean coast, Morocco, *Parapenaeus longirostris*, Population dynamics

Introduction

The deep water rose shrimp *Parapenaeus longirostris* (Lucas, 1846) is an important component of the trawl fisheries resources in the Mediterranean coast of Morocco. The species occurs in the sandy as well as in the sandy-muddy bottoms in the Mediterranean and adjacent seas, as well as in the eastern Atlantic, north of Spain (Holthuis, 1980; Olaso, 1990) to the southern waters of Angola (Crosnier *et al.*, 1968). *P. longirostris* shows a wide bathymetric distribution, occurring from 20 to 750 m in the Mediterranean Sea (Tom *et al.*, 1988), though it is more common between 70 and 400 m (Holthuis, 1987). It forms one of the most important crustacean resource along the coasts of Algeria, Italy, France, Spain, Tunisia, Turkey (Sbrana *et al.*, 2006) and Morocco (INRH, 2016).

In the Moroccan coast, *P. longirostris* is targeted by coastal trawlers operating between 100 and 400 m. The catch of the coastal fishery is always landed fresh for local consumption in Madiq and Nador ports. *P. longirostris* is the dominant species among the deepsea shrimps landed, followed by *Aristeus antennatus*, *Plesiopenaeus edwardsianus*, *Aristaeomorpha foliacea*, *Penaeopsis serrata*, *Crangon crangon*, *Plesionika martia* and *Plesionika heterocarpus* (INRH, 2016). The rose shrimp represents 92% of the total landing of shrimps

(INRH, 2017). The average landings was around 500 t in 2009, 2011, 2012 and 2013, which then declined to nearly 50% during the period from 2014 to 2016 (INRH, 2017). Owing to its commercial importance, a number of studies concerning biology and fishery of *P. longirostris*, were undertaken from different seas around the world (Yahiaoui *et al.*, 1986; Ribeiro-Cascalho and Arrobas 1987; Ardizzone *et al.*, 1990; Levi *et al.*, 1995; Sobrino 1998; D'Onghia *et al.*, 1998; Abello *et al.*, 2002; Zengin *et al.*, 2004; Ragonese *et al.*, 2004; Kasalica 2005; Manaşirli, 2008; Markovic, 2012; Bekadja *et al.*, 2014). However, there are no biological studies on the species available from the Mediterranean coast of Morocco, in spite of its commercial importance in the region. The present study aimed to investigate the basic population and stock parameters of *P. longirostris* in M'diq zone in order to suggest appropriate management measures for the sustainable development of its fishery.

Materials and methods

Fishing area

Study was conducted in the western coast of Moroccan Mediterranean, between coasts of the city of M'diq and the village of Jebha, lying between lat. 35.21° and 35.68°N and long. 4.66° and 5.32° W (Fig. 1).

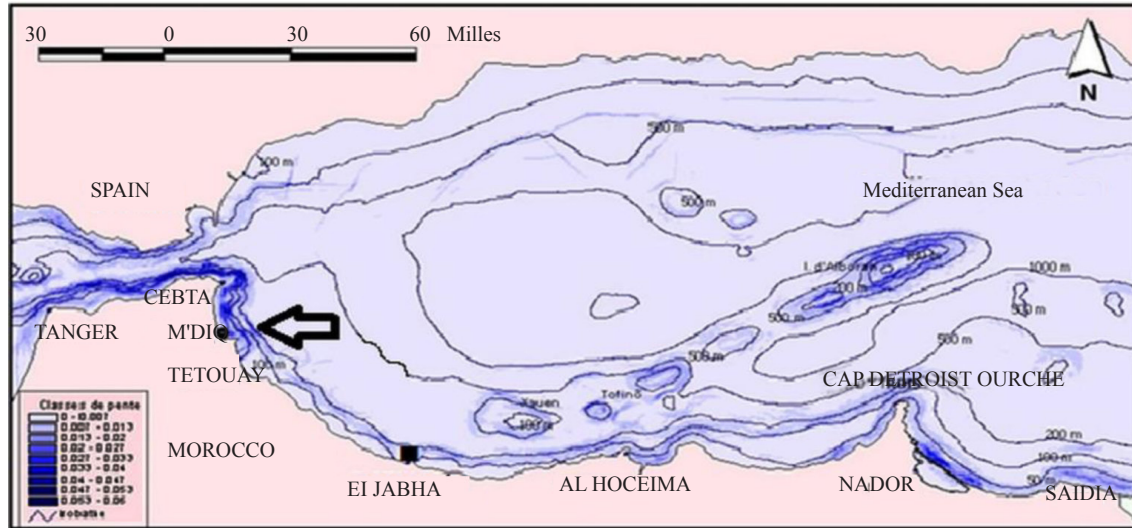


Fig. 1. Study area in the Mediterranean coast of Morocco

Sampling

Monthly, random samples of *P. longirostris* caught in bottom trawlers were collected from landings at M'diq Port during April 2017 to April 2018. After sex-wise sorting, carapace length (CL) was measured in mm using digital calipers with a precision of 0.01 mm, as the distance from the orbital margin to the posterior dorsal edge of the carapace and grouped into 2 mm class intervals for size frequency analysis. Weight (W) was measured using a digital balance with a precision of 0.01 g.

The data were processed and analysed to estimate the biological parameters. Population parameters were estimated using FAO-ICLARM Stock Assessment Tools (FiSAT II) (Gayanilo *et al.*, 2005). The von Bertalanffy growth equation in the form: $L_t = L_\infty [1 - e^{-K(t-t_0)}]$ was applied to estimate the growth parameters for combined sex using ELEFAN I method (Pauly, 1987), where, L_t is the length (mm) at age t , L_∞ is the asymptotic length, K is the growth coefficient, t_0 is theoretical age at zero length and e is base of natural log. The initial parameter, t_0 was estimated using Pauly's formula, $\log(-t_0) = -0.3922 - 0.2752 \log L_\infty - 1.038 \log K$ (Pauly, 1983). Length-weight relationship was estimated using the equation $W = aL^b$, where W is the total weight in g and L is the carapace length in mm.

Total mortality (Z) was estimated following the cumulative catch curve (Jones and Van Zalinge, 1981) method, while natural mortality (M) was calculated using two different methods: (i) method of Rikhter and Efanov (1976) using the formula, $M = 1.521/t_m^{0.75} - 0.155$, where t_m is the age at which 50% of the population matures, and (ii) method of Pauly (1980) using the formula, $\ln M = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.4634 \ln$

(T), where L_∞ is the total length in cm and T is the annual mean sea surface temperature. The fishing mortality (F) was computed as $F = Z - M$.

The exploitation rate (E) was estimated as $E = F/Z$ (Gulland, 1971), where F is the fishing mortality coefficient that is equal to $Z - M$. Exploitation ratio (U) was calculated using the equation given by Beverton and Holt (1957) and Ricker (1975): $U = F/Z (1 - e^{-z})$. Yield (Y) was computed as the fraction of shrimp population in weight taken by the fishery and then the standing stock was estimated as Y/F , while total stock as Y/U .

The length at which 50% of the catch is retained in the net (L_{c50}) was calculated by plotting the curve for probability of capture by length (Pauly, 1983), while optimum length of exploitation (L_{opt}) was estimated empirically from the equation, $L_{opt} = 3 * L_\infty / 3 + M/K$ (Froese and Binohlan, 2000).

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length-frequency data as described in FiSAT. The length structured virtual population analysis (VPA) (Pauly, 1984), a modified version of Jones and Van Zalinge (1981) was used to provide information on natural mortality, fishing mortality and survivors in each length group, using FiSAT II software.

The relative yield per recruit (Y'/R) was estimated using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986), *i.e.*, $(Y'/R)' = E U M/K [1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m)]$, where $m = (1-E)/(M/K) = (K/Z)$; $U = 1 - (L_c/L_\infty)$ and L_c is length at first capture. Relative biomass-per-recruit (B'/R) was calculated from the relationship, $B'/R = (Y'/R)/F$.

The maximum sustainable yield (MSY) was calculated using the formula: $MSY = Z(Y/F) * 0.5$ (Gulland, 1965).

Results and discussion

Growth

The growth parameters estimated for *P. longirostris* using ELEFAN I were $CL_{\infty} = 52.87$ mm, $K = 0.39$ yr⁻¹ and $t_0 = -0.35$. The von Bertalanffy equation derived using the calculated constants is, $L_t = 52.87[1 - \exp^{-0.39(t-0.35)}]$. The growth coefficient, K obtained was found to be similar to the estimate of García-Rodríguez *et al.* (2009) from Spain and lower than the value reported by Levi *et al.* (1995) from central Mediterranean. Our results are in agreement with the general concept proposed by Pauly *et al.* (1984) that penaeid shrimps show a value of K between 0.25 and 2.5 per year.

Length-weight relationship

The length-weight relationship (n=1510) derived for *P. longirostris* in the present study was, $W = 0.00340 CL^{2.312}$ (Fig. 2), correlation coefficient being 0.978. The value of b obtained is below 3 indicating a decrease in growth rate in relation to length. This negative allometry observed corroborates the reports of other authors from the Mediterranean (Levi *et al.*, 1995; García-Rodríguez *et al.*, 2009; Guijarro *et al.*, 2009; Markovic, 2012). Jayachandran and Joseph (1988) opined that weight in case of most of the crustaceans is close to the cube of length.

Mortalities and exploitation rate

Total mortality rate (Z) of *P. longirostris* was estimated as 3.49 yr⁻¹ following Jones and van Zalinge method (1981) (Fig. 3). Estimated value of the current total mortality rate (Z) in this study cannot be directly compared with the values reported from other areas as the fishing gear as well as the selectivity of these gear

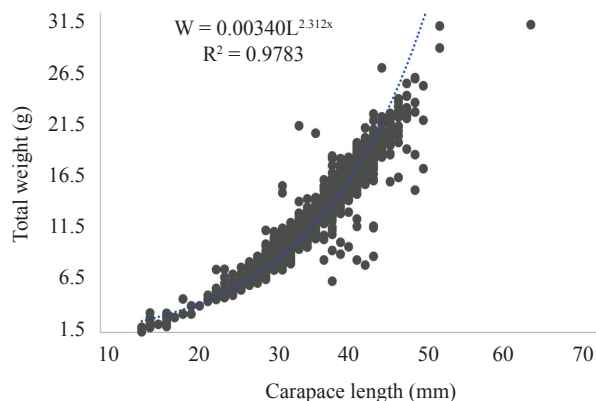


Fig. 2. Length-weight relationship of *P. longirostris* from Moroccan Mediterranean coast

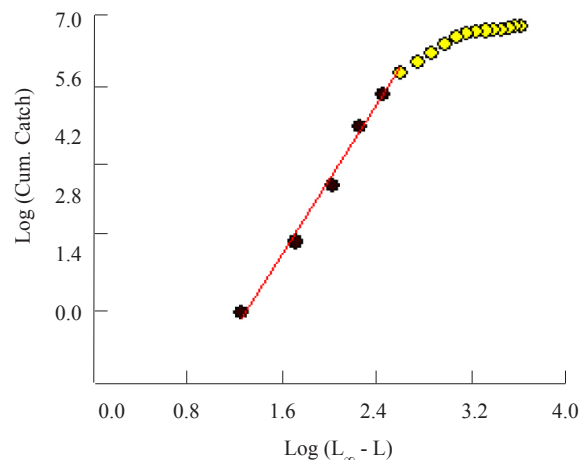


Fig. 3. Jones and Van Zalinge's cumulative catch curve for *P. longirostris* during the period 2017-2018

differ. This high value of Z is acceptable, as most of the penaeid fisheries in different regions have high fishing mortalities.

Natural mortality coefficient (M) of *P. longirostris* was estimated by two different methods and the values obtained were 1.98 yr⁻¹ and 1.36 yr⁻¹ using Pauly's empirical formula (Pauly, 1980) and Rikhter and Efanov method (Rikhter and Efanov, 1976) respectively. Correspondingly, the fishing mortality coefficient (F) was computed as 1.51 yr⁻¹ and 2.13 yr⁻¹ as per the methods of Pauly and as per Rikhter and Efanov respectively at $Z = 3.49$ yr⁻¹. Natural mortality is influenced by several biological and environmental factors and it is difficult to get an accurate estimate (Pauly, 1980). Pauly *et al.* (1984) suggested that the value of natural mortality M ranges from 0.77 to 3.12 per year.

Exploitation rate (E) calculated for *P. longirostris* fishery in the coastal waters of Moroccan Mediterranean was 0.68 and 0.65, using the two different estimates of F. The exploitation ratio (U) was estimated at 0.65 during April 2017 to April 2018 for the pooled data. Pauly (1984) suggested that the estimated fishing mortality (F) range from 0.43 (which corresponds to population under weak fishing pressure) to 4.68 (for population that are severely overfished). Gulland (1971) proposed that the optimum exploitation rate for any exploited stock is about 0.5 at $F_{opt} = M$. In the present work, fishing mortality rate F (1.51 and 2.13) was found to be higher than the natural mortality rates which accounted for 62.16% of total mortality, and were higher than the values of F_{opt} which indicates that the stock is under strong fishing pressure, which is confirmed by the values of the exploitation rate E.

Length at first capture

The length at first capture (L_c , the length at which 50% of the shrimp becomes vulnerable to the gear) was calculated as 27.25 mm (Fig. 4). The lengths at which 25 and 75% of the shrimps are retained in the gear were estimated as $L_{25\%} = 25.59$ mm and $L_{75\%} = 28.92$ mm. On the other hand, the optimum length (L_{opt}) estimated empirically was 25.90 mm. Estimated L_{opt}/L_{∞} value was 0.49. Age at first capture (t_{50}) was calculated as 1.25 years. Optimum length of exploitation (L_{opt}) estimated was 25.90 mm against the present length at first capture ($L_{c_{50}}$) of 27.25 mm suggesting that the length at first capture needs to be lowered.

Recruitment pattern

The recruitment pattern of *P. longirostris* was continuous throughout the year with one major peak observed during the month of August. It was very high between June and October with significantly high values in July, August and September (Fig. 5). The values of recruitment ranged from 0.51 to 29.60 during the study period. Well defined peaks in recruitment observed during

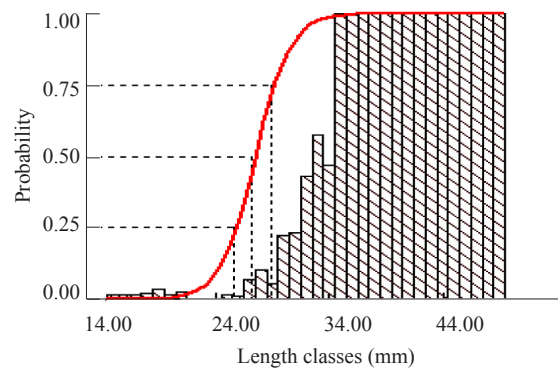


Fig. 4. Probability of capture of each length class of *P. longirostris*

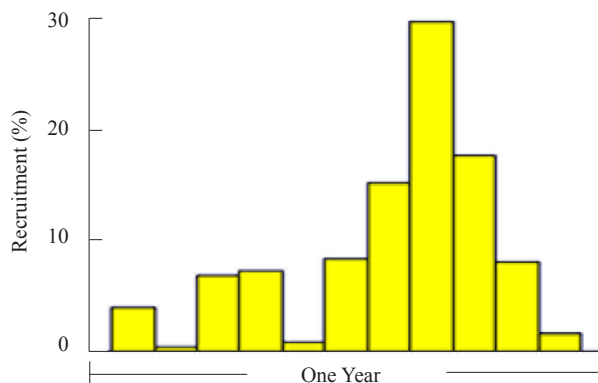


Fig. 5. Average annual recruitment pattern of *P. longirostris*

July - September correspond to the spawning that occurred during March and April.

Virtual population analysis (VPA)

Results of virtual population analysis (VPA) indicated that the minimum and maximum fishing mortalities were 0.002 yr^{-1} and 1.51 yr^{-1} , respectively for the mid length groups. The results of length based VPA showed that the mid length groups (41.5-49.5 mm) experience higher fishing mortalities, with maximum values of 1.51 yr^{-1} for the mid length group of 49.5 mm (Fig. 6). The mean numbers, in each mid length showed that catch was dominated by 39.5-41.5 mm mid length group. The yield increased from the mid length group of 15.5 mm to the maximum in the mid length 31.5 mm and then gradually decreased. The results indicated that species upto 25.5 mm length group succumbed mainly to natural causes whereas from 27.5 mm onwards, become more vulnerable to the gear leading to fishing mortality exceeding natural mortality.

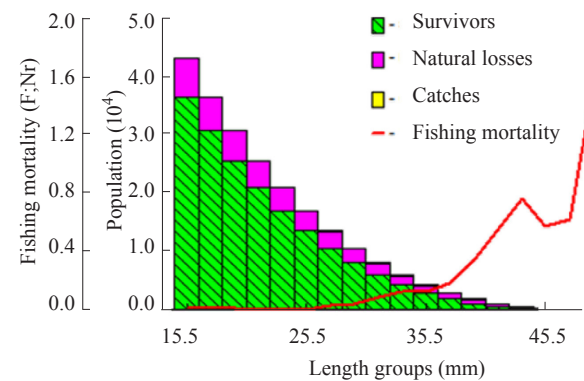


Fig. 6. Results of length-structured virtual population analysis of *P. longirostris*; with length-frequency data pooled for 2017-2018

Relative Recruitment Values	
Relative Time	Percent Recruitment
Month 1	4.07
Month 2	0.56
Month 3	6.65
Month 4	7.12
Month 5	0.93
Month 6	8.39
Month 7	15.26
Month 8	29.60
Month 9	17.66
Month 10	8.15
Month 11	1.62
Month 12	0.51

Relative yield per recruit

The plot of (Y'/R) and (B'/R) against exploitation rate (E) showed that the maximum Y'/R was obtained at $E_{max}=0.75$. The values obtained for $E_{0.1}$ and $E_{0.5}$ were 0.65 and 0.36 respectively (Fig. 7). During 2017-2018, the plot of Y'/R and B'/R against exploitation rate, E showed that the E value of 0.68 obtained was less than the value of 0.75 obtained for maximum exploitation rate (E_{max}). It is obvious that the current exploitation rate ($E = 0.68$) is higher than $E_{0.5} = 0.36$ and hence it is advised to decrease the present exploitation rate to $E_{0.5}$ which will maintain the spawning stock biomass at 50%.

Stock size and maximum sustainable yield (MSY)

The yield (Y) of *P. longirostris* estimated from the trawl landings in the M'diq zone of the Moroccan Mediterranean coast was 93078.5 t. The estimated total stock (Y/U) was 169482 t. The standing stock (Y/F) was estimated as 49691 t. MSY of *P. longirostris* for 2017-2018 was calculated as 82362 t using Gulland's formula (Gulland, 1971). As the estimate of MSY is 82362 t in the present study, against the present average catch of 93078.5 t, it is evident that the stock of *P. longirostris* is exploited above the MSY level.

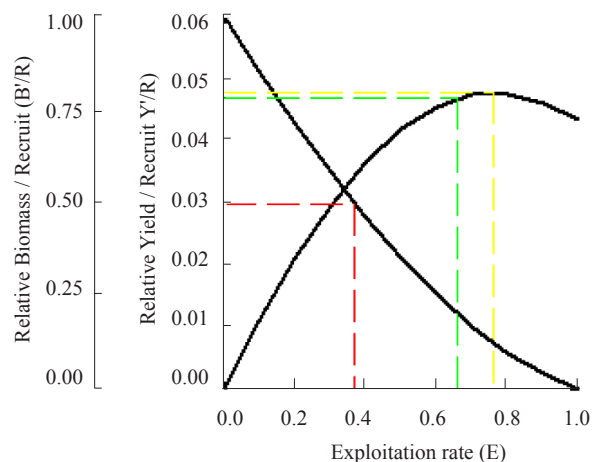


Fig. 7. Relative yield per recruit and biomass per recruit curve of *P. longirostris*

The population of *P. longirostris* in the M'diq fishing zone is overexploited at the present level of fishing effort. Therefore, it is recommended to reduce the current level of fishing effort. However, further studies on the biology and stock parameters of the shrimps along the entire Moroccan Mediterranean coast are warranted.

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