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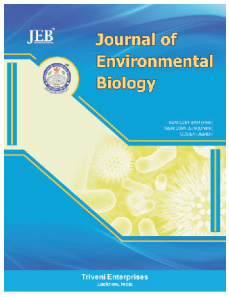

Age, growth, population dynamics and stock status of *Perna perna* in Omani waters

Authors Info

S.M. Al-Barwani[1]*, S.M. Nurul Amin[2], A. Arshad[2], A. Govender[1], H. Al-Habsi[1], K. Al-Riyami[1] and Jassim A. Al Khayat[3]

[1]Department of Marine Science and Fisheries, College of Agricultural and Marine Sciences, Sultan Qaboos University, P. O. Box 34, PC 123, Sultanate of Oman

[2] Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

[3]Department of Biological and Environmental Sciences, College of Arts and Science, Qatar University, P.O. Box 2713, Doha, Qatar

*Corresponding Author Email : sharthi@squ.edu.om.

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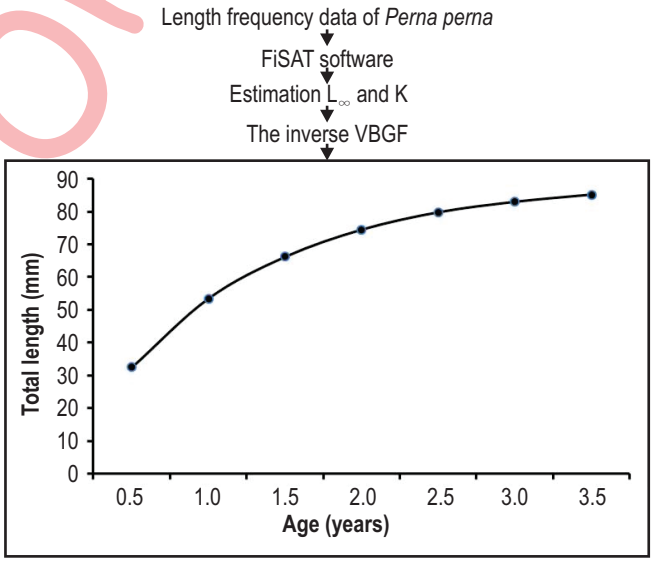
Abstract

Aim : Population parameters such as growth, recruitment pattern, mortality, exploitation rate and the length-weight relationship were investigated for the brown mussel, *Perna perna* in Omani waters.

Methodology : Monthly shell-length frequency of *P. perna* were collected from three different locations, namely, Mirbat, Ra's Al-Had and Ra's Madrakah for one year from December 2010 to November 2011. The data were analysed using the FiSAT (FAO-ICLARM Stock Assessment Tools) software to estimate population parameters.

Results : The length of individuals ranged from 10.34 to 104.03 mm and the weight from 0.12 to 52.45 g. The estimated relative growth coefficient (b) was 3.079 (± 0.019), and the 95% confidence level of b ranged from 3.045 to 3.116. The annual recruitment pattern of *P. perna* showed a continuous trend throughout the year. The peak recruitment at Mirbat (19%) and Ra's Al Had (21%) was observed in June, whereas at Ra's Madrakah (24%) it was observed in July. The estimated total mortality values of *P. perna* were 2.84 yr^{-1}, 3.28 yr^{-1} and 2.48 yr^{-1} at Mirbat, Ra's Al Had and Ra's Madrakah, respectively, while the natural mortality rates were 1.25 yr^{-1} at Mirbat, 1.29 yr^{-1} at Ra's Al Had, and 1.23 yr^{-1} at Ra's Madrakah. The fishing mortality rates were 1.59 yr^{-1} at Mirbat, 1.99 yr^{-1} at Ra's Al Had and 1.25 yr^{-1} at Ra's Madrakah. The *Perna perna* attained an approximate length of 53.5 mm at the end of one year. Exploitation rate (E) was 0.56, 0.60 and 0.50 at Mirbat, Ra's Al Had and Ra's Madrakah, respectively.

Interpretation : The results revealed that the stock of *P. perna* at Mirbat and Ra's Al Had areas was over exploited. However, currently at Ra's Madrakah the stock of *P. perna* is currently optimally exploited.



Introduction

The brown mussel, *Perna perna* is abundant on rocky shores along the coastal areas of the Arabian Sea of the Sultanate of Oman (Al-Barwani *et al.,* 2013). This species is considered endemic to Yemen, southern India, Sri Lanka, Madagascar, the southwestern Indian Oceans along the east coast of Africa, north of Luderiz Bay, the Mediterranean from Gibraltar to the Gulf of Tunis, the central and southwestern Atlantic Ocean along the coasts of Brazil, Uruguay, Venezuela, the West Indies, and recently colonized much of the Texan coast of the Gulf of Mexico (Hicks and Tunnell, 1995; Hicks *et al*., 2001; Sokolowski *et al.,* 2010). The brown mussel in Oman has little economic value due to limited demands by the local people, and is only consumed by local coastal communities where it is prolific. However, recently the demand for imported mussels from Europe and New Zealand has increased due to the demand from the increasing expatriate communities in Oman. Nowadays, *P. perna* has gained some economic importance due the demand from hotels and seafood restaurants which cater to tourists and the expatriate communities.

The purpose of fish population dynamics studies in open waters, where recruitment is a natural process, is to assess the stock size to provide advice on its optimum exploitation level. Fish stock assessment describes the exploitation level in both time and space. Thus, studies on population dynamics and assessment of a stock in an open water fishery are of the utmost importance, as it is a means to guide effective fisheries management based on scientific principles, with the aim to achieve a sustainable yield.

Knowledge of important population parameters such as growth, recruitment, mortality, exploitation rate, amongst others, are required as stock assessment input parameters that lead to effective fisheries management norms. In spite of its great importance, little is known about *P. perna* in Omani waters. Therefore, the present study was undertaken to estimate the key population parameters and exploitation levels of *P. perna* in order to assess the stock status of the species in the Sultanate of Oman.

Materials and Methods

Monthly total wet weight in gram and shell total length frequency data in millinetrem of *P. perna* were collected from three different locations in Omani waters, namely, Mirbat, Ra's Al-Had and Ra's Madrakah (Fig. 1) from December 2010 to November 2011. The collected shell length frequency data were grouped into length classes at 4 mm intervals. The data were analysed using the FiSAT (FAO-ICLARM Stock Assessment Tools) software (Gayanilo *et al.,* 1996) to estimate the mortality and the von Bertalanffy growth parameters. Asymptotic length (L_∞) and growth co-efficient (K) of the von Bertalanffy growth equation (VBGE) were estimated by means of ELEFAN-1 (Pauly and David, 1981; Saeger and Gayanilo, 1986). A growth performance for *P. perna* was calculated using the growth performances index (φ') equation: $\varphi' = 2 \log_{10} L\infty + \log_{10} K$ (Pauly and Munro, 1984). The inverse VBGF (Sparre and Venama, 1992) was used for determining *P. perna* length at various ages. The inverse VBGF is expressed by the following equation:

$$L_t = L\,[1-e^{-k\,(t-t0)}]$$

Where, L_t = mean length at age t; L = asymptotic length; K = growth co-efficient; t = age of the *P. perna* and t_0 = the hypothetical age at which the length is zero (Newman, 2002).

To establish the length-weight relationship, the cubic or power curve equation $W = aL^b$ was applied (Ricker, 1975; Quinn II and Deriso, 1999). Where W is the weight (g); L is the total length (mm) and 'a' and 'b' are constants. The parameters a and b were estimated by least squares linear regression on log-log transformed data: $\text{Log}_{10} W = \text{Log}_{10} a + b \text{ Log}_{10} L$. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regressing (Scherrer, 1984). Additionally, 95% confidence limits of the parameters a and b were estimated, and the statistical significance level of r^2 was also estimated.

Natural mortality rate (M) was estimated by the equation given below (Pauly, 1980):

$$\text{Log}_{10} M = -0.0066 - 0.279 \text{Log}_{10} L_\infty + 0.6543 . \text{Log}_{10} K + 0.4634 \text{ Log}_{10} T$$

Table 1 : Comparison of population parameters for three different stations in Sultanate of Omani waters

Parameters	Mirbat	Ra's Al Had	Ra's Madrakah
Asymptotic length (L_∞) in mm	71.40	88.20	107.10
Growth co-efficient (K yr^{-1})	0.84	0.94	0.95
Growth performance index (φ')	3.63	3.86	4.04
Natural mortality (M yr^{-1})	1.25	1.29	1.23
Fishing mortality (F yr^{-1})	1.59	1.99	1.25
Total mortality (Z yr^{-1})	2.84	3.28	2.48
Exploitation rate (E)	0.56	0.60	0.50
Sample size (n)	2920	2297	2085
Length range (mm)	10-80	12-84	16-104
Weight range (g)	0.12- 34.28	0.44- 29.12	0.52- 52.45

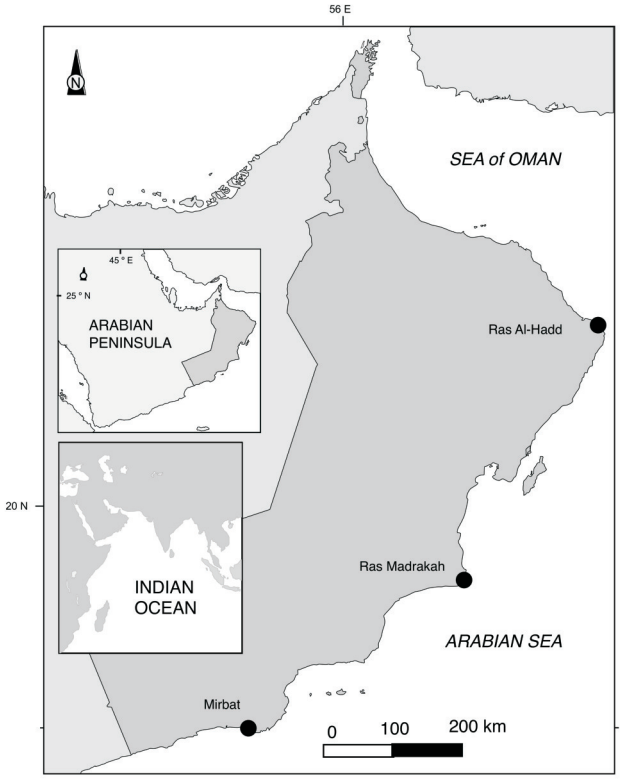


Fig. 1 : Sampling locations of brown mussel *Perna perna* (shown as by black dots)

Where, M is the instantaneous natural mortality; L_∞ the asymptotic length; K refers to the growth co-efficient of the VBGF and T is the mean annual habitat temperature of the water in which the stocks live (Pauly, 1980).

Jones and van Zalinge plot (Jones and van Zalinge 1981) was used to estimate total mortality (Z). Fishing mortality (F) was estimated by the following formula: F = Z-M.

Where, Z is the total mortality and M is natural mortality. Exploitation rate (E) was calculated as F/Z (Gulland, 1971).

A routine in FiSAT reconstructs the recruitment pulse from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse, using the von Bertalanffy growth parameters L_∞, K and t_0 (t_0= 0). Normal distribution of the recruitment pattern was determined by NORMSEP in FiSAT (Gayanilo *et al.,* 1996).

Results and Discussion

Growth parameters: The values of various population parameters obtained during the present study are given in Table 1. It was observed that the asymptotic lengths (L_∞) was calculated as 71.40 mm in Mirbat, 88.20 mm in Ra's Al Had and

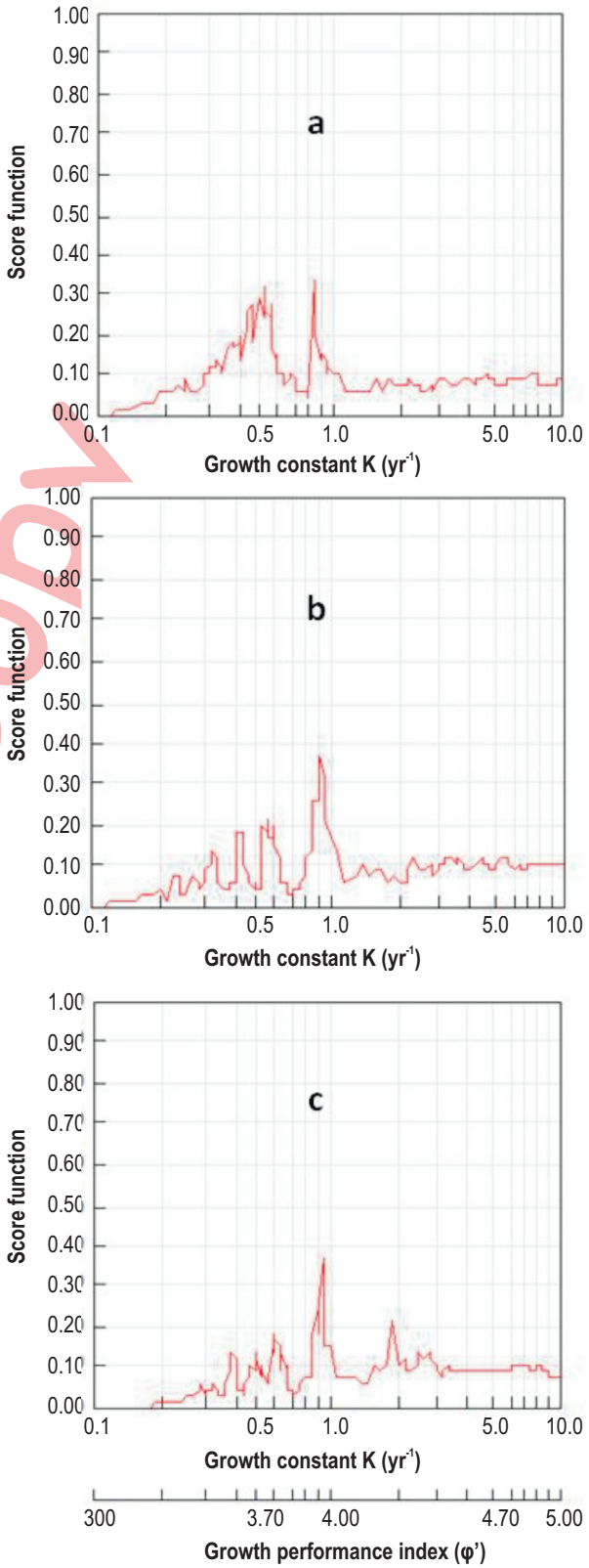


Fig. 2 : K-scan routine for determination of the best growth curvature giving the best value of K for *Perna perna* at (a) Mirbat; (b) Ra's Al Had and (c) Ra's Madrakah

107.10 mm in Ra's Madrakah. The highest values of the growth co-efficient (K) were 0.84 yr^{-1} in Mirbat (Fig. 2a), 0.94 in Ra's Al Had (Fig. 2b) and 0.95 in Ra's Madrakah (Fig. 2c). The growth curves of *P. perna* superimposed over their restructured length-frequency data for three sampling sites (Fig. 3a-c) The largest asymptotic length was observed in Ra's Madrakah and lowest at Mirbat. The asymptotic length (L_∞) values of *P. viridis* recorded by Al-Barwani *et al.* (2007) in the coastal waters of Malacca and by Amin *et al.* (2005) in Bangladesh waters were much higher (Table 2) than the values observed at Mirbat and Ra's Al Had. However, the L_∞ reported by Al-Barwani *et al.* (2007) was more or less similar to the value found at Ra's Madrakah waters. This could be due the heavy pressure imposed on the mussel stock at both Mirbat and Ra's Al Had leading to a lower L_∞. The mussel beds at the two sites are confined and easily accessible by a large number of collectors who target large sized animals. However, at Ra's Madrakah the mussel beds are widely spread and are difficult to access which gives opportunity for the mussels to grow larger because of the lower fishing pressure.

The growth co-efficient, K values of *P. perna,* varied between 0.84 yr^{-1} and 0.95 yr^{-1} among the three stations. The mean K value which represents the coastal waters of Oman was 0.91 yr^{-1}. This value, however, is a little bit higher than the value of K obtained for *P. viridis* from Bangladesh, India and Hong-Kong and lower than Thailand and Malaysia (Table 2). This could be due to the fact that shell growth rate in tropical pernids is greater than that found in temperate mytilids (Vakily, 1989; Hicks *et al*., 2001). The species *P. perna* in its native geographical distribution is known for its rapid growth rate which enables the animal to reach a size of 50 - 70 mm in 6 - 7 months (Chung and Acuna, 1981; Sokolowski *et al.*, 2010).

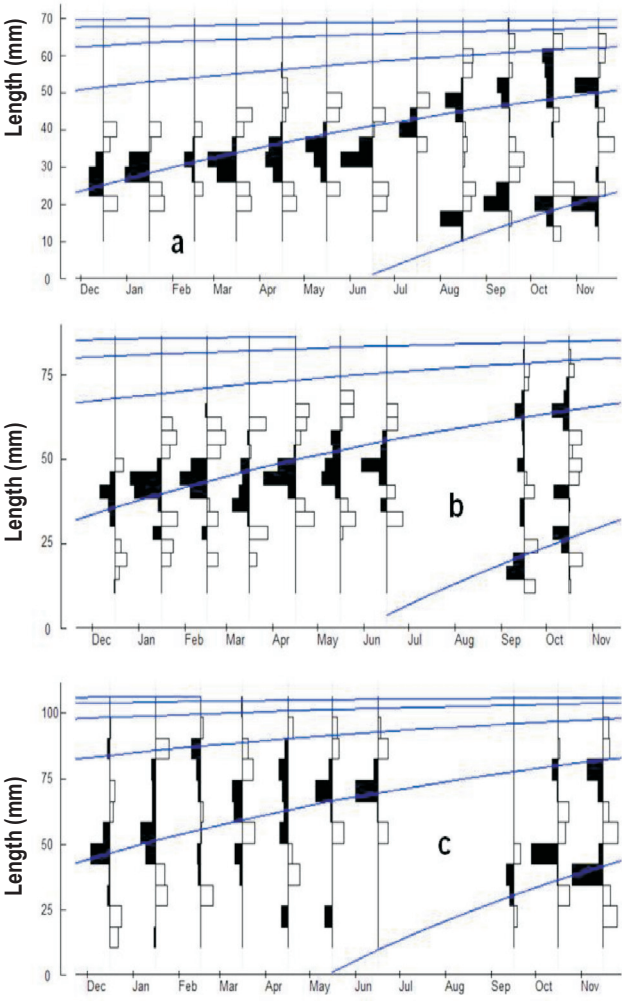


Fig. 3 : Von Bertalanffy growth curves of *Perna perna* at (a) Mirbat, (b) Ra's Al Had and (c) Ra's Madrakah superimposed on the restructured length-frequency histograms

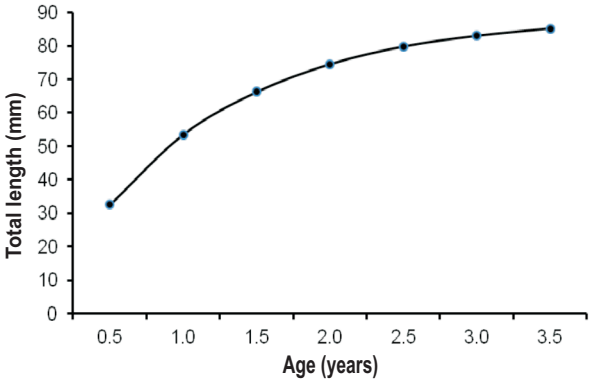


Fig. 4 : Plot of age and growth of *Perna perna* based on computed growth parameters

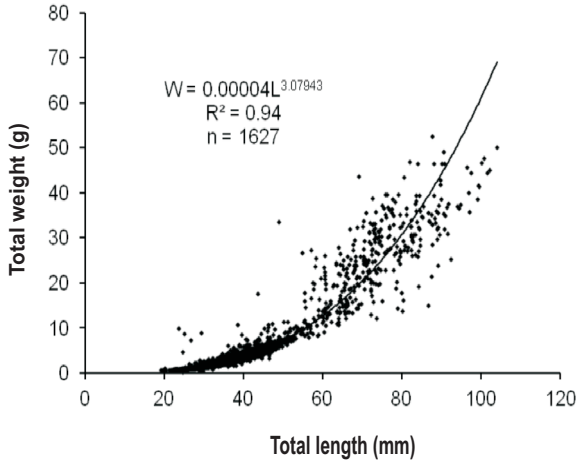


Fig. 5 : Length-weight relationship of *Perna perna* from Omani waters for both sexes

Table 2 : Parameter values of von Bertalanffy growth function for *Perna viridis* from different countries and *Perna perna* from Oman

Location	Species	L_∞ (mm)	K yr $^{-1}$	φ'	T (^{0}C)	Source
Oman	*P. perna*	88.90	0.91	3.84	-	Present study
Malaysia	*P. viridis*	102.3	1.50	4.19	29.4	Al-Barwani *et al.* (2007)
Bangladesh	*P. viridis*	194.3	0.56	2.32	28.0	Amin *et al.* (2005)
India	*P. viridis*	184.6	0.25	-	-	Narasimham (1981)
Thailand	*P. viridis*	112.0	1.00	-	-	Tuaycharoen *et al.* (1988)
Hong Kong	*P. viridis*	101.9	0.30	-	-	Lee (1985)

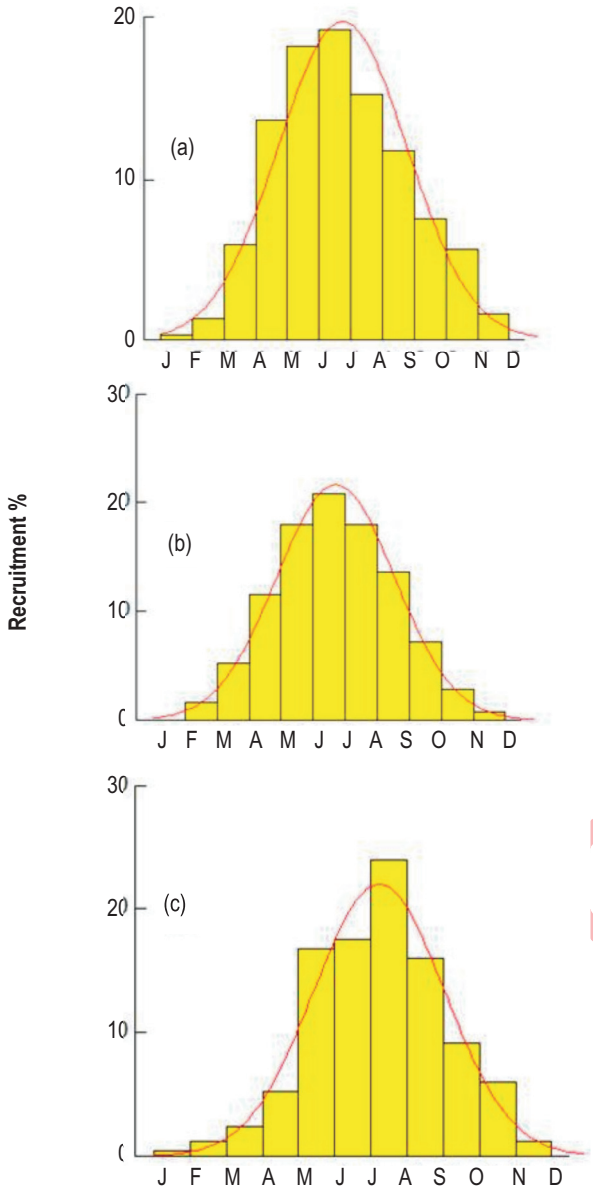


Fig. 6 : (a) Annual recruitment pattern of *Perna perna* at Mirbat, (b) Ra's Al Had and (c) Ra's Madraka

The growth performance index (φ') values of *P. perna* different locations were found to be high and varied between 3.63 and 4.04 (Table 1). These values differed very little among the three locations despite varying fishing mortalities. *P. perna* distribution in the coastal waters of Oman is only along the Arabian Sea. The Arabian Sea is characterised to be one of the most highly productive regions of the world's oceans (Nair *et al.,* 1989), and this will definitely have an effect on the growth performance of *P. perna*.

Age and growth : The sizes attained by *P. perna* were 32.5 mm, 53.5 mm, 74.5 mm and 83.1 mm at the end of 0.5, 1, 2 and 3 years of age, respectively. The absolute increase is presented in Fig. 4 The estimated growth increment was 21 mm and 8.6 mm from 1st to 2nd and 2nd to 3rd year, respectively. Similar studies were conducted and reported on *P. viridis* by Amin *et al*. (2005) and Al-Barwani *et al.* (2007) and on *Crassostrea madrasensis* by Amin *et al.* (2008), by inverse VBGF which was also followed in this study.

Length-weight relationship : The length size and the weight of individuals ranged from 10.34 to 104.03 mm (Table 1) and the weight from 0.12 to 52.45 g at three sites. The length-weight relationship curve is presented in Fig. 5. The calculated length-weight equation was log W = - 4.3724 + 3.0794 log L.

In exponential form the equation was $W = 0.00004L^{3.0794}$ ($r^2 = 0.94$, $p < 0.01$). The estimated relative growth coefficient (b) was 3.079 (± 0.019). The 95% confidence level for the parameter b ranged from 3.045 to 3.116. The growth coefficient b generally lies between 2.5 and 3.5 and the length-weight relationship is said to be isometric when it is equal to 3 (Carlander, 1977). In the present case, the estimated b (3.079) was very close to the isometric value mentioned by Carlander (1977). This indicates the isometric nature of growth for *P. perna* in the coastal waters of Oman.

Recruitment pattern : The annual recruitment pattern of *P. perna* was continuous throughout the year with one major peak in all the investigated areas (Fig. 6a-c). The peak recruitment values calculated by FiSAT were 19% at Mirbat, 21% at Ra's Al Had during the month of June and 24% in Ra's Madrakah during the month of July. The results revealed that the recruitment pattern

three different locations consisted of one seasonal pulse, *i.e*., one cohort is produced per year and the highest peak occurs in May-August. There is no published report on recruitment of *P. perna* in Oman for comparison. Al-Barwani *et al.* (2007) reported a single cohort of recruitment for *P. viridis* in the coastal waters of Malaysia, which is similar to the present study's findings.

Mortality and exploitation : The estimated total mortality values of *P. perna* were 2.84 yr^{-1} at Mirbat, 3.28 yr^{-1} at Ra's Al Had and 2.48 yr^{-1} at Ra's Madrakah (Table 1). The natural mortality rates of *P. perna* were 1.25 yr^{-1} at Mirbat, 1.29 yr^{-1} at Ra's Al Had and 1.23 yr^{-1} at Ra's Madrakah. The fishing mortality rates of *P. perna* were 1.59 yr^{-1} at Mirbat, 1.99 yr^{-1} at Ra's Al Had and 1.25 yr^{-1} at Ra's Madrakah. The fishing mortality was higher than natural mortality at Mirbat and Ra's Al Had site. However, at Ra's Madrakah the rate of fishing mortality was more or less similar to natural mortality. Exploitation level E of *P. perna* was 0.56, 0.60 and 0.50 at Mirbat, Ra's Al Had and Ra's Madrakah, respectively. The exploitation rates, E for *P. perna* revealed that the stock of *P. perna* in Mirbat and Ra's Al Had areas was over exploited. However, at Ra's Madrakah the stock of *P. perna* was in the process of becoming optimally exploited.

According to Gulland (1965), the yield is optimized when F = M; therefore, when E is more than 0.50, the population stock is considered over-fished. The higher value of E (E > 0.50) indicates the 'over-fishing' condition of *P. perna* in Mirbat and Ra's Al Had areas. It could be concluded that the resource of *P. perna* is under heavy pressure in Mirbat and Ra's Al Had areas. Hence, Ra's Madrakah, which has a difficult access terrain, should be protected as it can serve as a source of recruitment for the other two more heavily exploited areas.

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