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Population dynamics and management of scalloped spiny lobster *Panulirus homarus* in Oman coastal waters

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Abstract

Spiny lobster (*Panulirus homarus*) population, one of the most valuable fishery resources in Oman, is assessed based on the length frequency data collected from the Arabian Sea during the lobster fishing season. The assessment was carried out using 6,498 lobsters covering a length range of 37- 134 mm carapace length (CL), sampled in Arabian Sea coastal waters during March and April, 2011 and 2012. By applying the Y/R analysis on the pseudo-cohort of 2011-2012 using VIT program, it is noticed that this stock is heavily exploited, being the fishery operating below the optimal yield level since the current Y/R is greatly lower than the maximum. Results suggest a decreasing trend in the average fishing mortality along the studied period by about 40-60%. The effects of different management scenarios including present strategy on the short-term yield of the stock were explored and some addition management measures were proposed.

Keywords: Oman, Arabian Sea, *Panulirus homarus*, population dynamics, stock assessment, management.

1. Introduction

Lobsters are one of the most valuable and highly priced crustaceans in Oman, as well as an important export commodity. Though it distributed along the entire coast of Oman, major fisheries are located in the area between Ras Al-Hadd and Dalkut (a distance of approximately 1100 km) (Fig. 1). The lobster fishery of Oman is mainly supported by the palinurid spiny lobster *Panulirus homarus* (Linnaeus) which represents 33% of the total lobster catch (Annual fishery statistics book, 2011).

The scalloped spiny lobster *Panulirus homarus* is widely distributed in the tropical and subtropical Indo-West Pacific, where it inhabits shallow (1–90 m depth) rocky substrates and coral reefs (Holthuis 1991, Berry 1971&1974, Thuy 2000, Kulmiye & Mavuti 2005). The near shore distribution of lobsters along the Arabian Sea coast of Oman makes them easily accessible to traditional fishers using traps, gill nets and tangle nets from their small (4-11 m length) motorized fiberglass boats.

In general, lobster catches in Oman coastal waters have declined over the past decades, and this has been attributed to the effects of destructive fishing methods, over-fishing and illegal behavior of some fishers. Reported lobster catch from Oman coastal waters have declined from about 2000 ton in 1988 to only about 158 ton in 2011. At the same time the gross revenue from lobster fishery seriously decreased from up to 6 million OR (OR ≈ 2.6 $) to less than one million OR in 2011.

The spiny lobster fishery is managed with a minimum size limit of 80 mm carapace length (CL) for all species along the coast of Oman, only two months fishing season (15th October-15th December until 2008 changed to March and April since 2010) and prohibition of fishing berried females (Articles12&14 of the Marine Fishing Law). However, these regulations have not been strictly enforced. Small lobsters and berried females were common in the catch and the fishermen went to catch lobster in the closed months using illegal fishing gears. This lack of protection of spawners and young lobsters damages the reproductive potential of the lobster population, resulting in recruitment failure and overexploitation.

Despite the importance of the *P. homarus* fisheries to Oman economy and its wide distribution in the Indo- Pacific region, information about its key life history parameters is limited. Previous studies on *P. homarus* in Oman coastal waters are very scarce and need to update (Al-Abdulsalaam 1989, Johnson 1990, Johnson & Al-Abdulsalaam 1991,

Mohan 1997, Fatemi 2001, Ben Meriem *et al.* 2003 and Al-Marzouqi *et al.* 2007 based on data of 2003-2005). In this paper we discuss the present situation of lobster fishery in Oman and estimate the population parameters of *P. homarus* required for its effective management based on the most recent fisheries dependent and independent data.

2. Material and Methods

2.1 Collection of fishery statistics

Data concerning the total and spiny lobster catches in Oman coastal waters, as well as the fishing effort expressed as the number of fiberglass boats were obtained from the Fisheries statistics Department, Ministry of Agriculture and Fisheries Wealth, Sultanate of Oman. The data collection involved also interviewing the fishermen at selected fishing landing sites. These data include the boats characteristics, type and size of fishing gear, catch size and the reasons of catch declining from fishermen point of view. The collected data were analyzed to estimate the catch per unit of fishing effort (CPUE) which reflects the relative abundance of lobster stock.

2.2 Collection of samples

During March and April 2011 and 2012, the lobster fishing season, length measurements were obtained from three Governorates along the Arabian Sea coast of Oman (Al-Wusta, Al-Sharqiyah and Dhofar).This sample is represented of all lengths recorded in the landing sites and exploited by the artisanal fishery. Samples of spiny lobster *P. homarus* were collected from the commercial catch of artisanal lobster fishery in seven different landing sites; Al-Ashkharah (Al-Sharqiyah), Ras Madrakah, Al-Doqm, Al-Jazir (Al-Wusta), Mirbat, Salalah and Dalkut (Dhofar) (Fig. 1). A total of 3073 males (37-134 mm CL) and 3425 females (43 -123 mm CL) were measured for carapace length, from the tip of the rostral spine to the posterior edge, to the nearest mm. Sex, reproductive state and the presence of external eggs were recorded for all measured specimens. Length measurements were grouped into 5 mm CL size classes for modal progression analysis (MPA).

2.3 Age and growth

For each sex the length frequency was resolved into normally distributed cohort components using Hasselblad's NORMSEP (Hasselblad 1966).To reduce the bias resulting from size selectivity, missing length measurements and variation in sample size, the raised length frequency data were used as it provided better estimation of growth parameters. The results were used as input to the modal progression analysis (MPA) and Ford (1933)–Walford (1946) plot ţǫ estimate the asymptotic carapace length (CL_∞, in mm) and the rate at which the asymptotic length is attained (K y). The growth parameters were also estimated using the ELEFAN I program (Pauly 1987) and SLCA method (Shepherd 1987). Growth performance index Ǿ in terms of growth in length was estimated to validate the growth parameters (Gayanilo & Pauly 1997).

2.4 Mortality and exploitation rates

Cumulated catch curve method as described in Jones & Van Zalinge (1981) and linearized catch curve method of Pauly (1983) were used to estimate the total mortality coefficient (Z). The natural mortality coefficient (M) was estimated using the formula of Pauly (1980) with mean annual temperature of 26^0C. The fishing mortality coefficient (F) was computed as F= Z – M, while the exploitation rate (E) was calculated from the ratio F/Z (Gulland 1971).

2.5 Length at first capture and Length at first sexual maturity

The length at first capture (L_c) was estimated by the analysis of catch curve using the method of Pauly (1984). The length at first sexual maturity L_{50} and maturation curve were taken from Al-Marzouqi *et al.* (2005&2007) where they had the chance to get samples during almost of months during 2003-2005 (Lobster fishery in Oman project; Phase I&II) .

2.6 Spawning stock biomass and Yield per recruit

Spawning stock biomass (SSB) and yield per Recruit (Y/R) were estimated using the VIT program (Lleonart & Salat 1997). All these calculations were done for sexes combined as any management measures were planned for sexes combined.

2.7 Management

The following reference points were used to improve the current management strategy for spiny lobster stock in

Oman coastal waters: $F_{0.1}$ (the fishing mortality rate corresponding to the point where the slope of the yield per recruit curve equals 10% of the slope at the origin) (Gulland & Boerema 1973), F_{max} (the fishing mortality rate that produces the maximum yield per recruit).

3. Results and discussion

3.1 Lobster fishery in Oman

In the last 25 years, the annual landing of lobsters sharply declined from up to 2000 ton in 1988 to 157 ton in 2008. At this level of the declined catch, the government ceased the fishing of lobster completely in 2009. This action lead to a slight increase in the catch (407 ton in 2010) followed by a serious drop in 2011 (158 ton). At the same time the number of fibreglass boats increased (Fig. 2). Accordingly, the relative abundance of the lobster fishery (catch per unit fishing effort) decreased dramatically from its maximum at 0.16 ton/boat during 1988 to its lowest value at 0.008 ton/boat in 2011. Although the lobster caught along the Oman coastal waters, Arabian Sea constitute the main fishery ground of lobster in Oman where 86% of the total lobster catch was landed from the three governorates located on the Arabian Sea, Al-Wusta, Al-Sharqiyah and Dhofar. The most productive region is Dhofar Governorate which gives 67.5% of the total lobster catch in the Arabian Sea followed by Al-Wusta Governorate (26.2%) and then Al-Sharqiyah Governorate (6.3%) (Annual fishery statistics book, 2011) (Fig. 3).

3.2 Longevity and growth

The length frequency data for all collected samples combined (Fig. 4) was used for age and growth analysis. The maximum life span of *P. homarus* was three years for both males and females and age group one was the most frequent group in the catch constituting 61% for males and 50% for females. The values of mean length-at-age obtained Hasselblad's NORMSEP were used to estimate the growth parameters. The values of K obtained were 0.72, 0.77 and 0.71 $year^{-1}$ for males, females and pooled data respectively, while L_∞ was 146.80, 136.51 and 143.16 mm CL for males, females and pooled data respectively. The best growth parameters estimates obtained from ELEFAN I were K = 0.75 $year^{-1}$ and L_∞ = 144.5 mm for males, K = 0.81 $year^{-1}$ and L_∞ = 134.7 mm for females and K = 0.72 $year^{-1}$ and L_∞ = 144.85 mm for pooled data. The growth parameters estimates from SLCA method (Shepherd 1987) were almost similar to those of ELEFAN I (Table 1). It is obvious that, males grew to a greater asymptotic length (L_∞) than females, but the rate at which this was achieved (K) was slightly less than that in females. The growth parameters of spiny lobster in Oman are consistent with those of fast-growing tropical lobster species, where Beverton & Holt (1959) found that the fast growing species have high K and M values. The growth parameters estimated by different authors in Oman and other localities were given in Table 2.

3.3 Growth performance index

Growth performance index Ǿ in terms of growth in length was estimated to validate the growth parameters of *P. homarus* obtained from the non-linear least square method, ELEFAN I method and SLCA method (Table 1). The Ǿ values were within a very narrow range indicating that all estimates from the three methods pointed towards similarity in the growth pattern. The growth parameters of non-linear least square method were used for subsequent calculations of stock assessment.

3.4 Mortality and exploitation rates

The results indicated that Z differed between sexes. Mean total mortality estimates were 4.11, 4.76 and 4.54 $year^{-1}$ for males, females and sexes combined respectively. The estimated values of M were 0.95, 0.95 and 0.89 $year^{-1}$ for males, females and sexes combined respectively while the respective values of F were 3.16, 3.81 and 3.65 $year^{-1}$ for males, females and sexes combined respectively. The difference in M values between males and females could be attributed to the difference in growth rate,. The exploitation rate of males was 0.78 and that of females was 0.80. The high values of both fishing mortality and exploitation rates suggesting a very intensive exploitation. Gulland (1971) suggested that the optimum exploitation rate for any exploited stock is about 0.5 at F_{opt} = M. More recent, Pauly (1987) proposed a lower optimum F that equal to 0.4 M.

3.5 Length and age at first capture L_c

The length at first capture (the length at which 50% of the lobster at that size are vulnerable to capture) was

estimated as 65.00, 62.50 and 63.75 mm CL for males, females and sexes combined respectively

3.6 Length at first maturity

The length at first maturity for females spiny lobster in Oman waters was estimated at 69-84 mm CL (Al-Abdulsalaam 1989), 69.2-79.5 mm CL (Mohan 1997) and 66.6-76.7 mm CL (Al-Marzouqi *et al.* 2007). On the other hand this length was given as 60-70 mm CL in adjacent areas (George 1963 in Yemen, Jayakody 1989 & 1993 in Iran, Kulmiye *et al.* 2006 in Kenya and Fatemi 2001 in Persian Gulf and Sea of Oman). On the light of the previous results, the length at first maturity of spiny lobster in the Arabian Sea lies between 65 and 80 mm CL which greater than the length at first capture. This means that the exploited *P. homarus* must be protected till reaching 80 mm CL to be sure that the species able to spawn at least once.

The estimated lengths at first capture, the length at maturity and the observed lengths of *P. homarus* indicated growth and recruitment overfishing and the minimum size limit (80 mm) should be enforced. Moreover, strong actions should be taken to conserve the spawning stock and berried females.

3.7 Reference points and management

SSB and Y/R analysis using VIT model showed a clear status of growth overfishing, due to the high fishing mortality and the exploitation of the fishery based on individuals under the minimum legal size. Also, the stock is in danger of recruitment overexploitation due to the decreasing trend in recruitment and very low levels of the spawning stock. The Y/R and SSB analysis (Fig. 5) confirms the urgent reduction of the current F by at least 35% to achieve the F_{MSY}. This reduction will be accompanied by an increase of SSB by about 56%. To achieve the $F_{0.1}$ as a reference point, the current F should be reduced by about 61%. Also, the surviving fraction of the SSB expressed as the rate between the current value (SSBc) and the same value for the stock in pristine (virgin) condition (SSBv) was 0.12, which is lower than the threshold value of 0.3. Therefore, the latter calls for immediate management action to prevent a possible stock collapse.

4-Conclusion

In conclusion, the spiny lobster seems to be highly exploited and the current regulations not enough to recover the lobster fishery and to protect the stock from collapse in Oman. The drastic decline of the lobster fishery along the coast of Oman is still of serious concern and demands urgent complementary management measures such as: reducing the fishing pressure especially fishing of spawners and juveniles by at least 40% of its current level, defining specific critical areas such as nursery and spawning grounds and protecting them, the necessity of constructing a data base with reliable fishery statistical records enabling stock assessment of higher precision, improving tools of fighting and controlling the illegal, unreported and unregulated catch, enacting the laws and tougher punishment for offenders, banning the use of nets on the entire Oman coasts and replace it by traps this may prevent exploitation of juveniles which comprise a considerable part of the catch. Finally, it is important to establish some form of cooperation among fishers, scientists, and government agencies for implementing sustainable management programs.

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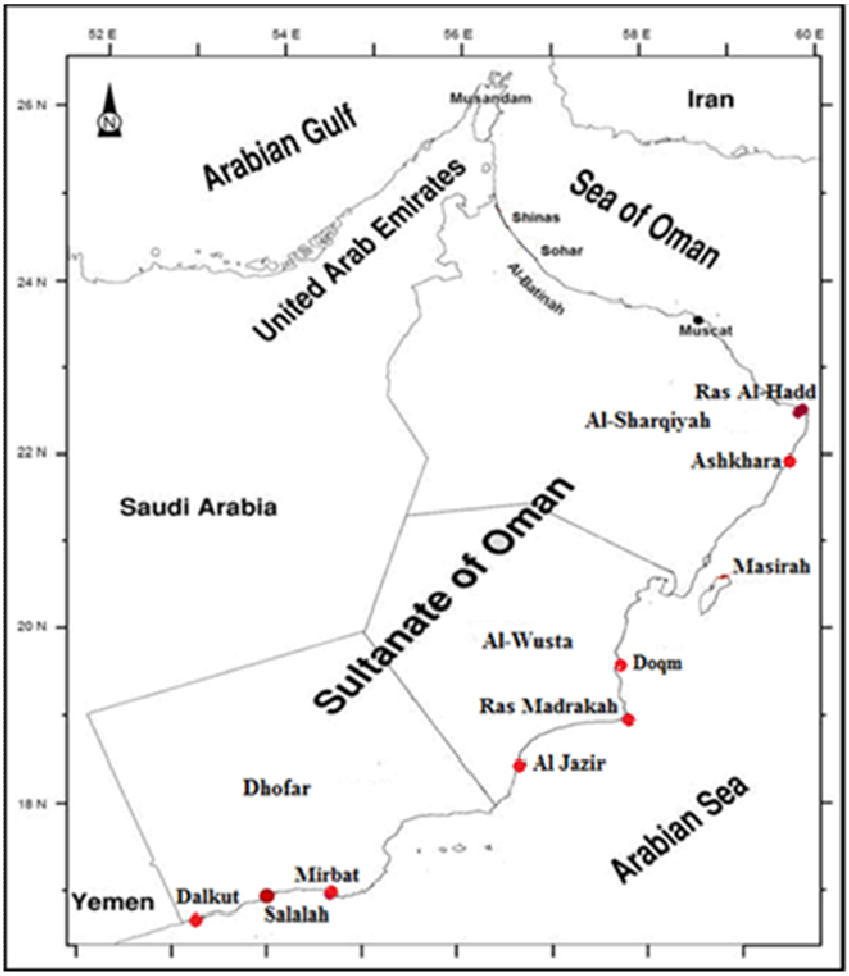

Figure 1: Oman map showing the main fishing grounds of lobster

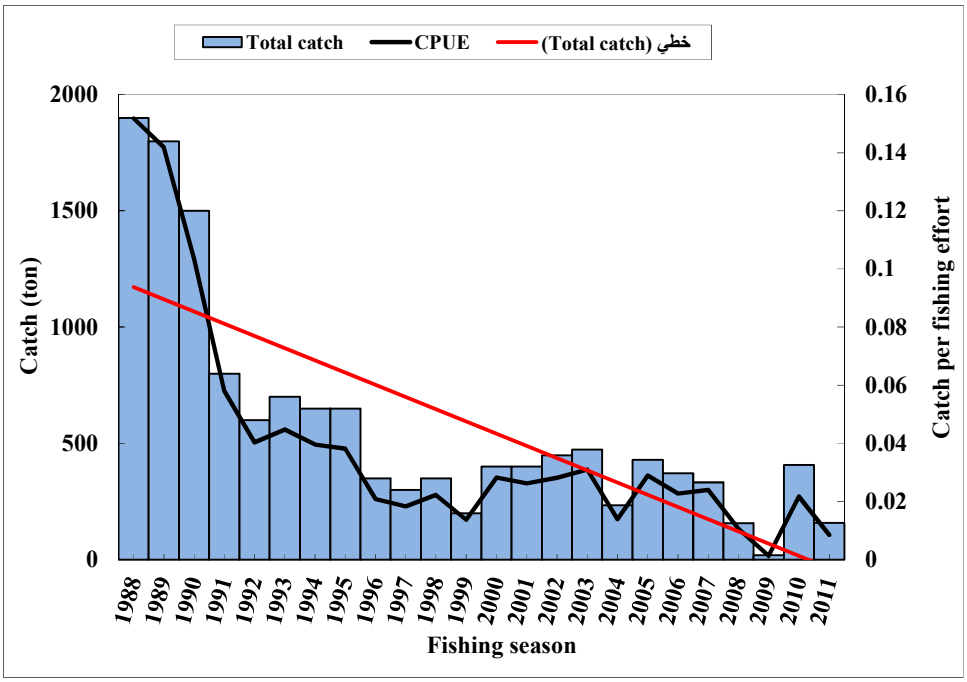

Figure 2: Lobster catch, catch per fishing effort (ton/number of small fiberglass boats) and catch trend in Oman Coastal waters

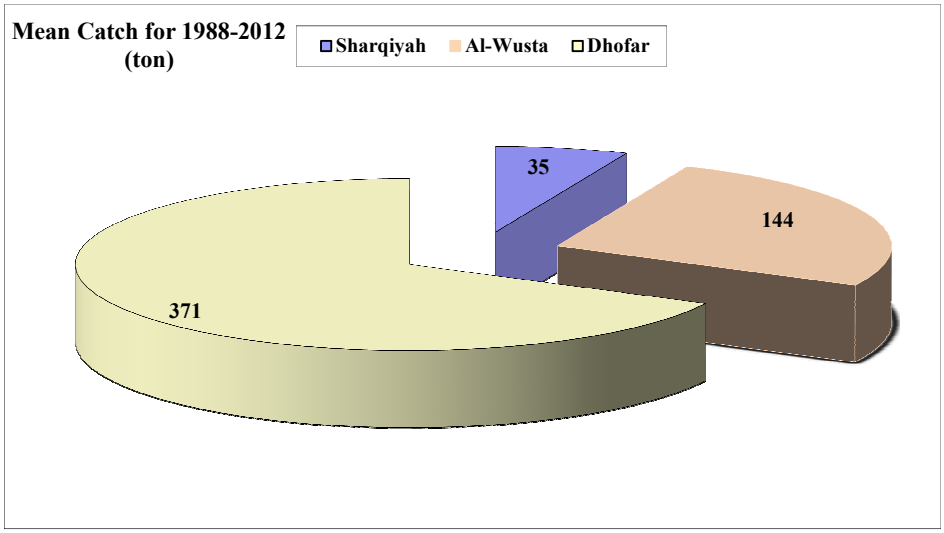

Figure 3: Lobster mean catch (ton) by region during the period from 1988 to 2012

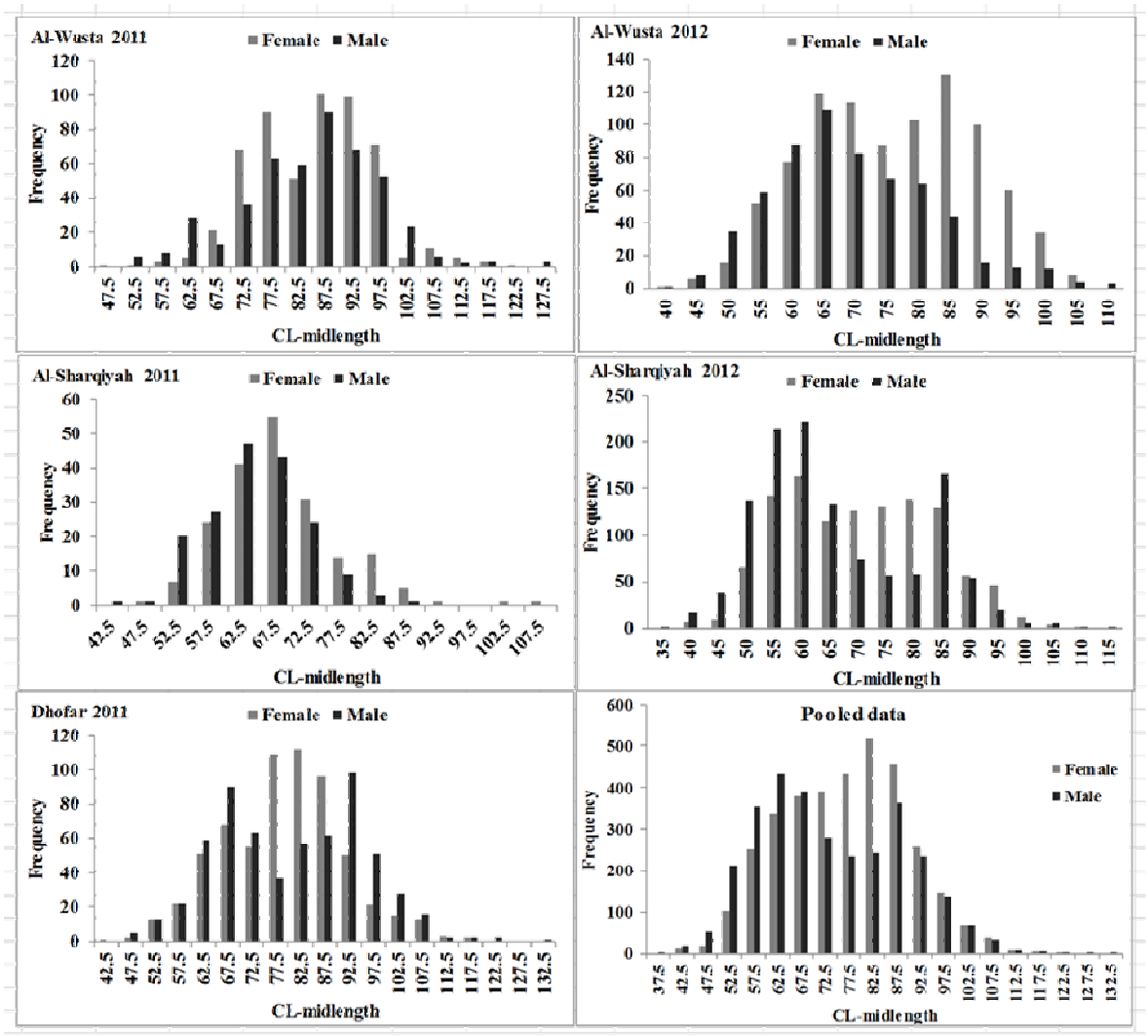

Figure 4. Length frequency data of spiny lobster during 2011-2012.

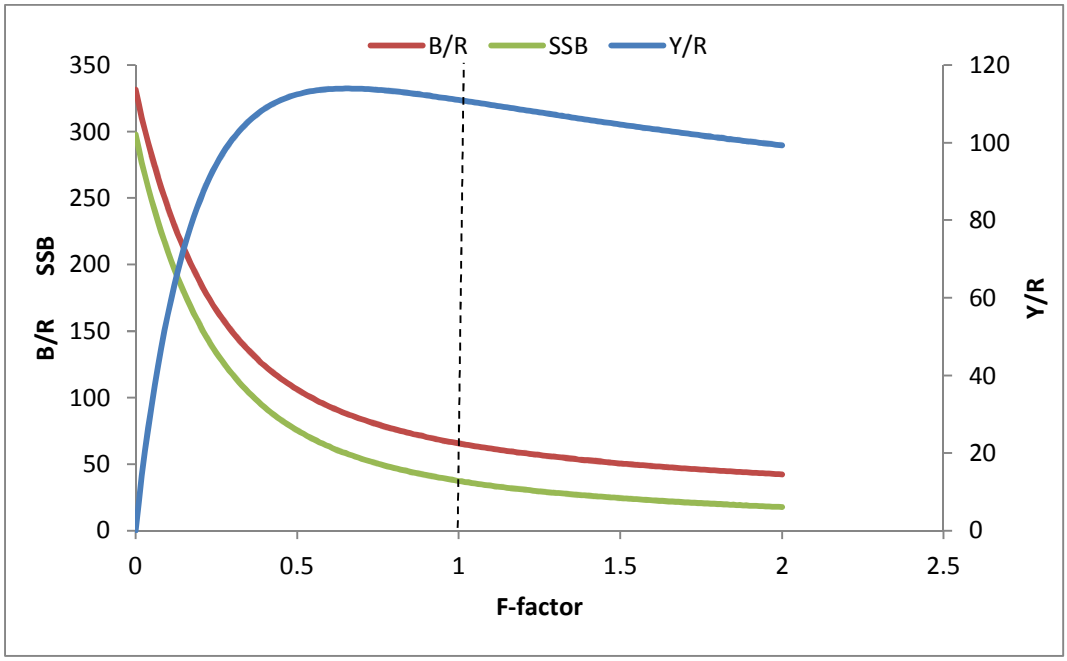

Figure 5: VIT results

Table 1. Growth parameters and growth performance index of *P. homarus*.

Method	Female			Male			Sexes combined		
	K	CL_∞	Ø	K	CL_∞	Ø	K	CL_∞	Ø
Least Square	0.77	136.51	4.157	0.72	146.80	4.191	0.71	143.16	4.163
ELEFAN I	0.81	134.70	4.167	0.75	144.50	4.195	0.72	144.85	4.179
SLCA	0.82	134.29	4.170	0.75	144.82	4.197	0.73	144.82	4.185

Table 2. Growth parameter estimates in *P. homarus*

Locality	L_∞ (CL) mm	K (Y^{-1})	t_o	Author
Yemen	225 TL	0.45	---	Sanders & Bouhlel, 1984
Sri Lanka	287 TL	0.43	0.38	Jayaweckrema, 1991
Somalia	♂127	0.46	-0.61	Fielding, 1997; Fielding & Mann, 1999
	♀110	0.43	-0.53	
Somalia	♂115	0.49	---	Kulmiye & Mann, 2005
	♀105	0.40	---	
Oman				Al-Abdulsalam, 1989
Hadbin	♂139	0.36	---	
	♀119	0.60	---	
Sudh	♂125	0.70	---	
	♀119	0.80	---	
Mirbhat	♂124	0.75	---	
	♀106	1.20	---	
Al-Wusta & Dhofar	131.0	0.37	-0.34	Al-Marzouqi *et al.* 2005
Arabian Sea	128.9	0.33	-0.35	Al-Marzouqi *et al.* 2007
Arabian Sea	♂146.8	0.72		Present study
	♀136.5	0.77		
	143.16	0.71		