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Fisheries and population dynamics of the green tiger shrimp, *Penaeus semisulcatus* from the Arabian Sea, Oman

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ABSTRACT

Monthly carapace length frequency data of the green tiger shrimp *Penaeus semisulcatus* were collected from commercial cast net catch from Oman coast of the Arabian Sea. Sampling covered the first three months of the shrimp fishing season from September to November, where more than 95% of shrimp catch was landed. It was observed that females *P. semisulcatus* were significantly larger than males and had dominated in the catch, whereas the over all sex ratio was 1:1.18 male: female. Growth parameters (K and L_∞) were estimated based on age-length data obtained from Bhattacharya (1967) method. Also, the instantaneous rate of total mortality (Z) and the natural mortality (M) were estimated. Accordingly, the fishing mortality was estimated as F= Z-M and the exploitation ratio were determined as F/Z. Both fishing mortality and exploitation rates were relatively high, indicating high level of exploitation. Relative yield per recruit and relative biomass per recruit analysis showed that *P. semisulcatus* stock in the Arabian Sea is heavily exploited and the present level of exploitation should be reduced by about 50% in order to maintain a sustainable spawning biomass.

1. INTRODUCTION

Prawns of genus *Penaeus* have a great demand in the export market. Their intensive exploitation leads to a decline in per unit landings in many seas of the world. Although *Penaeus* spp. are commonly caught along the coasts of Oman, Al-Wusta Province alone contributes as much as 95% of the penaeid shrimp landings.

The penaeid shrimp fishery is one of the most important fishery resources in Oman. The shrimp catch is composed of at least ten species (Siddeek *et al*., 2001) of which the Indian white shrimp *Fenneropenaeus* (*Penaeus) indicus* and the green tiger shrimp *Penaeus semisulcatus* are the most important ones. Those two species are of commercial importance in the tropical and sub-tropical areas of Indo-Pacific region. They greatly contribute to the Oman economy, where 854 tons were landed in 2010 from which 790 tons were exported, earning more than two million Omani Rial (OR=2.6 US$).

Although the shrimp fishery has a great economic importance at Oman, few studies of lace shrimp species are available (Siddeek *et al.,* 2001; Mehanna *et al*., 2011).

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On the other hand, several studies concerning biology and fishery of the green tiger shrimp Sea coasts in different water bodies around the world (Van Zalinge *et al*., 1981; Garcia and Le Reste, 1981; Mathews and Al-Hossaini, 1982; Dall *et al*., 1990; Somers and Kirkwood, 1991; Xucai & Mohammed, 1996; Maheswarudu *et al*., 1996; Mehanna, 2000; Villarta *et al*., 2006; Niamaimandi *et al*., 2007). The present work aimed to assess the green tiger shrimp status and proposing some regulations for its sustainable management.

2. MATERIAL AND METHODS

2.1 Fishing area

Al-Wusta Province lies on the Arabian Sea coast and is the first in shrimp production in Oman, where about 95% of the shrimp catch was landed (Fishery statistics book, 2010). There are a number of fishing grounds along Al-Wusta Province from which Mahout is the most productive one. Mahout fishing ground (Fig. 1) has a number of small landing sites along the Arabian Sea and considered as a source of important local fishery in Oman.

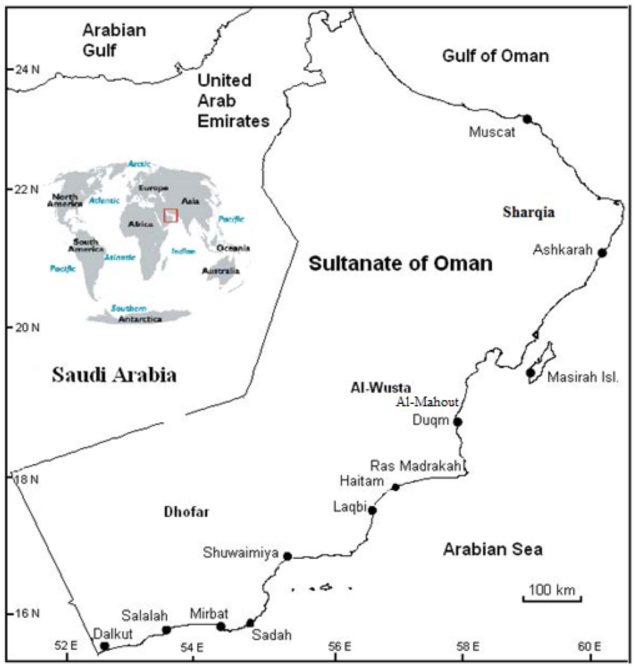

Fig. 1: Al-Wusta province in Oman with the main landing sites.

2.2 Sampling

Length frequency data of the green tiger shrimp *P. semisulcatus* were obtained from the commercial catch of the cast net fishery in Mahout Area (Al-Khalouf landing site) during the period from September to November 2011. It is worth mentioning that the shrimp fishery in Oman is seasonal, starting at September and extending to the end of April. Nearly the whole shrimp catch is landed during the first three months of the season, with a very little proportion landed during December (Fishery statistics book, 2010). So, the length-frequency data during these months can be considered as representative samples of shrimp stock in the Arabian Sea coast of Oman.

After sex-wise sorting out of the caught specimens the carapace length (straight length from posterior margin of the orbit to the median dorsal posterior edge of the carapace) to the nearest mm was measured by caliper and the monthly carapace length frequency was grouped into 2 mm classes for further analysis.

2.3 Methods

The following length-based methods were applied to estimate population parameters for the green tiger shrimp:

For each sex, the carapace length frequency was resolved into normally distributed cohort components, using Bhattacharya (1967) method and the results were used as input to the modal progression analysis (MPA) and Ford (1933)-Walford (1946) equation to estimate the von Bertalanffy growth parameters; asymptotic carapace length (CL_∞, in mm) and the rate at which the asymptotic length was attained (K, in y^{-1}). The Ford (1933)-Walford (1946) equation was applied as follows:

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

Where L_t and L_{t+1} are the total length of the shrimp at age t and t+1 respectively. By plotting L_t against L_{t+1}, the resulting slope $b = e^{-K}$ and the intercept $a = L_\infty (1 - e^{-K})$.

Total mortality (Z) was estimated using the length converted catch curve (Pauly, 1983) while natural mortality (M) was calculated by applying Pauly's (1980) formula using SST (annual mean sea surface temperature) that equals 26^{o}c. The fishing mortality (F) was computed as F = Z – M and the exploitation rate was computed from the rate F/Z (Gulland, 1971). The relative yield per recruit analysis as the most appropriate tool for the shortage of data was done to evaluate the stock status of this species.

The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the Beverton and Holt model (1966) as modified by Pauly and Soriano (1986).

3. RESULTS AND DISCUSSION

3.1 Size structure

The monthly CL distribution of *P. semisulcatus* is shown in Fig. 2. In September, the CL of males ranged from 20 mm to 55 mm with an average of 33.67±3.04 mm, while that of females varied from 21 to 56 mm, with an average of 40.03±2.13 mm. For pooled data, the CL range was 20-56 mm, with an average of 36.12±1.11 mm. In October, the CL of both males and females *P. semisulcatus* showed an increase in the minimum value and a slight decrease in the maximum CL (range 29-51 mm, average 39.1±4.27 mm CL).

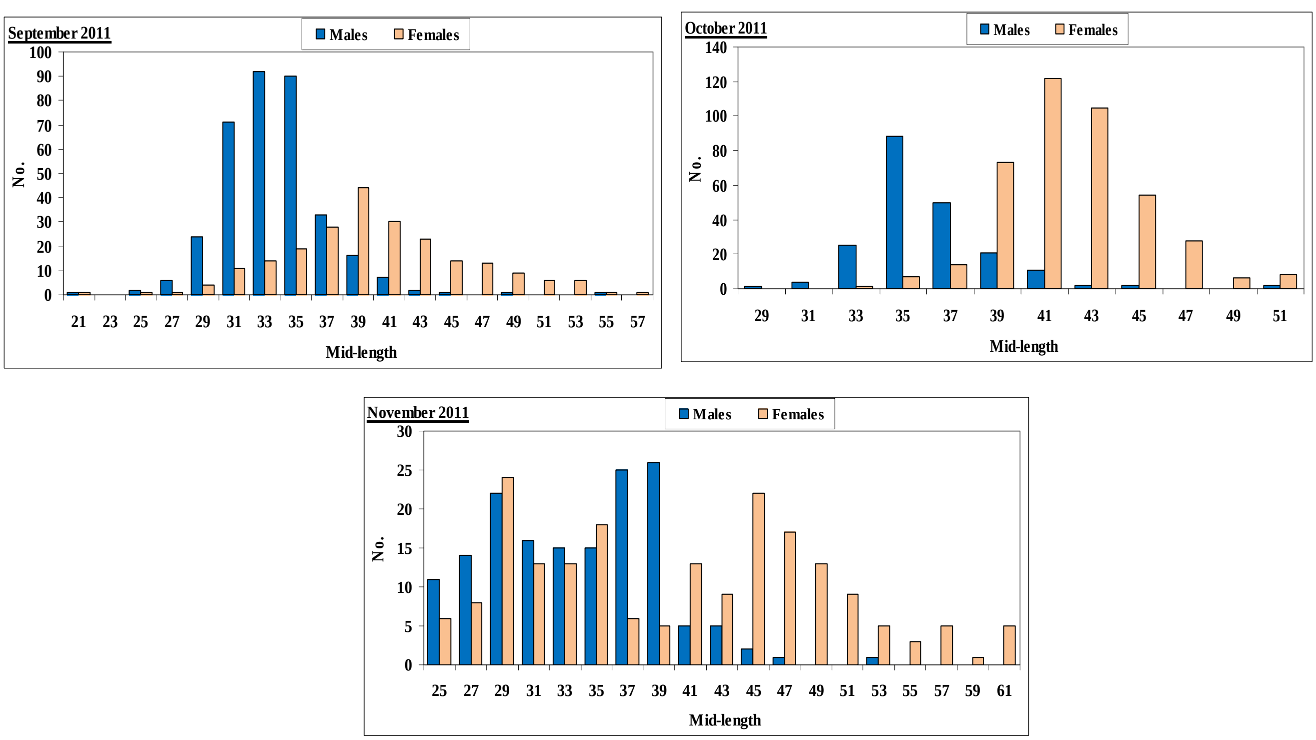

Fig. 2: Monthly carapace length frequency of *P. semisulcatus* from Mahout Area.

In November, the distributed sizes covered a wide range from 24 to 61mm with an average of 37.65±1.26 mm CL. The annual CL distribution showed that a total of 1550 specimens of *P. semisulcatus* with sizes from 20 to 61mm and an average value of 37.72±1.71 mm were collected during 2011 (Fig. 3).

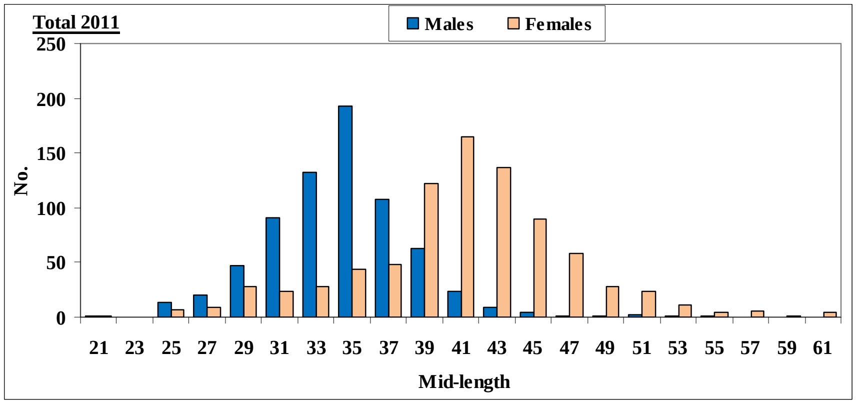

Fig. 3: Annual carapace length distribution of *P. semisulcatus* from Mahout Area.

One way ANOVA analysis showed that, there is a significant difference in the size structure of males and females of *P. semisulcatus* in the three months; September, October and November ($p<0.01$) showing a sexual dimorphism, where females attain larger sizes than males.

3.2 Sex ratio

The sex composition of the green tiger shrimp showed a predominance of females, where out of the total 1550 individuals examined, 711 (46%) were males and 839 (54%) females. The *P. semisulcatus* sex composition in cast nets samples varied monthly, where it was 61% males: 39% females in September, 33%:67% in October and 45%:55% in November. The overall ratio of males to females was 1:1.18. Chi-square (χ^2) test for both sexes indicated that the ratio of males to females was not significantly different from the theoretical 1:1 sex ratio.

3.3 Longevity and growth in length

The maximum life span of males *P. semisulcatus* was 15 months and that of females was 18 months. These accords agreement with the fact that penaeid shrimp are characterized by a short life span in the order of two years (Garcia and Le Reste, 1981). They also agree with the findings of Thomas (1975); Garcia and Van Zalinge (1982); Tom *et al.* (1984); Somers and Kirkwood (1991); Morgan (1995); Mehanna (2000); Siddeek *et al.* (2001) and Villarta *et al.* (2006). The mean lengths for cohorts estimated by the Bhattacharya method for males and females were illustrated in Fig. 4, with the growth increment in length. Both males and females attain their highest rate of increase in length during the first three months of life, after which a gradual decline in growth increment was noticed with further increase in age. It was also apparent that females have a higher growth rate than males. The same results were observed for all penaeid shrimp studied before (Mohamed *et al*., 1978; Van Zalinge *et al*., 1981; Garcia, 1984 & 1985; Mehanna, 1993 & 2003; Mehanna & Khalifa, 2007; Mehanna & El-Gammal, 2008).

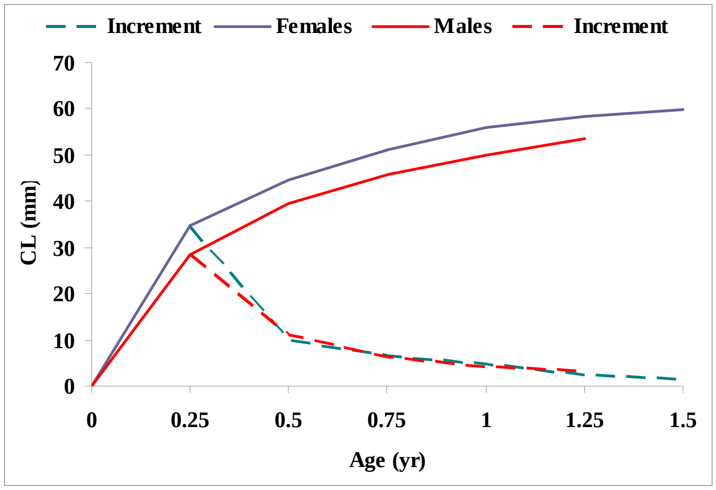

Fig. 4: Length at age and growth increment of *P. semisulcatus* from Mahout Area

3.4 Population Parameters

P. semisulcatus males attained K value of 1.8 y^{-1} and CL_∞ of 58.16 mm, while females attained K = 1.69 y^{-1} and CL_∞ of 63.59 mm. The estimates of growth parameters of the present shrimp were in agreement with the short longevity of other species (Beverton and Holt, 1957 and Garcia and Le Reste, 1981). Also, the values obtained were consistent with those reported in other studies for the same species, where $L\infty$ ranged from 38.1 to 62.2 mm CL and K ranged from 0.7 to 3.17 (Dall *et al.*, 1990; Xucai and Mohammed, 1996; Siddeek *et al.*, 2001; Mehanna, 2000; Ye *et al.*, 2003; Villarta *et al.*, 2006). The wide variation in the growth parameter estimates may be due to crude earlier estimates, different observed maximum size, different environments and/or sex related growth differences.

3.5 Mortality and exploitation rate

The results (Fig. 5) indicated that the total mortality coefficient differs between the two sexes (Z = 7.84 yr^{-1} for males and 9.67 yr^{-1} for females). These high values of Z are acceptable, since most of penaeid fisheries around the world have high fishing mortalities, reaching 9.2 for males and 8.8 for females in Kuwait (Jones and Van Zalinge, 1981) but 6.7 for combined sexes in Kuwait (Van Zalinge *et al.* 1981), and reached 8.18 for males and 6.77 for females in the Red Sea (Mehanna, 2000), but 3.61 for males and 5.65 for females in Philippines (Villarta *et al.*, 2006). The obtained values of M were 2.11 and 2.39 yr^{-1} for males and females respectively. These values lie within the range reported by Garcia and LeReste (1981). They stated that for penaeid shrimp with a maximum life span of two years, the natural mortality should be within the range of 2 to 3. Both the fishing mortality and exploitation rates showed an increasing trend, indicating an overexploitation condition as the F values were 5.73 yr^{-1} for males and 7.28 yr^{-1} for females, while the exploitation rate was estimated as 0.73 for males and 0.75 for females. In the present study, F was higher than the values of F_{opt} given by Gulland (1971) and Pauly (1987), indicating a high level of exploitation of the *P. semisulcatus* stock in the Arabian Sea.

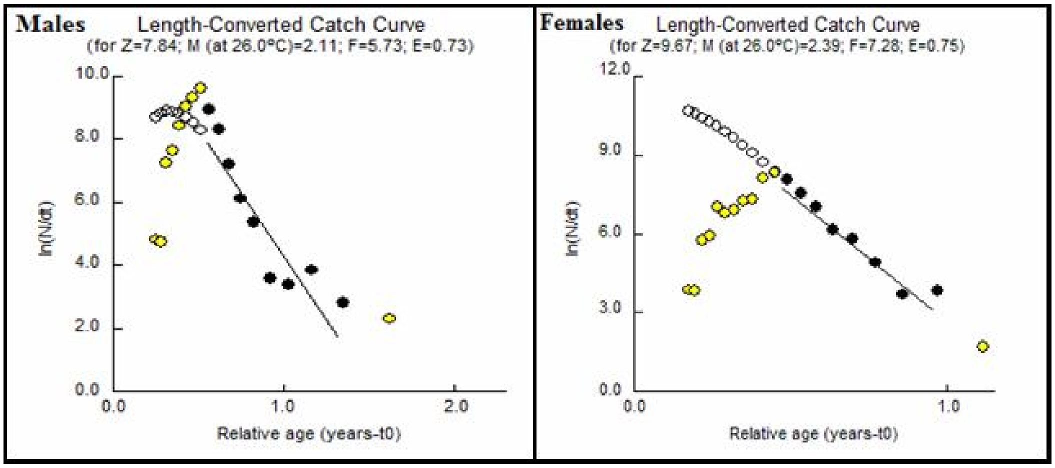

Fig. 5: Converted catch curve of *P. semisulcatus* from Mahout Area.

3.6 Length and age at first capture L_c

The length at first capture (the length at which 50% of the present shrimp at that size are vulnerable to capture) was estimated as 28.75 and 34.8 mm CL for males and females respectively (Fig. 6). The corresponding age was around three months for both sexes.

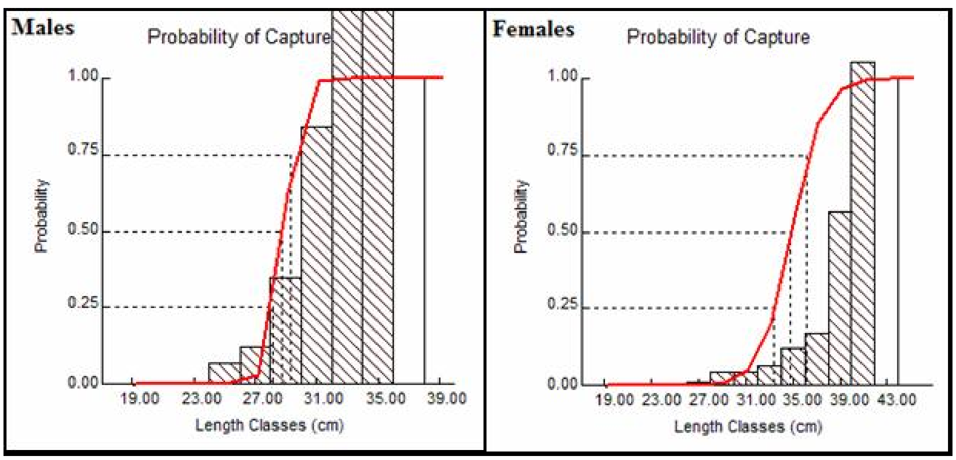

Fig. 6: Probability of capture of *P. semisulcatus* from Mahout Area

3.7 Relative yield per recruit analysis

The use of yield-per-recruit models may be particularly restrictive for fast growing tropical species with high rates of natural mortality because the curves may not reach a maximum within a reasonable range of fishing mortality values (Gayanilo and Pauly, 1997).

Since management recommendations were taken for both sexes, the input parameters used in the Beverton & Holt (1966) model were the growth and mortality parameters of the sexes combined. These parameters were: CL_∞ = 64.09 mm, K= 1.54/yr, M = 1.85/yr, F = 5.66/yr, E = 0.75, CL_c = 33.9 mm. The plot of relative yield per recruit (Y/R)' and biomass per recruit (B/R)' against exploitation rate (E) for pooled data of the green tiger shrimp (Fig. 7) show that the maximum (Y/R)' was obtained at E_{max} = 0.71, which is lower than the current level of exploitation. Both of $E_{0.1}$ (the level of exploitation at which the marginal increase in yield per recruit reaches 1/10 of the marginal increase computed at a very low value of E) and $E_{0.5}$ (the exploitation level which will result in a reduction of the unexploited biomass by 50%) were estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$ were 0.62 and 0.37, respectively. The results indicated that the present level of E was higher than that which gives the maximum (Y/R)'. The (B/R)' analysis showed that, the present level of exploitation was higher than the exploitation rate ($E_{0.5}$) which maintains 50% of the stock biomass. For management purpose, the exploitation rate of *P. semisulcatus* should be reduced from 0.7 to 0.37 (about half their current value) to maintain a sufficient spawning biomass, since of the maximum (Y/R)' is not the target point but the maximum constant yield (the maximum constant catch that is estimated to be sustainable, with an acceptable level of risk, at all probable future levels of biomass) is the target reference point in fisheries assessment (Sissenwine, 1978; Smith *et al.*, 1993; Caddy and Mahon, 1995; Sinclair *et al.*, 1996). Besides, it is always safe to be on the left of the maximum (Y/R)' than to use its current value. This could be achieved by reducing fishing effort exerted on shrimp fishery (number of fishing boats, number of fishing days, number of landings or number of hours trawling). Also, nursery grounds should be identified and protected from illegal fishing and destructive fishing techniques.

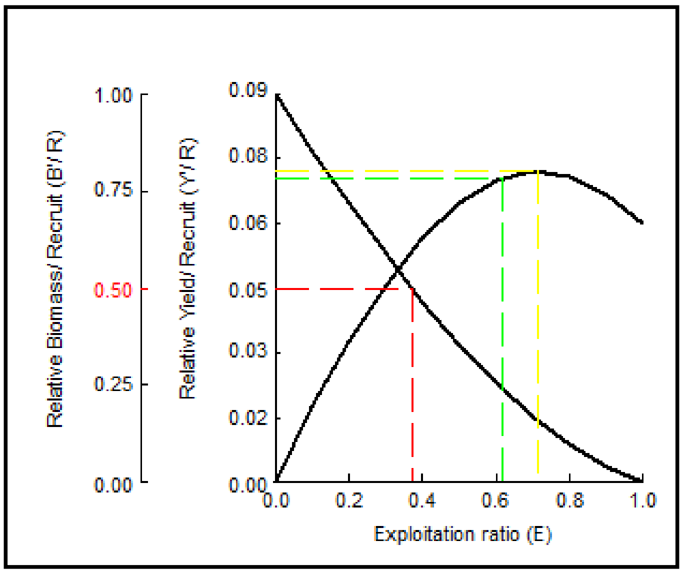

Fig. 7: Relative yield per recruit analysis of *P. semisulcatus* from Mahout Area

4. ACKNOWLEDGEMENT

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