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Population Dynamics of *Penaeus semisulcatus* in the Gulf of Suez, Egypt

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Abstract

Monthly length frequency data of *Penaeus semisulcatus* were analyzed to determine the age, growth, mortality rates and yield per recruit. The maximum life span of *P. semisulcatus* was found to be 15 months for males and 18 months for females. The asymptotic total length was estimated to be 22.4 cm for males and 26.8 cm for females. The growth parameter K was calculated as 1.77 $year^{-1}$ for males and 1.56 $year^{-1}$ for females. The total mortality coefficient Z, was estimated to be 8.18 for males and 6.77 for females. The natural mortality coefficient was estimated to be 2.52 for males and 2.40 for females. Yield per recruit (Y/R) analysis indicated that a high value of Y/R can be obtained at high values of fishing mortality but this may not be biologically appropriate.

Introduction

The Gulf of Suez is one of the most productive fishing grounds in Egypt. It contains a large variety of the economically important fish and crustacean species of which the penaeid shrimp are the most important. The penaeid shrimp catch in the Gulf of Suez is sorted into two categories: large shrimp and small shrimp. The large shrimp category consists of three species *Penaeus semisulcatus, P. japonicus* and *P. latisulcatus,* which constitute about 12% of the total trawl catch. This provides more than 40% of the gross revenue of the trawl fishery. Due to the high price of shrimp and strong demand in the local market, a rapid increase in the fishing effort has occurred in the trawl fishery. This increased fishing effort had already affected the total trawl production and consequently the shrimp production (Fig. 1).

Although the penaeid shrimp greatly contributes to the economy of Egypt, only limited studies of these species are available. The only previous work dealing with the dynamics of penaeid shrimp in the Gulf of Suez is that of Mehanna (1993) who studied the fishery statistics, age, growth, mortality and survival rates, exploitation rates, maximum sustainable yield and yield per recruit of *Penaeus japonicus* in the Gulf of Suez.

Several studies of this species have been undertaken in localities other than Egypt: Jones and Van Zalinge (1979); Van Zalinge et al. (1981); Garcia and Le Reste (1981); Mathews and Al-Hossaini (1982); Garcia (1983 1985 and 1989); Kirkwood and Somers (1984 and 1991). The present study is the first attempt to estimate the basic parameters needed for the management of *P. semisulcatus* in the Gulf of Suez.

Materials and Methods

Materials

Monthly samples of large shrimp were collected from the commercial catch of trawl fishery in the Gulf of Suez during the fishing season 1997/ 1998. The shrimp in the samples were identified into species. The samples of *P. semisulcatus* were separated by sex and the following measurements were taken: total length to the nearest millimeter and total weight to the nearest tenth of a gram. The length data were grouped into 0.5 cm classes.

The length frequency data of *P. semisulcatus* collected during the first three months at the beginning of the fishing season (October, November and December) were used to construct the growth curve function. The

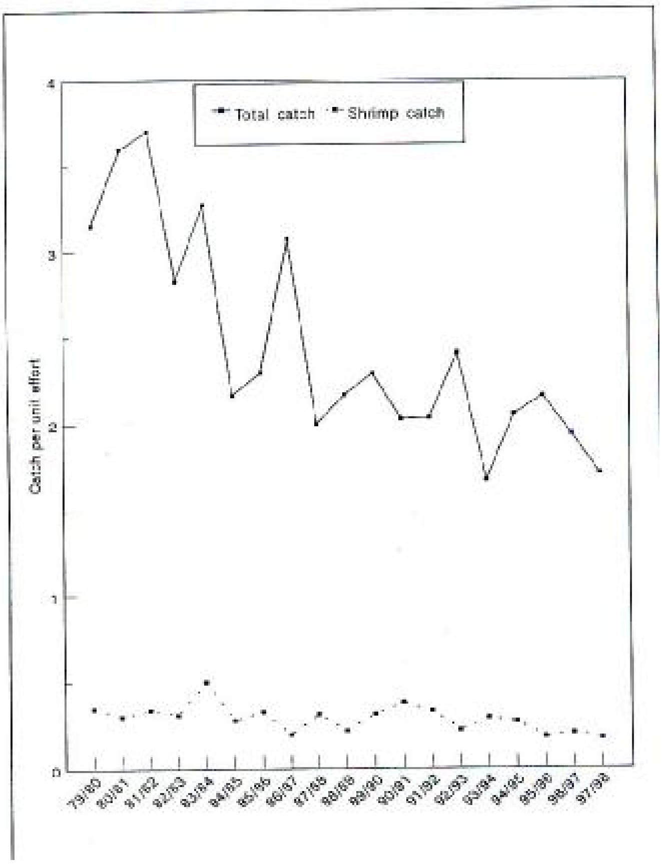

Fig. 1. Catch per unit of fishing effort (ton/landing) of total catch and shrimp catch from the Gulf of Suez during the fishing seasons from 1979/80to 1997/98.

length-frequency data can be considered as representative samples of shrimp stock in the Gulf of Suez due to the relatively high abundance of shrimp stock during these months. These length frequency data are repeated along the time axis (quarter year) until a single stabilized curve interconnected most of the peaks (Figs. 2 and 3).

Methods

Age was determined using the integrated method of Pauly (1983). The length-weight relationship was computed using the power equation:

$$W = a L^b$$

where W is the total weight, L is the total length and a and b are constants whose values were estimated by means of least square method. The length and weight measurements of 566 males and 620 females were used for the

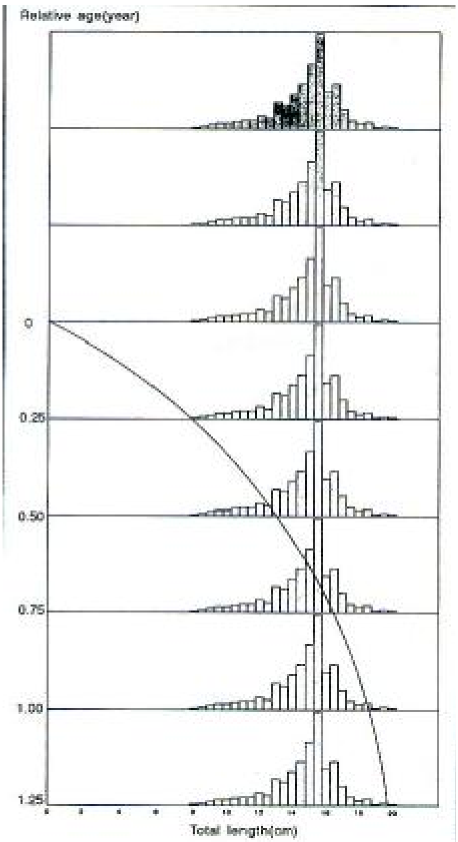

Fig. 2. Longevity of *Penaeus semisulcatus* (male) from the Gulf of Suez.

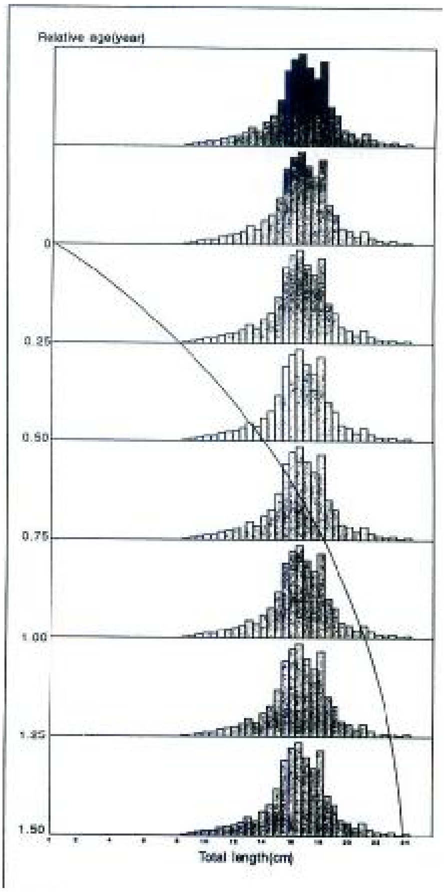

Fig. 3. Longevity of *Penaeus semisulcatus* (female) from the Gulf of Suez.

estimation of length-weight relationship of *P. semisulcatus* from the Gulf of Suez.

The weights at the end of each quarter year of life for males and females of *P. semisulcatus* were estimated by applying the corresponding length- weight relationship to the estimated lengths.

The von Bertalanffy growth parameters (L_∞ and K) were estimated using the Ford (1933)-Walford (1946) plot 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 an intercept $a = L_\infty (1 - e^{-K})$. The theoretical age at length zero (t_o) was estimated by the equation:

$$t_o = t + 1/K \ln\{(L_\infty - L_t) / L_8\}$$

where L_t is the length at age t.

The basic age-length data obtained by means of the integrated method were used to study the growth patterns of the male and female *P. semisulcatus*.

The total mortality coefficient (Z) was estimated from the cumulated catch curve (Jones and Van Zalinge 1981). This method is based on the existence of a linear relationship (over at least the central part of its range) between the natural logarithms of the cumulated frequency and the natural logarithms of (L_∞ - L). This relationship can be expressed as follows:

$$\ln(CN) = a + (Z / K) \ln (L_\infty - L)$$

where ln(CN) is the natural logarithm of cumulated frequency, Z is the total mortality coefficient and K is the growth coefficient.

The natural mortality coefficient (M) was calculated using Pauly's (1980) formula as follows:

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

where T is the annual mean temperature of the water in which the stock lives.

The fishing mortality coefficient (F) was computed as F = Z - M while the exploitation rate was computed from the ratio F/Z.

Yield per recruit of *P. semisulcatus* (combined sexes) was estimated using the model of Beverton and Holt (1957) as follows:

$$Y/R = F e^{-M (Tc - Tr)} W_\infty [1/Z - 3S/ Z+K + 3S^2 / Z+ 2K - S^3/ Z + 3K]$$

where $S = e^{-K\,(Tc\,-\,to)}$
K = von Bertalanffy growth parameter
T_c = age at first capture
T_r = age at recruitment
t_o = age at which the length is nil
W_∞ = asymptotic body weight
F = fishing mortality coefficient
M = natural mortality coefficient
Z = total mortality coefficient

Results

Longevity

The results obtained indicated that the maximum life span of males is 15 months while that of females is 18 months.

Growth in length

The modal lengths corresponding to the various ages for males and females of *P. semisulcatus* are given in table 1. The results show that both males and females attain their highest rate of increase in length during the first three months of life after which a gradual decrease in growth increment was noticed with further increase in age. It was also apparent that females have a higher growth rate than males.

Length - weight relationship

The total length of males varied between 8 and 20.2 cm while their weights ranged between 6 and 69 g. The total length of females ranged between 8.5 and 24.4 cm while their weights varied between 5 and 136 g. The weight-length equations obtained were as follows:

Males $W = 0.00665\ L^{3.06803}$
Females $W = 0.00644\ L^{3.09221}$
Combined sexes $W = 0.00654\ L^{3.07522}$

Table 1. Estimated age and total length (cm) of *Penaeus semisulcatus* in the Gulf of Suez.

Age (year)	Estimated total length at the end of each quarter year		
	Males	Females	Sexes combined
0.25	7.9	8.2	8.1
0.50	13.0	14.1	4.2
0.75	16.5	18.3	18.8
1.00	18.8	21.2	21.8
1.25	19.9	23.1	23.5
1.50	—-	24.1	24.2

Growth in weight

The growth in weight for both males and females is much slower during the first three months of life, while the seasonal increment in weight increases with further increase in age and reaches its maximum value at the age of nine months for males and one year for females, after which a gradual decrease was noticed (Table 2). It is evident that after the first three months of life, females show a higher growth rate than males.

Growth parameters

The values of K obtained were 1.77 for males and 1.56 for females while L_∞ = 22.42 cm is the total length for males and 26.84 cm is the total length for females. The results indicated that K for males is higher than that for females indicating the faster decrease in growth rates of males, i.e. males reach their asymptotic length faster than females.

Estimation of t_0

The estimated values of t_0 were - 0.001 for males and - 0.012 for females.

Total mortality coefficient z

The results (Figs. 4 and 5) indicate that the total mortality coefficient Z, differed markedly between sexes and was estimated as 8.18 for males and 6.77 for females.

Natural mortality coefficient m

The values of M obtained were 2.52 for males and 2.20 for females.

Fishing mortality coefficient F

Using the relationship Z = M + F, the values obtained for F were 5.66 for males and 4.57 for females.

Table 2. Estimated age and total weight (g) of *Penaeus semisulcatus* in the Gulf of Suez.

Age (year)	Estimated total length at the end of each quarter year		
	Males	Females	Sexes combined
0.25	3.77	4.31	4.07
0.50	17.39	23.04	22.86
0.75	36.15	51.60	54.19
1.00	53.95	81.32	85.43
1.25	64.23	106.04	107.62
1.50	—-	120.88	117.79

Exploitation rate E

The exploitation rate of males was estimated to be 0.69 while that of females was estimated to be 0.68.

Yield per recruit Y/R

The following parameter values were used:

L_∞	=	26.61 cm total length
K	=	1.69 $year^{-1}$
W_∞	=	157.86 gram
M	=	2.33
F	=	variable
T_r	=	0.21 year (the age at recruitment)
t_0	=	- 0.028 year
T_c	=	variable (the age at first capture)

The two parameters F and T_c can be controlled by fishery managers because F is proportional to the fishing effort and T_c is a function of the gear selectivity.

The estimation of yield per recruit shows that the present value of fishing mortality (F = 5.45) and age at first capture (T_c = 0.44 year) give a Y/R of 16.61 g and increasing the F - value to seven would give a higher Y/R (16.72 g).

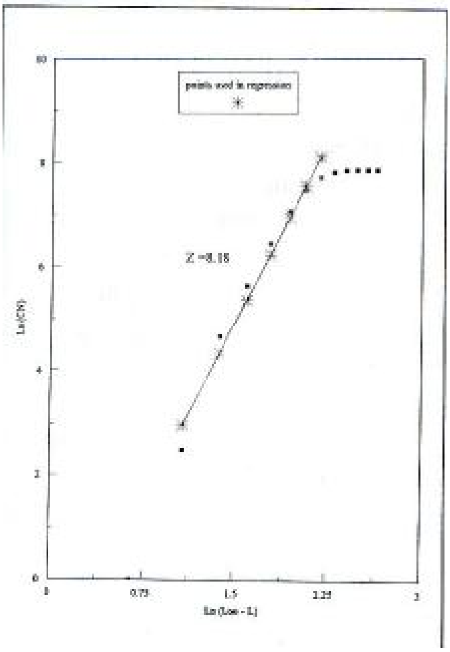

Fig. 4. Estimation of total mortality coefficient "Z" of *Penaeus semisulcatus* (males) from the Gulf of Suez using Jones and Van Zalinge's (1981) method.

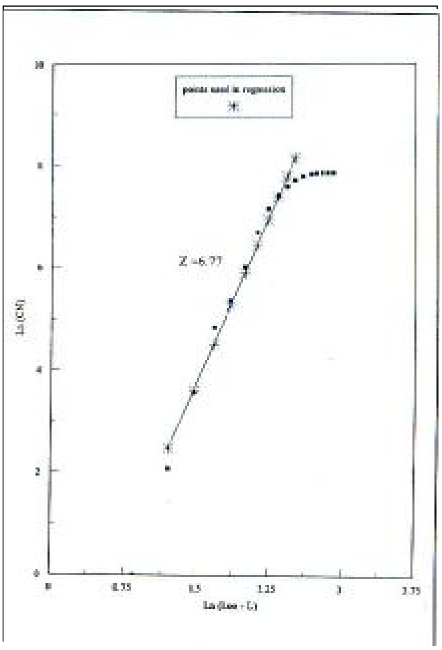

Fig. 5. Estimation of total mortality coefficient "Z" of *Penaeus semisulcatus* (females) from the Gulf of Suez using Jones and Van Zalinge's (1981) method.

Discussion

Age determination and consequently the estimation of the growth rate of shrimp has many difficulties because there are no direct methods for this purpose. Further, shrimp often show an extended reproduction period which makes it difficult to use polymodal length frequency curve analysis to separate the age groups from the modes of the curves. It is well known that age can be determined indirectly using standard statistical methods that allow conversion of length frequency data into age groups, but these methods are often fraught with uncertainties because they are subjective in the sense that several options are available for attributing ages to the various age groups or because of interconnecting peaks. Pauly (1983) has developed an integrated method to overcome these uncertainties by drawing a growth curve directly upon the length frequency samples sequentially arranged in time or onto the same sample repeated along the time axis.

In the present study, the method of Pauly was used for age determination and consequently for the estimation of length-at-age of *P. semisulcatus* in the Gulf of Suez. The results dealing with the life span of *P. semisulcatus* obtained by applying the integrated method of Pauly show agreement with the fact that penaeid shrimp are characterised by a short life span in the order of two years. The results also agree with the findings of Thomas (1975); Garcia and Van Zalinge (1982); Tom et al. (1984) and Somers and Kirkwood (1991).

It was found that both males and females attain their highest growth rate during the first three months of life where males attain 7.9 cm total length for samples collected during the period of study while females attain 8.2 cm total length. After these three months the increment in length gradually decreased with further increase in age. The results obtained also indicate that females are characterised by a higher growth rate than males. These results are in close agreement with those of Garcia's (1985). He pointed out that the typical *Penaeus* spawns at the sea and enters the inshore waters at an age of about three weeks to one month as a postlarva. Here it grows for about three months before migrating back to the sea. It is then about four months old and 80 to 100 mm in total length.

Imai (1977) reported that the growth rate of young and immature shrimp is much higher than that of adults, and for the latter the growth rate of females is higher than that of males. Mohamed et al. (1981) found that the growth rates of both males and females of *P. semisulcatus* in Kuwait are nearly the same during the first three months of life after which the females are characterised by a higher growth rate than males.

The rapid growth of *P. semisulcatus* implied by K = 1.77 and L_∞ = 22.42 cm for males and K= 1.56 and L_∞ = 26.84 cm for females agrees with the fact that short-lived animals like shrimp reach their asymptotic length in a year or two and are characterised by a high K - value (Beverton and Holt 1957 and Garcia and Le Reste 1981). The results obtained are also in agreement with those reported by other workers (Table 3).

The estimated values of Z (8.18 for males and 6.77 for females) using the cumulated catch curve of Jones and Van Zalinge (1981) appear to be within the acceptable range. Most of the penaeid fisheries around the world have high fishing mortalities and thus show high Z values e.g., Z = 9.2 for males and 8.8 for females in Kuwait (Jones and Van Zalinge 1981) and Z = 6.7 for combined sexes in Kuwait (Van Zalinge et al. 1981).

The values for M of 2.52 for males and 2.20 for females are within the range given by Garcia and Le Reste (1981). They stated that for the penaeid shrimp with a maximum life span of two years, the natural mortality should be within the range of 2 to 3. Beverton and Holt (1959) found that fish of high growth rates have high values of natural mortality; this is also observed in shrimp populations.

The values of both fishing mortality and exploitation rates are relatively high indicating a high level of exploitation. However, the increase in fishing mortality by about 28% would be associated with a negligable increase in yield per recruit of the order of 0.006%. This result is in agreement with the finding of Garcia (1985) who pointed out that because of the values characteristic of penaeids for natural mortality (M), growth rate (K) critical length (L_c) and asymptotic length (L_∞), the yield per recruit (Y/R) increases exponentially towards a quassi asymptot with increasing fishing mortality and the maximum yield per recruit is reached only at an unreasonably high level of fishing mortality. Bowen and Hancock (1985) also believe that the model of Beverton and Holt (1957) have little value in shrimp management due to the short life span of penaeid shrimp as well as their high natural mortality coefficient.

To determine the most appropriate age at first capture T_c of *P. semisulcatus* which is closely related to the estimation of the optimum mesh size, the Y/R was calculated by applying different values of "T_c" (Fig. 6). The results obtained indicated that the maximum yield per recruit

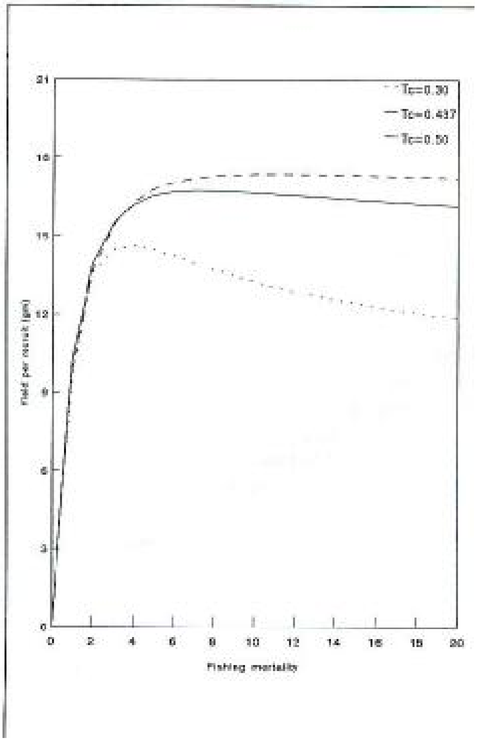

Fig. 6. Yield per recruit of *Penaeus semisulcatus* as a function of fishing mortality and age at first capture.

Table 3. Summary of the growth parameter (K) available for *Penaeus semisulcatus.*

Author	K		Locality
	Females	Males	
Van Zalinge et al. 1981	1.44	2.15	Kuwait
Mathews and Al-Hossaini 1982	1.12	2.0	Kuwait
Kirkwood and Somers 1984	1.25	3.07	Gulf of Carpentaria
Somers et al. 1991	2.24	3.22	Gulf of Carpentaria

increases with increase of both T_c and F but increasing F to such high level is not biologically appropriate.

From these results, it is most likely that the shrimp stocks in the Gulf of Suez are in a situation of economic over-fishing and that the savings from reduced fishing effort would be much greater than any revenue that was forgone. In fact, if average shrimp size should increase with reduced F, revenues could increase if fishing effort was reduced.

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