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BIOLOGY AND FISHERY OF THE GREEN TIGER PRAWN *PENAEUS SEMISULCATUS* DE HAAN (1850) IN BARDAWIL LAGOON, NORTHERN SINAI, EGYPT.

MOHAMED HAMED YASSIEN
National Institute of Oceanography and Fisheries

Key words: *Bardawil lagoon, Penaeus semisulcatus, Fishery, Biology.*

ABSTRACT

The prawn production in Bardawil Lagoon started with the beginning of the fishing season 1994. It expanded rapidly since 1995 with the increase of the prawn abundance in the lagoon. The annual prawn catch showed an average increase of 98.7 ton per year. *Penaeus semisulcatus* is the most economic species in the lagoon because its relatively large sizes and high prices, it represents about 25% of the total prawn production in the lagoon. Sex ratio of males to females showed that females predominated in the catch. The species is characterized by fast growth, attains 16.5 cm and 18.9 cm in total length after 18 and 24 months for males and females respectively. The estimated von Bertalanffy growth parameters are L_∞= 19.721 cm, K = 1.104 y^{-1} and t_o = -0.230 years for males and L_∞ = 22.149 cm, K = 1.004 y^{-1} and t_o = 0.0018 years for females. The exploitation ratio (E=F/Z) was calculated as E = 0.735 for males and E = 0.713 for females which is higher than that associated with the maximum relative yield per recruit. The study recommended that the fishing pressure exerted in the Bardawil lagoon must be reduced by about 20-25% of its current value to achieve the maximum yield per recruit.

INTODUCTION

Penaeid prawns are considered recently as one of the most valuable fishery resources in Bardawil Lagoon. The prawn production was started with the beginning of the fishing season 1994, where it was represented by about 1.83 ton (0.12%) of the total production of the Lagoon (GADFR 2002). Then it markedly increased in the following years, where they attained 814 tons (26.4% of the total lagoon production) during 2002. Prawn production contributed about 29.1% of the total lagoon income (8 millions Egyptian Pounds) in 2002. The species composition of prawn catch in Bardawil Lagoon is represented by *Metapenaeus stebbingi* Nobili 1904, *Penaeus japonicus Bate 1888, Penaeus semisulcatus De Haan 1850, Metapenaeus monoceros* Fabricius 1798 and *Penaeus kerathurus* Forskal 1775. *M. stebbingi* is the most abundant species followed by *P. semisulcatus,* which is considered the most economic penaeid species in the lagoon due its relatively large sizes and high prices.

In Bardawil lagoon, the studies on the fishery and biology of penaeid species are very scarce. Emeran (2004) studied the fishery of crustaceans *Metapenaeus stebbingi* and *Portunus pelagicus*. The only previous work dealing with the life cycle and longevity of *P. semisulcatus* was that of Tom *et al.* (1984).

On the other hand, the biology and population dynamics of this species were the subject of many studies in other Egyptian waters (Yassien, 1992; Abdel-Razek *et al*, 1993; Ezzat *et al*, 1993; Abdel-Razek & Taha, 2001). The species was the subject of

intensive investigations in the Indo-Pacific (El-Musa, 1982; Kirkwood & Somers, 1984; Al-Sayes and Al-Khayat, 1986; Somers & Kirkwood, 1991; Mathews *et al*, 1994; Seddeek *et al,* 1994; Xu *et al*, 1995; Ye and Mohammed, 1999). The present work is the first attempt to study the fishery and population structure of *P. semisulcatus* in Bardawil lagoon.

MATERIAL AND METHODS

Study area

Bardawil lagoon is located in the north of the Sinai Peninsula, bordered northerly by the Mediterranean Sea and southerly by Sinai desert (Fig 1). It is approximately 75 Km long and 22 Km across at its widest point, extending from 31° 03` N to 31° 14` N and 32° 40` E to 33° 30` E, and covers an area of approximately 595 km^2. The lake is extremely shallow and the water depth never exceeds 3m. Sand-bar measuring 300 m – 1 Km wide, separates the lake from the Mediterranean Sea. Three opening (Boughaz) connect the lagoon to the sea. Two of these; the western Boughaz I and the Middle Eastern Boughaz II, are man-made, while the third one the eastern Boughaz III at El Zaranik is natural. Sea water enters mostly through Boughaz I while the others are mainly outlets from the lagoon (Variy, 1990). The bottom of the lagoon is sandy along its shores, silt-muddy in the deepest part. The rest of the area is composed of muddy-sandy substrate (Tom *et al.* 1984). The salinity is 45 to 55 ppt and the water temperature ranges from 12.7° C in January to 30.5° C in June (Pisanty, 1981). The fishery is seasonal, starts from the beginning of May to the end of December.

Collection of Data

Monthly random samples of *Penaeus semisulcatus* were collected from the commercial catch of the main landing site (El-Telul) in Bardawil Lagoon during the fishing season 1999. The data were based on prawn samples caught by small scale gear called trawling or locally called (Kalsa) operating in the lagoon. Each sample was sorted according to sex and the frequency distribution of each sex was carried out. A total of 1663 individuals were measured, for total length (TL), from the tip of the rostrum to the end of the telson with the abdomen fully stretched to the nearest mm; and total weight to the nearest 0.1 gm. A subsample of 546 individuals was measured for carapace length (CL), from the tip of the rostrum to the posterior mid-dorsal edge of the carapace and body length (BL), from the mid-dorsal line, opposite the posterior orbital margin to the end of the telson to the nearest millimeter.

The data of catch and effort statistics were obtained from the office of the General Authority for the Development Fish Resources (GADFR).

Data analysis

For each sex, the total length-total weight; carapace length-total weight and body length-total weight relationships were calculated, following a logarithmic transformation for the exponential regression formula:

$$W = a\ L^{b}$$

Where W is the total weight in gm., and L is the length in cm.

The total length-carapace length relationship was estimated from the linear equation of $Y = a + b\ X$, where Y is the carapace length; X is its total length and *a* and *b* are constants. In each relationship the upper and lower 95% confidence limits were estimated to determine whether the growth is isometric or allometric according to Rhoads and Lutz (1980).

The average sex ratio for each month was calculated for the whole size range. The T test (Zar, 1984) was applied to test the significance of any deviation of the sex ratios from 1:1.

The monthly length frequency distributions in 5 mm class intervals for each sex were pooled in seasonal distributions and investigated through the integrated method developed by Pauly (1983). This enabled the identification of the number of age groups and mean lengths that the growth curve could pass through of the different normally

distributed size groups occurring in the seasonal polymodal distributions.

The theoretical growth in length was estimated from the von Bertalanffy (1938) growth formula:

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

Where L_t is the thength of prawn at age t, L_∞ is the asymptotic length; K is the growth coefficient and t_o is the hypothetical age of prawn, which would have at zero length. The corresponding estimates of covariance and standard errors for each growth parameter were estimated by applying the method of least squares (Sparre and Venema, 1998). The reliability of these growth parameters was tested using the Munro's phi prime index Φ (Pauly and Munro, 1984).

Indirect estimate of the natural mortality rate (M) was calculated for each sex following the method proposed by Pauly (1980). The total mortality rate (Z) was estimated from the annual cumulative length frequency distributions through the method of Jones and Van Zalinge (1981). The rate of fishing mortality (F) was extracted as F = Z-M. The exploitation ratio (E) was calculated as equal to the fraction of death caused by fishing E = F/Z.

The relative yield per recruit (Y`/R) and relative biomass per recruit (B`/R) were estimated by applying the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986). The maximum exploitation rate (E_{max}) associated with relative maximum yield per recruit was then estimated, along with $E_{0.1}$, the rate at which the marginal increase of Y`/R is 1/10 of its value at E = 0 and the value of E corresponding to 50% of unexploited B`/R ($E_{0.5}$).

RESULTS

The Fishery

The commercial fisheries for prawns in Bardawil Lagoon began in 1994 by about 1.83 ton. The prawn fishery, conducted by small trawlers, expanded rapidly since 1995 with the increase of the prawn abundance in the lagoon. Landings increased to more than 800 t in 2002 (Fig 2). The monthly catches of prawn during the period from 1994 to 2002 show that the most productive months were those at the beginning of each fishing season, thus more than 80% of the annual prawn catches were landed during the first three months of the season (April, May and June), and then the landings progressively decrease toward the end of the season in December (Fig 3).

The annual prawn catch (Fig 4) showed an overall-increasing tendency. This tendency could be estimated by means of linear fitting of the data in an average increasing trend of 98.7 ton per year, that represent increasing catch of around 25% every year. However, this increment was not constant for the whole period, it being smaller in the first 4 years, and increased in the last five years.

Morphometric measurements

The relationships between the prawn weight and each of the total length, carapace length and body length as well as the relationship between the total length and carapace length (Fig 5) were estimated for each sex separately. The lower and upper 95% confidence limits showed that *P. semisulcatus* growth in total, carapace and body length was different than the total weight. The slops (b) of the regressions were significantly less than 3 (Table 1) indicating allometric growth. On the other hand, the prawn grows in total length at the same proportion as the carapace length, the slops were not significantly different than 1 (Table 1).

Sex ratio

The overall sex ratio of males to females (Fig 6) deviated significantly from the expected ratio of 1:1, (P<0.05). Females predominated in the total catch (1 males: 1.48 females) for most months, except in autumn months (October, November and December) when the sex ratio was not significantly different (P> 0.1, P>0.9, P>0.4 respectively) for the whole size range.

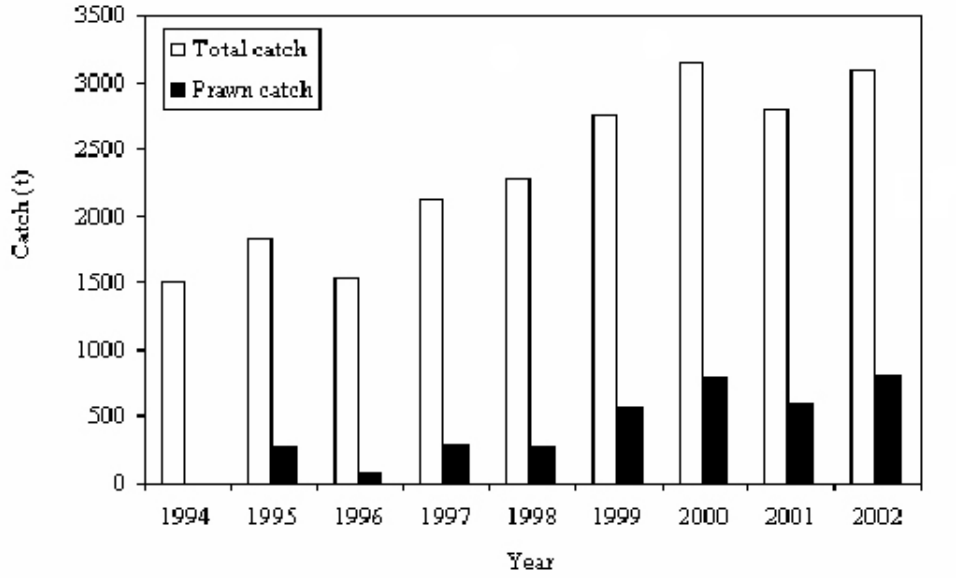

Fig (2): Prawn catch and total Bardawil catch in the period from 1994 to 2002.

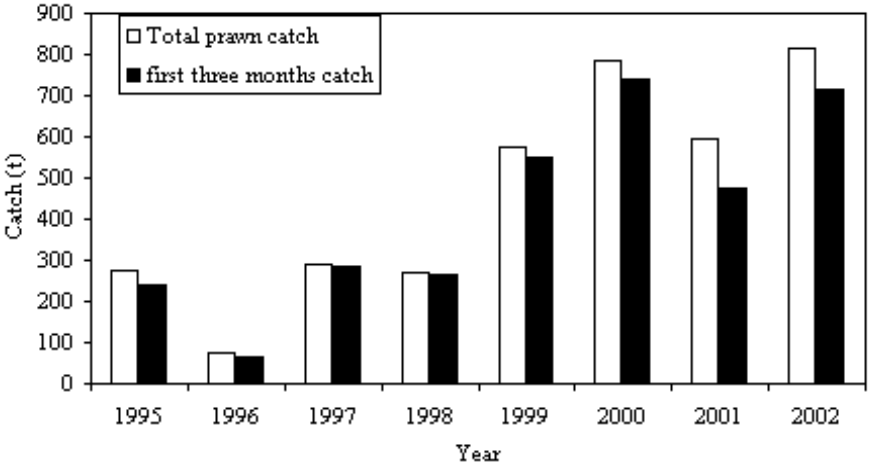

Fig (3): Total prawn catch in bardawil lagoon compared with the prawn catch of the first three months of the season (April, May and June).

Table (1): Summary of the different morphometric relationships for *Penaeus semisulcatus* from Bardawil lagoon.

X	Y	a	b	r2	95% confidence interval	
					Lower	Upper
Males						
Total length	Total weight	0.0125	2.8111	0.9337	2.7194	2.9068
Carapace length	Total weight	0.3321	2.5423	0.8705	2.3841	2.6193
Body length	Total weight	0.0175	2.8524	0.9214	2.6991	3.0056
Total length	Carapace length	0.1115	0.3426	0.9452	0.3177	0.3719
Females						
Total length	Total weight	0.0098	2.9291	0.9632	2.8293	2.9606
Carapace length	Total weight	0.1981	2.9797	0.9687	2.8341	3.0535
Body length	Total weight	0.0174	2.8820	0.9546	2.7938	2.9658
Total length	Carapace length	0.1009	0.3447	0.9825	0.3258	0.3969

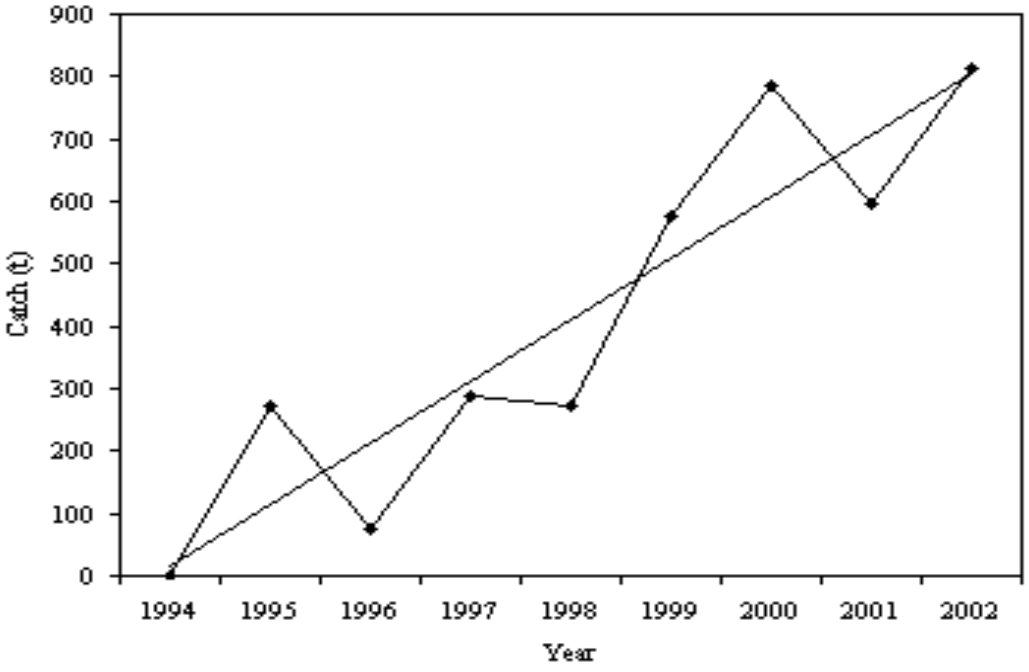

Fig (4): Trend in the catch of prawn from bardawil lagoon in the period from 1994 to 2002.

Females dominated the catch of the small (< 7.5 cm) and large (>13.5) sized individuals (Fig 7).

Age and Growth

Age and growth of *P. semisulcatus* were determined by tracing the progression of modes identified by the growth curve (Pauly, 1983) in the seasonal length frequency distributions repeated along the time axis. The results show that the life span of males is 18 months (Fig 8), while that of females is 24 months (Fig 9). The assigned seasonal modal lengths indicate that the rate of growth of males is about 7.0 mm per month, while that of females is about 7.7 mm per month.

A summary of the estimated von Bertalanffy growth parameters that describe growth in length (L_∞, K, and t_o) and the derived growth performance index (Φ) are presented in Table (2). The estimated growth performance index (Φ) was slightly higher for females with similar sizes.

The von Bertalanffy growth equations for both males and females were described as:

$L_t = 19.721\ (1- e^{-1.104\ (t\ +0.230)})$ for males

$L_t = 22.149\ (1- e^{-1.004\ (t\ -0.018)})$ for females

Table (2): Estimated growth parameters, their standard error and coefficient of variation for *P. semisulcatus* from Bardawil lagoon.

	Estimates	**Standard error**	**Coefficient of variation**
Males			
L_∞	19.721	1.894	0.093
K	1.104	0.067	0.241
t_o	-0.230	0.238	-1.036
Φ	2.056	0.557	0.271
Females			
L_∞	22.149	0.578	0.026
K	1.004	0.018	0.070
t_o	0.018	0.079	1.381
Φ	2.090	0.543	0.260

Mortality rates

The total mortality rates (Z) of *P. semisulcatus* were estimated using the cumulated catch curve (Jones and Van Zalinge, 1981). The slops of the resultant curves (Z/K) differ significantly between sexes (ANCOVA, $P<0.05$). The total mortality corresponding to the slope of the males curve (Fig 10 a) was found to be Z = 7.391 y^{-1} with confidence intervals of 6.744 – 8.038 and the correlation coefficient of the regression line r^2 is 0.9905. The total mortality estimated from females curve (Fig 10 b) was Z = 6.253 y^{-1} with confidence intervals of 5.054 – 7.453 and the correlation coefficient of the regression line r^2 is 0.9645.

The natural mortality (M) was calculated as M = 1.956 y^{-1} for males and M = 1.795 y^{-1} for females. Then the corresponding estimates of the fishing mortality rates were F = 5.435 y^{-1} and F = 4.458 y^{-1} for both sexes respectively.

Exploitation rate

The exploitation ratio (E=F/Z) was calculated as E = 0.735 for males and E = 0.713 for females. According to Gulland (1971) the optimum exploitation ratio E_{opt} = 0.5, this implies that the stock of *P. semisulcatus* in Bardawil Lagoon is heavily exploited and the fishing pressure exerted in the lagoon is very high.

Relative yield per recruit and relative biomass per recruit

Figures (11 a and b) show the results of relative yield per recruit (Y`/R) and relative biomass per recruit (B`/R) analysis for males and females *P. semisulcatus*. The computed optimal exploitation rates for males and females are as follow:

Males	Females
E_{max} = 0.607	E_{max} = 0.565
$E_{0.1}$ = 0.516	$E_{0.1}$ = 0.467
$E_{0.5}$ = 0.328	$E_{0.5}$ = 0.316

These results indicate that the present values of the exploitation ratio E = 0.735 for males and E = 0.713 for females are higher than that associated with the maximum relative yield per recruit (E_{max} = 0.607 and 0.565 for males and females respectively). This means that the fishing pressure exerted in the Bardawil lagoon must be reduced by about 20-25% of its current value to achieve the maximum yield per recruit.

DISCUSSION

The species composition of Bardawil lagoon has markedly changed since the appearance of adult prawns in 1994. The green tiger prawn *Penaeus semisulcatus* is the most economic species in the lagoon because its relatively large sizes (19.5 cm maximum total length) and high prices. This species established an adult population in Bardawil lagoon, formerly the lagoon was considered as a suitable nursery ground for *P. semisulcatus* (Tom *et al*, 1984) where the adult population was found in the eastern Mediterranean. Shlagman (1981) reported that gravid females were found outside the Bardawil lagoon in the Mediterranean throughout the year. Tom *et al,* (1984) followed the entrance of post-larvae into the lagoon through its narrow inlets, they recorded that the largest mean body length (9.5 cm) of an age group caught inside the lagoon was smaller than the smallest mean value recorded for an age group in the open sea.

Recently, *P. semisulcatus* represents about 25% of the total shrimp production; it is caught from all the lagoon depths all over the year.

Growth rates of shrimps were usually determined from monthly size frequency distributions and the movement of the modes (Garcia, 1985). Growth rate of P. semisulcatus in Bardawil Lagoon was determined by tracing the progression of modes identified by the growth curve in the seasonal length frequency distributions repeated along the time axis. Considering these modal lengths as distinct age groups indicate that the species grows to 14.0 cm (males) and 14.2 cm (females) within its first year of life, and then the females attain 18.9 cm at the end of the second year. These results are similar to those recorded by Al-Sayes and Al-Khayat (1986) in Qatari waters and close to those reported by Yassien (1992) in the Gulf of Suez.

The results show that the species is characterized by fast growth, attains 16.5 cm and 18.9 cm in total length (5.8 cm and 6.6 cm carapace length) after 18 and 24 months for males and females respectively. Mathews (1981) reported that some shrimp populations contain up to three year classes but usually penaeid fisheries contain shrimp from 1-2 years of age at most. Garcia (1988) stated that growth of penaeid shrimps are very fast and the maximum size is reached in about 2 to 3 years. Fitting linear regression to the seasonal assigned modal lengths of *P. semisulcatus* from the lagoon gave an estimate of monthly growth rate of 7.1 mm per month for males and 7.7 mm per month for females (3.5 mm and 3.7 mm carapace length per month).

Many studies concerning age and growth of *P. semisulcatus* in different areas of the Indo-Pacific region (Thomas, 1975; El-Musa, 1982; Siva and Ibrahim, 1981; El-Hady, 1988 and Yassien, 1992); estimated a growth rate range from 1.14 to 3.3 mm carapace length per month for males and a range from 1.37 to 7 mm per month for females. The estimated von Bertalanffy growth parameters are very reasonable and in accord with the parameters estimated by El-Hady (1988), Somers and Kirkwood (1991) and Yassien (1992).

Estimates of mortality rates in shrimp species, particularly of natural mortality, are difficult to obtain (Garcia, 1985). However, the high values of the estimated mortality parameters are similar to those of other shallow water, penaeid shrimp, intensively exploited (Edwards, 1978; Pauly *et al,* 1984; Garcia, 1985). The natural mortality of *P. semisulcatus* has been investigated by a number of authors (Mathews *et al,* 1987; Siddeek *et al*, 1989; Yassien, 1992; Xu *et al,* 1995; Mohammed *et al*, 1996; Ye and Mohammed, 1999), their results range from 1.8 to $4.0y^{-1}$. The results of the present study lie in this range.

Yield per recruit assessment techniques have been widely used for penaeid stocks (Garcia, 1985; Penn *et al,* 1989). The preliminary yield per recruit analysis of *P. semisulcatus* in Bardawil lagoon indicates that the stock is overexploited and the exerted effort should be reduced by about 20-25% of its current value to sustain the maximum yield. These results show that utmost caution must be taken in the future fisheries management and that a full assessment of the multispecies resource base should be made.

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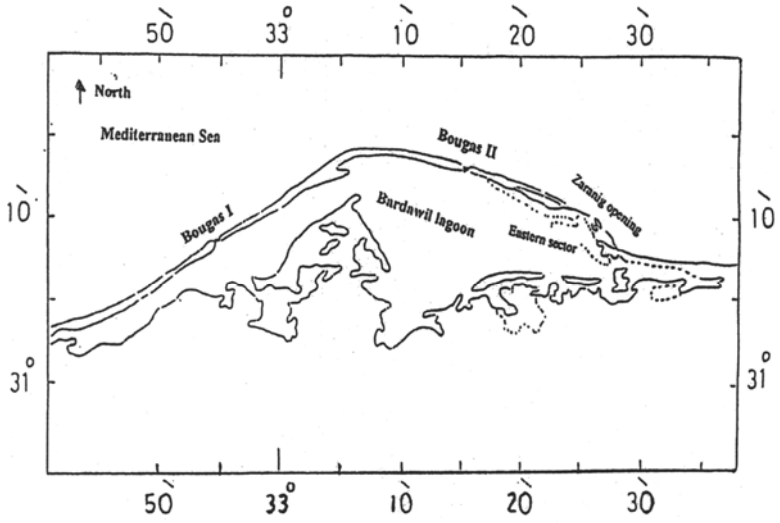

Fig.1: Map of the Bardawil Lagoon.

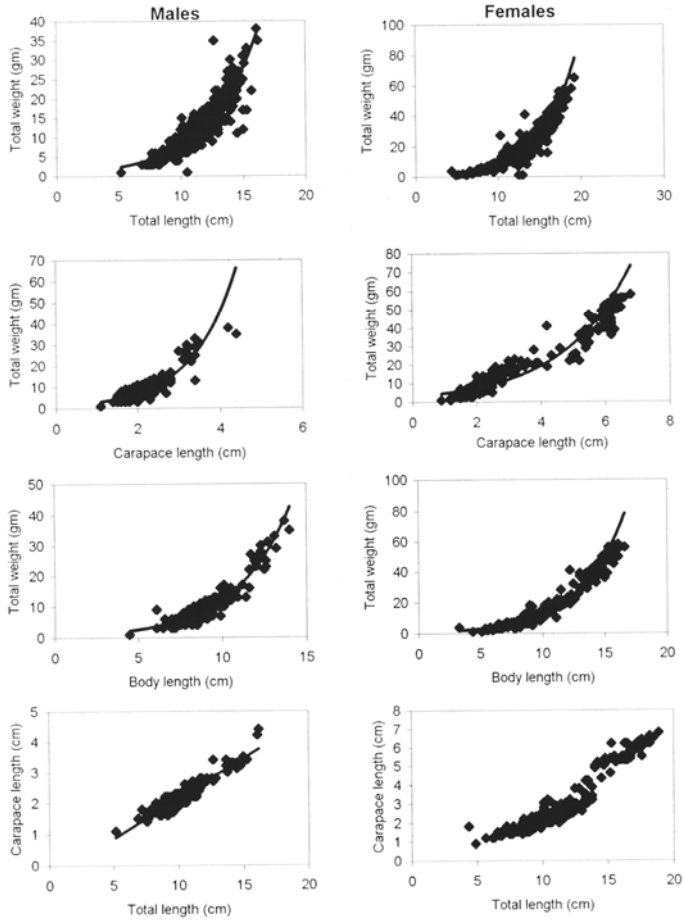

Fig (5) Morphometric relationships of males and females *P. semisulcatus* from Bardawil lagoon.

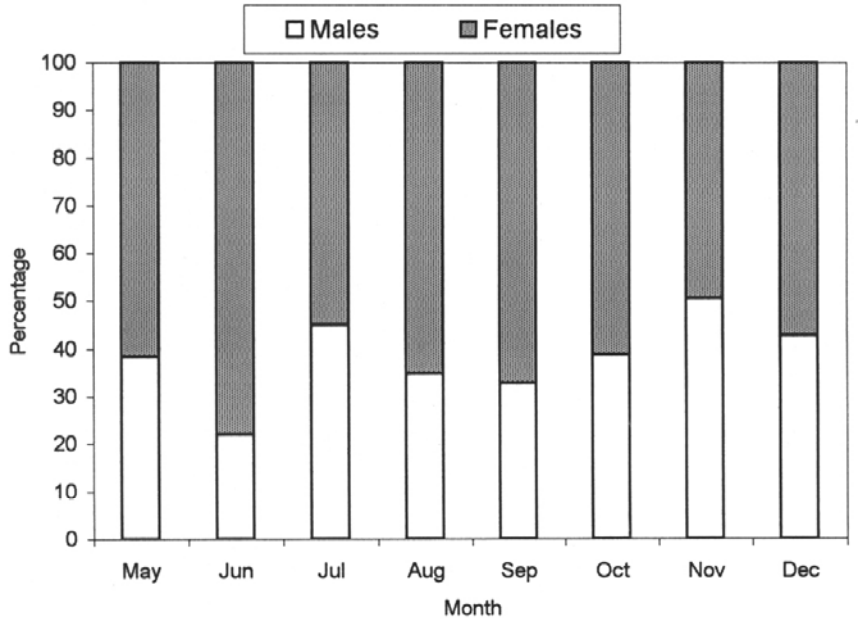

Fig (6) Monthly variations in sex ratio of *P. semisulcatus* from Bardawil lagoon.

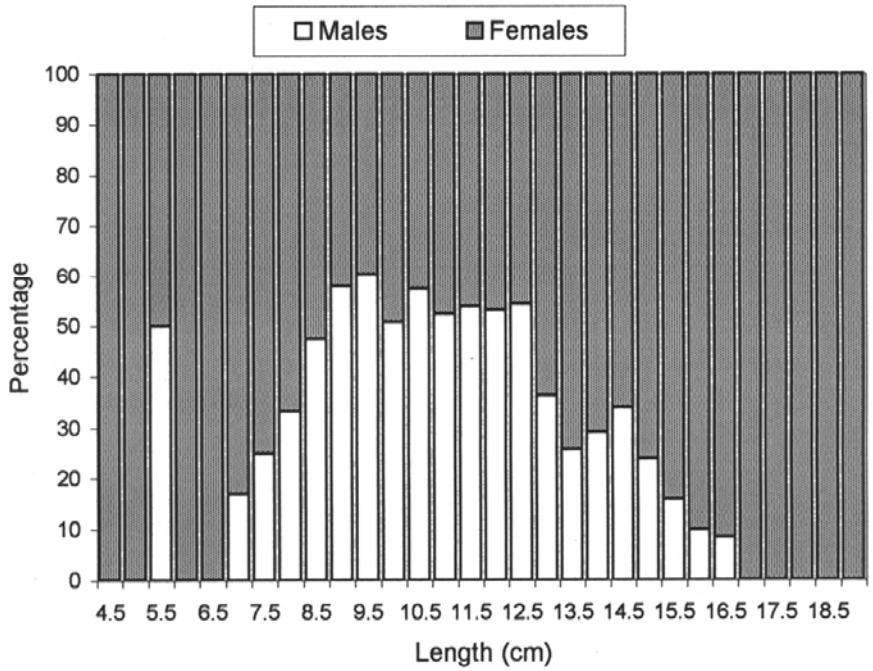

Fig (7) Variation in sex ratio according to length groups of *P. semisulcatus* from Bardawil lagoon.

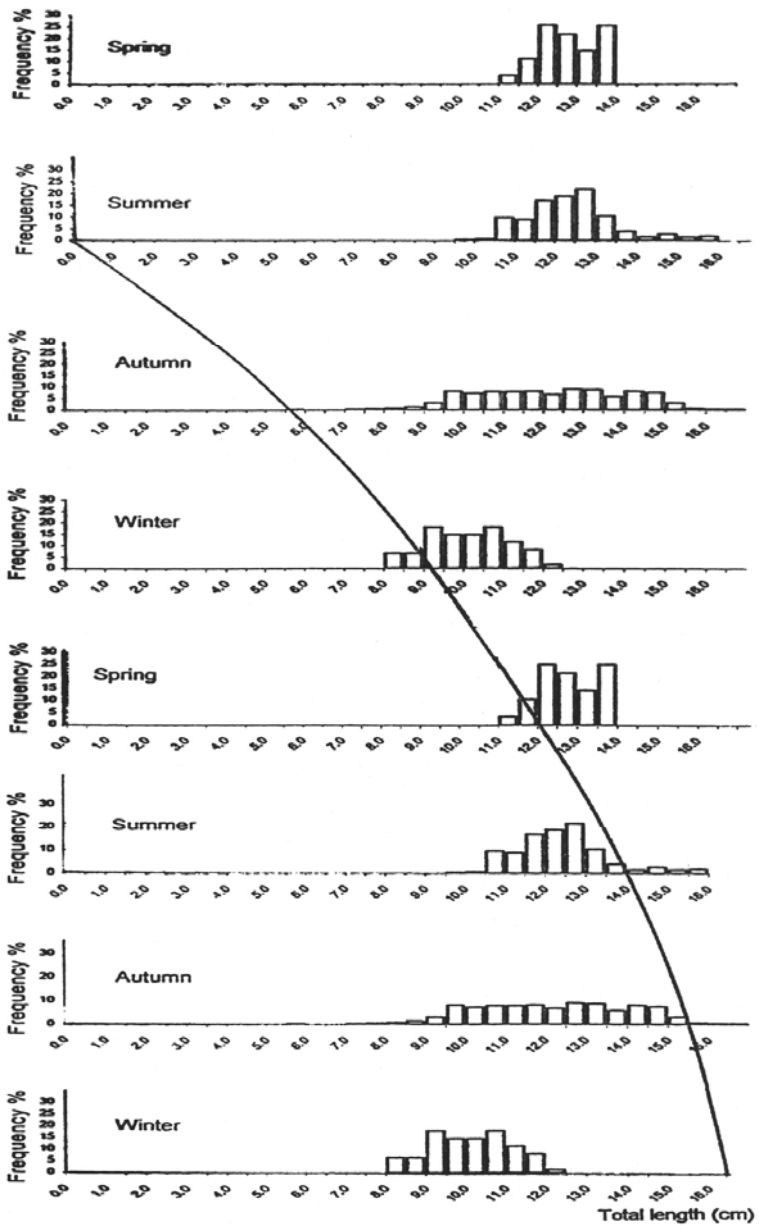

Fig (8) Seasonal length frequency distribution and growth curve of male *P. semisulcatus* from Bardawil lagoon.

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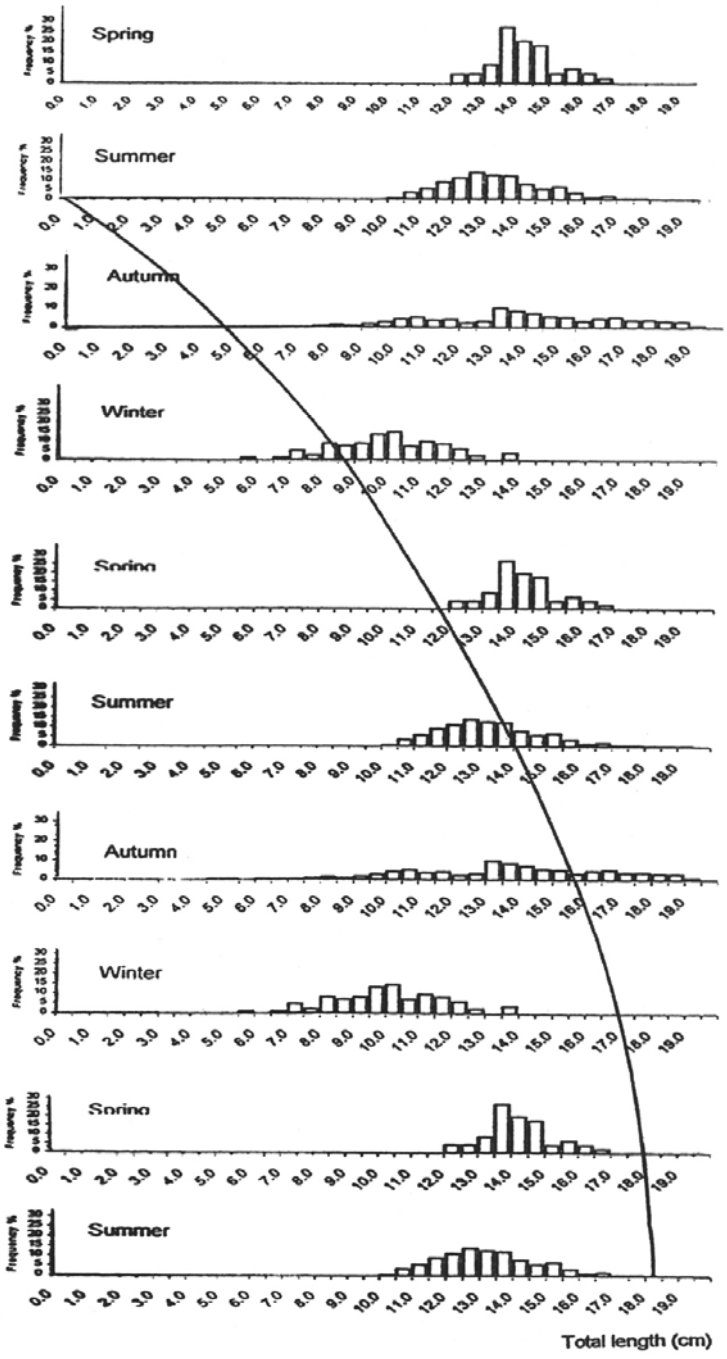

Fig (9) **Seasonal length** frequency distribution and growth curve **of female** *P. semisulcatus* from Bardawil lagoon.

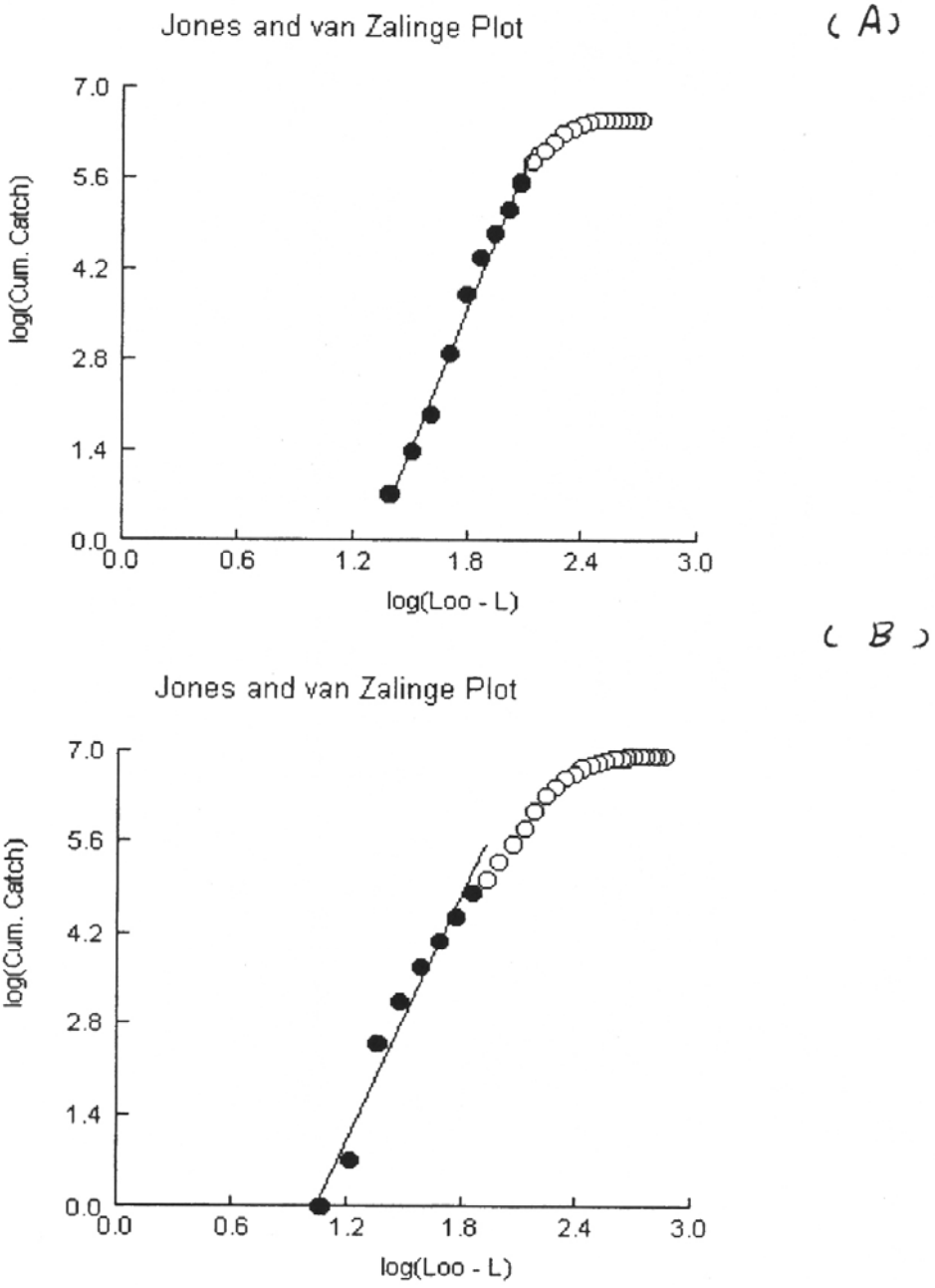

Fig (10) Jones and van Zalinge plots for estimating total mortality rates for (A) males and (B) females *P. semisulcatus* from bardawil lagoon.

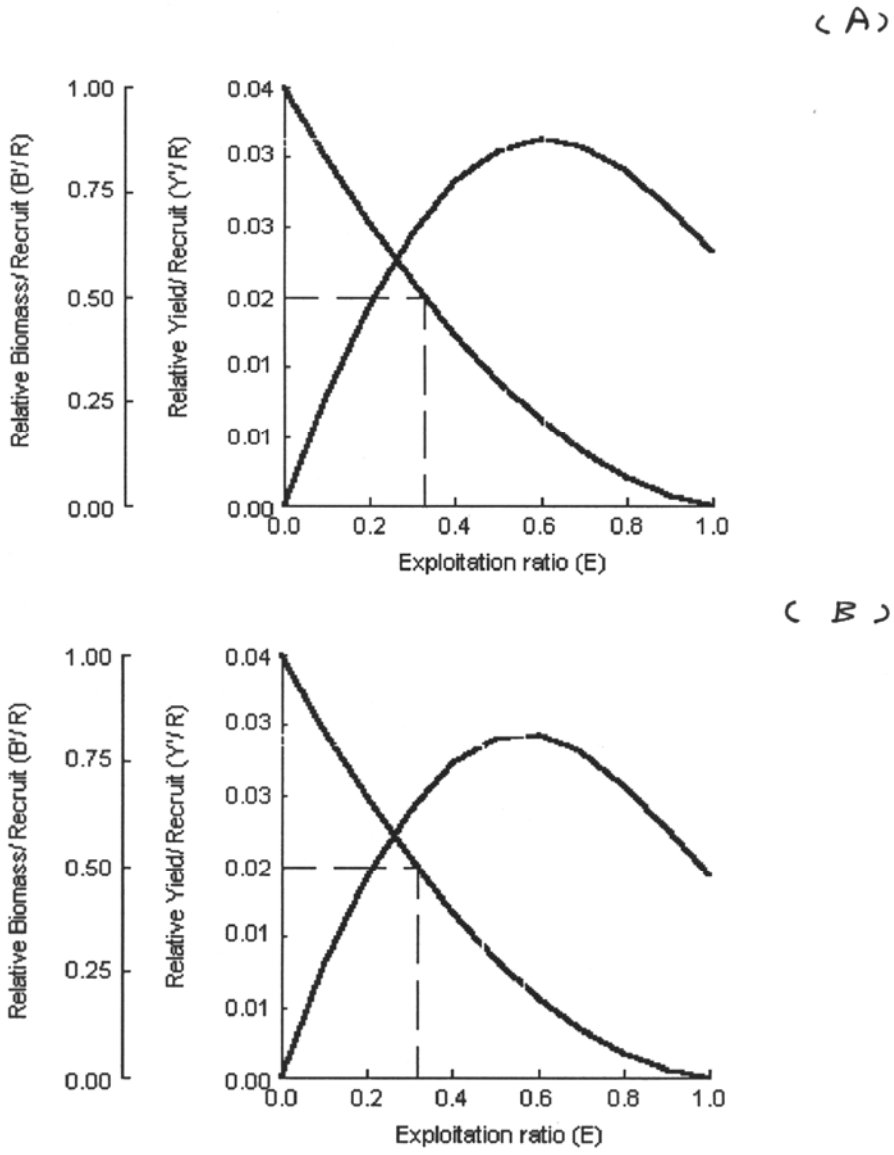

Fig (11) Relative yield per recruit and biomass per recruit of male (A) and female (B) *P. semisulcatus* from bardawil lagoon.