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Original Article

Estimation of growth, population parameters, and exploitation rate of *Penaeus semisulcatus* (De Haan, 1844) in Bardawil Lagoon, North Sinai, Egypt

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ABSTRACT: Among other crustaceans in the Bardawil Lagoon, *Penaeus semisulcatus* has a significant marketing value. Many biological parameters and population structure of green tiger prawn; investigated in this study during the fishing season 2022/2023. Seasonal growth in length and weight assessed for males and females by five seasons (ages) life span. The constant of total length-total weight relationship b= 2.50 for males, 2.15 for females, and 2.26 for both . Parameters of theoretical growth in length and weight L∞, K, t0, and W∞ were (22.76 cm, 0.21, -0.89 yr-1, and 94.90 gm for males), (29.32 cm, 0.14, -1.20 yr-1, and136.38 gm for females), and (23.05 cm, 0.2, -0 .89 yr-1, and 79.19 gm for all individuals). Instantaneous mortality rates Z, M, and F were (0.79, 0.43, and 0.36 yr-1 for males), (1.01, 0.42, and 0.59 yr-1 for females), and (0.92, 0.42, and 0.49 yr-1 for both sex). The exploitation rate was 0.46, 0.58, and 0.54 yr-1 for males, females, and all individuals. That indicates the *P. semisulcatus* population is over exploited in the Lagoon. Accordingly, the recommended procedure for reduction of fishing efforts or changing the mesh sizes of bottom trawl gear must apply.

Key word: *Penaeus semisulcatus*, Biology, Exploitation rate, and Bardawil lagoon

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1. INTRODUCTION

Shrimp are the most significant crustaceans in the Bardawil Lagoon. Crustacean total catch statistics in the Lagoon represent 34% from of its overall production (GAFRD, 2021). Five species of penaeid shrimps were identified in the Lagoon *Penaeus semisulcatus, Penaeus japonicus, Metapenaeus monoceros, Metapenaeus stebbingi*, and *Penaeus kerathurus* (Samar, et al. 2021). Green tiger prawn was found in Indo-West Pacific: Red Sea and Southeast Africa to Japan, Korea, the Malay Archipelago, and northern Australia. *P. semisulcatus* reached the eastern Mediterranean through the Suez Canal; it is now found along the coasts of Egypt (Holthuis, 1980).

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Growth estimation in crustaceans is a cornerstone in population studies for ecological, fisheries, and farming purposes. Shrimps and other species produced from this Lagoon have remarkable economic importance because of their acceptance in the local market. Age and growth studies and its related biology and population parameters were not assessed previously on this species or in the Lagoon. Because of the importance of the knowledge on species individual growth, it leads to determination of other parameters of its stock and eventually to a more precise resource development. The definite objectives of this study are *i)* to describe the sex ratio, size structure, and ages of the *Penaeus semisulcatus* (green tiger prawn) stock that occurs in the Bardawil Lagoon. *ii)* to examine the gender variations of growth parameters on this crustacean species. *iii)* to determine the other main parameters of population dynamics such as total mortality, natural mortality, and fishing mortality. *v)* to assess its exploitation rate in the Lagoon during the study period. These parameters will enable us to estimate the shrimp fisheries in Bardawil Lagoon and help to make necessary recommendations for the protection and sustainable management of this valuable marine resource.

2. MATERIALS AND METHODS

2.1.Study area

The Bardawil lagoon is located in the north of the Sinai Peninsula between E 32 ° 40, N 31 ° 03 and E 33 ° 30, N 31 ° 14. It is about 90 km long with a maximum width of 22 km. Separated from the Mediterranean Sea by a narrow sandbar with average width of 500 m. The flooded area is approximately 650 km^2. The Lagoon is a natural depression directly connected to the Mediterranean Sea by three openings (Boughazes). Two of them are man-made, while the third one is natural. These opining are used as inlet for exchanging water between the Lagoon and the Mediterranean Sea. Each inlet is acute on the sandbar approximately 500 m wide and 6 m deep (Figure 1).

Fig. 1. Map of Bardawil lagoon, North Sinia, Egypt

2.2.Sampling and Data Analysis

Monthly random samples of green tiger prawns collected from the commercial catch of the Bardawil Lagoon during the fishing season 2022/2023. Shrimps identified into species within overall samples, and *P. semisulcatus* sexes were separated by male and female. The following measurements were taken for all individuals; the total length to the nearest centimeter and the total body weight to the nearest tenth of a gram. The length frequencies are grouped into 0.4 cm classes. Data were processed and analyzed to estimate biological parameters. The length-frequency distribution is applied by determining the individual normal distribution method of (Bhattacharya, 1967).

The relationship between length and weight (LWR) was described by the potential equation as $W = a*L^b$ (Ricker, 1975), where (W) is proportional to a certain power (b) of the total body length (L). (a) & (b) are constants whose values were estimated by least-square methods.

The constants of von Bertalanffy's (1938) growth equation were calculated by applying

Ford (1933) and Walford (1946) plot. Estimation of the theoretical age at zero length (t_0) done by the equation:
$\log_{10}(-t_0) = -0.3922 - 0.275 * \log_{10} L_\infty - 1.038 * \log_{10} K$ (Pauly, 1979)

Age composition by sex was determined. Chi-square test (χ^2) also was adopted to determine the numeric proportions of sexes, were expressed as male and female percentages also as a male: female ratio, then were compared with a balanced sex-ratio (1:1).
Instantaneous total mortality coefficient "Z" was estimated from a linearized catch curve based on age composition data (Ricker, 1975). Instantaneous natural mortality coefficient "M" was estimated by Ursin (1967) equation as $M=W'^{(-1/3)}$, were W` is the mean weight of the whole sample. The fishing mortality coefficient "F" was estimated by subtracting the natural mortality coefficient from the total mortality coefficient. The exploitation rate "E" was estimated by the formula suggested by Gulland (1971). Estimation of survival rates "S" as a number of fish alive after a specified time interval, divided by the initial number, usually on a yearly basis was done according to Ricker (1975) equation.

3. RESULTS

3.1. Growth in length and weight

3.2. Length-weight relationship

A total of 636 individuals of *P. semisulcatus* were collected and examined monthly during fishing season 2022/2023 from Bardawil Lagoon. Total lengths (TL) ranged from 2.6 to 16.5 cm (average 10.72 cm) for both male and female (Male TL 5.5 to 16.1 cm, and Female TL 2.6 to 16.5 cm). Total weights (TW) were ranged between 1.5 to 31.7 g (average 13.1 g) for both male and female (Male TW 1.9 to 30.8 g, and Female TW 1.5 to 31.7 g). Females shows larger size and heavier weight than males (Figure 2).

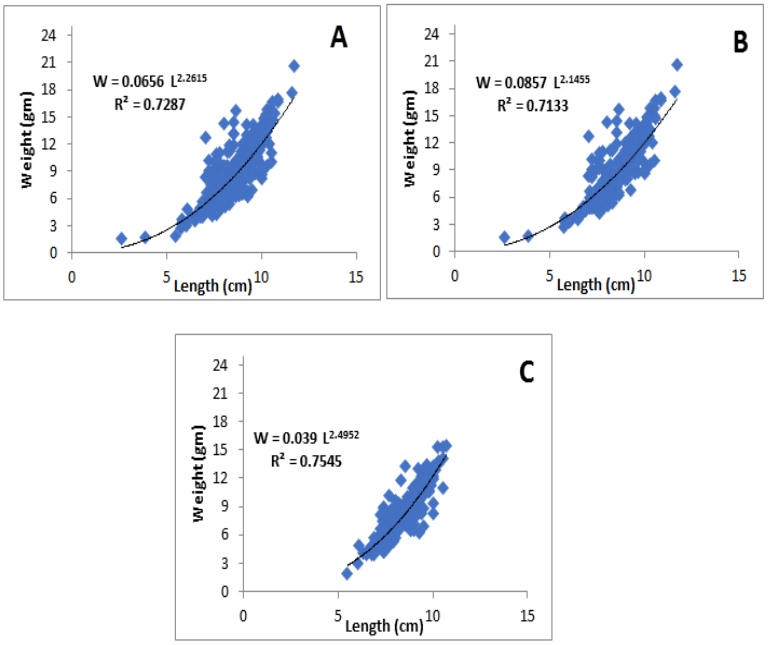


Fig. (2): Total length – total weight relationship of *P. semisulcatus* from the Bardawil lagoon. *A:* all individuals, *B:* Females, and *C:* males.

Parameters of length-weight regression estimated for males, females and all individuals and found "b= 2.50" parameter for male, b= 2.15 for females, and b= 2.26 for both with formula:
$W = 0.0656\ L^{2.2615}$ for all individuals
$W = 0.0857\ L^{2.1455}$ for females
$W = 0.039\ L^{2.4952}$ for males

3.3.Length frequency distribution

A total of 38 size groups were demonstrated with 0.4 cm intervals for males, females, and all individuals. Five ages were observed by apply normal distribution method of (Bhattacharya, 1967) for males and females (Table1).

3.4. Theoretical growth parameters

Von Bertalanffy derived his equation in 1938 by assume that the rate of growth of an organism declines with age. Theoretical growth in length and weight, and von Bertalanffy's parameters L_∞, K, and t_0

represents in Table (2) for males, females, and all individuals.

Table 1. Length frequencies by age for females, males, and all individuals of *P. semisulcatus* from Bardawil Lagoon.

All individuals				**Females**			**Males**		
Length	Frequencie	Frq.	Observe	Frequenc	Frq.	Observed	Frequencies	Frq. By Age	Observed
2	0	10	0	0	5	0	0	3	0
2.4	1		1.5	1		1.6	0		0
2.8	0		0	0		0	0		0
3.2	0		0	0		0	0		0
3.6	1		1.7	1		1.7	0		0
4	0		0	0		0	0		0
4.4	0		0	0		0	0		0
4.8	0		0	0		0	0		0
5.2	1		1.9	0		0	1		1.9
5.6	3		3.5	3		2.8	0		0
6	4		3.7	2	147	3.4	2		4.0
6.4	10	280	4.1	6		4.1	4	135	4.1
6.8	26		6.1	14		6.1	12		5.0
7.2	46		6.3	24		6.5	22		6.2
7.6	61		6.7	30		7.1	31		6.5
8	63		7.6	29		7.6	34		7.5
8.4	74		8.5	42		8.4	32		8.6
8.8	68	232	9.3	37	121	9.5	31	104	9.0
9.2	60		10.6	34		10.9	26		10.3
9.6	32		11.9	17		11.9	15		11.9
10.0	29		12.6	19		12.6	10		12.6
10.4	11		14.3	5		13.9	6		13.9
10.8	2		15.2	2		15.8	0		0
11.2	5		15.6	0		0	5		13.7
11.6	2		16.1	2		16.8	0		0
12.0	10		14.8	5		15.3	5		15.4
12.4	13		15.4	6	41	16.5	7	40	16.4
12.8	13	77	16.8	10		17.1	3		17.2
13.2	25		16.1	16		16.0	9		16.3
13.6	22		16.3	9		17.2	13		16.5
14.0	17		17.2	3	16	18.8	14		17.9
14.4	11	37	18.4	4		19.6	7	28	18.0
14.8	9		19.5	3		19.9	6		19.4
15.2	5		19.8	0		0	5		19.8
15.6	5		22.5	2		23.8	3		22.1
16.0	2		23.4	2		27.3	0		0
16.4	3		28.9	1		28.3	2		28.6
16.8	2		31.9	1		31.7	1		32.1
Total	*640*			*330*			*310*		

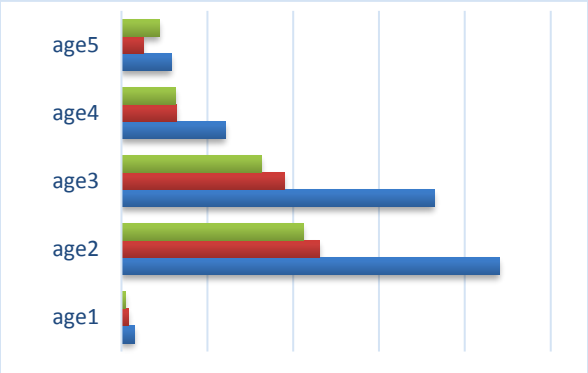
Table 2. Back calculated length and theoretical growth in length and weight of *P. semisulcatus*

Age (Seasonal)	1	2	3	4	5	Von Bertalanffy's parameters					
	Lengths (cm)					L_∞	K	t_0	W_∞	a	b
All individuals	6.2	8.4	12.4	14.2	15.6	23.05	0.2	-0 .89	79.19	4.249	0.8157
Females	5.6	8.4	12.0	13.6	16.0	29.32	0.14	-1.20	136.38	3.925	0.8661
Males	6.0	8.4	12.2	13.8	15.4	22.76	0.21	-0.89	94.90	4.226	0.8143

3.5.Structure of the population

3.5.1. Age composition

Age composition is defined as the proportion of a fish population belonging to each age class and is an informative input to stock assessment models, and it can be estimated from fishery independent and dependent sources (Giancarlo, et al. 2020). Shrimps have seasonal growths and five seasonal ages composition found in this study. Age 2nd is the dominant for males, females, and all individuals. A gradual decline in the number of individual *P. semisulcatus* of 3, 4, and 5 ages was noticeable (Figure 3)



% Percentage	age1	age2	age3	age4	age5
Male	0.5	21.2	16.4	6.3	4.4
Female	0.8	23.1	19.0	6.4	2.5
Both	1.6	44.0	36.5	12.1	5.8

Fig. 3. Age composition by season of *P. semisulcatus* from the Bardawil lagoon.

3.5.2. Sex ratio

The overall sex ratio of 636 *P. semisulcatus* samples used during this study 330 was females and 306 was males that conform 1.08:1. Sex ratio M: F by age of *P. semisulcatus* was significantly different from the expected 1:1 ratio ($p<0.05$). Female was dominant in most ages 1, 2, 3, and 4 with ratios 1.7, 1.07, 1.16, and 1.03:1 (Figure 4).

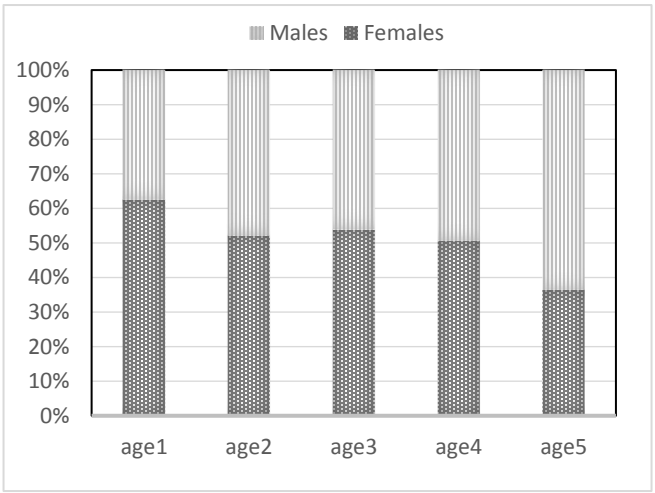


Fig. 4. The overall sex ratio of *P. semisulcatus* from the Bardawil lagoon

3.5.3. Mortalities, Survival, and Exploitation rate

Linearized catch curve based on age composition data of green tiger prawn (Figure 5) reveals total mortality (Z) values by 1.012, 0.790, and 0.918 yr^{-1} of females, males, and all individuals, respectively. Instantaneous

natural mortality values (M) were 0.423, 0.426, and 0.424 yr^{-1} of females, males, and all individuals, respectively.

Therefore, fishing mortality coefficient (F) obtained from total and natural mortalities were 0.589, 0.364, and 0.494 yr^{-1} of females, males, and all individuals, respectively. Representative survival data computed from the slope of the exponential decline in numbers over time curve; the results were S= 0.364, 0.454, and 0.399 yr^{-1} of females, males, and all individuals, respectively. Exploitation rate (E) estimated by quotient Z/F were 0.582, 0.461, and 0.538 yr^{-1} for females, males, and all individuals, respectively.

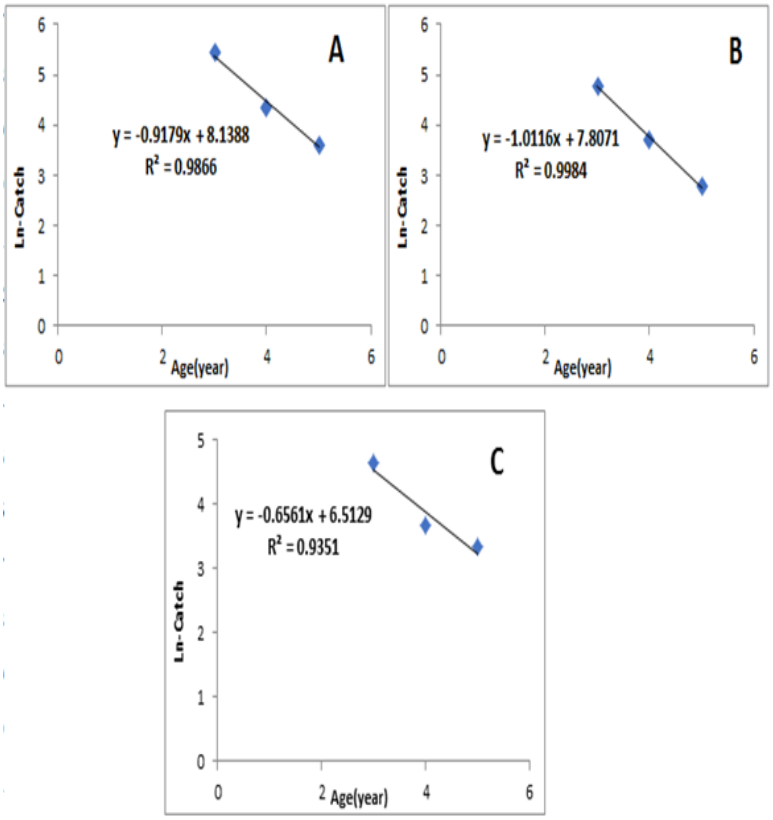


Fig. 5. Instantaneous total mortality from linearized catch curve of *P. semisulcatus* from the Bardawil lagoon. *A:* all individuals, *B:* Females, and *C:* males.

4. DISCUSSION

Slope values (b) of the relationship between length and weight regression of *P. semisulcatus* were slightly different between geographic locations; in the Sea of Oman, Iran, Alizadeh, et al. 2022, found it was 2.42 for males and 2.39 for females, 2.40 for pooled sex, also, it was found 2.69 by Abdul-Wahab, 2014, for pooled sex in the Yemeni Red Sea waters. According to many researchers, the value of b is between 2.5 -3.5, and if the value is close to 3, growth will be isometric (Pauly, 1984). The estimated values for slope b in the linear equation of logarithmic regression of the total length – total weight relationship in this study indicate negative allometric growth in both morphotypes of *P. semisulcatus*. The values of a and b vary not only in different species but also in individuals of the same species based on sex, stage of maturity, and nutritional intensity (Pauly, 1984).

In the present study, we use the length frequency method to estimate the growth parameters of *P. semisulcatus*, where that method is suitable for species for which recruitment occurs over a short period and growth rates are relatively high (Mohamed and El-Aiatt, 2012). No differences found between total length and carapace length frequency methods for aging this species, comparing with other studies on the same species; five ages life spans were found by other authors (Ameran, 2004; Mohamed and El-Aiatt, 2012; Abdul-Wahab, 2014; Alsolami and Jastania, 2017, and Alizadeh, et al. 2022 for females).

Theoretical growth in length and weight parameters was in agreement with Mehanna, 2000, in the Gulf of Suez, Egypt, where L_∞ = 26.3 & 27.1 cm, K= 0.7 & 1.6 yr^{-1}, and t_0 = -0.001 & -0.012 for males and females respectively, W_∞= 157.86 gm for both, Villarta et al., 2006 in West Central, Philippines, where L_∞ = 26.3 cm for males, and 27.1 cm for females, K= 0.7 and 1.6 yr^{-1} for males and females respectively. On the other hand, many authors measures *P.*

semisulcatus carapace lengths and analyze the von Bertalanffy growth parameters; Mohamed and El-Aiatt, 2012 in Bardawil Lagoon found CL_∞ = 53.5 & 66.7 mm, K= 0.92 & 1.1 yr^{-1}, and t_0 = -0.154 & -0.022 for males and females respectively, Alizadeh, et al. 2022 in the northern coast of Iran found CL_∞ = 55 & 69 mm, K= 1.7 & 2.1 yr^{-1}, and t_0 = -0.077 & -0.058 for males and females respectively. The difference in growth parameters between different localities can attributed to the difference in size-composition of the species.

During this study, the sex ratio reveals the prevalence of females at different ages. Also, the sex ratio by size classes of shrimp showed that the females were significantly predominant in higher length classes and males in lower classes. Similarly, many authors found the same results as Mehanna, 2000 Male: Female ratio was 1:1.1; Alsolami and Jastania, 2017 Male: Female ratio was 1:1.1, and Alizadeh, et al. 2022 M: F ratio was 1:1.16. Similarity in sex ratio at different geographic locations exposes the phylogenetic relation between this species.

Instantaneous mortality rates and exploitation rate of *P. semisulcatus* represented in table (3) comparing with other authors in different geographic locations. Exploitation rate (E) was 0.582, 0.461, and 0.580 yr^{-1} for females, males, and both sexes. The current exploitation rate was heavily exploiting females' stock established by Gulland, 1971 who suggested that the optimum exploitation rate for any fish stock is about 0.5 at F=M, and more recently, Pauly, 1987 proposed a lower optimum F that is equal to 0.4 M. Patterson, 1992 reported that an exploitation rate of about 0.4 is safe for the stock. On the other hand, high values of instantaneous total mortality (Z) in this study reflect the lower values of survival rates.

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