# POPULATION DYNAMICS AND FISHERIES MANAGEMENT OF Penaeus semisulcatus EXPLOITED BY SHRIMP TRAWL OF BARDAWIL LAGOON, NORTH SINAI, EGYPT 

S. Mohamed ${ }^{1}$ and A. El-Aiatt ${ }^{2}$<br>1- Faculty of Environmental Agriculture Sciences, El-Arish - Suez Canal University, 2-GAFRD<br>SUMMARY

Based on length frequency data, growth, mortality, exploitation rates and relative yield per recruit were examined for Penaeus semisulcatus collected from Bardawil lagoon for two fishing seasons 20102011. A total of 2451 specimens were collected between April through December of the two fishing seasons were measured for carapace length from 26 to 62 mm . The von Bertalanffy growth parameters were identified $\left(L_{\infty}=53.5 \& 66.7 \mathrm{~mm}, K=0.92 \& 1.1\right.$ year $^{-1}$, and $t_{0}=-0.154 \&-0.022$ years of males and females respectively). The growth performance index ( $\varphi^{\prime}$ ) was 3.42 for males and 3.69 for females. Total ( Z: $3.24 \& 5.34 y^{-1}$ ), natural (M: $1.05 \& 1.16 \mathrm{yr}^{-1}$ ) and fishing mortality ( $F: 2.18 \& 4.17$ yr $r^{-1}$ ) for male and female respectively. Exploitation rates $(E)=0.67$ for males, and $(E)=0.78$ for females indicated that the population of $P$. semisulcatus is heavily exploited. Length at first capture ( $L_{c}$ ) equal 32 and 39.6 mm of male and female. According to the relative yield analysis per recruit, for $P$. semisulcatus stock in Bardawil lagoon is overexploited. Thus, the reduction of fishing efforts or reevaluation of mesh sizes for bottom trawl fisheries are highly recommended.

Keywords: Bardawil lagoon, Penaeus semisulcatus, growth parameters, per-recruit analysis, fisheries management

## INTRODUCTION

Bardawil lagoon is one of the most important lagoons in Egypt as a source of economic fish and wetland region. It is a hyper saline lagoon connected to the Mediterranean Sea by two artificial openings. Now, shrimps are a dominant species and successful group in the lagoon production. The commercial fishing of shrimp in Bardawil lagoon began in 1994 by about 1.83 ton as $0.12 \%$ of total catch (GAFRD, 2002). The shrimp fisheries were conducted by small trawlers, and expanded rapidly since 1995 with the increase of the shrimp abundance in the lagoon to more than 1221 tons as $25.8 \%$ of the total catch in 2010 (GAFRD, 2010). In spite of shrimp diversity (Metapenaeus stbbing Nobili 1904, Penaeus japonicus Bate 1888, and Metapenaeus monoceros Fabricius 1798), Penaeus semisulcatus De Haan 1850) was the major contributor in shrimp catches from the Bardawil lagoon. Studies on fishery and biology of penaeid species in the Bardawil lagoon are scarce. However, Ameran (2004) studied the fishery of crustaceans Metapenaeus stbbing and Portunus pelagicus, while Yassien (2004) studied the fishery and population structure of P. semisulcatus and Abdel Razek et al. (2008) studied the biological of penaeid shrimp population. Also, Ameran et al. (2009) studied the population biology and exploitation rates of $P$. semisulcatus.

The present study introduces the information about age, growth, mortality and exploitation rates of $P$. semisulcatus in Bardawil lagoon, which may help to sustain and manage this valuable resource.

## MATERIAL AND METHODS

The study area is Bardawil lagoon (Figure 1). The lagoon is located in north Sinai Peninsula, bordered northerly by the Mediterranean Sea and southerly by Sinai desert. It is approximately 90 km long and 22 km across its widest point, and covers area of approximately $595 \mathrm{~km}^{2}$. The lagoon is extremely shallow and the water level never exceeds three meters in depth.

A total of $2451 \quad P$. semisulcatus were collected monthly from April 2010 through December, 2011 (two fishing seasons). The study area extended from Zaranik in the north to the end south of the lagoon. Monthly samplings were obtained from well mixed batches of commercial catches. The commercial catches were caught by two small boats comprised of bottom trawling gear (kalsa as locally called) with 60 mm mesh size. The carapace length of each sex individuals were measured to the nearest mm from the tip of the rostrum to the end of the telson., Total weight was recorded to the nearest 0.1 g . For each sex, the total carapace length - total weight were based on the regression formula: $\mathrm{W}=\mathrm{a} \mathrm{CL}^{\mathrm{b}}$, (Farmer, 1986), where $\underline{W}$ is the total weight in
$\mathrm{g}, \underline{C L}$ is the carapace length in $\mathrm{cm}, \underline{a}$ is the intercept and $\underline{b}$ is the slop (relative growth rate).

Electronic length frequency analysis (ELEFAN I) method (Pauly and Morgan, 1987) using the FiSAT program (Gayanilo et al., 2005) was used to estimate the asymptotic carapace length ( $\mathrm{CL} \infty$ ) and growth coefficient (K) for both males and females. The asymptotic length ( $\mathrm{L} \infty$ ) was estimated as total length $=$ carapace length $\times 3$ (Waffy, 1990). Input data were separated by sex and the values of $K$ and $L \infty$ were estimated for each sex by the von Bertalanffy growth equation: $L_{t}$ $=L_{\infty}\left(1-e^{-K(t-t)} 0\right)$ where, $L_{t}$ is the carapace length at time $\mathrm{t}, \mathrm{L}_{\infty}$ is the asymptotic carapace length, K is the growth coefficient, and $\mathrm{t}_{0}$ is the hypothetical age when the size is zero.

The growth performance index, $\varphi^{\prime}=\log k$ $+2 \log L \infty$, was computed using the $\mathrm{L}_{\infty}$ and K values according to the formula of Pauly and Munro (1984). The length-converted catch curve method (Pauly, 1984a) was used to estimate the instantaneous rate of total mortality $(\mathrm{Z})$ by using the FiSAT program. The instantaneous rate of natural mortality (M) was obtained using two methods: 1) Pauly's empirical formula (1980) as $\log \mathrm{M}=-0.0066-$ $0.279 \log \mathrm{~L} \infty+0.6543 \log \mathrm{~K}+0.463 \log \mathrm{~T}$; and 2) Ursin (1967) formula as $\mathrm{M}=\mathrm{W}^{-1 / 3}$ where W is the mean weight of the whole sample. The fishing mortality coefficient (F) was estimated as $\mathrm{F}=\mathrm{Z}-\mathrm{M}$. The exploitation rate "E" was estimated using the formula of Gulland (1971) as E = F / Z.

The probability of capture was estimated from length-converted catch curve, using the running average technique to determine $\mathrm{L}_{\mathrm{c}}$ (Pauly, 1984b). Relative yield per recruit $(Y / R)^{\prime}$ and relative biomass per recruit $(B / R)^{\prime}$ were estimated using the model of Beverton and Holt (1966) as follows:
$Y^{\prime} / R=E U^{M / K}\left\{1-(3 U / 1+\mathrm{m})+\left(3 U^{2} / 1+2 \mathrm{~m}\right)-\right.$ $\left.\left(U^{3} / 1+3 \mathrm{~m}\right)\right\}$
$(B / R)^{\prime}=(Y / R)^{\prime} / F$
where $\mathrm{m}=(1-\mathrm{E}) /(\mathrm{M} / \mathrm{K})=(\mathrm{K} / \mathrm{Z})$
$\mathrm{U}=1-(\mathrm{Lc} / \mathrm{L} \infty)$
$\mathrm{Z}, \mathrm{M}$ and F are the total, natural and fishing mortality coefficients respectively, E is the exploitation rate and K is the growth parameter

## RESULTS AND DISCUSSION

## Length-weight relationship and growth parameters:

The carapace length (Figure 2) ranged from 26 to 50 mm for males and ranged from 23 to 62 mm for females (males individual weight ranged from 3 to 24 g , and 2 to 63 g for females). The length frequency distribution showed that the largest female weighed more than 50 mm CL , which was represented in the
sample with low numbers. However, the young and mid-sized individuals weighed less than 40 mm CL were the dominant. The decline in size of adults, and the increase of young in size in the catch could be attributed to the increasing of the exploitation effort on the young stock of $P$. semisulcatus. Thus, in the near future this species may be in danger of severe declines. The carapace length-weight relationship of males and females are shown in Figures (3) and (4) and calculated as $\mathrm{W}=0.0003 \mathrm{~L}^{2.87}$ for males and $\mathrm{W}=0.0002 \mathrm{~L}^{2.99}$ for females, showed the close of isometric growth where the value of the parameter (b) of the lengthweight relationship characterizes an isometric growth when equal to three (Ricker, 1975). In the present study, the values of (b) were 2.87 for males and 2.99 for females showed a slightly negative allometry in the growth of both sexes. These values differ from the values, which were obtained by Ameran et al. (2009) ( $b=2.21,2.17$ ) for males and females. These differences may be due to the unstable environmental conditions of the Bardawil lagoon.

## Growth parameters:

The growth curve is superimposed on the restructured length-frequency data for males and females (Figure 5). The constant of the von Bertalanffy's growth model was estimated and the obtained equations were:
$\mathrm{L}_{\mathrm{t}}=53.5\left(1-\mathrm{e}^{-0.92(\mathrm{t}+0.154)}\right)$ for males and $\mathrm{L}_{\mathrm{t}}$ $=66.7\left(1-\mathrm{e}^{-1.1(t+0.022)}\right)$ for females.

The value of growth performance index ( $\varphi^{\prime}$ ) was calculated as 3.42 and 3.69 of males and females, respectively.

In the present study, length frequency method was used to estimate the growth parameters of $P$. semisulcatus where that method is suitable for species for which recruitment occurs over a short time period and growth rates are relatively high (King, 1984). Moreover, $\mathrm{L}_{\infty}(\mathrm{CL})$ and K estimated as 53.5 mm and $0.92 \mathrm{yr}^{-1}$ for male and 66.7 mm and $1.1 \mathrm{yr}^{-1}$ for female. The growth parameters $\mathrm{L}_{\infty}$ mm as CL and K of $P$. semisulcatus are different between localities, where, $\mathrm{L}_{\infty}$ equal 38 and 50.4 mm for males and females in the Persian Gulf (Niamaimandi et al., 2007), equal 66.15 for both sexes in Arabian Gulf (Hosny, 2007) and equal 51 and 62 mm for male and female in the eastern water of Yemen (Abdulwahab, 2005). The value of K is a relatively low compared with studies in the Persian Gulf, K equal 1.8 and 2.6 for male and female (Niamaimandi et al., 2007) but similar to those from Arabian Gulf, K equal $1.2 \mathrm{yr}^{-1}$ (Hosny, 2007). The difference in growth parameters between different localities can be attributed to the difference in size-composition of the species. $L_{\infty}$ is interpreted by the mean length of
very old fish and $k$ determines how fast the fish approaches its $L_{\infty}$ (Sparre and Venema, 1992). The relatively low K indicated the slow attainment of maximum size. The growth performance index value $\left(\varphi^{\prime}=3.39\right.$ and 3.69 for male and female) of $P$. semisulcatus in Bardawil lagoon illustrates that the growth is faster in female and higher compared with that obtained by Ameran et al. (2009) $\varphi^{\prime}=2.22$ but the values are similar to results from previous investigation at Arabian Gulf in Bahrain ( $\varphi^{\prime}=$ 3.53); Qatar $\left(\varphi^{\prime}=3.23\right)$ and $\operatorname{KSA}\left(\varphi^{\prime}=3.72\right)$ as recorded by Kisr (2001).

## Mortalities and exploitation rates

Total mortality ( Z ) from length-converted catch curves was estimated as 3.24 and 5.34 $\mathrm{yr}^{1}$ for males and females, respectively (Figure 6 ), while natural mortality (M) was determined as 1.05 and $1.16 \mathrm{yr}^{-1}$ and the fishing mortality rate ( F ) was 2.18 and 4.17 for males and females, respectively. Exploitation rate (E) was computed as 0.67 of males and 0.78 of females. The current exploitation rate was heavily exploiting stock according to Gulland (1971) who suggested that the optimum exploitation rate for any fish stock is about 0.5 at $\mathrm{F}=\mathrm{M}$ and more recent, Pauly (1987) proposed a lower optimum F that equal to 0.4 M. Patterson (1992) reported that an exploitation rate of about 0.4 is safe for the stock.

## Length at first capture ( $L_{c}$ ) and relative yield per recruit

The length at first capture $\left(\mathrm{L}_{\mathrm{c}}\right)$ at which $50 \%$ of the fish are vulnerable to capture for $P$. semisulcatus was estimated at 32 and 39.6 mm as a carapace length (Figure 7). Length at first capture is an important factor where it is a function of mesh size and gear selectivity (Beverton and Holt, 1966). At 32 and 39.6 mm as a carapace length, the relative yield-perrecruit $\left(\mathrm{Y}^{\prime} / \mathrm{R}\right)$ and biomass per-recruit $(B / R)$ of $P$. semisulcatus vs. the exploitation rate (both sexes) gave an: $E_{\max }=0.78, E_{0.1}=0.66$ and $E_{0.5}=0.389 \quad$ (Figure. 8).

The present study indicated that the computed current exploitation rates $\left(\mathrm{E}_{\text {cur }}=0.67\right.$ of males and $\mathrm{E}_{\text {cur. }}=0.78$ of females) are higher than that produces the economic relative yield-per-recruit $\left(E_{0.1}=0.60\right)$ and higher than the exploitation rate $\left(E_{0.5}=0.389\right)$ which maintain $50 \%$ of the stock biomass as spawning stock. Thus the current exploitation rate should be reduced at least from 0.78 to $0.66(16 \%)$. This means that the value of $L_{c}$ (whish is a proxy of mesh size) and the current exploitation rate (which is a proxy of effort) indicated that the small shrimp are caught at higher effort level.

It is not easy to balance between the reduction of effort and socio-economic needs of the fishermen. The application of optimum mesh size is recommended where increase of $L_{c}$ to 45 mm for both sexes may be balanced between current exploitation rate and socioeconomic needs. Also, an increase of $L_{c}$ to 45 mm would be associated with an increase of $Y^{\prime} /$ R by $4 \%$ (Figure 8).

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Figure 1. Bardawil lagoon, showing the Bughaz1 and Bughaz2


Figure 2. Carapace length distribution of $P$. semisulcatus (一 males) and ( $\Delta$ females) in Bardawil lagoon during the two fishing season of 2010-2011


Figure 3. Length-weight relationship (males) of $\boldsymbol{P}$. semisulcatus in Bardawil lagoon during the two fishing season of 2010 - 2011


Figure 4. Length-weight relationship (females) of $\boldsymbol{P}$. semisulcatus in Bardawil lagoon during the two fishing season of 2010 - 2011.


Figure 5. Length frequency curves of male (a) and female (b) of Penaeus semisulcatus in Bardawil lagoon during the two fishing season of 2010-2011


Figure. 6. Length-converted catch curves for estimating total mortality rates males (a) and females (b) of $\boldsymbol{P}$. semisulcatus from Bardawil lagoon


Figure 7. Length at first capture for males (a) and females (b) of P. semisulcatus from Bardawil lagoon


Fig. 8. Yield per recruit analysis of $P$. semisulcatus (Males and Females) from Bardawil lagoon


Figure 9. Yield per recruit analysis of $P$. semisulcatus (Males and females) using $L \mathbf{c}=\mathbf{4 5} \mathbf{~ m m}$.
ديناميكية العشائر وادارة مصايد الجمبري اللسويسى Penaeus semisulcatus المستغلة بجرافة الجمبرى بمنخفض البردويل ـ شمـال سينـاءـ مصر

محمد سالم أحمد¹, عطية علي العياط²
1ـ كلية العلوم النزراعية البيئية، جامعة قناة السويس، 2- الهيئة العامة لتتمية الثروة السمكية
تشكل القشريات حوالي 56 \% من إنتاج بحيرة البردويل ويمثل الجمبري منفردا حوالي 26\% من الإنتاج العام. تم تجميع عينات الجمبرى السويسى لموسمين متتاليين (2010 - 2011) لتقييم حالة الصصيد في هذا النوع الهام. تم تجميع 2451 عينة في الفنترة من ابريل حتى ديسمبر لكل موسم صيل. أخذت قياسات طول الدرقة من 26 الى 62 مم للأكور والاناث. اعتمدت لتققيرات مثل متغيرات النمو, معدلات النفوق ومعدلات الاستغلال على النكرار الطولي للارقة فى العينات. أظهرت النتائج أن النسبة الجنسية للإناث أعلى من الذكور في المصيد وكانت متغيرات النمو في معادلة فون بيرتلانفى للذكور هي: الطول عند ما لانهاية =53.5 مم، منحنى النمو=0.92/سنة، العمر عند الطول صفر =- 0.154 سنة وللإناث هي: الطول عند ما لانهاية =66.7 سم، منحنى النمو = 1.1/سنة العمر عند الطول صفر =- 0.022 معدل النمو= 3.42 للذكور و 3.69 للإناث. النفوق الكلى= 3.24 ،5.34 النفوق الطبيعي=65 1.05, 1.16 والنفوق بالصيد= 2.18 ، 4.17 للذكور والإناث على الترتيب. معدل الاستغلال في المصيد= 0.67 للأكور و0.78 للإناث وهى معدلات اعلي من معدل الاستغلال الأمتل ومعدل الإنتاج الاقتصادي المستمر. من الارْاسة يتضح أن مخزون الجمبري في بحيرة البردويل تحت مصيد جائر . وتوصى الار اسة بتعديل فتحات الثباكّ لتكون بداية صيد هنا النوع عند الطول الارقي 45 مم بدلا من الطول الدرقي الحالي (39.6مم) والاستمرار بجها الصيد الحالي لأنه ليس من اللسهل تحقيق التوازن بين الانخفاض بجهـ الصيا الحالي وظروف الصياد إجتماعيا وإقتصاديا. مع العلم ان تعديل فتحات الثنباك سوف يزيد من معدل الإنتاج النسبي بقيمه 4\%.

