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Population Dynamics and Management of White Shrimp *Metapenaeus Stebbingi* (Penaeidae) at Lake Timsah, Suez Canal, Egypt

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Abstract

Studies were conducted on the dynamics of the exploited population of white shrimp *Metapenaeus stebbingi* Nobili 1904 at Lake Timsah (Suez Canal, Egypt). Growth parameters were determined using the length frequency distribution over a 13-month period. The asymptotic total length was estimated as 14.84, 16.95 and 17.07 cm for males, females and sexes combined, respectively. The growth parameter K was 2.63, 2.16 and 2.10 yr^{-1} for males, females and sexes combined, respectively. The longevity was 9 months for males and 12 months for females. The instantaneous rate of total mortality was estimated at 10.75, 7.9 and 9.1 yr^{-1} for males, females and sexes combined, respectively, while natural mortality was 3.73 yr^{-1} for males, 3.16 yr^{-1} for females and 3.09 yr^{-1} for sexes combined. Hence, the fishing mortality was calculated at 7.02, 4.74 and 6.01 yr^{-1} for males, females and sexes combined respectively. The current rate of exploitation E was given as 0.65 for males, 0.60 for females and 0.66 for sexes combined, indicating that the stock of white shrimp is overfished. Relative yield per recruit and relative biomass per recruit analysis for sexes combined showed that *M. stebbingi* stock at Lake Timsah is in a situation of overfishing and the present level of exploitation rate should be reduced by about 46% to maintain a sufficient spawning biomass.

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Introduction

Crustaceans, such as penaeid shrimp, crabs and clawed and spiny lobsters have recently become very important due to the high demand for them in world markets. Coastal penaeid shrimp stocks have become more intensely studied in the intertropical region in the last three decades as their importance in tropical fisheries has increased (Garcia 1985). As the penaeid shrimps are short-lived animals living in highly variable inshore areas during the juvenile phase, they are frequently subjected to strong environmentally driven variability in recruitment and stock size (Garcia & Le Reste 1981; Garcia 1984). The family Penaeidae makes up approximately 70% of the world's shrimp catch (Rothlisberg et al. 1983). These penaeid stocks are also characterized by very large fluctuations in size (Kirkegaard 1975), with little apparent relationship between spawner abundance and recruitment strength (Neal 1975; Rothschild & Gulland 1982).

The penaeid shrimp fishery is one of the most important fishery resources at Lake Timsah, Egypt. According to the fisheries statistics collected from the General Authority for Fish Resources Development, shrimps constituted about 7% of the total catch of the lake during the period from 2000 to 2005 (GAFRD annual statistical reports). This contributed about 14% of the gross revenue from the lake. White shrimp *Metapenaeus stebbingi* is the target species in the catch and contributed about 90% of the shrimp catch. The white shrimp *M. stebbingi* was of Indo-West Pacific origin, migrated through the Suez Canal and was well established along the Egyptian coast of the Mediterranean and Suez Canal lakes (Samocha & Lewinsohn 1977). Although the shrimp fishery has a great economical importance at Lake Timsah, no studies of these species are available. On the other hand, a number of studies concerning biology and fishery of shrimps were undertaken in different Egyptian waters (Dowidar & Ramadan 1976; Mehanna 1993; El-Gammal & Mehanna 1999; Mehanna 2000; 2003). This study investigated the basic population dynamics parameters of *M. stebbingi* at Lake Timsah and suggested appropriate management recommendations for its sustainable development.

Materials and Methods

Lake Timsah (Fig. 1), one of the small lakes in Egypt is located on the north of the Suez Canal and is considered as a source of important local fishery. It is a land-engulfed embayment with a total area of 15 km^2 (Pietro et al. 2004). The Suez Canal lakes (Lake Timsah and Bitter Lakes) constituted about 1.2% of the annual fish production from the Egyptian lakes (GAFRD annual statistical reports). The fish fauna of Lake Timsah originates from the adjacent Mediterranean Sea and Red Sea through the Lessepsian migration after the construction of the Suez Canal. Most of the fish and crustacean species recorded in Lake Timsah are Red Sea immigrants (Norman 1929; Por 1978).

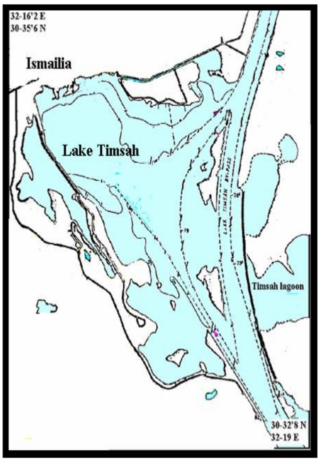

Fig. 1. Lake Timsah

Length frequency data of *M. stebbingi* were obtained from the commercial catch from the landing site of Lake Timsah during the period from March 2003 to April 2004. After sex-wise sorting, the total length to the nearest mm was measured and total weight to the nearest 0.1 g was taken for each specimen, then the monthly length frequency was grouped into 0.5 cm classes.

Length – weight relationship

The length-weight relationship was estimated using the power equation $W= aL^b$ where W is the total weight in g, L is the total length in cm. Confidence intervals of 95% were calculated for the slope (b) to see if b was statistically different from 3.

Age and growth

For each month and each sex the length frequency was resolved into normally distributed cohort components using the Bhattacharya (1967) method and the results were used as input to the modal progression analysis (MPA) and Ford (1933) – Walford (1946) plot to estimate the asymptotic length (L_∞, in cm) and the rate at which the asymptotic length is attained (K, in yr^{-1}). The growth parameters were also estimated using the ELEFAN I program. Initial values for L_∞ were obtained using the Powell-Wetherall method (Powell 1979; Wetherall et al. 1987) while the age at zero length (t_o) was calculated from the empirical formula of Pauly et al. (1984).

Mortality and exploitation rate

Total mortality (Z) was estimated using the cumulated catch curve (Jones & Van Zalinge 1981) while natural mortality (M) was calculated using Pauly's (1980) formula. The fishing mortality (F) was computed as F = Z – M and the exploitation rate was computed from the rate F/Z (Gulland 1971).

Recruitment and length at first capture

Recruitment pattern was detected by projecting length frequencies backward onto a one-year time scale using ELEFAN II software (Pauly 1987) while the length at first capture (L_c, cm) was estimated from the catch curve analysis (Pauly 1984).

Per – recruit analysis

The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated by using the model of Beverton & Holt (1966) as modified by Pauly & Soriano (1986). The relative yield per recruit (Y'/R) model was used because it can provide the kind of information needed for management (Sparre & Venema 1998).

Reference points

The following reference points were used to determine the status of white shrimp stock at Lake Timsah: $E_{0.1}$, the level of exploitation at which the slope of the Y/R is 1/10 of its value at origin; E_{max}, the level of exploitation that produces the maximum Y/R; and $E_{0.5}$, the exploitation level associated with a 50% reduction of the biomass per recruit in the unexploited stock.

Results and Discussion

Length - weight relationship

The relationship between the total length and total weight of *M. stebbingi* (Fig. 2) was estimated from a sample of 612 males and 730 females. The total length of males varied from 5 to 13.4 cm and their weights ranged between 1.0 and 17.5 g. The total length of females ranged between 5.1 and 15.5 cm and their weights varied from 1 to 34 g. The obtained equations were:

Males	$W = 0.009\ L^{2.886}$
Females	$W = 0.008\ L^{2.981}$
Pooled data	$W = 0.008\ L^{2.973}$

Isometric growth was observed for *M. stebbingi* in Lake Timsah (95% confidence interval for b was 2.848-2.968 for males and 2.928-3.034 for females).

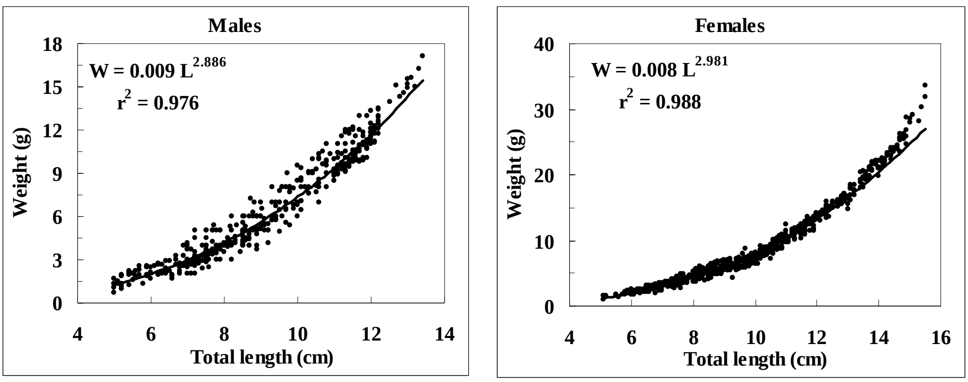

Fig. 2. Length-weight relationship of *Metapenaeus stebbingi* from Lake Timsah

Growth parameters

The mean lengths for cohorts estimated by the Bhattacharya method for males and females are given in table 1. By applying Ford - Walford plot, the values of K were 2.63 and 2.16 yr^{-1} for males and females, respectively, while L_∞ = 14.84 and 16.95 cm total length for males and females, respectively. The estimated values of t_0 were 0.07 and 0.08 yr for males and females, respectively. Table 2 shows the growth parameters estimates obtained from ELEFAN I program and Wetherall method (Fig. 3). The value of K for males is higher than that for females indicating the faster decrease in growth rates of males than females. The estimates of growth parameters of white shrimp were in agreement with the short longevity of these organisms (Beverton & Holt 1957; Garcia & Le Reste 1981) where the results indicated that the average lifespan of this species was about 9 months for males and 12 months for females. Also, the values obtained were consistent with those reported in other studies for related species (Table 3) and are within the reported range for other penaeids (D'Incao & Fonseca 2000). Various growth parameter estimates have been reported for penaeid shrimps from different waters (Chavez 1973; White 1975; Garcia 1978; Garcia & Le Reste 1981; Siddeek et al. 1989; Dall et al. 1990; Mehanna 1993; Xucai & Mohammed 1996; Mehanna 2000; Siddeek et al. 2001; Mehanna 2003). This wide variation in the growth parameter estimates was possible due to a number of reasons: crude earlier estimates; different environments, large fluctuations in size, sex related growth differences, and high correlation between L_∞ and K.

Table 1. Mean lengths (cm) estimated using the Bhattacharya method for *Metapenaeus stebbingi* at Lake Timsah

		Males		Females		Sexes combined	
t_1	t_2	L_1	L_2	L_1	L_2	L_1	L_2
Oct. 15	Nov. 15	5	7	5.25	7.23	5.31	7.25
Nov. 15	Dec. 15	7	8.5	7.23	8.73	7.25	8.73
Dec. 15	Jan. 15	8.5	10	8.73	10.12	8.73	10.10
Jan. 15	Feb. 15	10	11	10.12	11.23	10.10	11.22
Feb. 15	Mar. 15	11	11.9	11.23	12.20	11.22	12.18
Mar. 15	Apr. 15	11.9	12.5	12.20	12.97	12.18	12.96
Apr. 15	May 15	12.5	13	12.97	13.64	12.96	13.63
May 15	Jun. 15	13	13.2	13.64	14.19	13.63	14.19
Jun. 15	Jul. 15	13.2	13.3	14.19	14.64	14.19	14.64
Jul. 15	Aug. 15	--	--	14.64	15.02	14.64	15.04
Aug. 15	Sep. 15	--	--	15.02	15.33	15.04	15.35
Sep. 15	Oct. 15	--	--	15.33	15.60	15.35	15.63

Table 2. Estimates of growth parameters for *Metapenaeus stebbingi* at Lake Timsah using different methods

Method	L_∞			K		
	♂♂	♀♀	♂+♀	♂♂	♀♀	♂+♀
Bhattacharya and Ford-Walford	14.84	16.95	17.07	2.63	2.16	2.10
Wetherall and von Bertalanffy plot	14.91	16.89	16.97	2.55	2.20	2.14
ELEFAN I program	14.95	16.92	16.94	2.59	2.23	2.16

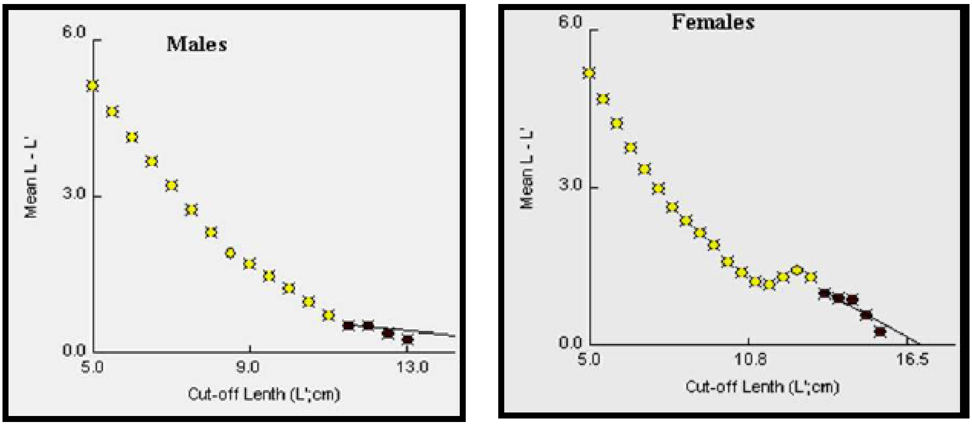

Fig. 3. Powell-Wetherall plot for *Metapenaeus stebbingi* from Lake Timsah

Table 3. Summary of the growth parameter (K), natural mortality (M) and longevity available for some penaeid shrimps in different localities

Species	*K*		M		Longevity (month)	Locality	Author
	♂♂	♀♀	♂♂	♀♀			
Penaeus semisulcatus	*2.15*	*1.44*	2.70	2.9	12	Kuwait	Van Zalinge et al. 1981
Penaeus semisulcatus	3.07	1.25				Gulf of Carpentaria	Kirkwood & Somers 1984
Penaeus notialis	2.46	2.04			23	Senegal	Lhomme & Garcia 1984
Penaeus indicus	1.20	1.00	2.20	1.94	12	Manila Bay	Agasen & Del Mundo 1988
Penaeus stylifera	1.19	1.05	2.60	2.30		India	Suseelan & Rajan 1988
Penaeus merguiensis	1.31	1.05	3.7	3.1		Indonesia	Sumiono 1988
Penaeus longistylus	2.05	1.12			12	Australia	Dredge 1990
Penaeus semisulcatus	3.22	2.24			18 - 24	Gulf of Carpentaria	Somers & Kirkwood 1991
Penaeus indicus	1.51	1.80	1.73	1.73		Sri Lanka	Jayawardane et al. 2002
Litopenaeus stylirostris	2.28	1.92			15 - 20	Gulf of California	Lopez-Martinez et al. 2005
Penaeus japonicus	1.82	1.65	2.73	2.44	15 - 18	Gulf of Suez, Egypt	Mehanna 1993
Penaeus semisulcatus	1.77	1.56	2.52	2.40	15 - 18	Gulf of Suez, Egypt	Mehanna 2000
Penaeus latisulcatus	1.91	1.70	2.74	2.45	12 – 15	Gulf of Suez, Egypt	Mehanna 2003
Metapenaeus stebbingi	2.63	2.16	3.73	3.16	9 - 12	Lake Timsah, Egypt	The present study

Mortality and exploitation rate

The results (Fig. 4) indicated that the total mortality coefficient differs markedly between the two sexes (Z = 10.75 yr^{-1} for males and 7.9 yr^{-1}

for females). These high values of Z are acceptable, because most of the penaeid fisheries around the world have high fishing mortalities and thus show high Z values. The values of M obtained were 3.73 and 3.16 yr^{-1} for males and females respectively. Beverton & Holt (1959) found that the fast growing species have high K- values with high natural mortalities (Table 3).The values of F were 7.02 yr^{-1} for males and 4.74 yr^{-1} for females while the exploitation rate was estimated as 0.65 for males and 0.6 for females. Gulland (1971) suggested that the optimum exploitation rate for any exploited stock is about 0.5 at F_{opt} = M. More recently, Pauly (1987) proposed a lower optimum F that is equal to 0.4 M. 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 *M. stebbingi* stock in Lake Timsah.

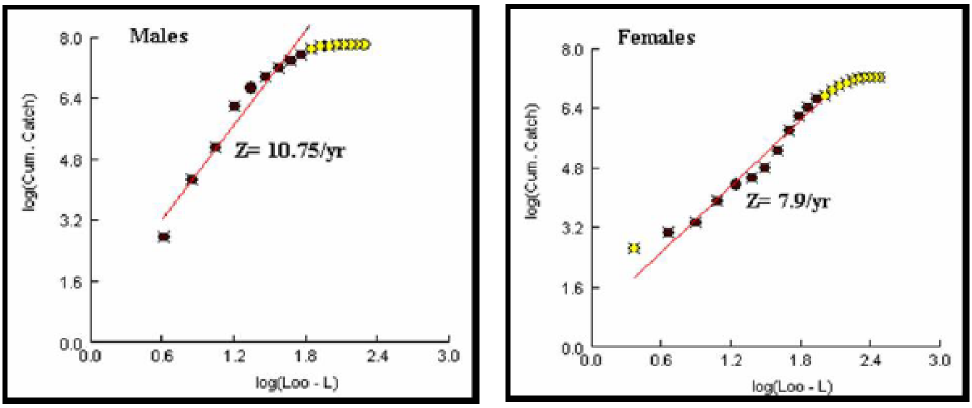

Fig. 4. Jones and vanZalinge plot for *Metapenaeus stebbingi* from Lake Timsah

Length at first capture

The lengths at first capture (the length at which 50% of the fish are vulnerable to capture) were estimated as $L_{50\%}$ = 7.49, 7.62 and 7.73 cm for males, females and sexes combined, respectively (Fig. 5).

Recruitment

The recruitment pattern of *M. stebbingi* is obtained by projecting a set of length frequencies backward into a one year time axis. The recruitment pattern suggests one recruitment pulse per year for males and females (Fig. 6). The recruitment pattern was extended from May to October with a maximum from July to September for males and extended from March to November with a maximum from August to October for females.

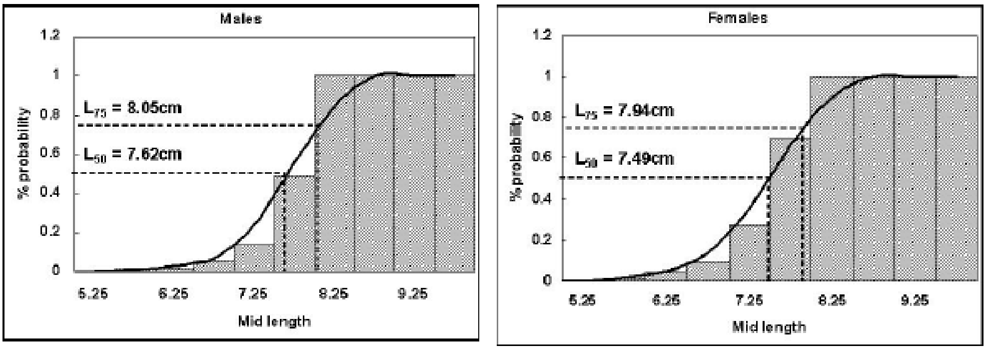

Fig. 5. Length at first capture of *Metapenaeus stebbingi* from Lake Timsah

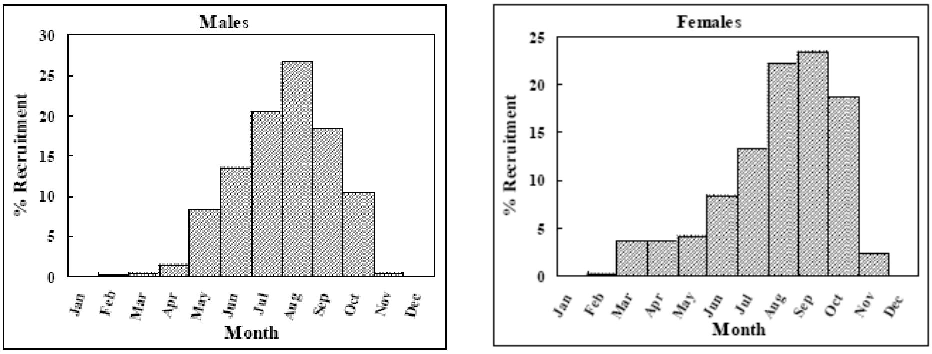

Fig. 6. Recruitment pattern for *Metapenaeus stebbingi* from Lake Timsah

Relative yield per recruit and relative biomass per recruit

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 sexes combined, the input parameters used in the Beverton & Holt (1966) model were the growth and mortality parameters of the combined sexes. These parameters were: L_∞ = 17.07 cm, K= 2.10 yr^{-1}, M = 3.09 yr^{-1}, F = 6.01 yr^{-1}, E = 0.66, L_c = 7.73 cm, L_c/L_∞ = 0.45 and M/K = 1.47.

The plot of relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for sexes combined of *M. stebbingi* (Fig. 7) showed that the maximum (Y'/R) was obtained at E_{MSY} = 0.64. Both of $E_{0.1}$ and $E_{0.5}$ were estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$

were 0.60 and 0.35, respectively. The results indicated that the present level of E (0.66) was higher than that which gives the maximum Y'/R. The results showed also that, the present level of exploitation rate was higher than the exploitation rate ($E_{0.5}$) which maintain 50% of the stock biomass ($E_{0.5}$ = 0.35).

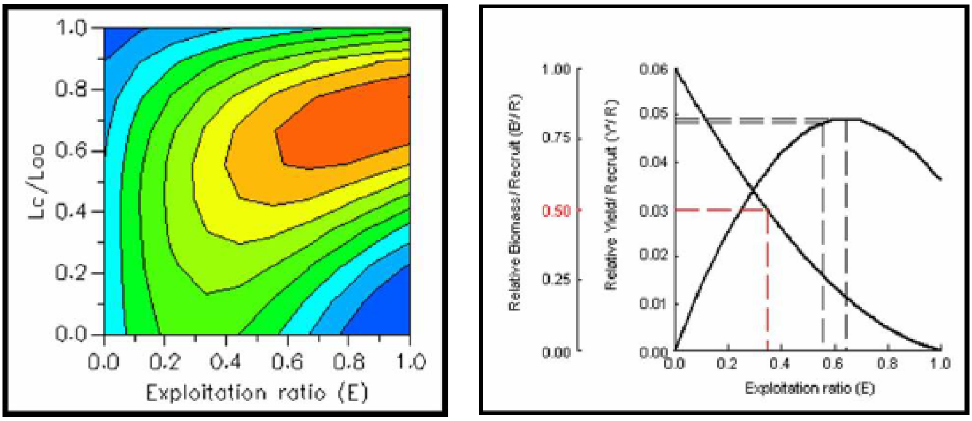

Fig. 7. Relative yield per recruit analysis for *Metapenaeus stebbingi* from Lake Timsah

For management purposes, the exploitation rate of *M. stebbingi* must be reduced from 0.66 to 0.35 (46.1%) to maintain a sufficient spawning biomass because 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) the target reference point in fisheries assessment (Sissenwine 1978; Smith et al. 1993; Caddy & 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.

The reduction of the current exploitation level can be achieved by reducing the fishing effort. If the direct reduction of fishing effort seems to be impossible due to socio-economic reasons, the number of fishing days or the number of fishing trips can be reduced or a suitable period at which all fishing operations were ceased can be suggested.

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