Egypt. J. Aquat. Biol. & Fish., Vol. 19, No. 2: 101-116 (2015) ISSN 1110 – 6131

# Population dynamics of the freshwater crayfish *Procambarus clarkii* (Girard, 1852) in the River Nile, Egypt

**Abd El-Halim A. Saad[1]; Sahar F. Mehanna[2]; Magdy T. Khalil[1] and Mohamed M. Said[1]**
1- Department of Zoology, Faculty of Science, Ain Shams University, Cairo, Egypt.
2- National Institute of Oceanography and Fisheries, Suez, Egypt.

## ABSTRACT

The red swamp crayfish, *Procambarus clarkii* was introduced into the River Nile in the early 1980s and has become a resident in the Egyptian freshwater ecosystems, but up till now no detailed study has been done to know its stock or even its population dynamic in the River Nile.

The population dynamical parameters of *Procambarus clarkii* were estimated during the period from 2009 to 2012; based on 3465 specimens (1455 males and 2010 females) (7.0 – 15.0 TL), collected from two locations along the River Nile. It was found that this species attains its highest growth rate during the first six months of life, after which, the increment in length is decreased with the further increase in age.

The growth of this species is isometric based on the b-value of length weight relationship. From the length frequency distribution analysis, the population parameters for combined sexes were: asymptotic length $L\infty$ = 16.45cm TL, growth coefficient K = 1.60/y, instantaneous total mortality Z = 3.65/y for male and 5.60/y for female, natural mortality M = 2.28/y for male and 1.91/y for female, fishing mortality F = 1.37/y for male and 3.69/y for female, exploitation ratio E = 0.38 /y for male and 0.66/y for female, length at first capture Lc = 9.11 and 9.25 cm TL for males and females, respectively. The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) analysis for *P. clarkii* in the River Nile gives a maximum (Y'/R) at E= 0.70 and the exploitation level which maintains the spawning stock biomass at 50% of the virgin spawning biomass E0.5 was estimated as 0.37. This indicates that there is a chance to expand the red swamp crayfish fishery by increasing the current E to that which gives the maximum Y'/R but raising the exploitation ratio to that level will not be reasonable and will be associated with a very little portion of yield. So, keeping the exploitation ratio at its current value or reducing it to E0.5 value (E= 0.37) to achieve more economic return

**Keywords**: *Procambarus clarii*, population dynamics, freshwater crayfish, River Nile

## INTRODUCTION

The red swamp crayfish, (Girard, 1852) (Decapoda, Astacidea, Cambaridae), is a native species in the southern and central regions of the United States. It was introduced world-wide, and has become the dominant crayfish in almost all areas colonized by its naturalized populations (Gherardi, 2006).

A number of life history traits make this species suitable for commercial exploitation, including rapid growth, high fecundity, polytrophism, behavioral plasticity, resistant to extreme environmental conditions and diseases (Huner & Lindqvist, 1995; Barbaresi & Gherardi, 2000; Hazlett *et al*., 2003). It is also well adapted to life in areas with strong seasonal fluctuations in the level of shallow waters, where it digs burrows (Huner & Barr, 1984).

Since the introduction of *P. clarkii* in early 1980s, from the United States into the Egyptian freshwater systems for aquaculture and its establishment at the commercial farm at Giza governorate (Manial Sheeha), it has been rapidly expended in all aquatic ecosystems in Egypt extended from Giza governorate to the whole Delta region in the north, and to Qena governorate in the south (Rawi, 1995; Ibrahim *et al.*, 1995 ; Tolba 1999 ).

The life history of *P. clarkii* in Egypt appears different from that described from the southern United States (Hunner, 1981); as the USA crayfish population has only one generation per year and a breeding peak taking place at early summer. While in Egypt they have 2 generations (Ibrahim *et al.*, 1995).

Knowledge of population dynamics of a species represents one of the most useful tools to understand the population status, since population structure and dynamics depend on recruitment, growth, mortality, and in the case of economic resources, on fishing methods (Jones & Coulson 2006). Population dynamics can also provide an estimate for the fitness of the population to its habitat. While also considering the importance of understanding how demography and population regulation enlighten the theory of biological control or ensure the viability of non-native species in harmony with human; needs developing new techniques for sustainable development and rational exploitation (Jones & Coulson 2006).

The present study aims to estimate the basic parameters of *P.clarkii* stock in two areas in the River Nile for the purpose of conservation for improving its production to meet demands.

## MATERIALS AND METHODS

**1. Study areas and sampling method:**

Two study areas were selected along the River Nile; the first one is located at Damietta branch in El-Qanater El-Khyria (31°8' E and latitude 30°11' N). The second area is situated on the main Nile stream at Nasser Institute (31° 14' E and latitude 30° 5' N). Specimens of *Procambarus clarkii* were collected monthly from both areas from October 2009 to February 2012, using Gobia trap

**2. Population Dynamics:**

Specimens were kept in plastic bags and transported immediately alive to the Invertebrates' Laboratory (Department of Zoology, Faculty of science, Ain Shams University). A total of 3465 crayfish specimens were collected then divided according to their sex. Length frequency for each sex was grouped in 1cm length classes and the number and weights of these classes were recorded. Representative samples for each sex were taken as sub-samples. Data were used to determine the biological characteristics of the species as well as carrying out age and growth.

The biological measurements for total length (TL), carapace length (CL) and total body weight (W) were recorded to estimate the following relationships:

1) Age determination by using the standard statistical method of Bhattacharya (1967) involved in the FiSAT software of Gayanilo and Pauly(1997), which allow the conversion of length frequency data into age groups.
2) Total length and carapace length - Body weight relationship was expressed by the following equation:

$$W = a L^b$$ (Beckman, 1948 and Le Cren, 1951)

[W = total weight, L = length (total body length or carapace length), a and b are constants]

3) Estimation of theoretical growth by applying von Bertalanffy growth in length model (1938):

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

[ $L_t$ = mean length at age t, $L_\infty$ = asymptotic length, , K = growth coefficient that determines the rate at which $L_\infty$ is attained, t = age at length $L_t$, $t_0$ = age at which the length is theoretically equals zero]

Von Bertalanffy growth in weight equation was derived from the growth in length equation:

$$W_t = W_\infty [1 - e^{-k(t - t_o)}]^b$$

[$W_t$ = weight at age t, $W_\infty$ = asymptotic weight]

4) Estimation of von Bertalanffy growth model constants: $L_\infty$ and K were estimated using the methods of Ford (1933), Walford (1946), Powell (1979), Wetherall (1986) and ELEFAN I method "K-scan routine" (Pauly, 1987). Powell and Wetherall method involved in the FiSAT software, allows the estimation of $L_\infty$ and Z/K from a sample by pooling a series of length-frequency data. While, ELEFAN I was applied to give an approximate value for $L_\infty$ and scan for the best estimation for K. $t_0$ was estimated from the following rearranged formula of the von Bertalanffy equation:

$$-\ln [1 - (L_t/L_\infty)] = -k*t_0 + k*t$$

5) Growth performance index (Ø') was computed according to the formula of Pauly and Munro (1984) as follows:

$$Ø' = \log_{10} K + 2 \log_{10} L_\infty$$

6) Length and age at first capture: The length at the first capture (Lc) is the length at which 50% of the crayfish retained in the gear was estimated by the analysis of catch curve using the method of Pauly (1984), while the corresponding age at the first capture (Tc) was computed by converting Lc to age using the von Bertalanffy growth equation as follows:

$$T_c = t_0 - (1/k * \ln [1 - (L_c/L_\infty)])$$

7) Length and age at first sexual maturity: The length at first sexual maturity (Lm) is the length at which 50% of crayfish reach their sexual maturity was estimated by fitting the percentage maturity against mid lengths. Lm was estimated as the point on X-axis corresponding to 50% point on Y-axis, while the corresponding age at first sexual maturity (Tm) was computed by converting Lm to age using the von Bertalanffy growth equation as follows:

$$T_m = t_0 - (1/k * \ln [1 - (L_m/L_\infty)])$$

8) Estimation of mortality rates (M): Two different methods were applied during this investigation; analysis of the cumulative catch curve (Jones and Van Zalinge, 1981) and analysis of the length converted catch curve (Pauly, 1983) and both are depending on length frequency data.

A- Ursin's equation (1967):

$$M = W^{-1/3}$$ [W = mean total body weight]

B- Pauly's empirical equation (1980):

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

[$L_\infty$ = asymptotic length, K = growth coefficient and T = average annual temperature of the stock's habitat, in °C]

The fishing mortality coefficient was estimated as follows:

$$F = Z - M$$

[F = fishing mortality coefficient. and Z= total mortality coefficient]

9) Exploitation rate (E) was estimated by the formula of Gulland (1971):

$$E = F / Z$$

10) Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986).

## RESULTS AND DISCUSSION

### I. Age composition:

A total of 3465 of *P. clarkii* (1455 males and 2010 females, 42 and 58 %, respectively) were used for the estimation of age composition by applying the Bhattacharya method and ELEFAN I software. The red swamp crayfish *P. clarkii* ranged between 7 and 13.8 cm TL (3.5-7.4 cm CL) for males and between 7 and 15 cm TL (3.5 – 8 cm CL) for females. The age composition as estimated from Modal Progression Aanalysis (MPA) for *P. clarkii* is given in Table (1) and presented in (Figs. 1 - 4).

By applying the MPA for the freshwater crayfish, it is obvious that, there are one mode (age group) for males and two modes for females indicating that the longevity extends to one year for males and one and half years for females (Figs.1&2). Also, ELEFAN I gave the same results (Figs. 3 & 4).

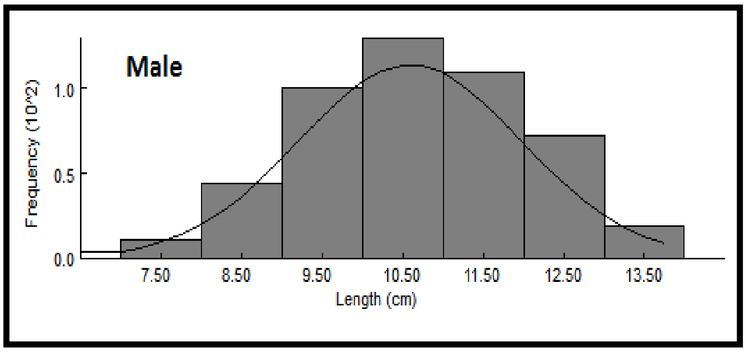


Fig. 1 : Age composition of *P. clarkii* males from the River Nile using Bhattacharya method.

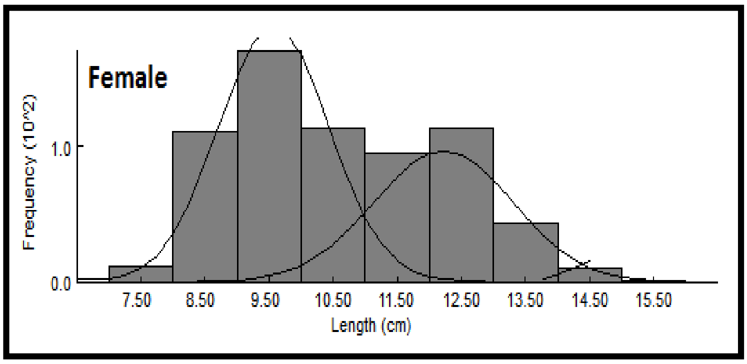


Fig. 2: Age composition of *P. clarkii* females from the River Nile using Bhattacharya method.

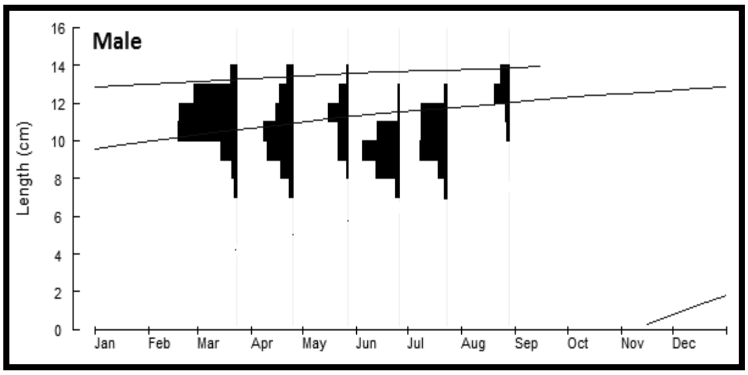


Fig. 3: Age composition of *P. clarkii* males from the River Nile using ELEFAN I analysis.

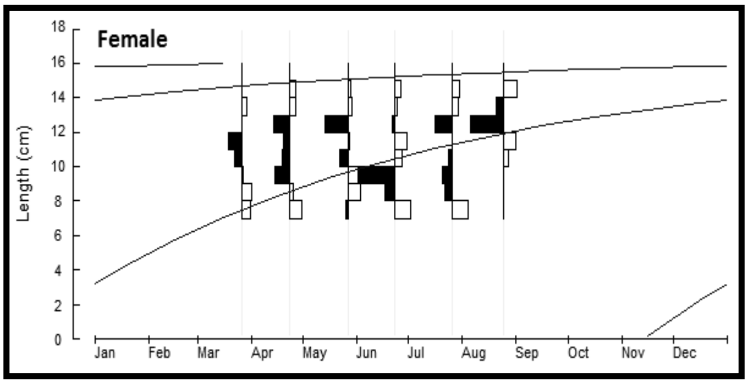


Fig. 4: Age composition of *P. clarkii* females from the River Nile using ELEFAN I analysis.

Table (1): Age composition of *P. clarkii* from the River Nile.

| Age group (year) | Calculated total length (cm) | | |
|---|---|---|---|
| | Male | Female | Pooled data |
| **0.50** | 8.2 | 8.1 | 8.12 |
| **1.00** | 12.9 | 12.6 | 12.76 |
| **1.50** | ----- | 14.8 | 14.79 |

Scalici *et al.* (2010) found that the collected *P. clarkii* males in their study were represented 39.3% from total specimens; and females represented 60.7%. This observation is greatly coincides with that of the present study as males and females represent 42% and 58% respectively. Similar observation of biased sex ratio was also demonstrated in other studies such as Anastácio & Marques (1995) and Fidalgo *et al.* (2001) have observed in the lower basin of Mondego River (Portugal), and Ligas (2008) in Central Italy.

On the other hand, in Louisiana and Kenya the number of females was slightly inferior or equal to the number of males (Huner 2002). Anastácio and Marques (1995) stated that there is apparently an increase in the proportion of females within populations with increasing latitude, as a response to unfavorable climates. The maintenance of stable populations in unfavorable regions seems, therefore, to depend on the production of more offspring, which can be attained with the increase of female numbers. In more favorable environments, a population feature is probably that of a lower investment in reproduction (Anastácio and Marques 1995).

The present study revealed that the longevity of *P. clarkii* can extend to one year for males and one and half years for females. According to Frutiger *et al.* (1999), Huner (2002), Chiesa *et al.* (2006), Scalici & Gherardi (2007) and Scalici *et al.* (2010); *P. clarkii* may live up to 4 - 5 years.

The population structure of adult *P. clarkii* is consisted of 6 age classes for females and 5–6 for males (scalici *et al*., 2010). While other studies (Lozano-Guerra and Escamilla- Niño, 1995, Chiesa *et al*., 2006 and Ligas, 2008) revealed three age classes of *P. clarkii* populations. In the present study 3 age classes were observed in female and 2 age classes in males (Fig. 13).

Scalici *et al.* (2010) revealed in their study that the value for expected longevity, is nearly 9 years for both sexes of *P. clarkii*. Moreover, these values for expected longevity were very high, and differed very much from other studies. In fact Huner (2002) and Scalici and Gherardi (2007) maintain that *P. clarkii* lifespan has a maximum duration of 4 years, while Frutiger *et al*. (1999) described how the majority of individuals live through the third year and how the bigger ones can live up to 5 years. In the current investigation, it was deduced that, the expected longevity of *P. clarkii* males was two years, whereas that of females was 3 years.

**II. Length –Weight relationship:**

The length and weight measurements of 1455 males and 2010 females of *P. clarkii* were used for the estimation of length weight relationship. Males varied in total length from 7 to 13.8 cm and in weight from 7 and 102 g, while females ranged between 7 and 15 cm in length and between 9 and 105 g in weight.

The estimated length - weight equations for the red swamp crayfish by sex (Figs. 5-7) were:

Male: $W = 0.0218\ L^{3.1910}$

Female: $W = 0.0233\ L^{3.0999}$

Sexes combined: $W = 0.026\ L^{3.0804}$

It was noticed that, the p-value was not significantly different from 3, so those species are grown isometrically.

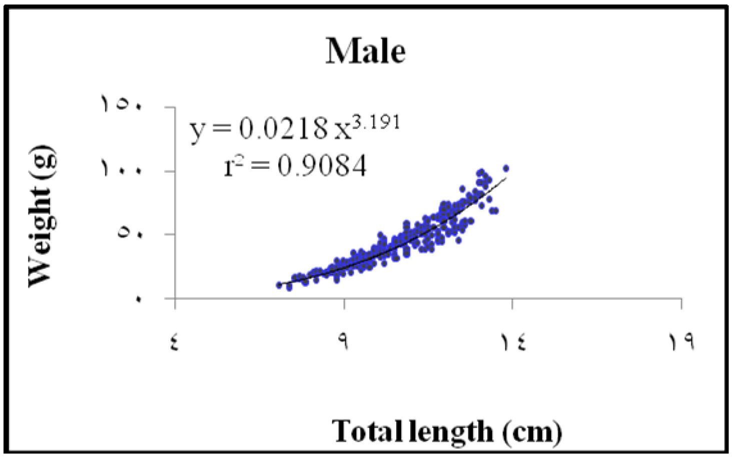


Fig. 5: Length – Weight relationship of *P. clarkii* from the River Nile.

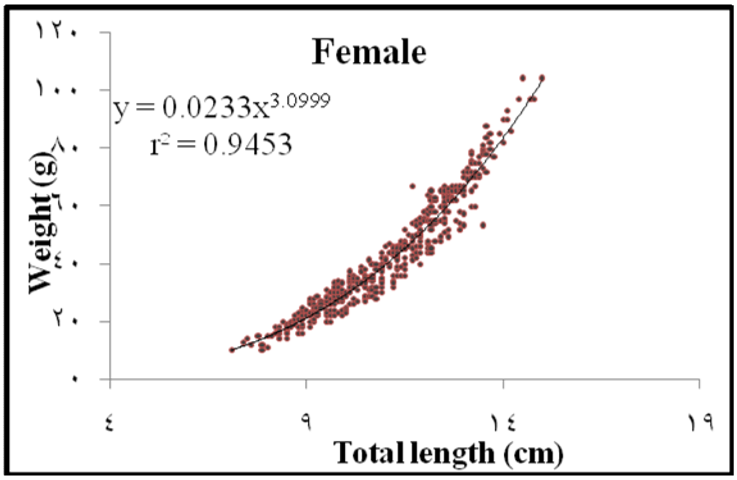


Fig. 6: Length – Weight relationship of *P. clarkii* from the River Nile.

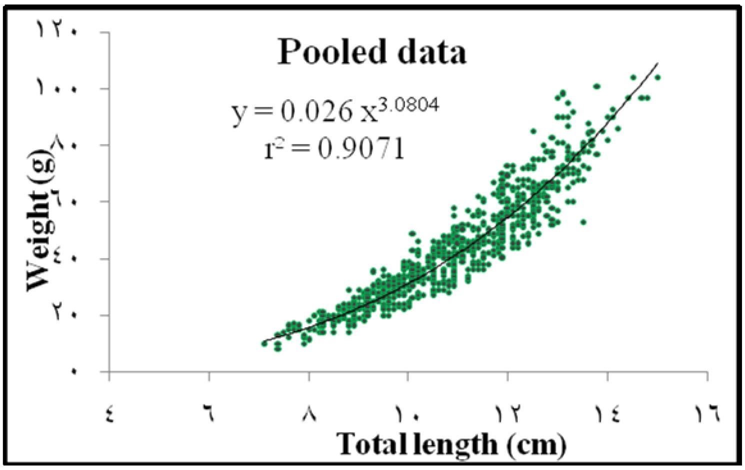


Fig. 7: Length – Weight relationship of *P. clarkii* from the River Nile.

Scalici *et al.* (2010) measured the carapace length (CL) of *P. clarkii*, in brackish Mediterranean biotope in Italy, and they found that the mean values of CL were 4.49 ± 0.68 cm in females and 4.24 ± 0.73 cm in males. These measurements are lower than that of the present study which were 5.7 ± 0.083 cm in females and 5.6 ± 0.088 cm in males. This difference in CL may be due to higher growth rate in *P. clarkii* in Egypt than its counterpart in Italy and this may be attributed to higher temperature and nutritive state of freshwater habitats of the River Nile.

Harper *et al.* (2002) found in their study a highly significant linear relationship ($r^2$ = 0.97) between carapace length and total length for *P. clarkii*; in the present investigation a very similar significant linear relationship ($r^2$=0.977) between the same parameters was recorded.

Length–weight relationships vary among crayfish species according to their sex, and ecological conditions (Lindqvist and Lathi, 1983). Such difference may be a reflection of a number of factors including photoperiod, population density, food abundance, water level fluctuations, water temperature, and water quality (Huner and Romaire, 1978; Chien, 1980; Huner and Barr, 1991).

Total length increased allometrically with weight for males and females of *Procambarus acutus acutus* (Mazlum *et al*. 2007), while in the present investigation the growth in *P. clarkii* is isometric as no significant difference was detected between males and females.

The relationship between the total length and the body weight of *P. clarkii* in the present work was considerably strong ($r^2$ = 0.90). In the work done by Harper *et al*. (2002), the relationship between carapace length and body weight is also elucidated ($r^2$ = 0.76) which is lower than that of the present study and this may be attributed to the low number (400) of measured *P. clarkii* specimens in the previous study; in contrast, the number of specimens measured in the present study was 3465.

**VI. Growth parameters:**

The obtained values of growth coefficient "K" for this species were relatively high indicating the high growth rate for this species. The growth parameters of the present study are given in Tables (2, 3 and 4). The differences in growth between regions can be attributed to the difference in size of the largest individual sampled in each area. On the other hand, it is also possible that the variations in population parameters of the species represent epigenetic responses (Bagenal and Tesch, 1978) to the different conditions (temperature and food) prevailing in different areas.

Table (2): Growth parameters of *P. clarkii* (males) as estimated from three different methods.

| Method | Growth parameters | | |
|---|---|---|---|
| | **L∞** | **K** | **$t_0$** |
| **Back-calculation and Ford-Walford plot** | 15.11 | 1.69 | - 0.05 |
| **Powell-Wetherall and von Bertalanffy plot** | 14.91 | 1.77 | |
| **ELEFAN I** | 15.18 | 1.74 | |

Table (3): Growth parameters of *P. clarkii* (females) as estimated from three different methods.

| Method | Growth parameters | | |
|---|---|---|---|
| | **L∞** | **K** | **$t_0$** |
| **Back-calculation and Ford-Walford plot** | 16.90 | 1.43 | -0.03 |
| **Powell-Wetherall and von Bertalanffy plot** | 17.35 | 1.51 | |
| **ELEFAN I** | 16.95 | 1.54 | |

Table 4: Growth parameters of *P. clarkii* (sexes combined) as estimated from three different methods.

| Method | Growth parameters | | |
|---|---|---|---|
| | **L∞** | **K** | **$t_0$** |
| **Back-calculation and Ford-Walford plot** | 16.37 | 1.65 | -0.03 |
| **Powell-Wetherall and von Bertalanffy plot** | 16.52 | 1.58 | |
| **ELEFAN I** | 16.45 | 1.60 | |

Scalici *et al.* (2010) showed that *P. clarkii* in Italy has a low growth rate (k = 0.33 and 0.32 in males and females respectively, and L∞= 6.83 and 7.46 in males and females respectively), and this is in contrary with that of the present study as the growth rate is much higher (k = 1.74 and 1.54 in males and females respectively, and L∞ = 15.18 and 16.95 in males and females respectively). In the present study, *P. clarkii* has high growth rate specially in the first six months of life; this may be attributed to higher temperature in the River Nile habitat.

Fidalgo *et al*. (2001) calculated Von Bertalanffy growth parameters of *P. clarkii* L∞, K and $t_0$ which were 6.2 cm, 0.23 and 0.11 month respectively. In the present study, values of L∞, K and $t_0$ was 15.18, 1.74 and 0.03 month respectively, this difference in values can be explained on the basis of growth rate which may be very high in the River Nile compared to that in Portugal.

From the present and previous studies (Frutiger *et al.,* 1999; Huner, 2002; Chiesa *et al.,* 2006; Scalici and Gherardi, 2007 and Scalici *et al.,* 2010) it is reported that there is an inverse relationship between growth rate and longevity of *P. clarkii* and this may be explained to change in climatic conditions.

**III. Growth performance index (Ø'):**

This index is used to measure the overall growth performance. Therefore, it can be applied to discriminate different species of fishes. The growth performance index for *P. clarkii* in the River Nile is 3.2, 2.7 and 3.19 for males, females and pooled data respectively.

Scalici and Gherardi (2007) calculated the growth performance index (Ø') for *P. clarkii* population in Mediterranean wetland in Italy and they found that the Ø' equals 3.445 and 3.405 for females and males respectively. However, in the present work Ø' was 2.7 and 3.2 for females and males respectively. The lower Ø' in the present study may be related to the different ecological conditions and pollution between the 2 study regions from which the specimens were collected.

**IV. Length ($L_c$) and age ($T_c$) at first capture:**

The length at first capture (the length at which 50% of the fish at that size are vulnerable to capture) for *P. clarkii* was estimated as a component of the length converted catch curve analysis (FiSAT, Pauly, 1984). The resultant curve derived from the catch curve provided an estimate of $L_c$ at 9.11 and 9.25 cm for males and females, respectively (Figs. 8 & 9). These values were corresponding to ages of 7 and 8 months for males and females, respectively.

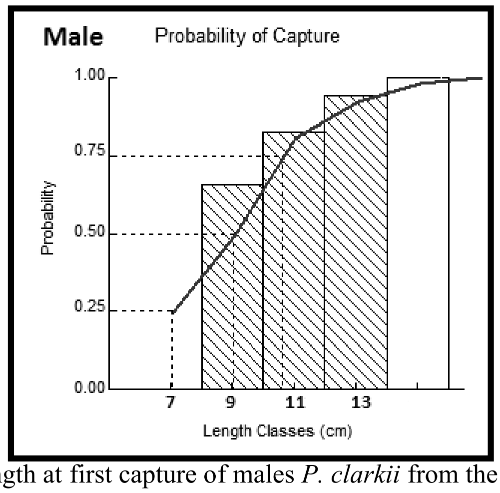


Fig. 8: Length at first capture of males *P. clarkii* from the River Nile.

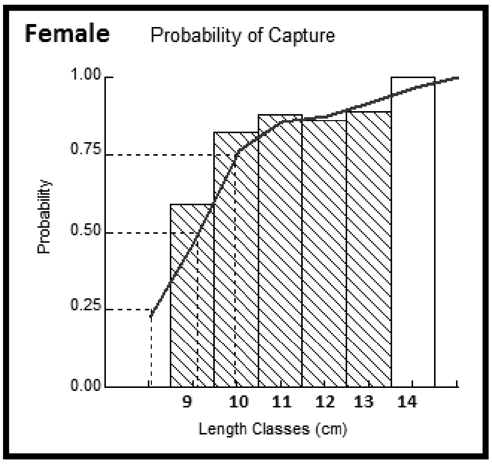


Fig. 9: Length at first capture of females *P. clarkii* from the River Nile.

## V. Mortality:

### V.1 Total mortality coefficient (Z):

The total mortality coefficient (Z) is defined as the total loss of individuals from a given population during a certain time interval. The rate of decrease in the number of the population can be expressed by:

$$dN/dt = -ZN$$

Where Z is the instantaneous rate of total mortality. and N is the number of individuals of a population at the time (t).

The total mortality coefficient (Z) is composed of two components namely fishing mortality (F) which is, the death resulting from capture removal by man and the natural mortality (M) which is defined as the death resulting from natural causes such as diseases, predation, accidents, senility … etc.

The total mortality coefficient is the sum of natural mortality coefficient and fishing mortality coefficient

$$\mathbf{Z= F+M}$$

In the present work, two of these methods were used for the estimation of the total mortality coefficient "Z": Linearized length converted catch curve (Pauly ,1983) and the cumulated catch curve method (Jones and Van Zalinge, 1981). The results were as follows (Table 5 and Figs10-13):

Table 5: Z Estimation of Z per year by different methods for *P. clarkii* in the River Nile.

| Method | Male | Female | Pooled data |
|---|---|---|---|
| **Pauly (1983)** | 3.59 | 5.51 | 5.19 |
| **Jones & Van Zalinge (1981)** | 3.71 | 5.68 | 5.22 |
| **Mean** | 3.65 | 5.60 | 5.21 |

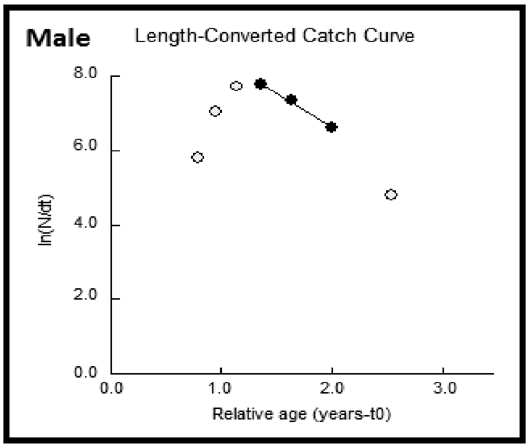


Fig. 10: Converted catch curve of males *P. clarkii* in the River Nile.

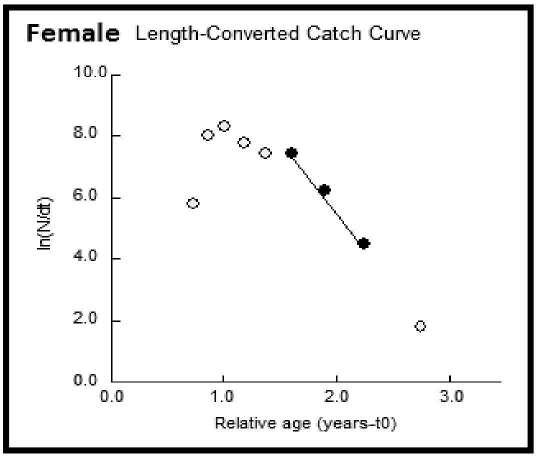


Fig. 11: Converted catch curve of females *P. clarkii* in the River Nile.

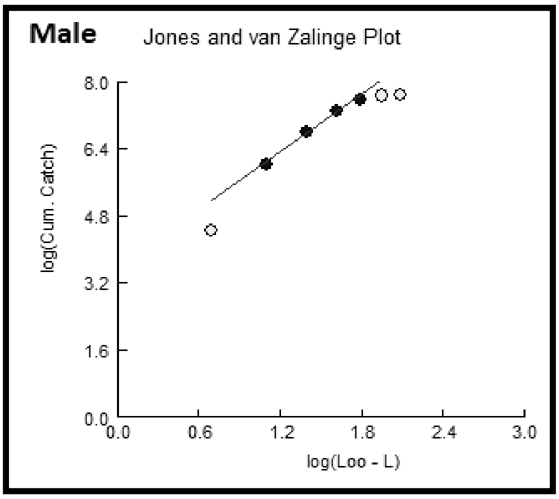


Fig. 12: Cumulated catch curve of males *P. clarkii* in the River Nile.

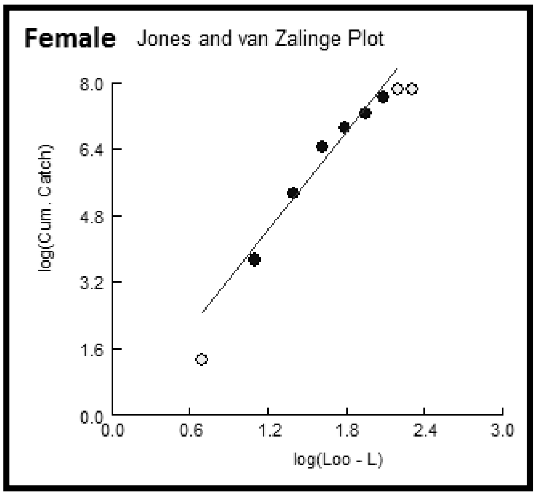


Fig. 13: Cumulated catch curve of females *P. clarkii* from the River Nile.

**V.2 Natural mortality coefficient (M):**

The natural mortality is defined as the death created by all other causes than fishing e.g. predation including cannibalism, diseases, spawning, stress, starvation, and old age. The same species may have different natural mortality rates in different areas depending on the density of predators. Direct measurement of (M) is often impossible to obtain. It has been attempted to identify quantities which can be assumed proportional to M and which are easier to estimate. In the literature, several methods were available for the rough estimation of (M).

In the present work, the geometric mean of two different methods was estimated. The formulae described by Tanaka (1960) and Pauly (1980) were used to estimate the natural mortality coefficient of *P. clarkii* from the River Nile. The estimated mean value of M was 2.28, 1.91 and 1.99 per year for male, female and sexes combined respectively.

**V.3 Fishing mortality coefficient (F):**

The fishing mortality coefficient (F) is the rate at which fish are being caught, as a proportion of the exploited fish stock. The available data are not sufficient to produce a direct estimation of the fishing mortality. So, it was estimated by subtracting the value of the natural mortality coefficient from the value of the total mortality coefficient as follows:

$$\mathbf{F = Z - M}$$

In the present study, the fishing mortality coefficient (F) of *P. clarkii* collected from the River Nile was found to be as follows:

**F = 1.37 / year for males**

**F = 3.69 / year for females**

**F = 3.22 / year for combined sexes**

The obtained results indicated that the fishing mortality coefficient of females is higher than that of males. The total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) recorded in the present study were comparatively higher than those recorded by Scalici *et al.* (2010). These higher values of Z, M and F in the River Nile may be attributed to many factors such as pollution of water with heavy metals, agricultural pesticides, industrial drainage and sewage. In addition to previous factors, increment of *P. clarkii* fishing may lead to increasing rates of F which directly raise Z value.

It was recorded that fishing mortality coefficient (F) of females (3.69) is much higher than that of males (1.37) and this may be due to high fishing levels targeting females of *P. clarkii* which are always larger than males.

**VI. Exploitation ratio (E):**

The exploitation ratio (E) of *P. clarkii* collected from the River Nile was estimated to be as follows:

**E = 0.38 / year for males**
**E = 0.66 / year for females**
**E = 0.62 / year for combined sexes**

It was noticed that the exploitation rate of females was higher than that of males indicating that females are more vulnerable for fishing activities than males. Ahmed (2012) estimated the exploitation rate (E) of *P. clarkii* (0.8); Gulland (1971) suggested that a fish stock is optimally exploited at a level of fishing mortality that generates E = 0.5 where optimum fishing mortality equals the natural mortality (F = M). However, in the present study E was 0.62 / year for combined sexes. Ahmed (2012) explained her results by referring that crayfish were over fished. In the present investigation similar explanation was also set (slight overfishing) and comparing to her results the exploitation rate is less than hers and this may be due to collecting crayfish from different study areas.

**VII. Management:**

It is well known that, management strategies and techniques are usually classified into two distinct categories namely: the regulation of catch-age composition and the regulation of the fishing effort (Mehanna, 1996).

For the regulation of catch-age composition, several analytical models have been developed. These models are based on the estimation of the yield per recruit under a particular set of fishing conditions. The Beverton and Holt (1957, 1966) model is the most commonly used model in this field.

In the present study, the relative yield per recruit was applied to evaluate the fishery status of *P. clarkii* in the River Nile. In general, it is clear from Fig. 14 that the curve starts at the origin where the relative yield per recruit is zero when the exploitation rate is zero. Then the relative yield per recruit increases rapidly as the fishing mortality and exploitation level increase and reached its maximum value, after which the yield per recruit decreases with further increasing of exploitation rate .

The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) analysis for *P. clarkii* in the River Nile gives a maximum (Y'/R) at E= 0.70 and the exploitation level which maintains the spawning stock biomass at 50% of the virgin spawning biomass $E_{0.5}$ was estimated at 0.37.

This indicates that there is a chance to expand the red swamp crayfish fishery by increasing the current E to that which gives the maximum Y'/R, but raising the exploitation ratio to that level will not be reasonable and will be associated with a very little portion of yield. So, keeping the exploitation ratio at its current value or reducing it to $E_{0.5}$ value (E= 0.37) will be achieve more economic return.

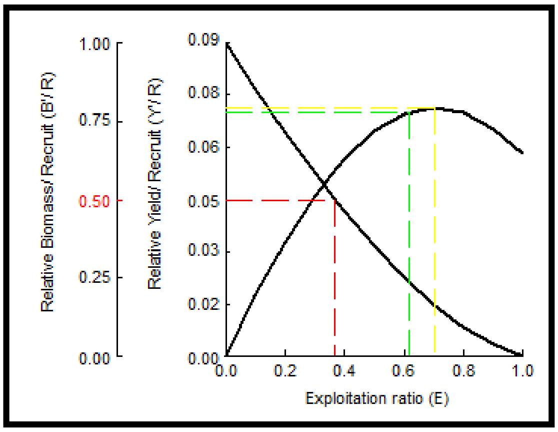


Fig. 14: Yield per recruit analysis of *P. clarkii* in the River Nile.

## REFERENCES


Ahmed, M. A. K. (2012). "Ecological studies on the crayfish, *Procambarus clarkii* (Girard, 1852) in some sectors of the River Nile and its tributaries in Egypt" M.Sc. thesis - Ain Shams university.

Anastácio, P. M. and Marques, J.C. (1995). Population biology and production of the red swamp crayfish *Procambarus clarkii* (Girard) in the lower Mondego river valley, Portugal. J. Crustac. Biol., 15:156–168.

Bagenal, T. B. and Tesch, F. W. (1978). Age and Growth. *In*: Methods for Assessing of Fish Production in Freshwaters. Bagenal, T.B. (Ed.). 3rd Edn. No. 3, Blackwell Scientific Publication Ltd., pp:

fish populations. Fisheries 101-136.

Beckman, W. C. (1948). The length-weight relationship, factors for conversions between standard and total lengths, and coefficient of condition for seven Michigan fishes. Trans. Am. Fish. Soc., 76:63-81.

Beverton, R. J. H. and Holt, S. J. (1957). On the dynamics of exploited Investigation , Series II 19. 533pp.

Beverton, R. J. H. and Holt, S. J. (1966). On the dynamics of the exploited fish populations. Fisheries Investigation Series, p. 2.

Chien, Y. (1980). Effects of flooding dates and disposals of rice straw on crayfish *Procambarus clarkii* (Girard) culture in rice fields. PhD Dissertation, Louisiana State University, Baton Rouge, LA, USA, 120 pp.

Chiesa, S.; Scalici, M. and Gibertini, G. (2006). Occurrence of allochthonous freshwater crayfishes in Latium (Central Italy). Bull Fr Peche Piscic pp.380-381:883-902.

Fidalgo, MRA.; Carvalho, P. and Santos, P. (2001). Population dynamics of the red swamp crayfish, *Procambarus clarkii* (Girard, 1852) from the Averio Region, Portugal (Decapoda, Cambaridae). Crustaceana, 74:369-375.

Frutiger, A.; Borner, S.; Büsser, T.;Eggen, R.; Müller, R.; Müller, S. and Wasmer, H. R. (1999). How to control unwanted populations of *Procambarus clarkii* in Central Europe? Freshwater Crayfish, 12:714–726.

Gayanilo, F.C. and Pauly, D. E. (1997). FiSAT: FAOICLARM stock assessment tools. (FiSAT). Reference manual. FAO Computerized Information Series (Fisheries), 8, FAO, Rome, 262 pp.

Girard, C. (1852). Revision of the North American Astaci with observations on their habits and geographical distribution. Proc. Acad. Nat. Sci. Phila., 6: 87-91.

Gulland, J. A. (1971). The Fish Resources of the Ocean West Poly Fleet, Survey Fishing News (Books) Ltd. FAO Tech. Paper No. 97, 428pp.

Harper, D. M.; Smart, A. C.; Coley, S.; Schmitz, S.; De Beauregard, A. C. G.; North, R.; Adams, C.; Obade, P. and Kamau, M. (2002). Distribution and abundance of the Louisiana red swamp crayfish *Procambarus clarkii* Girard at Lake Naivasha, Kenya between 1987 and 1999 Hydrobiol., 488: 143–151.

Hazlett, BA.; Burba, A.; Gherardi, F. and Acquistapace, P. (2003). Invasive species use a broader range of predation-risk cues than native species. Biol. Invas., 5:223–228.

Huner J. V. (2002) *Procambarus. In*: Holdich DM (eds), Biology of freshwater crayfish. Blackwell, Oxford, pp 541–584.

Huner J. V. and Barr J. E. (1984). Red swamp crayfish: Biology and exploitation. Baton Rouge, Louisiana: Louisiana Sea Grant College Program.

Huner, J. V. (1981). Information about the biology of red crawfish, Procambarus clarkii (Girard, 1852). (Decapoda, Cambaridae) for fisheries managers in Latin America. An. Inst. Mar. Limnol. Nal. Autón. México, 8: 43-50.

Huner, J. V. and Romaire, R. P. (1978). Size at maturity as a means of comparing populations of *Procambarus clarkii* (Girard) (Crustacea, Decapoda) from different habitats. P. J. Laurent. (Ed.). Proc. 4th Int. Crayfish Symp., 4, 53–65.

Huner, J.V. and Lindqvist O. V. (1995). Physiological adaptations of freshwater crayfish that permit successful aquacultural enterprises. American Zool., 35: 12-19.

Ibrahim, A. M.; Khalil, M. T. and Mubarak, M. F.(1995). On the feeding behavior of the exotic *Procambarus clarkii* in Egypt and its prospects in the bio-control of local vector snails. J. Union. Arab Biol., Cairo. 4 (A), Zool.: 321-340. ISSN 1110-5372.

Jones, JPG. and Coulson, T. (2006). Population regulation and demography in a harvested freshwater crayfish from Madagascar. Oikos, 112:602–611.

Jones, R. and van Zalinge, N.P. (1981). Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bull. Mar. Sci. 2:273–288.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology, 20: 201 – 219.

Ligas, A. (2008). Population dynamics of *Procambarus clarkii* (Girard, 1852) (Decapoda, Astacidea, Cambaridae) from southern Tuscany (Italy). Crustaceana, 81:601–609.

Lindqvist, O. V. and Lathi, E. (1983). On the sexual dimorphism and condition index in the crayfish, Astacus astacus L., in Finland. Freshwater Crayfish 5:3–11.

Lozano-Guerra, J. and Escamilla-Niño, A. (1995). Ecology of red swamp crayfish (*Procambarus clarkii*, Girard) in the Central Meseta of Spain. Freshwater Crayfish, 8:179-200.

Mazlum, Y.; Can, M. F. and Eversole, A. G. (2007). Morphometric relationship of length–weight and chelae length–width of eastern white river crayfish (*Procambarus acutus acutus*, Girard, 1852), under culture conditions J. Appl. Ichthyol., 23:616–620.

Mehanna, S. F. (1996). A study of the biology and population dynamics of *Lethrinus mahsena* (Forskål, 1775) in the Gulf of Suez. Ph.D. Thesis. Fac. Sci. Zagazig Univ., 230pp.

Pauly, D. and Soriano, M. L. (1986). Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: J.L. Maclean, L.B. Dizon & L.V. Hosillos (eds): The first Asian fisheries forum, pp. 491-495. Asian Fish. Soc., Manila.

Pauly, D. (1980). On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J Cons CIEM ,39:175–192.

Pauly, D. (1983). Length converted catch curves: A powerful tool for fisheries research in the tropics (Part 1) Fishbyte, 1(2): 9 -13.

Pauly, D. (1984). Length-converted catch curves: A powerful tool for fisheries research in the tropics (Part II). ICLARM Fishbyte, 2(1): 17-19.

Pauly, D. (1987). A review of the ELEFAN system for analysis of length- frequency data in fish and aquatic invertebrates. ICLARM Conf. Proc., 13: 7-34.

Powell, D. G. (1979). Estimation of mortality and growth parameters from length frequency of a catch. Rapp. P. V. Reun. CIEM, 175: 167-169. *Procambarus clarkii.* Mar. Freshw. Behav. Physiol. 39:175-191.

Rawi, M. S. (1995). Toxicological and physiological characteristics of Aluminum in some freshwater molluscs and crustaceans. Proc. Zool. Soc. A. R. Egypt, 24: 224-243.

Scalici, M. and Gherardi, F. (2007). Structure and dynamics of an invasive population of the red swamp crayfish (*Procambarus clarkii*) in a Mediterranean wetland. Hydrobiologia, 583:309–319.

Scalici, M.; Chiesa, S.; Scuderi, S.; Celauro, D.and Gibertini, G. (2010). Population structure and dynamics of *Procambarus clarkii* (Girard, 1852) in a Mediterranean brackish wetland (Central Italy). Biol. Invasions, 12(1): 415-1425

Tanaka, S. (1960). Studies on the dynamics and the management of fish populations. Bulletin of the Tokai Regional Fisheries Research Laboratory 28, 200 pp. [In Japanese with English summary.]

Tolba, M. R. (1999). The red swamp crayfish *Procambarus clarkii* (Decapoda: Cambaridae) as bio-indicator for total water quality including Cu and Pb pollution. Egypt. J. Aquat. Biol. Fish. 3(1): 59-71.

Walford, L. A. (1946). A new graphic method of describing the growth of animals. Biol. Bulletin of Marine Biological Lab., Woods Hole, 90 (2):141-147.

Wetherall, J. A. (1986). A new method for estimating growth and mortality parameters from length-frequency data. ICLARM Fishbyte, 4: 12-4.

## ARABIC SUMMARY

**ديناميكية عشائر استاكوزا المياه العذبة بروكامبرس كلاركي(Girard, 1852) في نهر النيل، مصر.**

**عبد الحليم عبده سعد[1] ، سحر فهمي مهنى[2] ، مجدي توفيق خليل[1] و محمد محمد سعيد[1]**

١- قسم علم الحيوان، كلية العلوم، جامعة عين شمس، القاهرة ، مصر.

٢- المعهد القومي لعلوم البحار و المصايد ، السويس، مصر.

إستاكوزا المياه العذبة بروكامبرس كلاركي (Decapoda, Cambaridae) هو من الأنواع المستوطنة في المناطق الجنوبية والوسطى من الولايات المتحدة. تم إدخاله إلى نهر النيل في مطلع الثمانينيات لتجربه استزراعه ، وأصبح جزء من النظام البيئي للمياه العذبة المصرية، ولكن حتى الآن لم يتم عمل دراسة تفصيلية لمعرفة ديناميكيات العشائر الخاصة به في نهر النيل.

قدرت معاملات ديناميكيات العشائر لإستاكوزا المياه العذبةعن طريق ٣٤٦٥ عينة (١٤٥٥ من الذكور و ٢٠١٠ من الإناث) (7.0 – 15.0 TL)، تم جمعها من موقعين على طول نهر النيل. من عام ٢٠٠٩ إلى عام ٢٠١٢. وقد وجد أن هذا النوع يبلغ أعلى معدل نموه خلال الأشهر الستة الأولى من عمره، وبعد ذلك تقل الزيادة في الطول مع الزيادة في العمر.

و يكون نمو هذا النوع متساوي القياس على أساس ال b-value الخاصة بعلاقة الطول بالوزن. و من توزيع التحليل التكراري للطول كانت معاملات النمو L∞ = 16.45cm TL ، K = 1.60/y ، و معدل الوفيات الكلية (Z) كان 3.56/y للذكور و 5.60/y للإناث، و معدل الوفيات الطبيعية (M) كان 2.28/y للذكور و 1.91 /y للإناث ، و معدل الوفيات الناتجة من الصيد (F) كان 1.37/y للذكور و 3.69/y للإناث ، و معدل الإستغلال (E) كان 0.38/y للذكور و 0.66/y للإناث ، و كان الطول عند أول إصطياد (Lc) 9.11, 9.25 cm TL للإناث و الذكور على التوالي، و أيضا تحليلات الإنتاجية النسبية (Y'/R) والكتلة الحيوية النسبية(B'/R) لإستاكوزا المياه العذبة (بروكامبارس كلاركي) في نهر النيل يعطي الحد الأقصى للإنتاجية النسبية (Y'/R) في E = 0.70 ومستوى الاستغلال الذي يحافظ على القدرة الحيوية لوضع البيض عند ٥٠٪ من الكتلة الحيوية العذراء E0.5 وضع البيض عند ٠.٣٧. و بناء على ذلك فإن الفرصة قائمة لزيادة مصايد إستاكوزا المياه العذبة و ذلك بزيادة معدل الإستهلاك الحالي لإعطاء أقصى إنتاجية نسبية و لكن الحفاظ على نسبة الاستغلال في قيمته الحالية أو تخفيضه لقيمة E = 0.3 سيتم تحقيق المزيد من العائد الاقتصادي.