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Biological Aspects and Fisheries Management of Tilapia Fish *Oreochromis niloticus* (Linnaeus, 1758) in El-Bahr El-Faraouny Canal, Al-Minufiya Province, Egypt

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ABSTRACT

In the present investigation, age, growth, mortality, exploitation, yield and biomass and reproduction of Nile tilapia (*Oreochromis niloticus*) from El-Bahr El-Faraouny Canal, Al-Minufiya Province, Egypt, were determined. The regression parameter "n" of dependence of total weight upon total length was found to be negative allometric growth. The coefficients of condition were computed. The annual rings on fish scales were used for age determination. The longevity of this species was found to be 6 years. The maximum increase in length was noted during the first year of life and showing a gradual decrease in growth as the fish got older. The *O. niloticus* population had a sex ratio of 1:1.08 (M:F), which did not deviates (χ^2 = 1.997, p>0.05) from the hypothetical distribution of 1:1. The maturity stages were classified macroscopically into five stages. Higher values of gonadosomatic index (GSI) for males and females occurred nearly throughout the year with peak from May to August indicating prolonged spawning season. There is a selective mortality towards smaller fish sizes. Therefore, for management purposes it is recommended that the local authorities must be set a regulation to control the illegal fishing activity and larger mesh sizes of fishing nets should be used to increase the mean lengths at first capture and their marketable sizes leading to more economic returns and also to conserve the spawning stock part of *O. niloticus* population. A comparison of the various parameters of *O. niloticus* in the present study with those of other authors in different localities and times in Egypt revealed year-to-year and geographically differences. These differences were discussed and were found to be attributed to the effect of increased pollution of the canal. Finally, the present study recommended that El-Bahr El-Faraouny Canal must be in protection against pollution.

Key words: *Oreochromis niloticus*, fisheries management, reproduction, pollution, El-Bahr El-Faraouny Canal, Egypt

INTRODUCTION

The natural fishery resources in Egypt are declining, so there is a need to considerably increase food production through safe and high-quality fishery products to bridge the widening gap between demand and supply (Shalloof and El-Far, 2009). Fisheries studies play a key role in the local economy and a sustainable fishing management is strongly recommended in order to minimize the environmental impact on the current ecosystem and assure stable resources for the future (Shalloof, 2009). Comprehensive age and growth studies of key commercial fish species are essential in assessing population characteristics that can impact the productivity of a fish population or fishery, including, life history traits, such as; age and size of sexual maturity (Bwanika *et al*., 2007). Study on fish population dynamics is the tool of fisheries management and development policies that eventually help conserve fish species diversity and their stocks (Bonfil, 2005).

El-Bahr El-Faraouny Canal (Fig. 1) is one of the most important water bodies in Al-Minufiya Province, Egypt. This canal was previously considered, a successful natural fishery resource. Early in the 19th century, this canal was shut off from the River Nile system by the road of Barrage to Shebeen Alkoom city. Since, then it became a drainage canal extending from Al-Khadra village to Menouf city. It takes an L-shape, moving from the south to the north and passes through three cities namely Ashmoun, Al-Bagour and Menouf. Locally, it is called Albahr Alaama (i.e., Blind Sea), also called Albahr Almaeet (i.e., Dead Sea). It lies 43.39 km northwest of Cairo and occupies the area between Latitudes 30°55'51.01" E and 31°0.2'12.12" E and Longitudes 30°21'57.71" N and 30°27' 16.9" N. It extends about 30.2 km in length and the width ranges from 100-200 m. Its current area is about 2,500 acres, after declining about 800 acres as a result of reduction of its aquatic area by peoples and local authorities. It exposed to different sources of pollution as sewage from sewage plant of Menouf city and the surrounding villages, industrial wastewater from some small industrial activities and plants and agricultural drainage water from adjacent fields and many other drainage canals. According to the GAFRD (General Authority for Fish Resources Development) office in Menouf city, which operating in El-Bahr El-Faraouny Canal, the total number of licensed fishermen and fishing assistants is ≈7,000. Although, the GAFRD, which is responsible for the management of fisheries in Egypt added millions fingerlings of tilapia, grass and

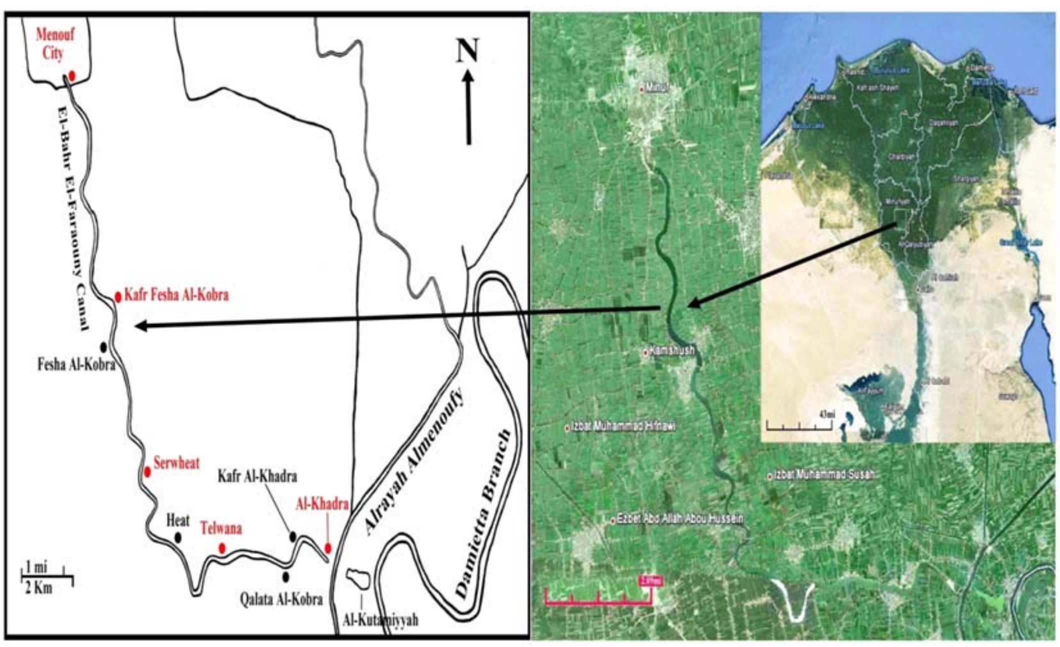

Fig. 1: Map showing El-Bahr El-Faraouny Canal (area of study) and sampling sites (red colour)

silver carps and *Mugil capito* each year; the statistics of the GAFRD office in Menouf city showed that its fish production during the period from 2000-2009 decreased significantly (≈3000 t $year^{-1}$) (GAFRD., 2009) and the fish composition was changed in recent years, where some species have either declined to insignificant levels or almost in their way to disappear from the canal, such as; *Bagrus*, *Anguilla*, *Alestes*, *Labeo*, *Barbus*, *Lates*, *Synodontis*, *Chryichthys* spp., while, *Tilapia* and *Clarias* spp., has become the prevailing in catch due to different sources of pollution. *Tilapia* is the main species produced and comprises about 39-40% of the total fish catch in 2009 (GAFRD., 2009).

Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) is native to Africa, ranging from the upper Nile River south to the equator and west to the Atlantic coast (Trewavas, 1983). The species is favored among aquaculturists due to its ability to tolerate a wide range of environmental conditions, fast growth, successful reproductive strategies and ability to feed at different trophic levels (Grammer *et al*., 2012). It has a wide distribution in Egypt (River Nile and its tributaries, coastal Lakes and Lake Nasser) (Bishai and Khalil, 1997; Authman *et al*., 2012). Various aspects of the biology of *O. niloticus* and other cichlids of commercial importance have been studied in Egypt (Mekkawy, 1998; Abd-Alla and Talaat, 2000; Khalifa *et al*., 2000; Khallaf, 2002; Khallaf *et al*., 2003; Mahmoud and Mazrouh, 2008; Authman *et al*., 2009; Shalloof and El-Far, 2009; Shalloof *et al*., 2009; El-Bokhty, 2010; Mekkawy *et al*., 1994, 2011, 2012; El-Bokhty *et al*., 2013; El-Kasheif *et al*., 2013; Mahmoud *et al*., 2013; Hassan and El-Kasheif, 2013).

Generally, to the best of our knowledge, studies on El-Bahr El-Faraouny Canal is scanty. Gad and Ibrahim (2005), Gaber *et al*. (2012) and Ibrahim *et al*. (2012) studied the effects of aquatic environmental pollution in El-Bahr El-Faraouny Canal on its water quality and some histological, hematological and biochemical parameters of teleost fish (*Clarias gariepinus*). Despite, the economic importance, popularity among consumers of *O. niloticus* and the ever increasing need to improve food production, the biology and management studies have not been developed for this species in El-Bahr El-Faraouny Canal. Therefore, the objective of the present study was intended to determine the age and growth, mortality and exploitation rates, yield and biomass per recruit, relative yield per recruit and some reproductive characteristics of Nile tilapia *Oreochromis niloticus* in El-Bahr El-Faraouny Canal to best management for this species inhabit the Canal.

MATERIALS AND METHODS

Random *O. niloticus* fish samples were collected monthly; throughout the period from January-December, 2013 from commercial fishing by fishermen using the common trammel gill nets. The samples were collected from five sites (Fig. 1) of El-Bahr El-Faraouny Canal namely Menouf city, Kafr Fesha Al-Kobra, Serwheat, Telwana and Al-Khadra. A total of 1405 fish specimens (651 males, 703 females and 51 samples were very small and difficult to identify their sex) were collected. The fish samples were brought directly after catching to the laboratory, where for each individual fish specimen, total length to the nearest 0.1 cm and whole weight to the nearest 0.1 g were reordered. Scales from the left side of the fish were removed from an area just below the lateral line and behind the pectoral fin. They were kept in special envelops with full information (date of capture, length, weight, sex, maturity stage and gonads weight) for further reading. The scales were placed in solution of 10% of NH_4OH for 24 h, then washed with distilled water, dried with filter paper and mounted between two glass slides. They were examined under a binocular microscope (X20) using an eye piece micrometer. The total scale radius and the radius of each annulus were measured to the nearest 0.001 mm.

The length-weight relationship is determined by using the general parabola:

$$W = a\ L^n \text{ or } \text{Log } W = \log a + n \log L$$

Where:
W = Weight (g)
L = Total length (cm)
a = Constant
n = Exponent value (Le Cren, 1951; Ricker, 1975)

The condition factor (K) was determined using the equation:

$$K_c = 100 \times \frac{W}{L^3} \quad \text{(Fulton, 1902; Ricker, 1975)}$$

Where:
W = Fish weight (g)
L = Fish total length (cm)

However, for more accuracy K_n is calculated as follows:

$$K_n = 10 \times \frac{W}{L^n} \quad \text{(Ricker, 1975)}$$

where, n is the exponent of the general length-weight equation. Also, the relative condition factor (K_w) was calculated according to the equation:

$$K_w = \frac{W}{\hat{W}} \quad \text{(Le Cren, 1951)}$$

Where:
W = The observed total weight in g
$\hat{W}$ = The calculated fish weight in g obtained from the equation $W = a\ L^n$

The age was determined by counting the number of completely developed annual rings on scales. The Linear length-scale radius relationships were established by using the equation:

$$L = a + b\ S \quad \text{(Lee, 1920)}$$

Where:
L = Fish total length at capture (cm)
a, b = Constants
S = Scale radius (mm)

The lengths of the previous ages were back-calculated using Lee (1920) equation as follows:

$$L_n = \frac{a + (L_c - a)}{S_c} \times S_n$$

Where:

L_n = The calculated fish total length in cm at annulus n
S_n = The scale radius at annulus n in mm
S_c = The scale radius at capture in mm
L_c = The total length of fish at capture
a = The y-intercept of Lee equation

The estimation of general growth in length was based on the grand average of back-calculated lengths and the growth in weight was studied from calculated weights corresponding to back-calculated lengths attained at the end of each year of life, by the length-weight relationship equation.

Relative growth (h) and instantaneous Growth (G) rates for length or weight were calculated (Ricker, 1975) as follows:

$$h_L = \frac{L_{j+1} - L_j}{L_j}$$

and:

$$h_W = \frac{W_{j+1} - W_j}{W_j},$$

$$G_L = \ln (h_L + 1)$$

and:

$$G_W = \ln (h_W + 1)$$

where, h_L and h_W = relative growth in length and weight at age-groups j and j+1 and G_L and G_W = instantaneous growth rates in length and weight.

The growth parameters of the Von Bertalanffy (1938) growth model (L_∞, K and t_o) were computed according to Gulland (1969) and Ricker (1975) by fitting the Ford (1933) and Walford (1946) plot. The common forms of this equation were as follows:

$$L_t = L_\infty\{1 - e^{-k(t-t_0)}\}$$

and:

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

Where:
L_t = The total length of fish in cm at age t
L_∞ = The maximum asymptotic length i.e., the theoretical length beyond which the fish would not grow
K = The Brody's coefficient of growth constant
t = The age in years
t_o = The theoretical time at which the fish would have been of zero size if it had always grown according to the equation
e = The logarithmic constant

While, the growth in weight was studied from calculated weights corresponding to calculated lengths attained at the end of each year of life, by the length-weight relationship equation:

$$W = a\, L^n$$

Consequently, the von Bertalanffy equation is transformed (Following Ricker, 1975) into:

$$W_t = W_\infty \{1 - e^{-k(t-t_0)}\}^n$$

Where:
W_t = Weight at time t
W_∞ = Asymptotic weight
n = Exponent value of length-weight relationship

FAO-ICLARM Fish Stock Assessment Tools (FiSAT) software of Gayanilo *et al.* (2005) was used to estimate the total instantaneous mortality rates "Z" by the analysis of length-converted catch curves based on length frequency data using the method of Pauly (1983b, 1984a, b). The survival and mortality rates would be calculated as follows:

$$S = e^{-Z} = 1\text{-}A$$

Where:
S = Annual survival rate
A = Annual mortality rate
Z = Instantaneous mortality rate

Ponderal mortality rate (Ricker, 1969) is introduced to fish if there is selective mortality by fishing gear. Thus, when mortality is not selective by size, ponderal mortality Z_w would be equal or near in its value to Z. If larger fish are more selected, die at a rate more readily, than the smaller fish, Z_w would be larger than Z and the reverse occurs if smaller fish are more selected (Z_w<Z). Accordingly:

$$Z_w\text{-}Z = G\text{-}G_x$$

Where:
G = Average growth rate per fish
G_x = The population growth rate
Z = Instantaneous mortality rate
Z_w = Ponderal mortality rate

Instantaneous natural mortality rate (M) was determined in this study according to Pauly (1980); who made a regression analysis of M (per year) on K (per year), L_∞ (cm) and T (annual average temperature of water column in degrees centigrade), as follows:

$$\ln M = -0.0152-0.279\times\ln L_\infty+0.6543\times\ln K+0.463\times\ln T$$

Where:
L_∞, K = Von Bertalanffy equation constants
T = Annual average temperature of water column in centigrade which equals to 20.615°C (Table 2)

The fishing mortality (F) was calculated as F = Z-M (Beverton and Holt, 1957). The expectation of death due to fishing or what is known as exploitation ratio (E = F/Z) was calculated according to Gulland (1983) and Pauly (1980, 1983a), where (Z) and (F) are the total and fishing mortality coefficients, respectively.

The length at first capture (L_c), which is considered by many authors as the mean selection length, was estimated according to Beverton and Holt (1956) by the equation:

$$L_c = L' - \left(\frac{k\,(L_\infty - L')}{Z}\right)$$

Where:
L' = The mean length
L∞ = Von Bertalanffy equation constant
Z = Instantaneous mortality rate

The corresponding age (t_c) was obtained by converting L_c using the von Bertalanffy growth equation:

$$t_c = -(1/k)\times\text{Ln}\left(1-\frac{L_c}{L_\infty}\right)+t_0 \qquad \text{(Sparre \textit{et al}., 1989)}$$

Length at recruitment (L_r) was estimated according to Beverton and Holt (1956) by the equation:

$$L_r = L' - \left(\frac{k\,(L_\infty - L_0)}{Z}\right)$$

Where:
L' = The mean length
L_0 = The length for which all fish of that length and longer are under run exploitation

The corresponding age at recruitment (t_r) was calculated by the following equation:

$$t_r = -(1/k)\times \mathrm{Ln}\left(1-\frac{L_r}{L_\infty}\right)+t_0 \qquad \text{(Sparre } et\ al.\text{, 1989)}$$

The corresponding weights at first capture (W_c) and recruitment (W_r) were calculated by the length-weight relationship equation.

The longevity of the fish species was calculated from the relation:

$$t_{max} = \frac{3}{k}+t_0 \qquad \text{(Pauly, 1983a)}$$

Where:
K, t_0 = Von Bertalanffy equation constants

The overall growth performance (Ø) (Pauly and Munro, 1984; Moreau *et al*., 1986) has been used as follows for length:

$$Ø_L = \log_{10} k+2 \log_{10} L_\infty$$

and for weight:

$$Ø_W = \log_{10} k+2/3 \log_{10} W_\infty$$

where, K, L_∞ and W_∞ are von Bertalanffy equation constants.

Yield per recruit model (Y/R) and biomass per recruit (B/R) were estimated by Beverton and Holt (1957) method using the current growth parameters. Such a model is in principle a "steady state model" (Sparre and Venema, 1992) and can be written according to Gulland (1969) in the following form:

$$Y/R = F\times \mathrm{Exp}^{-M(T_c-T_r)}\times W_\infty[(1/Z)-(3S/(Z+K))+(3S^2/(Z+2K))-S^3/(Z+3K)]$$

Where:
$S = e^{-k(T_c-T_0)}$

Moreover, Beverton and Holt's Biomass per recruit (B/R) was also calculated by the equation:

$$B/R = \frac{Y/R}{F}$$

Fishery managers can control the two parameters "F" and "T_c", Therefore, the model allows the authors to calculate Y/R with varying inputs of different values of T_c and F and then assess which effect the various input values have on Y/R of the *O. niloticus*.

The relative yield-per-recruit (Y/R)'and relative biomass-per-recruit (B/R)' were estimated by applying the model of Beverton and Holt (1966), as modified by Pauly and Soriano (1986), which is incorporated into the FiSAT software package (Gayanilo *et al*., 2005).

Fish were dissected, sexed and gonad samples were weighed to the nearest 0.1 g. Sex ratio was determined on monthly bases. By comparisons, if sex ratio (male:female) departed from the expected 1:1 ratio were carried out by Chi-square (χ^2) test at 0.05 significance level. The condition of the gonads were noted macroscopically and the maturity stages of ovary and testes were identified and distinguished according to Legendre and Ecoutin (1989) and West (1990). The maturity stages were rated as (1) Immature, (2) Developing, (3) Ripening, (4) Ripe and (5) Spent.

The gonadosomatic index (GSI) was calculated for each specimen using the following equation:

$$\text{GSI} = \frac{\text{Weight of gonads (g)}\times 100}{\text{Total body weight (g) of fish}}$$ (Authman, 1990; Khallaf and Authman, 1991b, 2010)

The length at first maturity (L_{m50}) was determined; taking into account the distribution of mature and immature fish within the different length classes; from the plot of cumulative percentage of maturation against the corresponding lengths (Sparre *et al*., 1989). The age (t_{m50}) at first maturity (the age, when 50% of the population is mature, also called the age of massive maturation) was obtained by converting L_{m50} using, von Bertalanffy equation:

$$t_{m50} = -(1/k)\times \text{Ln}\left(\frac{1-L_{m50}}{L_\infty}\right)+t_0$$

where, L_∞, t_0 and K are von Bertalanffy growth constants (Sparre *et al*., 1989). The corresponding weight at first maturity (W_{m50}) was calculated by the length-weight relationship equation.

Monthly water column temperature (°C) was measured at different depths at the studied area by YSI Model 33 S-C-T Meter (Yellow Spring Instrument Co., USA).

All statistical analyses were calculated, using the computer program of SPSS Inc. (version 17.0 for Windows) at the 0.05 level of significance.

RESULTS

Length-frequency distribution: The length frequency distributions of the studied fish species are illustrated in Fig. 2a. For males, the most frequent length group percentage were 9.83, 8.14, 11.67, 6.30, 5.53 and 5.84% corresponding to length groups 13, 14, 15, 16, 17 and 20 cm, respectively. While, for females, the most frequent length group percentages were 5.26, 5.55, 7.97, 5.26, 5.26, 7.25, 6.12, 6.40, 5.26 and 6.97% corresponding to length groups 13, 14, 20, 21, 22, 25, 26, 27, 28 and 29 cm, respectively. Whereas, for combined sexes, the most frequent length group percentages were 7.19, 6.55, 7.69 and 6.69% corresponding to length groups 13, 14, 15 and 20 cm, respectively.

Length-weight relationship: The total length varied between 6.3-29.7, 8.5-33.6 and 4.8-33.6 cm with an average of 17.57, 20.97 and 18.90 cm, whereas, the total weight varied between 9.5-540, 7.50-768 and 7.50-768 g with an average of. 144.21, 230.73 and 182.73 g for males, females and

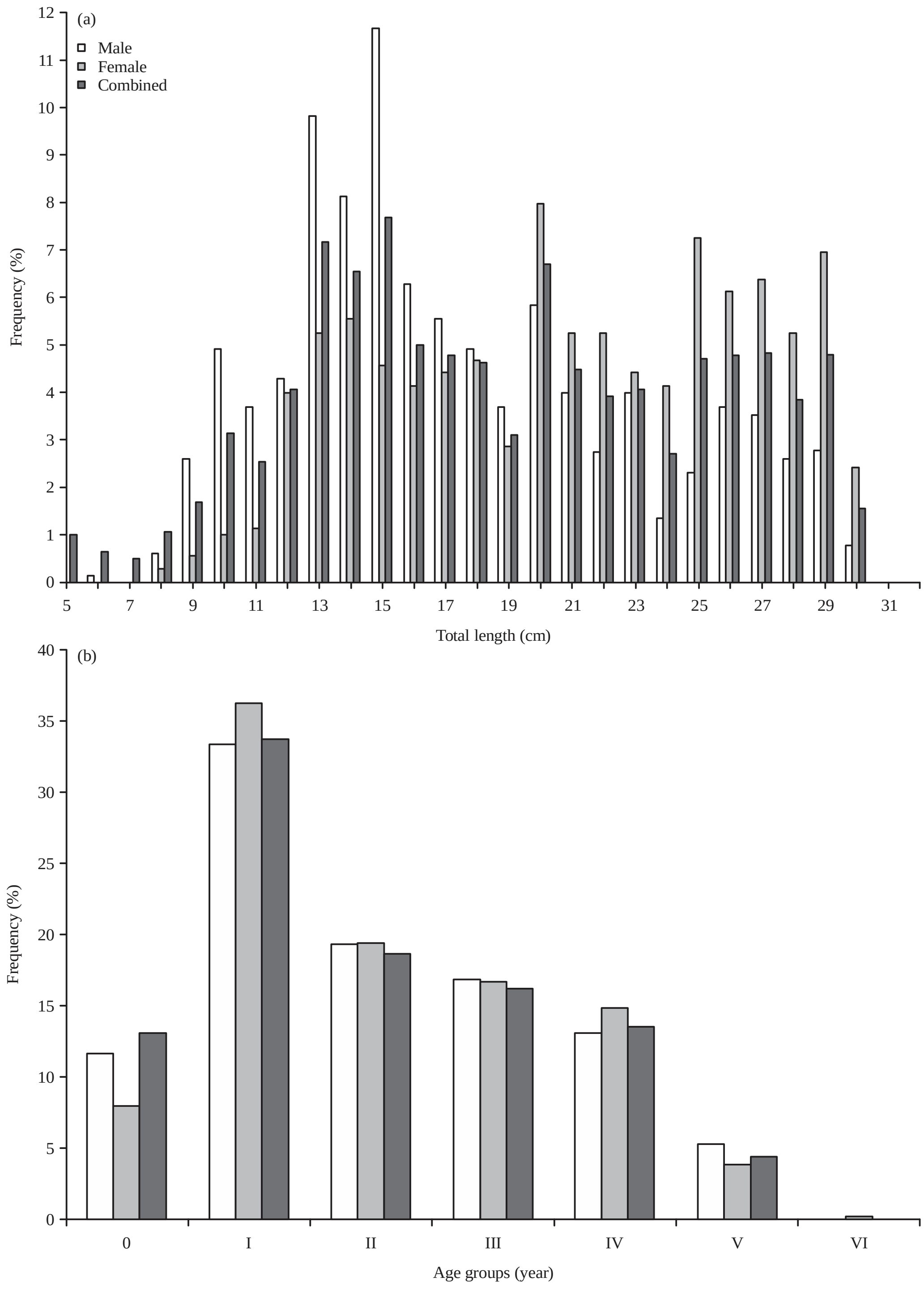

Fig. 2(a-b): (a) Length frequency and (b) Age composition of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

sexes combined of *O. niloticus*, respectively. The length-weight relationships for males, females and sexes combined are shown in Fig. 3a-c and the estimated length-weight equations (Table 1) were as follows:

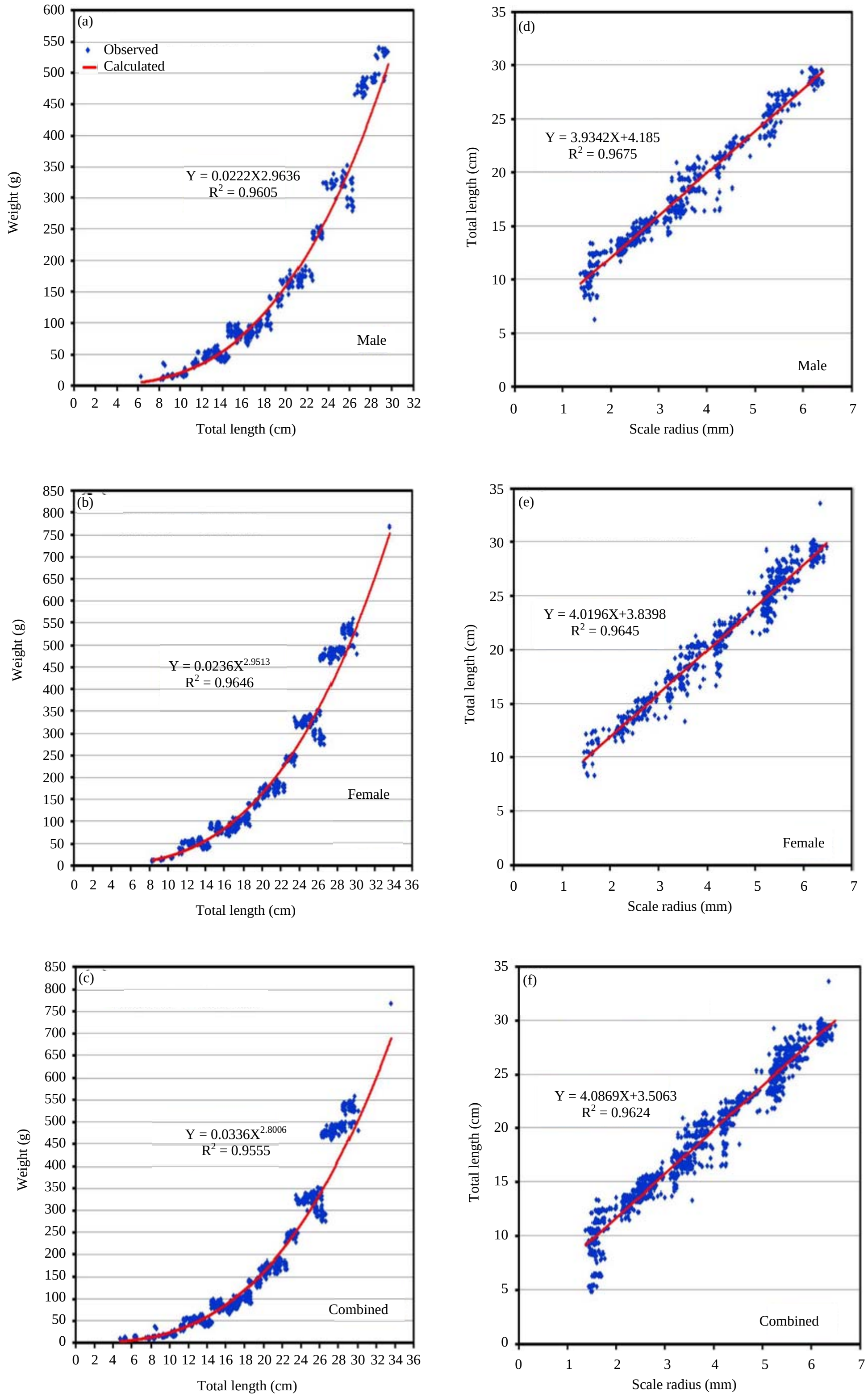

Fig. 3(a-f): (a-c) Total length-weight and (d-f) Scale radius-total length relationships of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

Table 1: Total length-weight relationship data and condition factors values (combined sexes), the total length–weight equations parameters and average condition factors of male, female and combined sexes of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

		Weight (g)				Condition factor		
		Actual						
Total length (cm)	No. of fishes	Range	Mean±SD	Mean calculated	Mean advantage of weight	K_c	K_n	K_w
4	14	8.0-12.0	9.41±1.13	3.78	+5.62	6.58	9.15	2.50
6	21	9.0-14.0	12.29±1.60	7.80	+4.49	4.27	6.21	1.70
8	39	9.0-36.0	15.49±5.84	17.21	-1.72	2.18	3.37	0.92
10	90	14.5-56.0	25.17±11.61	28.58	-3.41	1.93	3.11	0.85
12	199	37.0-64.0	49.85±5.65	48.57	+1.28	2.28	3.81	1.04
14	189	38.0-98.0	75.45±16.90	73.26	+2.19	2.18	3.74	1.02
16	121	65.0-106.0	87.08±10.33	101.29	-14.21	1.79	3.14	0.86
18	100	88.5-174.0	125.43±22.31	137.31	-11.89	1.85	3.32	0.91
20	171	145.0-194.0	169.56±8.09	181.78	-12.22	1.87	3.42	0.94
22	104	168.0-334.0	245.16±46.33	239.41	+5.76	1.99	3.72	1.02
24	99	285.0-352.0	323.80±12.94	302.51	+21.29	2.07	3.93	1.07
26	132	275.0-492.0	413.44±88.14	369.39	+44.05	2.11	4.06	1.11
28	123	468.0-558.0	514.47±23.93	449.44	+65.03	2.14	4.19	1.15
30	2	480.0-524.0	502.00±31.11	505.72	-3.72	1.84	3.63	0.99
32	1	768.0-768.0	768.00±0.00	688.18	+79.82	2.02	4.08	1.12
Total	1405	8.00-768.0	182.70±161.16	174.11	+8.58	2.13	3.75	1.03
F-value			2359.39	11245.79	77.26	193.81	121.28	121.28
(Sig.)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Sex	No. of fishes	Log a	a	n	SE (n)	r	r^2	SEE	F-value	Sig.	Avg. K_c±SD	Avg. K_n±SD	Avg. K_w±SD
Total length-weight equations parameters and average condition factors													
Male	651	-1.654	0.022	2.964	0.024	0.980	0.960	0.082	15764.78	0.000	2.04±0.45	2.26±0.48	1.02±0.22
Female	703	-1.628	0.024	2.951	0.021	0.982	0.965	0.072	19106.65	0.000	2.07±0.35	2.39±0.40	1.01±0.17
Combined	1405	-1.437	0.037	2.801	0.016	0.978	0.956	0.095	30129.06	0.000	2.13±0.67	3.75±0.95	1.03±0.26

SD: Standard deviation, K_c: $\frac{W}{L^3}\times 100$, K_n: $\frac{W}{L^n}\times 10$, K_w: Observed weight/calculated weight, Sig.: Significance level, a: Constant, n: Slope, SE (n): Standard error of "n", r: Correlation coefficient, r^2: Coefficient of determination, SEE: Standard error of the estimate, Avg.: Average

- log W = -1.6540+2.9636 log L or $W = 0.0222\ L^{2.9636}$ for males
- log W = -1.6277+2.9513 log L or $W = 0.0236\ L^{2.9513}$ for females
- log W = -1.4370+2.8006 log L or $W = 0.0366\ L^{2.8006}$ for combined sexes

The high values of the correlation coefficient (r) (Table 1) perform a good measure for the strength of these equations and closeness of observed and calculated values of fish weight. In addition, Table 1 shows that, the values of the constant "n" are less than 3, i.e., negative allometric growth Pattern.

Condition factors: The values of condition factors of *O. niloticus* revealed insignificant monthly variations (Fig. 4a-c), (K_c = 2.03, F = 1.425, p>0.05; K_n = 3.57, F = 0.890, p>0.05 and K_w = 0.99, F = 0.888, p>0.05, for males), (K_c = 2.06, F = 1.487, p>0.05; K_n = 3.75, F = 1.575, p>0.05 and K_w = 1.05, F = 1.575, p>0.05, for females) and (K_c = 2.12, F = 1.036, p>0.05; K_n = 3.74, F = 1.039, p>0.05 and K_w = 1.04, F = 1.039, p>0.05, for combined sexes). Generally, females have better condition than males during almost all months. When condition factors (K_c, K_n and K_w) were computed for each length interval (Table 1, Fig. 4d-f), it was clear that irregularity is found in these parameters and did not show a conspicuous trend. However, there was a somewhat decline in the fish condition factor in fish with larger size.

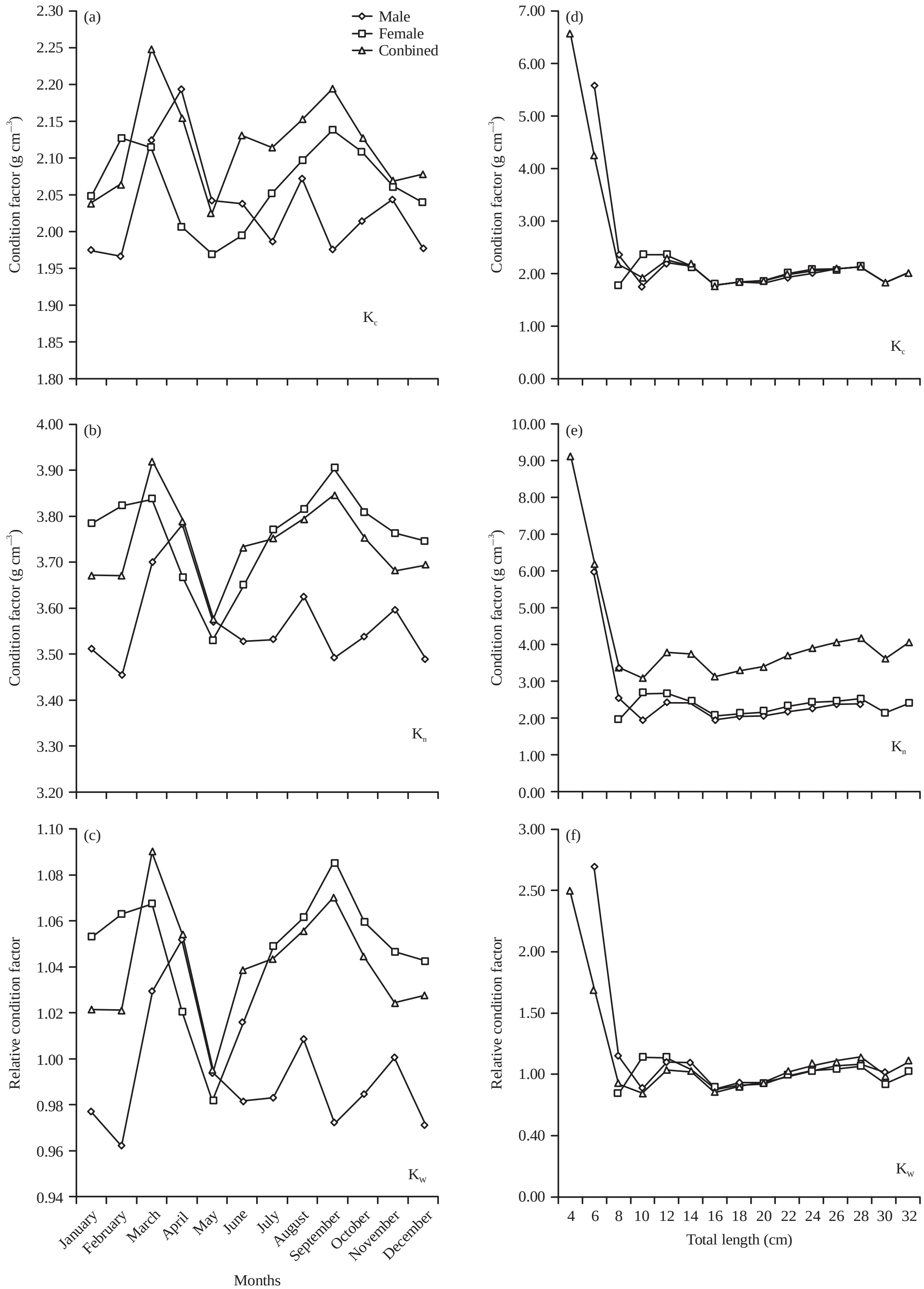

Fig. 4(a-f): Variations of (a-c) Condition factors monthly and (d-f) With total length of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

Age and growth: In the present study scale were used for age determination and by using the readings of its annual growth rings, it was found that the longevity of *O. niloticus* attained 6 years. Present study showed that the mean values of the monthly scale marginal increments for age-group I referred to minimal increment to occur in March-April whereas the maximal increments were in November-January (Table 2). This means that the time of annulus formation on the scale takes place in February-March period.

Scale radius-body total length relationships: The scale radius-total length relationships of *O. niloticus* males, females and combined sexes (Fig. 3d-f) were found to be linear (Table 2) and can be represented by the following equations:

- TL = 4.1850+3.9342 Sr for male
- TL = 3.8398+4.0196 Sr for female
- TL = 3.5064+4.0869 Sr for combined sexes

The following equations were adopted for back-calculation of length at different scale annuli:

- $L_n = 4.1850+(L_c-4.1850)/S_c \times S_n$ for male
- $L_n = 3.8398+(L_c-3.8398)/ S_c \times S_n$ for female
- $L_n = 3.5064+(L_c-3.5064)/ S_c \times S_n$ for combined sexes

Back calculations and growth in length and weight: As seen from Table 3, the increase in length, among the observed mean lengths at different age-groups, is irregular. The mean back-calculated lengths at the end of each year of life are given in Table 3 and Fig. 5a-c. Age readings indicated that *O. niloticus* attain their highest growth rate in length during the first year

Table 2: Monthly variation of average water temperature (°C) and scale marginal increment of age-group I (irrespective of sex), scale radius-total length equations parameters of male, female and combined sexes of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

Months	No. of fishes	Average water temperature (°C)	Annulus (r_1) (mm) Average±SD	Scale radius (R) (mm) Average±SD	Marginal increment ($R-r_1$) (mm) Average±SD
January	26	15.080	1.8796±0.3843	3.0792±1.0734	1.1996±1.1751
February	32	14.420	2.5022±1.2060	3.1722±1.4551	0.6700±0.5539
March	35	15.420	2.0695±0.4990	2.6935±0.5325	0.6240±0.4347
April	38	19.840	2.2515±0.5898	2.8885±0.8682	0.6370±0.5461
May	41	22.660	1.9710±0.4740	2.8055±0.7395	0.8345±0.6700
June	48	23.960	2.1139±0.6486	3.0055±1.0589	0.8916±0.8622
July	81	25.900	2.2380±0.5658	2.9549±0.7786	0.7169±0.5821
August	76	26.780	2.1965±0.5827	2.9200±0.8053	0.7235±0.6395
September	24	23.940	2.1233±0.5808	2.8013±0.7896	0.6780±0.4520
October	23	23.240	1.8907±0.3023	2.6557±0.8532	0.7650±0.7176
November	27	19.240	1.8481±0.3723	2.7762±0.6920	0.9281±0.8060
December	23	16.900	2.2060±0.5771	3.1920±0.9794	0.9860±0.7068
Total	474	20.615			

Sex	No. of fishes	a	b	SE (b)	r	r^2	SEE	F-value	Sig.
Scale radius-total length equations parameters									
Male	651	4.1850	3.9342	0.028	0.9836	0.9675	0.9941	19334.71	0.000
Female	703	3.8398	4.0196	0.029	0.9821	0.9645	1.0632	19071.86	0.000
Combined	1405	3.5064	4.0869	0.022	0.9810	0.9624	1.1951	35895.84	0.000

SD: Standard deviation, a: Constant (Intercept), b: Slope, SE (b): Standard error of "b", r: Correlation coefficient, r^2: Coefficient of determination, SEE: Standard Error of the Estimate, Sig.: Significance level

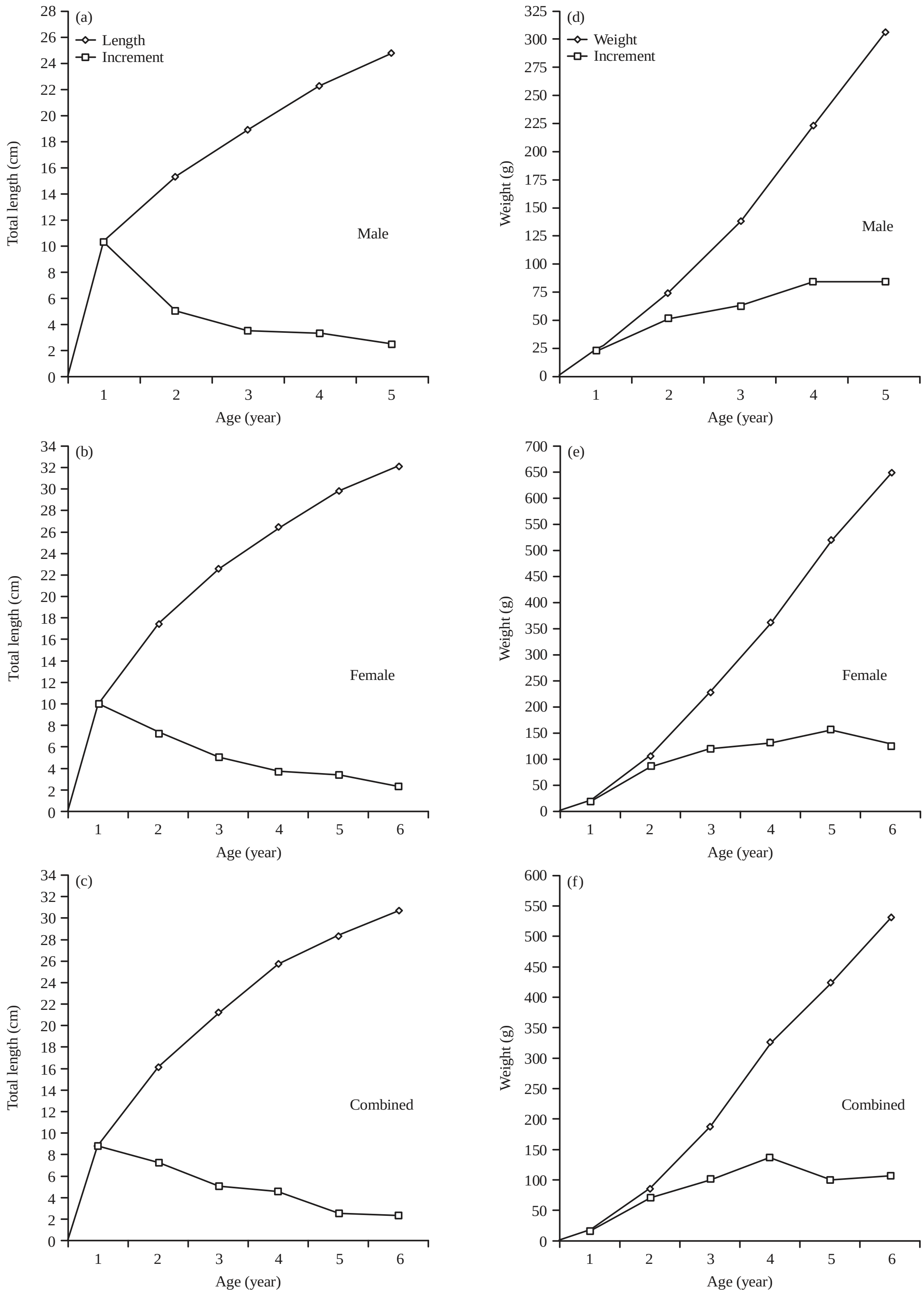

Fig. 5(a-f): Back-calculated (a-c) Length and (d-e) Weight at different ages of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

Table 3: Average total length (cm) and weights (g) at capture and back-calculated total length (cm) and weights (g) and percentage of annual increments of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

			Length (cm)				Weight (g)			
Age-groups	No. of fishes	%	Average total length at capture	Back-calculated total length	Increment	Increment (%)	Average weight at capture	Back-calculated weight	Increment	Increment (%)
Male										
0	76	11.67	10.60				25.97			
I	218	33.49	13.22	10.42	10.42	41.65	51.01	22.82	22.82	7.46
II	126	19.35	15.10	15.52	5.10	20.38	75.98	74.31	51.49	16.83
III	110	16.90	18.56	19.10	3.58	14.31	120.88	137.44	63.13	20.64
IV	86	13.21	24.57	22.45	3.35	13.39	308.76	221.86	84.42	27.60
V	35	5.38	28.5	25.02	2.57	10.27	501.76	305.88	84.02	27.47
VI	-	0.00	-	-	-	-	-	-	-	-
Total	651									
Female										
0	57	8.10	10.92				30.50			
I	256	36.42	13.00	10.04	10.04	31.17	54.78	20.79	20.79	3.21
II	137	19.49	15.10	17.52	7.48	23.22	74.98	107.50	86.71	13.37
III	118	16.79	19.11	22.65	5.13	15.93	134.17	229.37	121.87	18.80
IV	105	14.94	24.95	26.42	3.77	11.70	326.07	361.29	131.92	20.35
V	28	3.98	28.76	29.87	3.45	10.71	511.52	518.98	157.69	24.32
VI	2	0.28	31.60	32.21	2.34	7.27	658.00	648.35	129.37	19.95
Total	703									
Combined sexes										
0	184	13.10	9.77				23.18			
I	474	33.74	13.13	8.82	8.82	28.59	52.61	15.98	15.98	3.00
II	263	18.72	15.09	16.15	7.33	23.76	75.62	86.93	70.95	13.33
III	228	16.23	18.86	21.28	5.13	16.63	128.08	188.20	101.27	19.02
IV	191	13.59	24.82	25.88	4.60	14.91	320.10	325.54	137.34	25.80
V	63	4.48	28.73	28.47	2.59	8.40	508.74	425.19	99.66	18.72
VI	2	0.14	31.60	30.85	2.38	7.71	658.00	532.37	107.18	20.13
Total	1405									

of life, after which a gradual decrease in growth increment was observed with further increase in age. On the other hand, the calculated weights at the end of each year of life of *O. niloticus* are given in Table 3 and Fig. 5d-f. It was found that, the minimum annual increment is noticed during the first year of life then the annual increment increases with the increase in age to reach the maximum value at the fourth and fifth year of life for males, females and combined sexes, then there is a conspicuous drop in these values at age-groups V, VI and V for males, females and combined sexes, respectively. Based on these values, the relative and instantaneous rates of growth in length and weight were calculated and represented in Table 4. Thus, the maximum growth in length and weight was noticed during the first year but declined fast in the following years of life as the fish gets older.

The von Bertalanffy growth in length and weight: The von Bertalanffy growth parameters (Table 5) were estimated as L_∞ = 34.995, 38.940 and 37.265 cm and k = 0.224, 0.289 and 0.294 y^{-1} and t_o = -0.504, -0.024 and 0.089 year for male, female and combined sexes, respectively. Accordingly, the growth of *O. niloticus* was described by the following von Bertalanffy growth equations:

- $L_t = 34.995\ \{1\text{-}e^{-0.224\ (t+0.504)}\}$ and $L_{t+1} = 7.02+0.799\ L_t$ for male
- $L_t = 38.940\ \{1\text{-}e^{-0.289(t+0.024)}\}$ and $L_{t+1} = 9.77+0.749\ L_t$ for female
- $L_t = 37.265\ \{1\text{-}e^{-0.294(t\text{-}0.089)}\}$ and $L_{t+1} = 9.49+0.745\ L_t$ for combined sexes

The equations of theoretical growth in weight were obtained by applying the length-weight relationship equations to the growth in length equations as follows:

Table 4: Calculated lengths and weights, relative growth rates (h), instantaneous growth rates (G) and comparison between population (G_x) and individual (G) growth rates of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

Age-groups (years)	Male: Calculated length (cm) L. (cm)	Diff. (cm)	h	G	Male: Calculated weight (g) Wt. (g)	Diff. (g)	h	G	Female: Calculated length (cm) L. (cm)	Diff. (cm)	h	G	Female: Calculated weight (g) Wt. (g)	Diff. (g)	h	G
I	10.42				22.82				10.04				20.79			
II	15.52	5.10	0.489	0.398	74.31	51.49	2.256	1.181	17.52	7.48	0.745	0.557	107.50	86.71	4.171	1.643
III	19.10	3.58	0.231	0.208	137.44	63.13	0.850	0.615	22.65	5.13	0.293	0.257	229.37	121.87	1.134	0.758
IV	22.45	3.35	0.175	0.162	221.86	84.42	0.614	0.479	26.42	3.77	0.166	0.154	361.29	131.92	0.575	0.454
V	25.02	2.57	0.114	0.108	305.88	84.02	0.379	0.321	29.87	3.45	0.131	0.123	518.98	157.69	0.436	0.362
VI	-	-	-	-	-	-	-	-	32.21	2.34	0.078	0.075	648.35	129.37	0.249	0.223

Age groups	Population growth: Length intervals (cm)	Ln (L_{t+1}/L_t)	Population growth rate (G_x)	Mean individual growth: Length intervals (cm)	Ln (L_{t+1}/L_t)	Individual growth rate (G)	G-G_x
Male							
1-2	13.22-15.10	0.133	0.394	10.42-15.10	0.371	1.099	0.705
2-3	15.10-18.56	0.207	0.612	15.52-18.56	0.179	0.530	-0.082
3-4	18.56-24.57	0.281	0.832	19.10-24.57	0.252	0.747	-0.085
4-5	24.57-28.65	0.153	0.455	22.45-28.65	0.244	0.723	0.268
5-6	-	-	-	-	-	-	-
Female							
1-2	13.00-15.10	0.149	0.441	10.04-15.10	0.408	1.204	0.763
2-3	15.10-19.11	0.236	0.696	17.52-19.11	0.087	0.257	-0.439
3-4	19.11-24.95	0.267	0.787	22.65-24.95	0.097	0.285	-0.501
4-5	24.95-28.76	0.142	0.420	26.42-28.76	0.085	0.251	-0.169
5-6	28.76-31.60	0.094	0.278	29.87-31.60	0.056	0.166	-0.111

- $W_t = 826.63\ [1\text{-}e^{-0.224\ (t+0.504)]\ 2.963}$ for male
- $W_t = 1134.98\ [1\text{-}e^{-0.289(t+0.024)]\ 2.951}$ for female
- $W_t = 903.54\ [1\text{-}e^{-0.294(t-0.089)]\ 2.800}$ for combined sexes

The application of the von Bertalanffy growth equations gave the length and weight at different ages groups (Table 5) of *O. niloticus* males, females and combined sexes.

Fish population dynamics

Age composition: The data (Table 3, Fig. 2b) revealed that age group (VI) is the least and contributed about 0.00, 0.28 and 0.14% for males, females and sexes combined, respectively. While, the frequency of fishes of age group I are dominant in the catch and constitute about 33.49, 36.42 and 33.74% for *O. niloticus* males, females and sexes combined, respectively.

Survival, mortality and exploitation rates: The instantaneous total mortality coefficient “Z” was estimated (Fig. 6a-c) as 0.95, 1.22 and 1.15 year^{-1}, while the survival rate (S) was 0.43, 0.30 and 0.32, whereas the annual mortality rate (A) was 0.57, 0.70 and 0.68 for males, females and combined sexes (Table 5), respectively. The natural mortality coefficient “M” was estimated as 0.56, 0.64 and 0.65 year^{-1}, while the fishing mortality coefficient “F” was estimated as F = Z-M and found to be 0.39, 0.58 and 0.50 year^{-1} for males, females and combined sexes (Table 5), respectively. The exploitation rate of males was found to be 0.35, for females was 0.48, while for combined sexes, it was 0.43 (Table 5). Considering the ponderal selective mortality among different age- groups for either sex, as indicated in Table 4, it was found that there is a considerable difference for various age-groups and the difference; “G-G_x”; is negative for age-groups II and III of males and for age-groups from II to V of females. This means that there was a tendency towards selection for small fish of these ages.

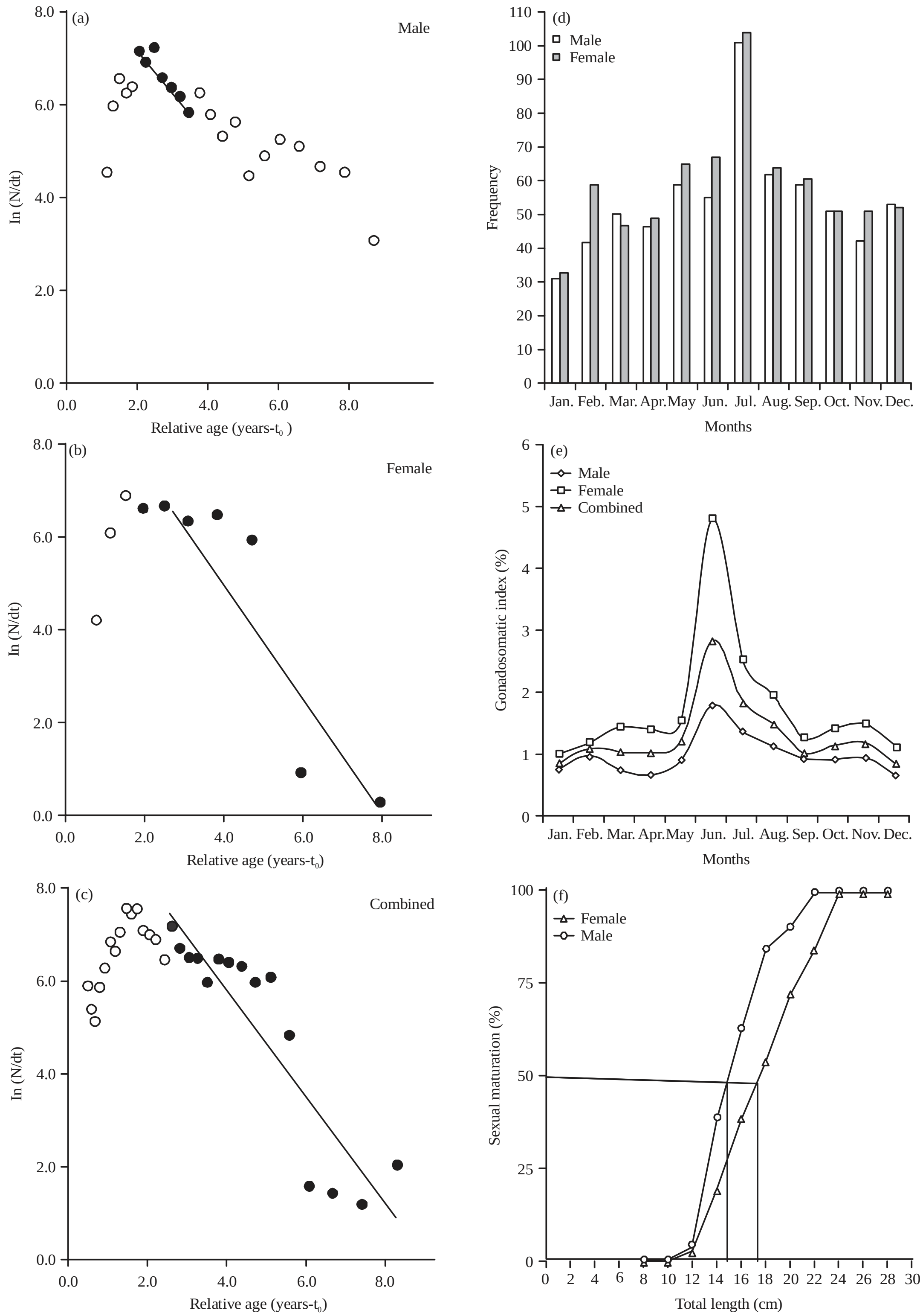

Fig. 6(a-f): (a-c) Length-converted catch curve, (d) Monthly frequencies of male and female, (e) Monthly gonadosomatic index and (f) Length at first maturity of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

Table 5: Population parameters and calculated von Bertalanffy total lengths and weights at different age-groups of male, female and combined sexes of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

Population parameters	Male	Female	Combined sexes
a Weight-total length relationship intercept	0.0222	0.0236	0.0366
n Weight-total length relationship slope	2.9636	2.9513	2.8006
L_∞ (asymptotic length, cm)	34.995	38.940	37.265
K (growth coefficient, year^{-1})	0.224	0.289	0.294
t_o (age at which length is nil, year)	-0.504	-0.024	0.089
W_∞ (asymptotic weight, g)	826.6325	1134.975	903.5364
S (survival rate)	0.4274	0.2952	0.3166
A (annual mortality rate)	0.5726	0.7048	0.6834
Z (total mortality coefficient, year^{-1})	0.95	1.22	1.15
M (natural mortality coefficient, year^{-1})	0.5571	0.6389	0.6536
F (fishing mortality coefficient, year^{-1})	0.3929	0.5811	0.4964
E (exploitation rate, year^{-1})	0.3446	0.4763	0.4317
L_c (length at first capture, cm)	12.9730	16.7119	14.2024
t_c (age at first capture, year)	1.56	1.92	1.72
Wt_c (weight at first capture, g)	43.69	93.51	60.66
L_r (length at recruitment, cm)	11.243	14.59	11.67
t_r (age at recruitment, year)	1.226	1.600	1.37
Wt_r (weight at recruitment, g)	28.59	62.61	35.02
Lm_{50} (length at first sexual maturity, cm)	14.80	17.40	-
tm_{50} (age at first sexual maturity, year)	1.950	2.025	-
Wtm_{50} (weight at first sexual maturity, g)	64.55	105.34	-
φ_L (growth performance in length)	2.4383	2.642	2.611
φ_W (growth performance in weight)	1.2951	1.498	1.439
t_{max} (maximum age, year)	12.89	10.36	10.29
Y/R (yield per recruit, g)	34.05	75.01	45.51
Y/R' (relative yield per recruit, g)	0.01569	0.02339	0.02181
B/R (biomass per recruit, g)	116.251	129.083	91.680
MSY/R (maximum yield per recruit, g)	43.0307	83.6025	51.0054
MSB/R (maximum biomass per recruit, g)	43.0307	52.2516	46.3686
F_{msy} (optimum fishing mortality coefficient, year^{-1})	1.00	1.60	1.10
$E_{maximum}$ (maximum exploitation rate, year^{-1})	0.648	0.706	0.638
$E_{0.1}$ (exploitation rate gives 1/10 of marginal increase in (Y/R)')	0.501	0.605	0.506
$E_{0.5}$ (exploitation rate which reduces the unexploited biomass to 50%)	0.326	0.344	0.328

	Age group (years)					
Parameters	I	II	III	IV	V	VI
von Bertalanffy lengths (cm)						
Male						
Length	10.01	15.02	19.03	22.24	24.80	26.84
Increment		5.01	4.01	3.21	2.56	2.04
Female						
Length	9.98	17.25	22.70	26.78	29.82	32.11
Increment		7.27	5.45	4.08	3.04	2.29
Combined sexes						
Length	8.76	16.02	21.43	25.46	28.47	30.71
Increment		7.26	5.41	4.03	3.01	2.24
von Bertalanffy weights (g)						
Male						
Weight	20.26	67.48	135.99	215.62	297.83	376.73
Increment		47.22	68.51	79.63	82.21	78.90
Female						
Weight	20.40	102.59	230.57	375.54	516.60	642.52
Increment		82.19	127.98	144.97	141.06	125.92
Combined sexes						
Weight	15.66	84.96	191.94	311.08	425.18	525.64
Increment		69.30	106.98	119.14	114.10	100.46

Length (L_c) and age (t_c) at first capture: The length at first capture (L_c), the size at which 50% of the fish are retained by the gear, was found to be 12.97, 16.71 and 14.20 cm for males, females and combined sexes (Table 5), respectively. The corresponding mean selection age (t_c) was calculated as 1.56, 1.92 and 1.72 years, whereas the corresponding mean selection weight (Wt_c) was calculated as 43.69, 93.51 and 60.66 g for males, females and combined sexes (Table 5), respectively.

Length (L_r) and age (t_r) at recruitment: The values of L_r were 11.24, 14.59 and 11.67 cm and those of t_r were 1.23, 1.60 and 1.37 year, whereas the calculated weights corresponding to L_r were 28.59, 62.61 and 35.02 g for males, females and combined sexes, respectively (Table 5).

Growth performance index (Ø) and the maximum age (t_{max}): The growth performance indices (Ø) were found to be 2.44, 2.64 and 2.61 of growth performance in length ($Ø_L$) and 1.30, 1.50 and 1.44 of growth performance in weight ($Ø_W$), while the values of maximum age (t_{max}) were found to be 12.89, 10.36 and 10.29 years for males, females and combined sexes, respectively (Table 5).

Yield per recruit (Y/R) and Biomass per recruit (B/R): The calculated yield per recruit (Y/R) was 34.05, 75.01 and 45.51 g, whereas the biomass per recruit (B/R) was 116.25, 129.08 and 91.68 g for males, females and combined sexes (Table 5), respectively. Figure 7a-c shows the yield per recruit (Y/R) and the biomass per recruit (B/R) of *O. niloticus* as a function of fishing mortality by various F-values. The results showed that, the estimated yield per recruit (Y/R) increases continuously with the increase of fishing mortality reaching its climax at Maximum Sustainable Yield (MSY), then it remained more or less constant or decreased. It appears that, the maximum sustainable yield per recruit (MSY/R) was 43.03, 83.60 and 51.01 g whereas the maximum sustainable biomass per recruit (MSB/R) was 43.03, 52.25 and 46.37 g for males, females and combined sexes (Table 5), respectively. The corresponding optimum fishing mortality value was 1.00, 1.60 and 1.10 year^{-1} for males, females and combined sexes (Table 5), respectively.

Relative yield per recruit (Y/R)' and relative biomass-per-recruit (B/R)': Relative Yield per Recruit (Y/R)' and relative Biomass per Recruit (B/R)' plot in relative Yield per Recruit (Y/R)' and Biomass per Recruit (B/R)' against exploitation rate (E), incorporated in FiSAT program (Fig. 7d-f), indicated that the maximum (Y/R)' was obtained at E = 0.65 for males and E = 0.71 for females while it was E = 0.64 for combined sexes (Table 5). As the exploitation rate increases beyond these values, (Y/R)' decreased. Both the $E_{0.1}$ (the level of exploitation at which the marginal increase in (Y/R)' reaches 1/10 of the marginal increase computed at a very low value of E) and $E_{0.5}$ (the exploitation level which reduces the unexploited biomass to 50%) were estimated. The $E_{0.1}$ and $E_{0.5}$ estimates were 0.50 and 0.33, 0.61 and 0.34 and 0.51 and 0.33 for males, females and combined sexes (Table 5), respectively.

Reproductive biology

Sex ratio: It was seen from sex distribution in Table 6 and Fig. 6d that the two sexes did not occur in the same proportion during different months of the year with the exception of October. It was found that females were slightly more numerous than males and sex ratio of 1:1.08 between males (651) and females (703) was obtained which did not deviated from the hypothetical distribution of 1:1 (χ^2 = 1.997, p>0.05). Also, it was found that females outnumbered males during all months with the exception of March and December. Statistical analysis by Chi-square (χ^2) test indicated that sex ratio was insignificantly (p>0.05) different from the expected ratio of 1:1 during different months.

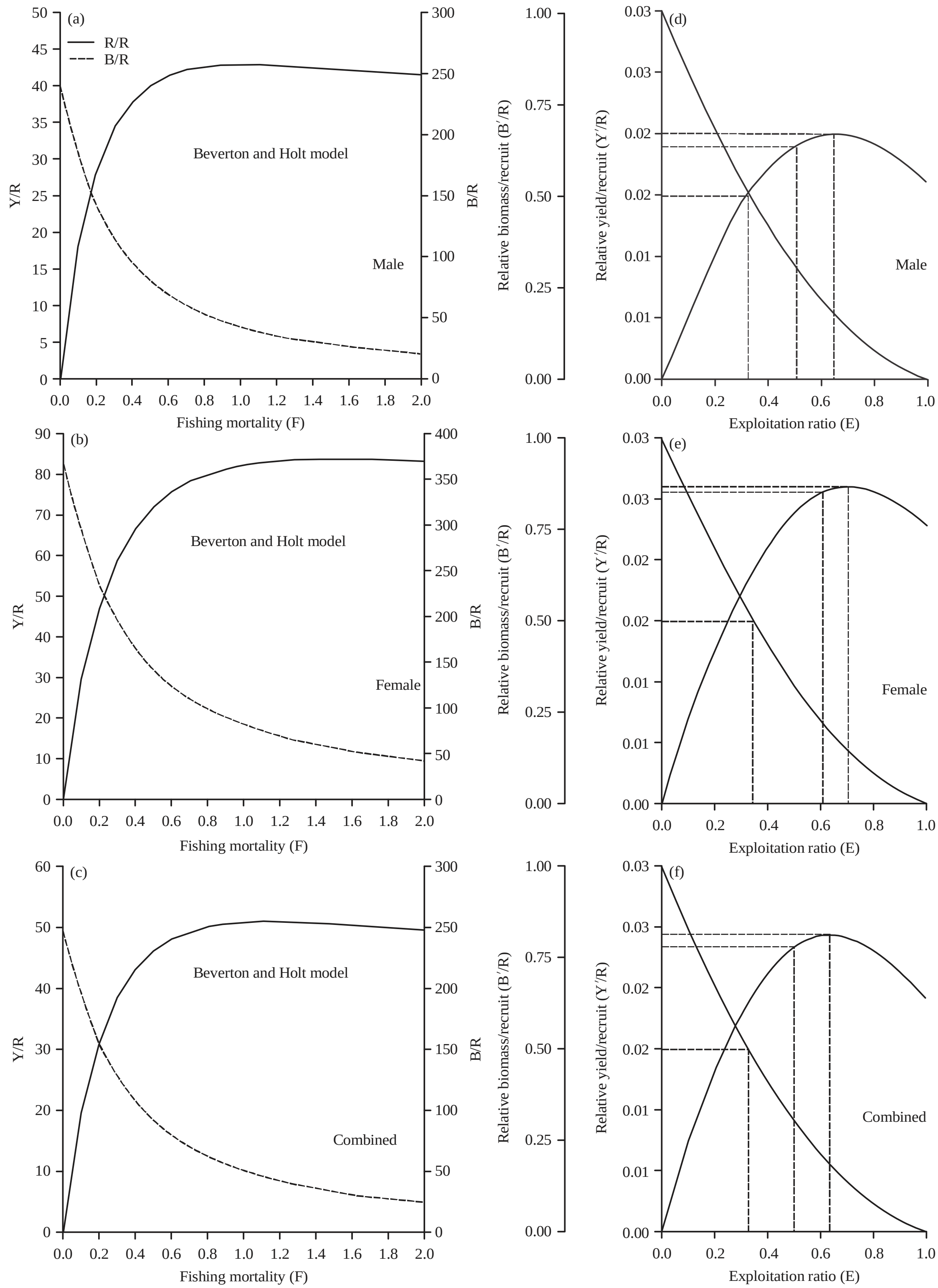

Fig. 7(a-f): (a-c) Yield per recruit (Y/R) and biomass per recruit (B/R) and (d-f) Relative yield per recruit (Y/R)' and biomass per recruit (B/R)' of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal

Table 6: Monthly variations of sex ratio, gonadosomatic index (GSI) and maturity stages of *O. niloticus* from El-Bahr El-Faraouny Canal, Egypt

	Male		Female		Unsexed samples						
Months	No.	%	No.	%	No.	%	Total No. of samples	M/F (%)	F/M (%)	Sex ratio M:F	Chi-square (χ^2)
January	31	46.97	33	50.00	2	3.03	66	93.94	106.45	1:1.06	0.063
February	42	41.18	59	57.84	1	0.98	102	71.19	140.48	1:1.40	2.843
March	50	49.51	47	46.53	4	3.96	101	106.38	94.00	1:0.94	0.102
April	46	46.94	49	50.00	3	3.06	98	93.88	106.52	1:1.07	0.104
May	59	47.20	65	52.00	1	0.80	125	90.77	110.17	1:1.10	0.290
June	55	43.31	67	52.75	5	3.94	127	82.09	121.82	1:1.22	1.180
July	101	46.76	104	48.15	11	5.09	216	97.12	102.97	1:1.03	0.049
August	62	47.69	64	49.23	4	3.08	130	96.88	103.23	1:1.03	0.032
September	59	45.73	61	47.29	9	6.98	129	96.72	103.39	1:1.03	0.033
October	51	49.04	51	49.04	2	1.92	104	100.00	100.00	1:1.00	-
November	42	42.86	51	52.04	5	5.10	98	82.35	121.43	1:1.21	0.871
December	53	48.62	52	47.71	4	3.67	109	101.92	98.11	1:0.98	0.019
Total	651	46.33	703	50.04	51	3.63	1405	92.60	107.99	1:1.08	1.997

	Gonadosomatic index (GSI)					
	Male		Female		Combined	
Months	Range	Mean±SE	Range	Mean±SE	Range	Mean±SE
January	0.05-2.53	0.77±0.13	0.11-3.07	1.01±0.11	0.05-3.07	0.86±0.08
February	0.01-2.59	0.98±0.11	0.01-2.86	1.18±0.09	0.01-2.86	1.09±0.07
March	0.01-2.07	0.74±0.09	0.11-2.93	1.44±0.10	0.01-2.93	1.04±0.08
April	0.01-2.41	0.67±0.10	0.02-3.25	1.40±0.10	0.01-3.25	1.01±0.08
May	0.02-2.82	0.91±0.09	0.01-2.84	1.54±0.10	0.01-2.84	1.23±0.07
June	0.01-4.82	1.79±0.09	0.10-9.02	4.80±2.99	0.01-5.73	2.83±1.58
July	0.01-4.15	1.36±0.09	0.19-5.73	2.50±0.44	0.01-9.02	1.84±0.22
August	0.16-4.32	1.12±0.11	0.16-4.53	1.94±0.13	0.16-4.53	1.49±0.09
September	0.12-2.93	0.93±0.09	0.12-5.34	1.27±0.11	0.12-5.34	1.02±0.07
October	0.11-3.91	0.91±0.11	0.09-4.67	1.42±0.13	0.09-4.67	1.14±0.09
November	0.01-2.78	0.95±0.12	0.09-3.97	1.48±0.12	0.01-3.97	1.18±0.09
December	0.01-1.89	0.65±0.07	0.10-2.61	1.12±0.08	0.01-2.61	0.85±0.06
Average	0.01-4.32	0.93±0.03	0.01-9.02	1.89±0.29	0.01-9.02	1.38±0.15

	Maturity stages (%)													
	Male							Female						
Months	I	II	I+II	III	IV	III+IV	V	I	II	I+II	III	IV	III+IV	V
January	30.51	49.15	79.66	11.86	5.08	16.94	3.40	20.37	36.07	56.44	22.95	13.77	36.72	6.84
February	17.39	55.90	73.29	17.04	7.14	24.18	2.53	19.61	33.34	52.95	23.53	15.76	39.29	7.76
March	33.33	50.00	83.33	9.52	4.76	14.28	2.39	22.17	27.69	49.86	25.93	18.46	44.39	5.75
April	38.00	46.00	84.00	10.00	4.00	14.00	2.00	17.65	19.61	37.26	35.32	18.69	54.01	8.73
May	29.03	41.94	70.97	16.13	9.45	25.58	3.45	19.40	20.40	39.80	23.90	24.39	48.29	11.91
June	24.75	30.69	55.44	16.84	19.96	36.80	7.76	12.50	15.63	28.13	22.18	36.81	58.99	12.88
July	13.56	50.85	64.41	15.25	14.86	30.11	5.48	9.62	19.23	28.85	24.24	32.76	57.00	14.15
August	23.90	42.86	66.76	17.29	11.81	29.10	4.14	12.12	25.07	37.19	23.21	29.28	52.49	10.32
September	25.81	46.77	72.58	11.29	9.68	20.97	6.45	24.42	27.81	52.23	23.34	16.56	39.90	7.87
October	21.57	50.98	72.55	17.65	5.88	23.53	3.92	26.14	30.33	56.47	22.37	16.15	38.52	5.01
November	10.91	65.45	76.36	10.91	7.27	18.18	5.46	19.02	29.66	48.68	23.90	19.15	43.05	8.27
December	18.09	66.04	84.13	10.21	3.77	13.98	1.89	21.23	33.77	55.00	26.92	10.54	37.46	7.54

SE: Standard error, M: Male, F: Female

Maturity stages: The monthly variations in the macroscopic characteristics incidence of different gonad developmental stages are summarized in Table 6 and Fig. 8. It is obvious that all different stages appeared in all months. The immature stages (I and II) represented the dominant maturity stages throughout the year with a peak in December (84.13%), April (84.00%) and March (83.33%)

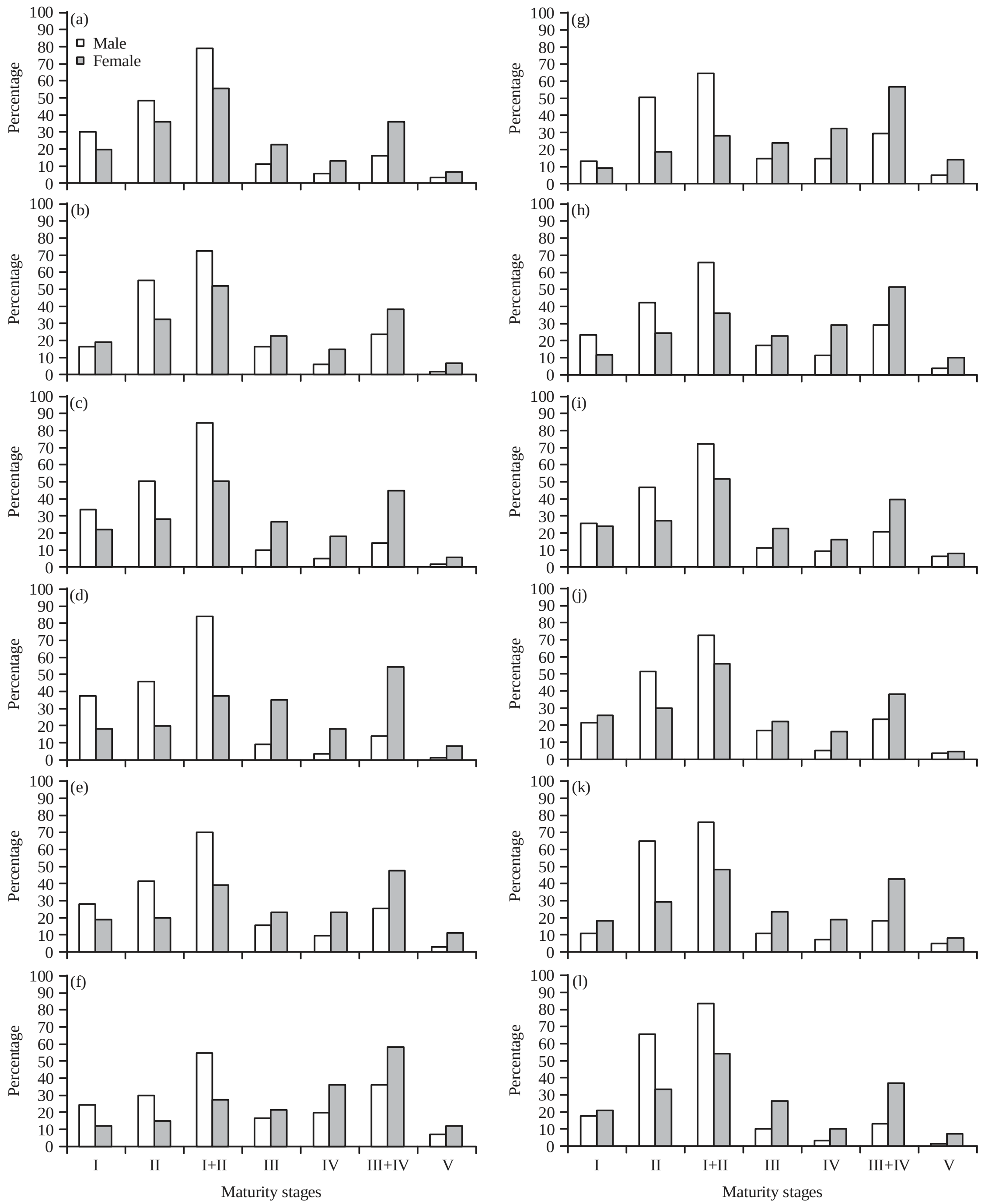

Fig. 8(a-l): Monthly variation of the percentage of maturity stages of *Oreochromis niloticus* in El-Bahr El-Faraouny Canal, (a) January, (b) February, (c) March, (d) April, (e) May, (f) June, (g) July, (h) August, (i) September, (j) October, (k) November and (l) December

for males and October (56.47%), January (56.44%), December (55.00%), February (52.95%) and September (52.23%) for females. Mature stage (III), spawning stage (IV) and spent stage (V) reached the maximum percentages in May-September and November for males and in

April-September and November for females. The percentage of reproductive process could be expressed by the sum of % of stages III and IV. So, the highest values of reproductive process were recorded during May-October, February and November for males and March-September, November and February for females.

Gonadosomatic index (GSI): The results show that the gonadosomatic indexes (GSI) values are higher in females than in males during all months of the year (Table 6, Fig. 6e). The highest values of GSI for males occur in January-February and May-November periods. The females GSI high values occur in February-November period. The present results indicate that both *O. niloticus* sexes in El-Bahr El-Faraouny Canal followed nearly the same trend and spawn in prolonged spawning season with peak in May to August.

Age and size at first sexual maturity: It was found that, *O. niloticus* males mature earlier than females and all males and females longer than 22 and 24 cm, respectively, are sexually mature. Figure 6f shows that the length at first sexual maturity (L_{m50}) is 14.80 and 17.40 cm in total length corresponding to 64.55 and 105.34 g in total weight and 1.95 and 2.03 years in age for males and females (Table 5), respectively.

DISCUSSION

The study of the dynamics of fish populations is mainly based on knowledge of biological processes, such as reproduction, growth, maturity and mortality. However, age and growth parameters of fishes constitute essential data to control the dynamic of ichthyological populations; they give an important indication on the fisheries management and on the level of their exploitation (Summerfelt and Hall, 1975; Omitoyin *et al*., 2013).

In the present study, the length frequency distribution showed that the investigated fish species was mostly caught less than two years of age, implying that it is normally caught before it grows large enough to contribute substantially to the stock biomass.

Commonly, in the study of the dynamics of a fish population, one of the initial steps is the derivation of a relationship between the weight and length of a fish (Wootton, 1992; Authman *et al*., 2009). Such data are essential for a wide number of studies, as estimating growth rate, age structure and other aspects of fish population dynamics (Kolher *et al*., 1995; El-Kasheif *et al*., 2007). In the present study, the values of the exponent (n) of length weight (L-W) relationships showed that the ponderal growth was found to be negative allometric in males, females and combined sexes. This means that the addition of length is more than the addition in weight and the studied fish species grow lighter as it become longer. This may be attributed to the worse ecological conditions of the canal as a result of a progressive accumulation of pollutants. Singh *et al*. (2012) mentioned that the actual relationship between length and weight may depart from the cubic value 3 and this may be due environmental condition in which the animal lives and also due to the physiological condition of the animal. The values of (n) in the present study are in accordance with that estimated by some authors working on the same species and differ from others (Table 7). This may reflect the impact of pollution of the canal causing stress load on fish. The deterioration of water quality of El-Bahr El-Faraouny Canal due to higher values of pollutants (industrial, agricultural and sewage) was reported by Ibrahim *et al*. (2012). Also, Gad and Ibrahim (2005) found higher levels of heavy metals (Fe, Pb, Zn, Cd and Cu) in the canal's water samples.

Table 7: Comparison of the regression of length (cm)-weight (g) relationships and the condition factor (K) irrespective of sex of *O. niloticus* from different Egyptian localities

Locality	a	n	K_c	K_n	K_w	Authors
El-Bahr El-Faraouny canal	0.0366	2.8006	2.13	3.75	1.03	Present study
Bahr Shebeen	0.040659	2.7889	2.19	-	-	Alne-na-ei (1986)
Lake Nasser	0.0571	2.8789	-	-	-	Latif and Khallaf (1987)
	0.101	2.72	-	-	-	Agaypi (1992)
	0.02466	2.93102	2.388*	1.886**	-	Mekkawy *et al.* (1994)
River Nile	0.014397	3.107633	1.91	1.01	-	Tharwat (1995)
	0.03711932	2.279612	2.423	-	1.1020	El-Kasheif (2003)
	0.0377	2.7924	1.345	-	1.445	Hassan and El-Kasheif (2013)
Lake Manzalah	0.0207	2.9838	1.96***	-	-	Bayoumi and Khalil (1988)
	0.0424	2.7036	-	-	1.010	Soliman *et al.* (1998)
	-	-	2.160	-	-	Shalloof (1991)
	0.01745	3.01043	-	-	-	El-Bokhty (2006)
Edku Lake	0.01702	3.03264	-	-	-	Abd-Alla and Talaat (2000)
Shanawan Drainage Canal	0.042696	2.7707	2.07	-	-	Khallaf *et al.* (2003)
Abu-Zabal lakes	0.0282	2.8592	1.86	-	-	Ibrahim *et al.* (2008)
	0.0894	2.4034	1.7056	-	-	Shalloof and El-Far (2009)
Rosetta branch	0.0184	3.0082	1.84	-	-	Mahmoud and Mazrouh (2008)
Damietta branch	0.0165	3.0755	-	-	1.0011	Authman *et al.* (2009)
Nozha Hydrodrome	0.0273	2.9093	2.05	-	-	Mahmoud *et al.* (2013)

K_c: W/L^{3}X100, K_n: W/L^{n}X100, K_w: W/$\hat{W}$, *K_c: W/L^{3}X10^5 **K_n: W/L^{n}X10^5 ***K_c: Log W/L^{3}X10^5

Pollution was seen to affect the condition of *O. niloticus* in Lake Marriut, Egypt (Bakhoum, 1994), that there were highly significant variations of L-W relationships of this species in polluted and non-polluted parts of the lake. Similarly, Khallaf *et al.* (2003) reported differences in L-W relationships of *O. niloticus* in a polluted canal compared with those of other authors in different localities and times. These differences were attributed to the effect of eutrophication and pollution on growth and other biological aspects of *O. niloticus*. In addition, the weight at length of *O. niloticus* from El-Bahr El-Faraouny Canal is lighter; especially of larger fish; when compared to those form other localities (Table 8). This confirms the mentioned above about that the studied fishes grow lighter, as it become longer. These variations could be attributed to different stages in ontogenetic development as well as to differences in age, maturity and sex. Geographic location and associated environmental conditions, such as; season (date and time of capture), pollution, disease and parasite can also affect the value of (n) and the fish weight (Le Cren, 1951; Bagenal and Tesch, 1978; Osman, 2005; El-Kasheif *et al.*, 2007; Authman *et al.*, 2009).

The condition coefficient (K), which measures physiological well-being of the fish (Wootton, 1994; Laleye *et al.*, 2006), is considered as a measure of the “fitness” of the fish in a population. It may also be considered as a rough measure of the state of the fish, whether healthy or unhealthy, starved or well-fed, spawning or spent (Patterson, 1992). It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005). In the present study, the higher mean K values observed in the females of *O. niloticus* compared to their male counterparts could be explained by differences in fatness and gonad development of the females. Similar explanations were advanced for higher K-values in the females of *Oreochromis niloticus* by Omitoyin *et al.* (2013). By comparing the condition factor for *O. niloticus* in different regions (Table 7), we can see that the grand average value of condition factor (K_c = 2.13) of *O. niloticus* in El-Bahr El-Faraouny Canal is low compared to the values of the same species in Bahr Shebeen (2.19; Alne-na-ei, 1986),

Table 8: Comparison of average calculated fish weights (g) with different total lengths (cm) of *O. niloticus* from different localities of Egypt

Total length (cm)	El-Bahr El-Faraouny canal Present study	Bahr Shebeen Alne-na-ei (1986)			Lake Nasser Latif and Khallaf (1987)			Lake Nasser Mekkawy *et al.* (1994)			River Nile (Cairo sector) Tharwat (1995)			Edku Lake Abd-Alla and Talaat (2000)			Shanawan Drainage Canal Khallaf *et al.* (2003)		
	W	W	D	%	W	D	%	W	D	%	W	D	%	W	D	%	W	D	%
4	1.77	1.94	-0.17	9.42	3.09	-1.31	74.08	1.43	+0.34	19.18	1.07	+0.71	39.73	1.14	+0.64	35.78	1.99	-0.21	12.04
6	5.52	6.02	-0.49	8.90	9.93	-4.40	79.70	4.71	+0.82	14.80	3.77	+1.75	31.74	3.90	+1.63	29.45	6.12	-0.59	10.69
8	12.37	13.42	-1.06	8.53	22.73	-10.36	83.79	10.94	+1.43	11.54	9.22	+3.15	25.44	9.33	+3.04	24.58	13.57	-1.20	9.74
10	23.10	25.01	-1.91	8.25	43.21	-20.10	87.03	21.04	+2.06	8.93	18.45	+4.65	20.15	18.35	+4.75	20.57	25.18	-2.08	9.01
12	38.49	41.58	-3.09	8.02	73.03	-34.54	89.72	35.90	+2.59	6.74	32.51	+5.99	15.55	31.90	+6.60	17.14	41.73	-3.24	8.42
14	59.28	63.91	-4.64	7.82	113.82	-54.55	92.02	56.40	+2.87	4.84	52.48	+6.79	11.46	50.90	+8.37	14.12	63.97	-4.69	7.92
16	86.16	92.75	-6.60	7.66	167.18	-81.02	94.04	83.42	+2.73	3.17	79.48	+6.68	7.75	76.32	+9.84	11.42	92.61	-6.45	7.49
18	119.82	128.82	-9.00	7.51	234.66	-114.84	95.84	117.82	+2.00	1.67	114.60	+5.22	4.36	109.08	+10.74	8.97	128.34	-8.52	7.11
20	160.95	172.82	-11.87	7.37	317.81	-156.86	97.46	160.45	+0.50	0.31	159.00	+1.95	1.21	150.15	+10.81	6.71	171.85	-10.90	6.77
22	210.19	225.44	-15.25	7.26	418.15	-207.96	98.94	212.16	-1.96	0.93	213.81	-3.62	1.72	200.47	+9.73	4.63	223.79	-13.59	6.47
24	268.20	287.36	-19.16	7.15	537.19	-268.99	100.30	273.79	-5.60	2.09	280.20	-12.00	4.47	261.00	+7.19	2.68	284.80	-16.60	6.19
26	335.59	359.23	-23.64	7.05	676.40	-340.81	101.56	346.19	-10.60	3.16	359.33	-23.74	7.07	332.71	+2.88	0.86	355.51	-19.92	5.94
28	413.00	441.71	-28.71	6.95	837.26	-424.26	102.73	430.17	-17.18	4.16	452.38	-39.39	9.54	416.55	-3.56	0.86	436.54	-23.55	5.70
30	501.03	535.43	-34.40	6.87	1021.22	-520.20	103.83	526.58	-25.55	5.10	560.56	-59.53	11.88	513.50	-12.47	2.49	528.50	-27.48	5.48
32	600.29	641.02	-40.73	6.79	1229.74	-629.45	104.86	636.24	-35.95	5.99	685.06	-84.77	14.12	624.51	-24.22	4.03	631.98	-31.70	5.28
34	711.37	759.10	-47.73	6.71	1464.23	-752.86	105.83	759.96	-48.59	6.83	827.08	-115.71	16.27	750.56	-39.19	5.51	747.58	-36.21	5.09
36	834.87	890.28	-55.42	6.64	1726.14	-891.27	106.76	898.56	-63.69	7.63	987.85	-152.98	18.32	892.62	-57.75	6.92	875.86	-40.99	4.91
38	971.36	1035.18	-63.82	6.57	2016.86	-1045.50	107.63	1052.86	-81.50	8.39	1168.58	-197.23	20.30	1051.66	-80.30	8.27	1017.40	-46.05	4.74
40	1121.41	1194.38	-72.96	6.51	2337.80	-1216.38	108.47	1223.67	-102.25	9.12	1370.52	-249.11	22.21	1228.66	-107.24	9.56	1172.78	-51.36	4.58

Total length (cm)	El-Bahr El-Faraouny canal Present study	Lake Manzala El-Bokhty (2006)			Rosetta branch of the Nile River Mahmoud and Mazrouh (2008)			Damietta branch of the Nile River Authman *et al.* (2009)			Abu-Zaabal Lakes Shalloof and El-Far (2009)			River Nile at Beni Suef Hassan and El-Kasheif (2013)			Nozha Hydrodrome Mahmoud *et al.* (2013)		
	W	W	D	%	W	D	%	W	D	%	W	D	%	W	D	%	W	D	%
4	1.77	1.13	+0.64	36.16	1.19	+0.58	32.89	1.17	+0.60	33.94	2.50	-0.73	40.99	1.81	-0.03	1.95	1.54	+0.23	13.19
6	5.52	3.84	+1.68	30.49	4.03	+1.49	27.00	4.08	+1.44	26.15	6.63	-1.11	20.01	5.61	-0.09	1.61	5.01	+0.51	9.28
8	12.37	9.13	+3.24	26.16	9.58	+2.78	22.50	9.88	+2.48	20.07	13.24	-0.87	7.05	12.54	-0.17	1.37	11.58	+0.79	6.39
10	23.10	17.87	+5.23	22.63	18.75	+4.35	18.83	19.63	+3.47	15.01	22.63	+0.47	2.03	23.37	-0.27	1.18	22.15	+0.95	4.10
12	38.49	30.95	+7.55	19.61	32.45	+6.04	15.70	34.40	+4.10	10.64	35.08	+3.41	8.87	38.89	-0.40	1.03	37.66	+0.84	2.18
14	59.28	49.22	+10.06	16.97	51.59	+7.68	12.96	55.26	+4.02	6.78	50.81	+8.47	14.28	59.81	-0.54	0.91	58.96	+0.31	0.52
16	86.16	73.57	+12.58	14.61	77.10	+9.06	10.51	83.32	+2.84	3.29	70.04	+16.12	18.71	86.84	-0.68	0.79	86.96	-0.80	0.93
18	119.82	104.88	+14.94	12.47	109.88	+9.94	8.30	119.69	+0.13	0.11	92.95	+26.87	22.43	120.66	-0.84	0.70	122.50	-2.67	2.23
20	160.95	144.03	+16.92	10.51	150.86	+10.09	6.27	165.50	-4.55	2.83	119.74	+41.21	25.61	161.93	-0.98	0.61	166.44	-5.48	3.41
22	210.19	191.90	+18.30	8.71	200.95	+9.24	4.40	221.87	-11.68	5.56	150.56	+59.63	28.37	211.31	-1.12	0.53	219.62	-9.43	4.48
24	268.20	249.36	+18.84	7.02	261.08	+7.12	2.65	289.95	-21.75	8.11	185.58	+82.61	30.80	269.43	-1.23	0.46	282.89	-14.69	5.48
26	335.59	317.30	+18.29	5.45	332.15	+3.43	1.02	370.88	-35.29	10.52	224.95	+110.64	32.97	336.91	-1.32	0.39	357.06	-21.47	6.40
28	413.00	396.61	+16.39	3.97	415.11	-2.11	0.51	465.82	-52.83	12.79	268.80	+144.19	34.91	414.37	-1.37	0.33	442.98	-29.98	7.26
30	501.03	488.16	+12.86	2.57	510.85	-9.82	1.96	575.93	-74.90	14.95	317.29	+183.74	36.67	502.41	-1.38	0.28	541.44	-40.42	8.07
32	600.29	592.85	+7.44	1.24	620.31	-20.03	3.34	702.38	-102.09	17.01	370.52	+229.76	38.28	601.62	-1.33	0.22	653.27	-52.99	8.83
34	711.37	711.55	-0.18	0.03	744.41	-33.04	4.64	846.34	-134.97	18.97	428.64	+282.73	39.74	712.60	-1.23	0.17	779.28	-67.91	9.55
36	834.87	845.15	-10.29	1.23	884.07	-49.20	5.89	1009.00	-174.14	20.86	491.76	+343.10	41.10	835.91	-1.05	0.13	920.27	-85.40	10.23
38	971.36	994.54	-23.19	2.39	1040.21	-68.86	7.09	1191.54	-220.18	22.67	560.00	+411.35	42.35	972.14	-0.78	0.08	1077.03	-105.67	10.88
40	1121.41	1160.61	-39.19	3.49	1213.77	-92.35	8.24	1395.15	-273.73	24.41	633.47	+487.94	43.51	1121.85	-0.43	0.04	1250.36	-128.95	11.50

W: Weight (g), D: Difference, %: Percent of difference

Lake Manzalah (2.16; Shalloof, 1991), Lake Nasser (2.39; Mekkawy *et al*., 1994) and river Nile (2.42; El-Kasheif, 2003) indicate the general stress on fish population of that species in this canal. In accordance, with earlier studies, similar results were also attributed to the high levels of pollution (Lowe-McConnell, 1975, 1987; Sindermann, 1979, 1990). In addition, among factors which can explain the difference obtained in the average condition factors of a fish species in two or more habitats, the fact that the fish are in better condition of feeding in a habitat than in the second one (Le Cren, 1951; Laleye *et al*., 2006).

The determination of age of fish is of great importance for solving the biological problems of fisheries. Present study showed that the time of annulus formation on the scales of *O. niloticus* was noticed during March-April period following the cold period of winter, which lasted between December and February. This is also noticed for *O. niloticus* of Bahr Shebeen canal (Alne-na-ei, 1986; Latif *et al*., 1989; El-Sehamy, 1993).

It was found that; *O. niloticus* from El-Bahr El-Faraouny Canal has a relatively higher longevity, as they attained 6 years. Longevity of *O. niloticus* varies at different regions (Table 9). These significant variations are due to the changes in the fishing efforts and exploitation rate of the fishery resources, as well as, over fishing throughout the past and present times (El-Kasheif *et al*., 2007; Authman *et al*., 2009). The back calculated lengths-at-age and weights-at-age of *O. niloticus* from El-Bahr El-Faraouny Canal were compared with other Egyptian localities (Table 9). It was found that, the growth rate in length was rapid during the first and second years of life, followed by a marked decrease as the fish got older. On the other hand, the growth in weight showed a marked increase as the fish got older. Apparently, this happens because the fish gets nearer to its asymptotic length and consequently weight, where theoretically cessation of growth may occur (Khallaf and Authman, 2010). This is also represented by the relative and instantaneous rates of growth in length and weight (Table 4). The results also indicated that the growth in length and weight of *O. niloticus* of El-Bahr El-Faraouny Canal is higher than those of other sites and lower than others. Different growth rates of *O. niloticus* in El-Bahr El-Faraouny Canal compared to those of other Egyptian localities may be due to the excessive intrusion of a large amount of different kinds of pollutants mostly untreated agricultural, domestic and industrial wastewater into the canal. The variations of weights and lengths among different regions are mainly attributed to water temperature, which can affect fish growth directly by affecting the physiology of the fish (Alliot *et al*., 1983; Weatherley and Gill, 1987) and food availability in these areas (Wassef and El-Emary, 1989; Bruton, 1990). Adding to that, low number of older age groups in the present study may be duo to serious ecological condition of El-Bahr El-Faraouny Canal especially, contamination with heavy metals as recorded by Gad and Ibrahim (2005). Also, other authors detected lesions indicating deformations in *C. gariepinus* in El-Bahr El-Faraouny Canal and they clarify the role of water pollution on the efficiency of fish (Gaber *et al*., 2012; Ibrahim *et al*., 2012). In addition, the calculated longevity (t_{max}) of the studied species ranged between 10 and 12 years indicating that it is short to median lived species.

The von Bertalanffy growth models accurately estimated theoretical growth in length and weight. Predicted lengths and weights-at-age of von Bertalanffy theoretical growth (Table 9) and back-calculated lengths and weights (Table 3) for *O. niloticus* in El-Bahr El-Faraouny Canal agree closely. *Oreochromis niloticus* in El-Bahr El-Faraouny Canal region characterized by having a largest asymptotic length (L_∞) in comparison with other localities with the exception of fishes of

Table 9: Comparison of longevity and back-calculated lengths (cm) and weights (g) at the end of different years of life of *O. niloticus* at different localities

Locality/age-groups	I	II	III	IV	V	VI	VII	Authors
Back-calculated length (cm)								
El-Bahr El-Faraouny Canal	8.82	16.15	21.28	25.88	28.47	30.85	-	Present study
Bahr Shebeen**	7.14	12.48	17.03	19.67	-	-	-	Alne-na-ei (1986)
	7.10	12.50	17.00	19.70	-	-	-	Latif *et al.* (1989)
	11.50	15.10	17.70	20.50	-	-	-	Khallaf (1992)
	14.20	20.80	23.00	24.50	-	-	-	El-Sehamy (1993)
Lake Nasser	6.90**	20.30**	29.80**	36.50**	41.30**	44.70**	47.20**	Latif and Khallaf (1987)
	21.80	26.30	30.60	39.00	-	-	-	Agaypi (1992)
	14.85	19.37	23.74	29.39	33.47	37.80	-	Mekkawy *et al.* (1994)
River Nile	13.00	19.14	22.62	25.06	-	-	-	Tharwat (1995)
	13.49	18.65	22.39	25.42	28.24	-	-	El-Kasheif (2003)
	16.13	21.32	25.01	28.50	-	-	-	Hassan and El-Kasheif (2013)
Lake Manzalah	7.80	14.30	19.70	30.20	-	-	-	Bayoumi and Khalil (1988)
	10.27	13.34	16.57	19.1	-	-	-	El-Bokhty (2006)
Edku Lake	9.11	13.74	17.53	20.63	23.16	25.25	27.06	Abd-Alla and Talaat (2000)
Shanawan Drainage Canal	9.10	18.10	-	-	-	-	-	Khallaf *et al.* (2003)
Abu-Zabal lakes	10.12	14.53	18.90	23.11	26.89	-	-	Ibrahim *et al.* (2008)
	11.65	14.61	17.03	19.25	-	-	-	Shalloof and El-Far (2009)
Damietta branch	8.38	11.43	14.35	17.23	19.82	21.32	-	Authman *et al.* (2009)
Back-calculated weight (g)								
El-Bahr El-Faraouny Canal	15.98	86.93	188.20	325.54	425.19	532.37	-	Present study
Bahr Shebeen	9.77*	46.39*	110.38*	164.99*	-	-	-	Alne-na-ei (1986)
Lake Nasser	14.85*	331.73*	1001.75*	1796.06*	2563.27*	3218.89*	3764.85*	Latif and Khallaf (1987)
	420.00	500.00	1100.00	2000.00	-	-	-	Agaypi (1992)
	71.51	153.59	277.74	517.79	759.10	1036.81	-	Mekkawy *et al.* (1994)
River Nile	41.69	138.70	233.10	320.48	-	-	-	Tharwat (1995)
	53.93	133.13	221.34	315.76	423.84	-	-	El-Kasheif (2003)
	88.83	193.57	302.30	435.36	-	-	-	Hassan and El-Kasheif (2013)
Lake Manzalah	9.50*	57.98*	150.80*	539.53*	-	-	-	Bayoumi and Khalil (1988)
	19.37*	42.56*	81.75*	125.39*	-	-	-	El-Bokhty (2006)
Edku Lake	13.83	48.09	100.67	164.95	234.27	304.45	375.57	Abd-Alla and Talaat (2000)
Shanawan Drainage Canal	19.40	130.30	-	-	-	-	-	Khallaf *et al.* (2003)
Abu-Zabal lakes	21.10*	59.35*	125.87*	223.68*	344.93*	-	-	Ibrahim *et al.* (2008)
	32.67*	56.29*	81.37*	109.23*	-	-	-	Shalloof and El-Far (2009)
Damietta branch	11.94	30.80	61.85	109.81	168.31	207.24	-	Authman *et al.* (2009)
Von Bertalanffy length (cm)								
El-Bahr El-Faraouny Canal	8.76	16.02	21.43	25.46	28.47	30.71	-	Present study
Bahr Shebeen**	7.16	12.64	16.72	19.78	-	-	-	Alne-na-ei (1986)
	7.20	12.60	16.70	19.80	-	-	-	Latif *et al.* (1989)
	15.50	19.80	22.80	24.80	-	-	-	El-Sehamy (1993)
Lake Nasser	6.92*	20.26*	29.75*	36.51*	41.32*	44.75*	47.18*	Latif and Khallaf (1987)
	20.14*	27.92*	33.80*	38.25*	-	-	-	Agaypi (1992)
River Nile	12.97	19.05	22.76	25.02	-	-	-	Tharwat (1995)
	13.64*	18.77*	22.64*	25.57*	27.79*	-	-	El-Kasheif (2003)
	16.13	20.51	24.29	27.55	-	-	-	Hassan and El-Kasheif (2013)
Edku Lake	9.11*	13.74*	17.53*	20.63*	23.16*	25.23*	26.92*	Abd-Alla and Talaat (2000)
Abu-Zabal lakes	11.70*	14.56*	17.07*	19.26*	-	-	-	Shalloof and El-Far (2009)
Rosetta branch	11.47*	16.97*	20.69*	23.21*	24.92*	-	-	Mahmoud and Mazrouh (2008)
Damietta branch	8.15	11.34	14.16	16.66	18.88	20.85	-	Authman *et al.* (2009)
Nozha Hydrodrome	9.93*	15.28*	19.61*	23.12*	25.96*	28.26*	30.13*	Mahmoud *et al.* (2013)
Von Bertalanffy weight (g)								
El-Bahr El-Faraouny Canal	15.66	84.96	191.94	311.08	425.18	525.64	-	Present study
Bahr Shebeen	20.26*	98.72*	215.73*	344.34*	-	-	-	Alne-na-ei (1986)
Lake Nasser	14.98*	329.90*	997.39*	1797.84*	2567.27*	3228.41*	3760.85*	Latif and Khallaf (1987)
	356.09*	865.67*	1455.75*	2037.00*	-	-	-	Agaypi (1992)
River Nile	41.34	136.69	237.64	319.04	-	-	-	Tharwat (1995)
	89.16*	184.58*	283.18*	373.69*	451.56*	-	-	El-Kasheif (2003)
	88.85	173.67	278.46	395.88	-	-	-	Hassan and El-Kasheif (2013)
Edku Lake	13.81*	48.10*	100.66*	164.86*	234.22*	303.64*	369.72*	Abd-Alla and Talaat (2000)
Abu-Zabal lakes	33.00*	55.85*	81.79*	109.34*	-	-	-	Shalloof and El-Far (2009)
Rosetta branch	28.39*	92.26*	167.58*	236.83*	293.19*	-	-	Mahmoud and Mazrouh (2008)
Damietta branch	10.79	29.71	58.87	97.13	142.69	193.59	-	Authman *et al.* (2009)
Nozha Hydrodrome	21.67*	76.01*	157.19*	253.76*	355.55*	455.20*	548.12*	Mahmoud *et al.* (2013)

*Calculated by the present authors, **Standard length

Lake Nasser, River Nile at Beni suef and Nozha Hydrodrome (Table 10). This may be attributed to the difference in size of collected sample and the difference in ecological environment of both habitats (Shalloof and El-Far, 2009).

Table 10: Comparison of growth parameters (L_∞, K, t_o and W_∞), growth performance index (Ø), mortality (Z, M, F and A), exploitation rate (E) and survival (S) rates of *O. niloticus* from different water bodies in Egypt

Locality	L_∞	K	t_o	W_∞	$Ø_L$	$Ø_W$	t_{max}	Z	M	F	E	S	A	Author
El-Bahr El-Faraouny Canal	37.265	0.294	0.089	903.5364	2.611	1.439	10.29	1.15	0.6536	0.4964	0.4317	0.3166	0.6834	Present study
Bahr Shebeen**	28.78	0.292	0.02	980.30*	2.38*	1.46*	10.29*	1.40	-	-	-	0.25	0.75	Alne-na-ei (1986)
	28.8	0.29	0.02	-	2.38*	-	10.36*	1.40	-	-	-	0.25	0.75	Latif *et al.* (1989)
	28.9	0.29	0.02	-	2.38*	-	10.36*	1.52	0.72	0.80*	0.53*	0.22	0.78	Khallaf (1992)
	29.33	0.37	-1.04	-	2.50*	-	7.07*	0.76	0.90	0.2128	0.28	0.47	0.53	El-Sehamy (1993)
Lake Nasser	61.1**	0.411	-0.34	-	3.19*	-	6.96*	1.179	-	-	-	0.31	069	Abdel-Azim (1974)
	53.2	0.34	0.59	5313.28*	2.98*	2.02*	9.41*	1.06	0.58	-	-	0.35	0.65	Latif and Khallaf (1987)
	52.0	0.28	-0.75	4697.32*	2.88*	1.90*	9.96*	-	-	-	-	-		Agaypi (1992)
	-	-	-	-	-	-	-	2.247	-	-	-	0.11	0.89	Mekkawy *et al.* (1994)
	54.730	0.270	-0.745	6414.871	2.91*	1.97*	10.37*	1.21	0.24	0.97	0.80	0.30*	0.70*	Khalifa *et al.* (2000)
Lake Burullos	32.80	0.33	-0.15	685.0	2.55	1.41*	8.94*	-	-	-	-	-	-	El-Haweet (1991)
	34.62	0.21	-0.42	801.0	2.41	1.26*	13.87*	-	-	-	-	-	-	Sangak (2010)
River Nile	28.56	0.494612	-0.223340	481.11	2.61*	1.48*	5.84*	1.12	-	-	-	0.33	0.67	Tharwat (1995)
	34.64	0.28	-0.7873	746.33	2.53*	1.36*	9.93*	-	-	-	-	-	-	El-Kasheif (2003)
	48.14	0.147	0.2237	1881.79	2.532	1.350*	20.63*	0.97	0.40	0.56	0.58	0.38	0.62	Hassan and El-Kasheif (2013)
Lake Manzalah	28.88	0.53	-	435.33	2.65	1.48*	-	3.38	1.04	2.34	0.69	0.03*	0.97*	El-Bokhty (2006)
Edku Lake	34.5	0.2015	-0.5209	784.53*	2.38	1.23*	14.37*	1.3909	0.6110	0.7799	0.4212	0.2489	0.7511	Abd-Alla and Talaat (2000)
	31.08	0.31	-0.02	614.3	2.47	1.35*	9.66*	-	-	-	-	-	-	Soliman (2005)
	27.50	0.52	-0.08	414.0	2.59	1.46*	5.69*	-	-	-	-	-	-	El-Sawy (2006)
Shanawan Drainage Canal	-	-	-	-	-	-	-	2.56	-	-	-	0.08	0.92	Khallaf *et al.* (2003)
Abu-Zabal lakes	34.59	0.1336	-2.09	446.74*	2.20*	0.89*	20.37*	-	-	-	-	-	-	Shalloof and El-Far (2009)
Rosetta branch	28.5	0.39	-0.32	439.0	2.50	1.36	7.63	1.62	0.80	0.82	0.51	0.20	0.80	Mahmoud and Mazrouh (2008)
Damietta branch	36.3	0.12	-1.12	1064.54	2.20	1.10	23.88	0.64	0.39	0.25	0.40	0.53	0.47	Authman *et al.* (2009)
Nozha Hydrodrome	38.06	0.211	-0.432	1081.94	2.485	1.347	14.23	0.873	0.519	0.354	0.406	0.42	0.58	Mahmoud *et al.* (2013)

*Calculated by the present authors, ** Standard length

The main causes of mortality in fishes can be either natural or fishing mortality (El-Kasheif *et al*., 2007; Authman *et al*., 2009). The present study shows that natural mortality coefficient of *O. niloticus* is higher (0.65) than the average given by Pauly (1980) for 175 fish stocks (0.2 and 0.3). This is in agreement with that obtained by other authors (Table 10). In addition, the low survival rate here in this study (S = 0.32), means that about 32% of *O. niloticus* survive per year, indicating higher fishing. Also, this may be attributed to the highly increased pollution of the water of El-Bahr El-Faraouny Canal. Saleh (1980), Dethlefsen and Tiews (1985) and Khallaf *et al*. (2003) mentioned that, pollution increased the susceptibility of fish to diseases and increased the mortality rates. This is farther shown by the exploitation ratio (E) and fishing mortality (F) in the present study as 0.43 and 0.50, respectively. Gulland (1971) suggested that the optimum exploitation rate for any fish stock was about 0.5. So, values of the present exploitation rate (Table 5) indicate that *O. niloticus* is moderately exploited (E = 43%). On the other hand, there is a selective mortality among different age groups for either sex, since the difference of "$G\text{-}G_x$" is negative (Table 4), it indicates that this selection is conspicuous towards smaller fish sizes (Khallaf and Authman, 1991a). This was even more pronounced among females apparently, because of their higher vulnerability, especially the young, to the fishing gears as they outnumbered males (Table 3). Adding to that, the older age's groups, which represented in small proportions may be reflecting the higher levels of mortality and overexploitation (Abd-Alla and Talaat, 2000) and pollution that tilapias suffer in the Canal.

Yield per recruit and biomass per recruit are the most common models used for the prescription of the fisheries state of any fish stock and to express the annual average biomass of survivors (Authman *et al*., 2009). These models depend upon the yield as a function of age and fishing mortality (Beverton and Holt, 1957). In the present study, it appears that the maximum sustainable yield per recruit (MSY/R) for *O. niloticus* was attained at fishing mortality of F = 1.00, 1.60 and 1.10 year^{-1}, for male, female and combined sexes, respectively, which are higher than the present fishing mortality values but increasing fishing efforts to reach to these values are unreasonable. Adding to that, the present levels of exploitation rate of *O. niloticus* were slightly lower than that which gives the maximum (Y/R)'. Also, the results show that, the present levels of exploitation rate of *O. niloticus* are higher than the exploitation rate ($E_{0.5}$), which will maintains 50% of the unexploited stock biomass. This means that, the exploitation rates of *O. niloticus* in El-Bahr El-Faraouny Canal should be reduced, as well as, the length at first capture should be increased to maintain a sufficient spawning biomass for recruitment.

When the population parameters of *O. niloticus* from different localities were compared, intra-differences between some of such parameters are evident (Table 10 and 11). These findings refer to variability in fisheries characteristics of *O. niloticus* population of different localities (Khallaf and Authman, 2010). Various endogenous and exogenous factors influence fish growth (Helfman *et al*., 2009), as food and temperature prevailing in these areas (Bruton, 1990; Weatherley and Gill, 1987) and these might be responsible for the observed differences (Offem *et al*., 2012). Also, the method of sampling can affect the calculated biological parameters (Mahmoud *et al*., 2013).

In fishes, the sex ratio varies from one species to another (Khallaf and Authman, 2010). The sex ratio of most fish species in the wild tends to be 1:1 but deviations can occur and seasonal variations are common (Helfman *et al*., 2009). The sex ratio is influenced by several factors, including mortality, longevity and growth rate; these in turn lead to differences in the catch rate (King and Etim, 2004; Novaes and Carvalho, 2012). The values of sex ratio in the present study are in accordance with that estimated by some authors for studied species and differ from others. It was found in the present study that the number of *O. niloticus* females exceeded that of males by a sex-ratio (M:F) of 1:1.08. In *T. nilotica* populations from Khartoum, Sudan, it was observed that, sex ratio (M:F) was 1.19:1 (Babiker and Ibrahim, 1979). Gomez-Marquez *et al*. (2003) found that sex ratio (M:F) of *O. niloticus*, in Coatetelco Lake, Mexico, was 1:1.02. Pena-Mendoza *et al*. (2005) found that sex ratio (M:F) of *O. niloticus* at Emiliano Zapata dam, Mexico, was 1:1.29. Komolafe and Arawomo (2007) fond that, for *O. niloticus* in Opa reservoir, Nigeria, the ratio (M:F) was 1:0.8. In *O. niloticus* populations from Cross River; Nigeria, it was observed that, sex ratio (M:F) was 1:0.97 (Offem *et al*., 2007). In *O. niloticus* populations from the Abu-Zabal Lakes, Egypt, it was observed that females were numerically dominant than males by overall sex-ratio (M:F) was 1:1.37 (Shalloof and Salama, 2008). El-Kasheif *et al*. (2013) found that the overall sex-ratio (M:F) of *O. niloticus* inhabited Damietta branch of the River Nile was 1:0.68.

In the present study, the maturity stages of *O. niloticus* were classified macroscopically into five stages and this agrees with that mentioned by Shalloof and Salama (2008). However, they were described in six stages by Babiker and Ibrahim (1979), Duponchelle *et al*. (1999, 2000), Komolafe and Arawomo (2007) and Mazrouh and Mahmoud (2009). Pena-Mendoza *et al*. (2005) found three maturity stages of gonads of *O. niloticus*. These differences arises, because the sexual maturity is a function of the size and may be influenced by the abundance and seasonal availability of food, the temperature, the photoperiod and other environmental factors and pollution at different localities (Nikolsky, 1963; Babiker and Ibrahim, 1979; Pena-Mendoza *et al*., 2005). However, the investigation of the various maturity stages during the period of the present study showed that, ripe and spent males and females were encountered throughout the year with considerable varied frequencies between months to ensure preservation and not extermination of the species (Khallaf *et al*., 2003). Probably this is in response to drastic conditions resulting from deterioration of water quality and various pollutants in the canal (Gad and Ibrahim, 2005; Gaber *et al*., 2012; Ibrahim *et al*., 2012). In accordance, Lein and Devries (1998) stated that increasing environmental degradation leads to extended spawning season, earlier sexual maturity at a smaller size, increased fecundity and high mortality.

The gonadosomatic index was used to follow the development of the gonads (Komolafe and Arawomo, 2007). *Oreochromis niloticus* in El-Bahr El-Faraouny Canal spawns throughout the year in prolonged spawning season with peak from May-August (expressed by GSI), because the fish is a multiple spawner, which was also indicated by Khallaf *et al*. (1986) and Shalloof (1991). Khallaf *et al*. (1986) reported that, *T. nilotica* high GSI values extended from September to April and fish with well-developed gonads and ripe eggs were noticed throughout the year. Duponchelle *et al*. (1999) found *O. niloticus* breeds all year long. Khallaf (2002) reported that the spawning of *O. niloticus* occurs in most of the year. Shalloof and Salama (2008) mentioned that, for *O. niloticus*, the period from March-September represented the spawning (breeding) period. Mazrouh and Mahmoud (2009) observed that, *O. niloticus* has prolonged spawning activities (higher values of GSI). These patterns of variations between *O. niloticus* populations reflect time and locality factors and perhaps different environmental conditions in the different habitats (El-Kasheif *et al*., 2012).

The estimation of size at first sexual maturity (Lm_{50}) has its practical application in the determination of the minimum legal size needed to protect an adequate spawning stock and to ensure at least one spawning for the mature individuals (Ghorab *et al*., 1986; El-Kasheif *et al*., 2012). Present results revealed that for *O. niloticus,* males ($Lm_{50} = 14.80$ cm) attained sexual

Table 11: Comparison of population dynamics parameters of *O. niloticus* fish from different water bodies in Egypt

Locality	L_c	t_c	L_r	t_r	L_{m50} male	t_{m50} male	L_{m50} female	t_{m50} female	Y/R	B/R	MSY/R	F_{max}	E_m	$E_{0.1}$	$E_{0.5}$	Author
El-Bahr El-Faraouny canal	14.2024	1.72	11.67	1.37	14.80	1.950	17.40	2.025	45.51	91.68	51.01	1.10	0.638	0.506	0.328	Present study
Bahr Shebeen**	10.70	1.62*	-	-	-	-	-	-	-	-	-	-	-	-	-	Latif *et al.* (1989)
	12.40	0.45*	-	-	-	-	-	-	-	-	-	-	-	-	-	El-Sehamy (1993)
Lake Nasser	19.00	0.83*	12.5	0.22*	-	-	-	-	-	-	681.00	0.30	-	-	-	Khalifa *et al.* (2000)
River Nile	14.50	1.25	-	-	15.06	1.31	16.02	1.46	-	-	-	-	-	-	-	Tharwat (1995)
Lake Manzalah	7.07	-	-	-	-	-	-	-	-	-	-	-	0.47	0.40	0.29	El-Bokhty (2006)
Rosetta branch	9.50	0.71	8.60	0.60	-	-	-	-	23.54	28.78	23.66	1.045	-	-	-	Mahmoud and Mazrouh (2008)
Damietta branch	12.72	2.48	11.88	2.18	-	-	-	-	38.6012	154.4048	46.4347	0.90	0.69	0.57	0.33	Authman *et al.* (2009)
Nozha Hydrodrome	14.66	1.87	13.524	1.650	-	-	-	-	56.3531	159.05	65.8714	1.037	-	-	-	Mahmoud *et al.* (2013)

*Calculated by the present authors, ** Standard length maturity at a slightly smaller length and age than females (Lm_{50} = 17.40 cm). This is in agreement with Tharwat (1995), who reported that, males (Lm_{50} = 15.06 cm) mature earlier than females (Lm_{50} = 16.02 cm) of *O. nioticus*, in Cairo sector of the River Nile (Table 11). The different environmental (i.e., pollution) and climatic conditions in the habitats could explain the discrepancies observed between the findings of different authors. Such variability in Lm_{50} may be affected by several physical and biological factors in time and fisheries in addition to the fishing efforts and these may account for the discrepancies observed between the aforementioned findings (Mekkawy and Hassan, 2011; El-Kasheif *et al*., 2012).

CONCLUSION

The assessment of the present state of the *O. niloticus* resource indicates that *O. niloticus* showed negative allometric growth pattern and low number of older age groups which referred to drastic condition of El-Bahr El-Faraouny Canal. Adding to that the current exploitation rate is lower than the estimated maximum exploitation level but raising the exploitation rate to this value is unreasonable. On the other hand, it is higher than the exploitation rate, which will maintains 50% of the unexploited stock biomass. Also, the estimated length at first capture is lower than the length at first sexual maturity. Besides, there is a selective mortality towards smaller fish sizes. This implies that juvenile individuals are the target of the fishery and the stock dynamics of this species in the area of study would be seriously affected. The high vulnerability of juvenile fish to capture by gears would result in the reduction of the future yield of this species. So, the use of illegal mesh sizes and other destructive fishing methods as well as raising the mesh sizes of nets used need to be urgently addressed by the authorities concerned to increase the lower limits of selection ranges corresponding to fishing gears, to increase the potential capacity of smaller fishes to grow and get higher marketable sizes and also to keep breeding and saving stock biomass of that species. Also, it was found that *O. niloticus* in El-Bahr El-Faraouny Canal breeds throughout the year but the breeding intensity was not equally distributed throughout the year. As such, the managers should consider these breeding fluctuations possibly by establishing non-fishing zones during the most sensitive stages and fishermen should take care not to capture the spawning fish mainly during the main breeding period. Finally, El-Bahr El-Faraouny Canal represents economically and environmentally an important aquatic ecosystem and must be in protection against pollution and reduction of its aquatic area. More efforts are required in terms of scientific academic and social projects and economic and political strategic plans in concern with its fisheries, the social life of fishermen, the water quality drained in and conservation of its biodiversity.

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