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Life-history Parameters of Shield-Head Catfish *Synodontis Schall* (Bloch and Schneider, 1801) in the Nile River, Egypt

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Abstract

Age and growth, mortality, and exploitation level of the shield-head catfish *Synodontis schall* inhabiting River Nile, Egypt are studied to evaluate its fishery status and proposed some reference points for its sustainability. A total number of 805 specimens comprising of 306 males and 499 females with the size range of 16.7 - 37.8 cm TL (mean = 26.71 ± 3.58) were investigated. The weight of specimens ranged from 60.0 to 650 g (mean = 194.88 ± 26.58). Statistically, there is no difference between males and females in the longevity and population parameters so all parameters were estimated for sexes combined. The maximum life span of this species was 4 years based on the pectoral fin spine sections. Asymptotic total length ($L\infty$) was 42.25 cm, growth coefficient (K) was 0.42 yr-1, and theoretical age at zero-length (t0) was -0.36 yr, while the growth performance index (Ø') was 2.87. The instantaneous total, natural, and fishing mortality coefficients were 1.23, 0.54, and 0.69 yr-1, respectively. The Exploitation rate (E) was 0.56. The body length at first sexual maturity (Lm) and mean selection length (Lc) were estimated at 24.1 and 23.6 cm, respectively. There is selective fishing mortality towards smaller fish sizes reflecting the adverse impact of fishing effort. Therefore, for management purposes, it is recommended to increase the length at first capture to maintain sufficient spawning biomass for recruitment and monitoring the exploitation level to control the fishing effort.

Keywords: Nile; *Synodontis schall;* Population parameters; Selectivity; Management.

1. Introduction

The Nile is the longest river in the world, stretching north for approximately 4,148 miles from East Africa to the Mediterranean. The length of the Nile in the Egyptian borders is about 1532 Km. North of Cairo, the Nile splits into two branches (or distributaries) that feed the Mediterranean: the Rosetta Branch to the west and the Damietta Branch to the east, forming the Nile Delta (Fig. 1).

Small scale fisheries play an important role in Egypt's economy and are the source of livelihood for many people in the coastal areas. Inland fisheries based on rivers, lakes, reservoirs which are small scale fisheries are very important fishery resources in Egypt. The Nile provides a rich and vital habitat for estuarine and freshwater fish species and their regeneration in Egypt, where about 12% of Egyptian fish production was harvested from it (2005 – 2011) decreased to only 3.8% in 2019 [1]. However, few studies were focused on the stock assessment as well as fish population dynamics of Nile fishes [2-9].

The genus *Synodontis*, commonly referred to as squeaker or upside-down catfish is widely distributed in African freshwaters ranging from the Nile basin, Chad, Niger, and much of the West African region [10]. The genus has over 112 species [11] and some of the species are commercially important comprising up to 40% of the total landings by weight in some regions of Africa [12, 13]. *Synodontis schall* (family: Mochokidae) is the most tolerant species of the genus to adverse environmental conditions and it has the widest distribution in Africa [14, 15]. In Egypt, *Synodontis schall* is one of the main species in the Nile fishery but unfortunately, there are no statistics for its catch.

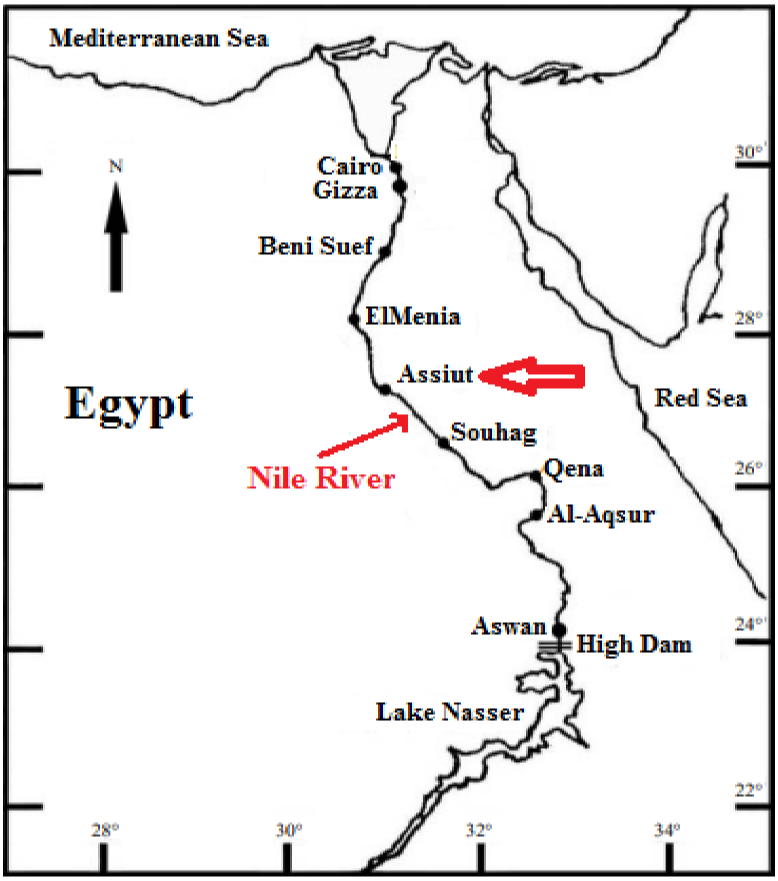
Data on age and growth, mortality and exploitation rate are fundamental to assess the status of a population of fish and to predict the potential output of fishing. The present work is undertaken to investigate growth rates, mortality coefficients and the exploitation rate of the shield-head catfish *Synodontis schall* in the Nile River using the cross sections of the pectoral spine for the first time. The present study aims to estimate age and growth, size at first capture, size at first sexual maturity, mortality rates and exploitation, which are essential tools in the management of this fish stock.

2. Material and Methods

2.1. Fish Sampling and Data Collection

The sampling was carried out in the Nile River at the Assiut fishing area. The *Synodontis schall* specimens were collected monthly from September 2019 to July 2020. The fish caught are preserved safely in ice boxes and transported to the laboratory of fish population dynamics. Sampled fishes were measured to the nearest 0.1 cm for the total lengths and weighed to the nearest 0.01 g.

Fig-1. Map of Nile River, Egypt showing the study area



2.2. Length–Weight Relationship

The length-weight relationship was determined by the allometric equation $W = a L^b$, where W is the weight (g), L is the total length (cm) and “a” and “b” are intercept and slope of the regression curve of the length and weight of the fish, respectively. The correlation (r^2), which is the degree of association between length and weight, was computed from the linear analysis. Confidence intervals of 95% were calculated for the slope (b) to see if it was statistically different from 3. The Student’s t-test determines the growth as isometric ($b = 3$) or allometric ($b >$ or <3).

2.3. Age Determination

Age determination of ***S. schall* was** done using the cross-sections of the pectoral spine. The base of the spine was embedded in clear epoxy resin and sectioned using a Buehler Isomet low-speed saw containing a diamond wagering blade that cuts a thin section of 300 µm. A grinding wheel fitted with silicon carbide paper with different grit sizes (400 to 1200 grit) flushed with water was used to remove excess resin on the face of the sections and to provide a polished face for viewing. The section is then mounted on a glass slide and read under a Zeiss compound microscope equipped with zoom lens and (magnification up to 60×) using transmitted light. The total radius of the section and the radius of each annulus was measured to the nearest mm. Regression analyses of total radius - total length was calculated by the method of least squares. Back-calculated lengths at the age were computed by using the Lee method [16].

2.4. Growth Parameters and Optimum Length

von Bertalanffy [17], equation for growth in length $L_t = L_\infty (1 - e^{-k(t-t_0)})$ was applied to determine the growth parameters where 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 and t_0 = age at which the length theoretically equals zero. Gulland and Holt [18], formula was used to estimate $L\infty$ and K by plotting ($L_{t+1} - L_t$) against (($L_{t+1} + L_t$)/2) which gives a straight line with a slope (b) equals to (-k) and an intercept (a) equals to ($k * L\infty$). While the theoretical age at length zero (t_0) was estimated using Pauly [19] empirical equation as:

$Log_{10}(-t_0) = -0.392 - 0.275 Log_{10}(L\infty) - 1.038 Log_{10}(K)$

The optimum length L_{opt} in cm was estimated using Beverton [20] equation as $L_{opt} = L\infty [3/(3+M/K)]$

2.5. Growth Performance Index

To compare the growth rates in this study with those of other authors, the standard growth index (φ') was used as a measure of overall growth performance [21]. The index is defined as $\phi' = Log_{10}(K) + 2 Log_{10}(L\infty)$.

2.6. Mortality Coefficients and Exploitation Rates

The catch curve method as described in Ricker [22] was used to estimate the total mortality coefficient (Z), this method expressed as: ln (Nt) = a + bt where Nt is the number of fish at age t, then Z= -b. Also, the linearized length-converted catch curve of Pauly [23] was applied to estimate Z as follows: $Ln(N_i / \Delta t_i) = a + b t_i$ where N_i is the number of individuals in length class i, Δt is the time needed for the fish to grow through length class i, t is the relative age corresponding to the mid-length of class i. Then Z = - b.

The natural mortality (M) was estimated using the empirical equation of [24] as following: $Log_{10}(M) = -0.0066 - 0.279 Log_{10}(L\infty) + 0.6543 Log_{10}(K) + 0.463 Log_{10}(T)$, where (T) is the annual mean of habitat temperature. The equation of Ursin [25], which predicts M from the average weight of the sample as $M = W^{-1/3}$ was also used. The validity of estimates of M can be judged by the M/K ratio as this ratio has been demonstrated to be within the range of 1.12–2.50 for most species around the world [26].

Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained using this formula E = F⁄ Z and exploitation ratio from $U = F/Z*(1-e^{-z})$. The exploitation rate indicates whether the stock is lightly (E < 0.5) or heavily (E > 0.5) exploited, based on the assumption that fish stock is optimally exploited when F = M or E = 0.5 [27].

Maximum fishing effort (F_{max}) was determined from the formula of Hoggarth, *et al.* [28] as: 0.6 K / (0.67 – Lc) where $Lc = L_{c50}/L\infty$.

The precautionary limit reference point (F_{limit}) was determined at 2/3* M [29], while the precautionary target reference point (F_{opt}) was considered as 0.4*M [23].

2.7. Length at First Capture and Length at First Sexual Maturity

The estimates of length-at-first-capture (Lc_{50}) were derived from probabilities of capture generated from the catch curve analysis. The selectivity curve was generated using linear regression fitted to the ascending data points from the plot of probability of capture against length, which was used to estimate the value of L_{c50} (lengths at which 50% of the fish will be vulnerable to the gear). While, the length at first sexual maturity was estimated from Froese and Binohlan [30] formula as $Log L_m = 0.8979 * Log L\infty - 0.0782$

3. Results

3.1. Length–Frequency Distribution and Age Structure

A total of 805 individual *S. schall* were measured to construct the length–frequency distributions. Lengths of *S. schall* ranged from 16.7 to 37.8 cm and the annual mean length for all samples combined was 26.71 ± 3.58. Fishes in the length range of 21-29 cm dominated the catch and contributed 67% of the catch. Results from K–S tests indicated that length frequency distribution data were non-normal and showed that there was not a statistical difference in mean L between sexes indicating that it was valid to combine the sexes in further analyses. Age structure of the *S. schall* specimens collected from the Nile, as determined from sections of the pectoral spine, was consisted of four age groups ranging from 1+ to 4+ years (Fig. 2). The dominant age group was 1+ and 2+ year old fish. These data suggest that *S. schall* is a short-lived fish species and the highest increase in the mean annual growth rate in length was observed in the first year of life and decreased with the increase of age (Fig. 3).

Fig-2. The sections of pectoral spine showing the annual rings

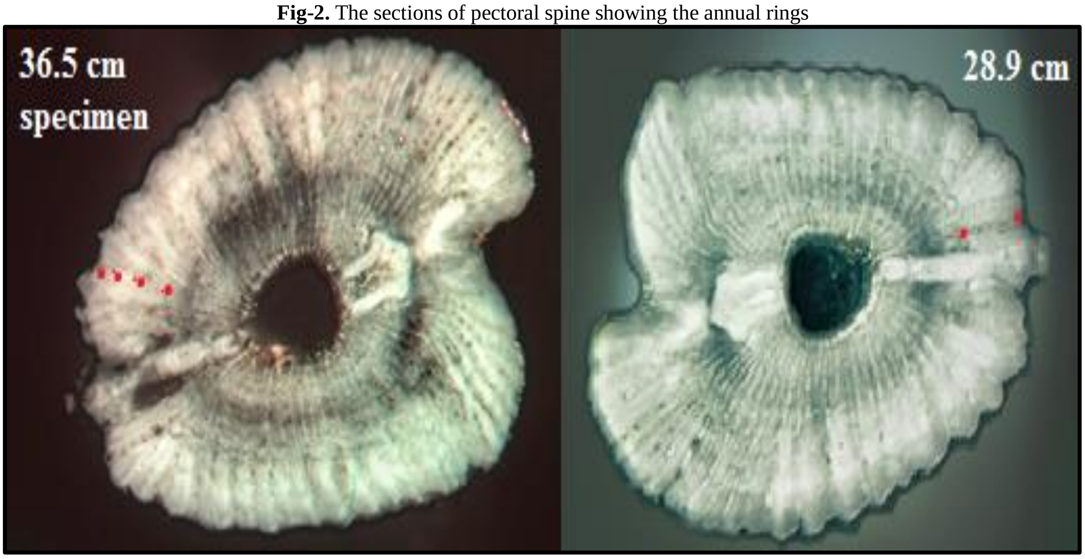
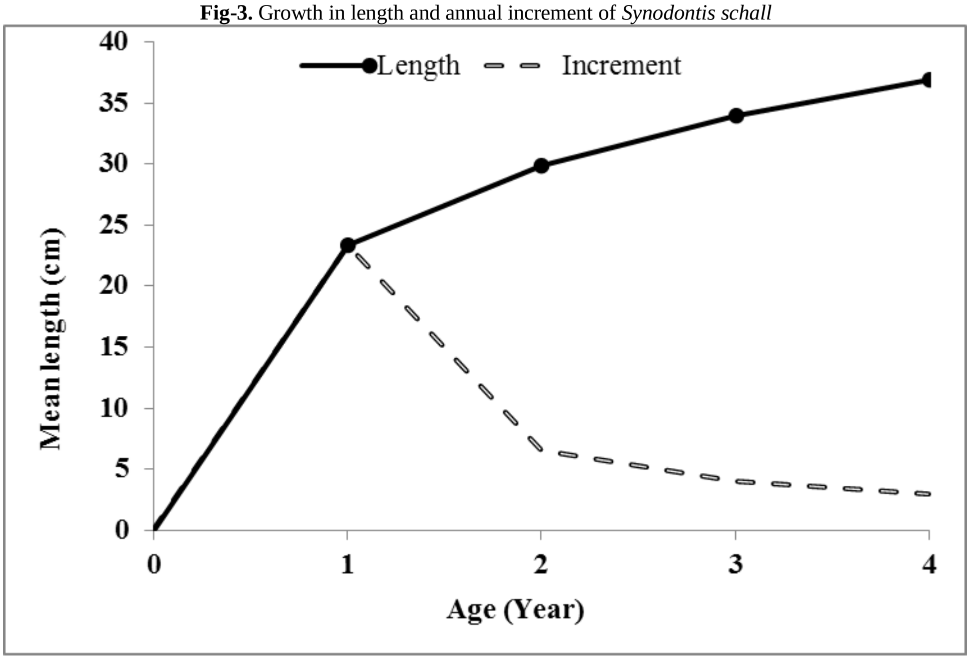


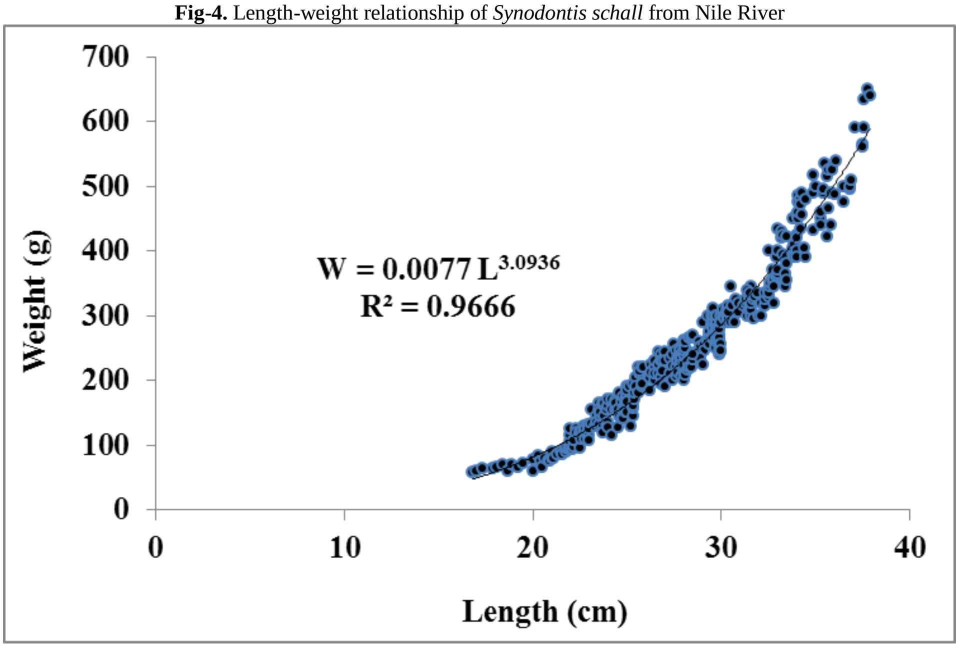
Fig-3. Growth in length and annual increment of *Synodontis schall*



3.2. Length-weight Relationship Parameters

The total length and total weight of the sexes combined ranged between 16.7 to 37.8 cm at average 26.71 ± 3.58 cm and 60 to 650 g with an average 194.88 ± 26.58 g (n= 805). The length-weight relationship for *S. schall* was described by the power equation $W = 0.0077\ L^{3.0936}$ (R^2= 0.967) (Fig. 4).

Fig-4. Length-weight relationship of *Synodontis schall* from Nile River



3.3. Growth Parameters and Growth Performance Index

The estimated values of L∞ and K were obtained for pooled sexes as L∞ = 42.25 cm and K= 0.42/year, while t0 = -0.36 year. Growth performances index Φ' derived as result of the input values of von Bertalanffy growth parameters was 2.87. The optimum length was computed as 29.57 cm TL.

3.4. Mortality and Exploitation Rates

The instantaneous total, natural and fishing mortality coefficients were 1.23, 0.54 and 0.69 yr-1, respectively. The Exploitation rate (E) was 0.56, which indicated that the stock in the present study area has been slightly overfished. Fmax, Flimit and Fopt were estimated as 2.29, 0.36 and 0.22 per year.

3.5. Length at First capture and Length at Maturity

The length at-first-capture (Lc) value estimated by backward extrapolation of the straight part of the right descending area of the catch curve was 23.6 cm while the length at first sexual maturity Lm was estimated at 24.1 cm TL.

4. Discussion

Population parameters such as asymptotic length L∞ and growth coefficient k, mortality (natural and fishing) rate and exploitation level E were studied with the major objective of rational management and resource conservation of S. schall from the Nile, Assiut, Egypt. Data on age and growth are especially important to describe the status of a population of fish and to predict the potential output of fishing [31]. Age determination and growth are important aspects of fisheries management [22]. The lifespan of the S. schall in the Nile River off Assiut was determined using the pectoral spine and found to be four years for total length range 16.7-37.8 cm. This result is lower than that reported for the same species in the previous studies. This species reached 5 years in River Nile from Gizza to Assiut [8] and in River Nile at Assiut [3], 6 years in Nile River, Gizza, Egypt [2] and 7 years in the River Nile at El-Kanater El-Khayria [32]. These differences are due to the differences in the samples size as a result of the excessive fishing effort which eliminates the big sized fish.

The Length-weight relationship of fish LWR is an important fishery management tool. It is vital in estimating the average weight at a given length group [33, 34]. LWRs of fishes are important in fisheries biology and population dynamics where many stock assessment models require the use of LWR parameters. In the present study, the value of LWR parameters was a= 0.0077 and b= 3.0936 indicating positive allometric growth (CI of 95% was 3.0347-3.1524). This is in agreement with the findings of Abass [35], Kheir [32], Hassan [3] and El- Kashif, *et al.* [2] for the same species in Lake Nasser, River Nile at El-Kanater El-Khayria, River Nile at Assiut, and River Nile at Gizza, respectively.

Compared with the studies done previously, the asymptotic length (L∞) and growth parameter (k) were found to be different in most studies. The results of this study (L∞ = 42.25 cm TL and K= 0.42 y-1) were different from Tharwat [8] and El- Kashif, *et al.* [2] who gave L∞ of 50.69 cm and 73.63 cm respectively for combined sexes of S. schall in Egypt at Gizza. The K estimates in their studies were 0.223 and 0.127 y-1 respectively. Pauly and Munro [21] computed the L∞ of S. schall as 50.4 cm. Abowei and Hart [33] reported the L∞ of S. schall to be 38.7 cm, from the Lower Nun River, Niger Delta. According to Sparre, *et al.* [36], growth of fishes differed from species to species and from stock to stock even within the same species as a result of different environmental conditions. The optimum body size (Lopt) to asymptotic length (L∞) ratio (Lopt/L∞) was estimated at 0.7 which is agreed with the findings of Cubillos [37] who mentioned that the ratio (Lopt/L∞) is constant with minimum and maximum values of 0.323 and 0.938, respectively, for all fish species.

The length at first maturity Lm along with the length at first capture Lc are important tools that enable fishery managers to determine what should be the minimum size of the target species of a fishery. The estimated Lm of S. schall, from the Assiut fishing area was 24.1 for pooled data. This value was lower than that reported in the previous studies. Abass [35], estimated the Lm of S. schall, in Lake Nasser as 31.4 cm for males and 33.1 cm for females. Tharwat [8], gave Lm = 26 cm for males and 28 cm for females of S. schall in River Nile from Gizza to Assiut. Mekkawy and Hassan [6], reported that the Lm of S. schall in River Nile at Assiut was 29.4 cm for males and 28.2 cm for females. El- Kashif, *et al.* [2], calculated the Lm of S. schall in River Nile from Gizza as 28.9 cm for males and 31.2 cm for females. The differences observed among the different studies could be attributed to the environmental and climatic conditions in the studied areas. Also, Lm values may be affected by several physical and biological factors such as the stress resulting from the fishing effort, length range, food availability. It was noticed that the estimated Lc in the present study was 23.6 cm TL which was lower than the Lm (24.1 cm) in an indication to that the mortality was selective towards smaller fish sizes.

In this study, the annual mortality rate values were calculated to be M = 0.54, F = 0.69 and Z = 1.23 yr-1. The M/K ratio obtained in the present study (1.29) was well within the normal range of 1 – 2.5, as suggested by Beverton and Holt [38]. Compared to the values reported by previous studies, the present F and M rates were higher, and this difference could be due to the fishing pressure by years, the type of fishing gear used and the biotic and abiotic factors. Using the mortality parameters, it was found that the exploitation rate was (E) = 0.56, meaning this species is subjected to overfishing. Comparing the current fishing mortality (0.69) with precautionary limit reference point (Flimit = 0.36) and the precautionary target reference point (Fopt = 0.22), is another evidence to the overfishing situation of this stock.

5. Conclusion

The population dynamics of S. schall in the Nile River at Assiut indicated that the stock is subjected to overfishing. The current exploitation rate is higher than the optimum one using the Gulland [27] criterion. Also, the length at first sexual maturity is higher than the length at first capture in another evidence for overfishing and the illegal mesh sizes used. Therefore, it could be recommended the development of a monitoring program to follow up the changes in exploitation rates, indices of overexploitation and changes in life-history traits as well as increasing the length at first capture to maintain a sufficient spawning biomass for recruitment

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Conflict of Interest

The authors declare that they have no conflict of interest.

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