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Length-weight relationship, condition factor and length frequency distribution of the common sole *Solea solea* in Lake Manzalah, Egypt, with the first record for *Atherinomorous forskalii*

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ABSTRACT

Length frequency distribution, weight-length relationship, Fulton's, and relative condition factors of the common sole (*Solea sloea*) in Lake Manzalah were investigated. The fish was caught by trammel nets from the northern region of Lake Manzalah near Bughaze El-Gamil where the marine species were found. The results of the length-weight relationship for 361 common soles showed a positive allometric growth ($W= 0.0029\ L^{3.3777}$) indicating the suitability of the area for the species growth. The mean value of the relative condition factor (K_n) of the common sole was 1.013, while the average value of Fulton's condition factor was 0.911. These values suggested a good condition in the northern Manzalah lake for *Solea solea*. Such results may be helpful for *S. Solea* management. It's worth mentioning that during the study period, only two Red Sea hardyhead silverside fish (*Atherinomorous forskalii*) of 9.4 cm were recorded. Therefore, more extensive studies are needed to assess the actual status of marine fish and to manage the fishery of common soles at Lake Manzalah. Also, a monitoring program should be established to detect any ecological and biological changes after deepening and cleansing processes.

INTRODUCTION

Lake Manzalah (**Fig. 1**) is located on the north-eastern edge of the Nile Delta, between the two port cities of Damietta and Port Said. Recently, Lake Manzalah undergoes a national project for the purification and development, which is supervised by the Engineering Authority of the Armed Forces, started in 2017 and continued to 2022. It includes pollutant removal, weeds and aquatic plants removal as well as making a radial canals. Deepening and cleansing proceses at the northern and middle regions by constructing three main radial canals ; 2 confronting El-Gamil (old and new) bougazes and one at El-Boghdady canal. Each canal of length 3 Km and width of 100-m beside a complete deepening of El-Gamil and El-Temsah regions with depth of 2m (Personal communication). Due to the farness of El-Boghdady canal from the sea by about 2.8 km, it was dredged to connect the outlet with the sea and other 10 km radial channel from outlet to inside the lake to increase water exchange between lake and sea (**Mirdan, 2019**).

Tilapia Fishery represents the bulk of catch forming 49.85% of the total lake's catch during 2020, followed by mugilid species (27.89%). The rest of catch was composed of a mix of marine and fresh water species like (Clariidae) especially *Clarias lazara* and *C. gariepinus*,

grass carp (Cyprinidae) especially *Cyprinus carpio* , silversides (Atherinidae), eel (Angullidae), bayad (Bagridae), soles (Soleidae), seabream (Sparidae), seabass (Moronidae), meager (Sciaenidae) and spotted seabass (Moronidae). Invertebrates were represented by shrimp (Penaeidae) especially *Metapenaeus stebbingi* and crab (Portunidae: *Portunus pelagicus* and *Callinectes sapidus*) (**Shaheen and Youssef, 1979; Mehanna *et al.*, 2014**; **GAFRD, 2020; Mehanna *et al.*, 2022**).

Soles (family Soleidae) occur in tropical and temperate regions of the world where about 281 are recognised **(Eschmeyer and Fong, 2017).** 56 species are commercially important worldwide and 10 in the Mediterranean **(Ulutürk, 2012).** Sole is an excellent consumption fish and has a great commercial importance. t lives buried in sandy or muddy bottoms, requiring heavy gear to be chased out so it caught mainly by trawls. Juveniles spend their first year of life in shallow coastal waters, and in estuaries. When they grow older they gradually disperse into deeper water.

Family soleidae received a great attention in Egypt for its importance and many studies were done on its biology and dynamics (eg. **Zaki and Hamza, 1986; Mehanna, 2007; Ahmed *et al.*, 2010; Mehanna and Salem, 2012; Mehanna *et al.*, 2013; Salman, 2014; Eid, 2015; Mehanna *et al.*, 2015 ; Khalifa *et al.*, 2018 and El-Aiatt *et al.*, 2019**).

This study is considered the first targetting the common sole *Solea solea*, caught by trammel nets in lake Manzalah during the cleansing process of the Lake. The length frequency distribution, the relationship of length and weight, condition factor and relative condition are studied.

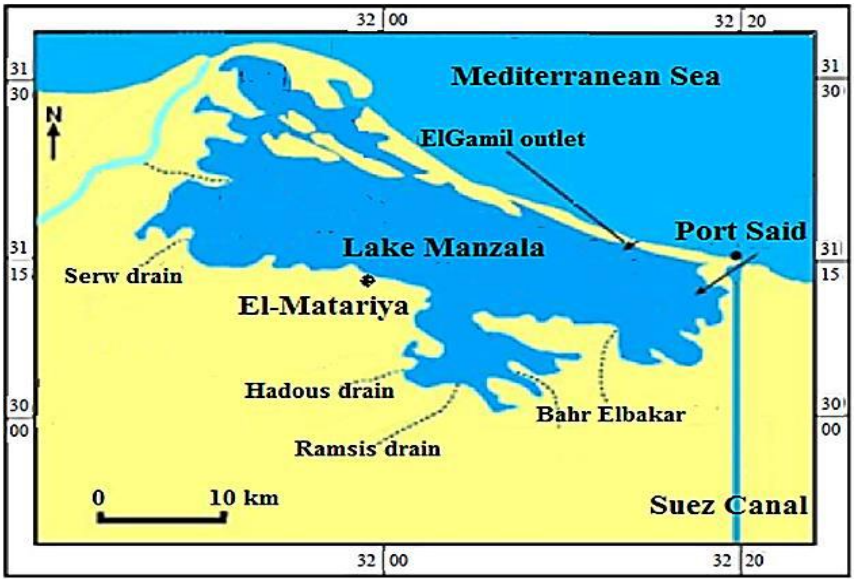

Fig. (1). Lake Manzala map (after Mehanna, 2020)

MATERIALS AND METHODS

Sole fish (Fig. 2) were collected from fishermen that use trammel nets during 2020 and 2021. Fish were measured in total length to the nearest millimeter on a measuring board and weighed to the nearest gram on a digital mono-pan balance at the laboratory.

The relationship between total length and body weight LWR of the sole specimens was expressed by the following equation: $W = a L^b$ (**Beckman, 1948 and Le Cren, 1951**), where W = total weight, L = length, and (a and b) = constants whose values were estimated by the least square method.

Fig. (2). *Solea solea* from lake Manzalah

The condition factor (K) was calculated according to **Fulton's (1902)** formula as:

$$\mathbf{K_c = 100W/L^3}$$

W denotes to the fish body weight (g) and *L* to the total fish length (cm). While, the relative condition factor (K_n) was calculated according to **Le Cren (1951)** by the following relation:

$$\mathbf{K_n = W_o/W_c}$$

The observed weight is denoted by $\mathbf{W_o}$ and $\mathbf{W_c}$ is the calculated weight from the length-weight relationship. Growth condition of fish is revealed good when $K_n \geq 1$. While, poor growth condition is revealed for the same fish length when $K_n < 1$.

All data was analyzed using SPSS statistics 20 software. To investigate the LWRs data, ANOVA was used to evaluate the statistical significance of the regression model detected when $P < 0.05$ (**Gökçe *et al.*, 2010**). To confirm if b value of the regression is statistically significantly different from 3, student t-test comparison was performed. If the b-value is statistically significant difference from 3, this indicates an allometric growth either positive or negative ($P < 0.05$), while an isometric growth is detected if b-value is not statistically different from 3 ($P > 0.05$) (**Yilmaz *et al.*, 2012**).

Beside the sample collection from local fishermen, an experimental fishing was undertaken during june 2020 at El-Gamil region near El-Boughaze. A new record of *Atherinomorus forskalii* (two specimens) was observed in the catch of fishermen to the first time in the lake where it never mentioned in any study before (Fig. 3).

Fig. (8). *Atherinomorus forskalii* (Family: Atherinidae) recorded for the first time at Lake Manzalah

RESULTS AND DISCUSSION

Lake Manzalah undergoes a pronounced change during and after cleansing and deepening processes and developing the different outlets connecting the lake with the Mediterranean Sea. So, increasing the saline water intrusion into the lake has led to appearing new species as *Atherinomorous forskalii* fish. During the sampling period, two specimens of *A. forskalii* were recorded in the catch for the first time in the lake with total length of 9.4 cm. So, a monitoring program should be established to detect any ecological and biological changes in the lake during and after the cleansing and development project.

Length frequency data have a practical application in the field of fisheries science. The analysis of length-frequency data can be used for the estimation of age, growth, survival and mortality rates (**Mehanna, 1997**). The structure of the common sole total length (TL) caught from Manzalah lake, Egypt consisted of a total number of 361 *Solea solea* ranged in total length between 11.0 and 26.0 cm (Fig. 4) with a corresponding weights of 6 and 188 g respectively. The fish sizes was peaked at 16.5 cm and lengths of 15 to 17.9 were constitute the bulk of sample (60%).

Appearance of small sized individuals with only 11-13 cm total length may be used as relevant indicators of nursery habitat quality (**Guindon and Miller, 1995; Able *et al.*, 1999; Duffy-Anderson and Able, 1999 and Phelan *et al.*, 2000)**.

On the other hand, cleansing, dredging and deeping process at the northern region of the lake could make it as a temporary nursery grounds for this species.

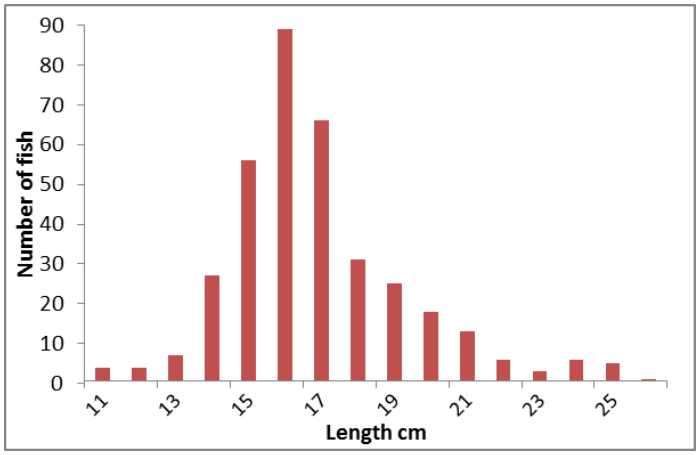

Fig. (4). Length frequency distribution of *Solea solea* caught from Lake Manzalah during 2020-2021

The LWRs are important and have many applications in fish stock assessments, biomass estimations, ecological studies and modeling aquatic ecosystems. The LWRs are also provides valuable information on the habitat where the fish lives, condition, reproduction history, life cycle and the general health of fish species (**Froese, 2006; Froese *et al.*, 2011; Mehanna and Farouk, 2021**). The LWR of the common sole (the whole sample) could be expressed as: $W = 0.0029\ L^{3.3777}$ with a high correlation coefficient $R^2 = 0.92$ (Fig. 5). The resultant value of b is significally difference of 3 indicating positive allometric growth (b>3) for the common sole in lake Manzalah. The positive allometric growth deduced for the common sole ($b > 3$, t-test, $P > 0.05$) suggested that this species have a relatively fast growth rate and tend to be heavier. While our results are in agreement with some of the previous findings, it was not agree with some others (Table 1).

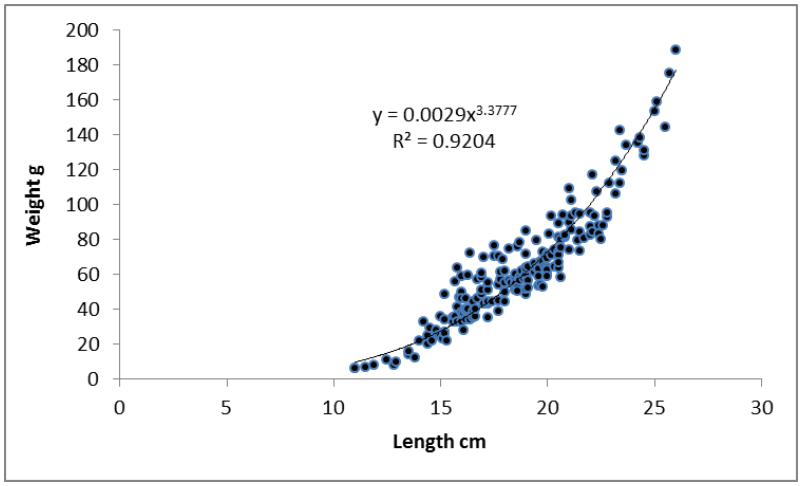

Fig (5). Length-weight relationship of *Solea solea* caught from Lake Manzalah during 2020-2021

Table 1. b-value of LWRs of *Solea solea* from different localities in Egypt

Author	Locality	b-value
Ezzat *et al.* (1982)	Abu-Qir Bay, Alexandria	2.861
Mosaad (1990)	Lake Qarun	2.949
Mosaad and El-Sayed (1991)	Red Sea	2.949
Mehanna and Salem (2012)	Bardawil lagoon,	3.106
Salman (2014)	Bardawil lagoon	3.0871
Eid (2015)	Alexandria	2.8615
Mehanna *et al.* (2015)	Alexandria	2.8615
Desouky (2016)	Qarun lake	2.932
El-Aiat *et al.* (2019)	Bardawil lagoon	3.2215
Meahanna and Farouk (2021)	Egyptian Mediterranean	3.092
Present study	Manzalah lake	3.3777

The variations in b-values among different localities and different times are acceptable, **Beverton (1963)** mentioned that the b-value depends on the shape and fitness of the fish as well as on various factors like the sex, sampling time and environmental conditions. Also, **Ghosh *et al.* (2010)** mentioned that these variations are probably due to factors related to ecosystem and biological condition like spawning time, sexual maturity, feeding behavior and competition for food. **Froese (2006)** and **Froese *et al.* (2011)** concluded that the variation in the exponent (b) of the LWRs of fish species could be also affected by geographic locations, sampling area, seasons, size range and ecological factors such as temperature.

The condition factor K (relative K_n and Fulton K_c condition factors), has been identified as a good indicator of nutritional condition and lipid reserves (**Lambert and Dutil, 1997**). Fulton's condition coefficient (K_c) shows the relation between length and weight of a fish reflecting the degree of robustness or wellbeing of fish and its value may be changed according to age, length, weight, sex, state of maturity…. etc.

Fulton condition factor K_c values of the common sole in lake Manzalah fluctuated between 0.66 and 1.18 with an average of 0.92 (Fig. 6). These values suggest a state of wellbeing for the species under study. Many factors affect the growth condition of fish including reproductive cycles, availability of food, as well as habitat and environmental factors (**Morato *et al.*, 2001**). The deviation of K_n from 1 reveals information concerning the differences in food availability and consequence of physicochemical features on the life cycle of fish species (**Le Cren, 1951**). While, the relative condition factor (K_n) ranged between 0.87 and 1.44 with an average 1.25 (Fig. 7).

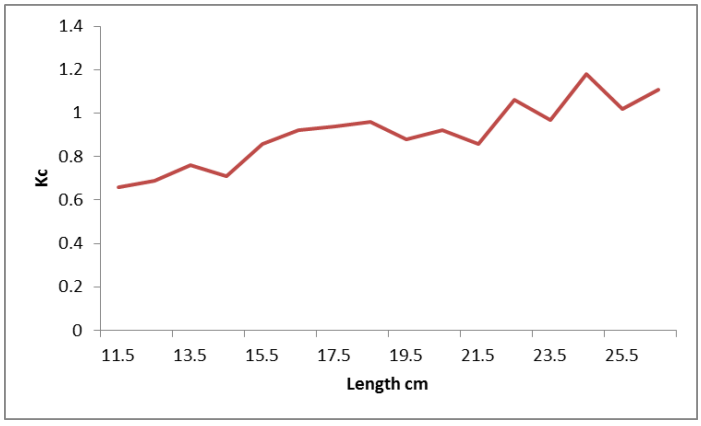

Fig. (6). Fulton's Condition factors (K_c) of *Solea solea* from lake Manzalah

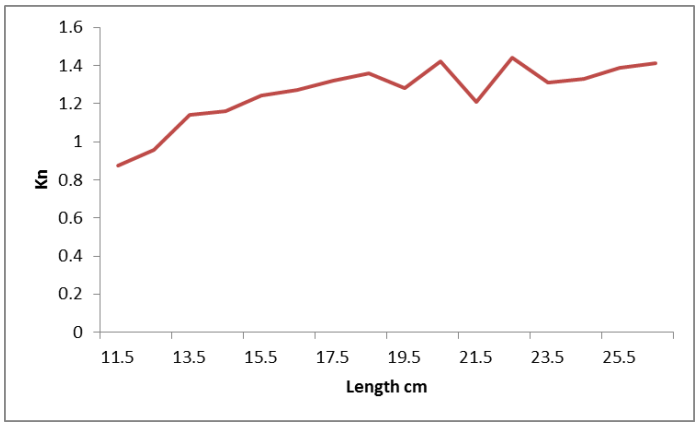

Fig. (7). Relative Condition factors (K_n) of *Solea solea* from lake Manzalah

Establishing the marine protected area (MPA) at the northern area of lake Manzalah at the Lake-Sea connecting canals or Boughazes (El-Gamil old and new one) has pushed the fishermen to fish at nights only. Hence, the catch of soles and other marine species should a decreasing trend. However, the obtained results could be taken as a preliminary to further detailed studies not depending only on the commercial fishing but also using an experimental fishing gears targeting not only soles but also all other marine fishes. Such studies will give a sound information about the native and invasive species like *Atherinomorous forskalii* after the cleansing processes and the ecological impacts on the lake fisheries.

It's worthy to mention that deepening and instructing the radial canals that connecting the boughazes area and middle of the lake has lead to increase the water salinity due to the entrance of sea water to the lake. This leads to the re-appearance of marine species in the lake and at the same time more parasitic isopods infestation was observed on most fish species in the lake like *Liza ramada, Coptodon zillii* (Fig. 8), *Dicentrarchus punctatus* and soles species. So, it is urgent to establish a monitoring system for water quality and fish health in the lake.

Fig. (8). *Coptodon zillii* fish infected with an isopod parasite in lake Manzalah

CONCLUSION

Deepening and cleansing processes at the northern and middle regions of the lake Manzalah resulted in appearing of new invaded species like, *Atherinomorous forskalii* which have been recorded in the present study. Length-weight relationship and condition factors (K_c & K_n) are among the biological parameters that constitute the main data for fisheries management. Therefore, the results obtained for sole fish could help to understand some of biological data concerning this species. More studies should be conducted on the northern area to to stand on the actual status of marine fish and to manage the fishery of common sole at lake Manzalah after deepening and cleansing processes.

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