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Impact of Water Deterioration on Growth Indices and Meat Quality of *Tilapia zillii* and *Solea aegyptiaca* Fish Inhabiting Lake Qaroun, Egypt

Khalid H. Zaghloul[1], Sara R. Ramadan[1], Safaa S. Aljilaney[2], Mohamed A. Helaly[1]

[1]Zoology Department, Faculty of Science, Fayoum University, Fayoum, Egypt
[2]Institute of Fisheries and Oceanography, El-Fayoum Station, Fayoum, Egypt
Email: khz00@fayoum.edu.eg

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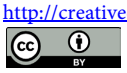

Abstract

The present work studies water deterioration, fish survival and production as a result of effluents discharged directly without prior treatments into lake Qaroun at Fayoum governorate, Egypt. Lake Qaroun represents heavily polluted wild habitat for both studied fish species, *Tilapia zillii* and *Solea aegyptiaca*, the most abundant species. Results revealed deterioration in water quality (low dissolved oxygen but high ammonia, nitrite, copper, lead and cadmium) of Northeastern sector where El-Bats drain discharge its effluents without prior treatment followed by that of eastern sector at four km from the point of El-Bats discharge. Water salinity and dissolved oxygen values were in the following order: Western lake Qaroun sector > Eastern lake Qaroun sector > Northeastern lake Qaroun sector. However, Ammonia and nitrite readings were in the following order: Northeastern sector of Lake Qaroun is followed by the Eastern sector, then the Western sector. Moreover, results of the present field study revealed a decrease in fish production with the lowest condition factor and a deterioration in meat quality (an increase in muscle water content and ash but a decrease total protein and total lipids) in case of fish collected from the polluted sites along the lake (Northeastern and eastern sectors). However, fish collected from the unpolluted western sector of the lake showed condition factor and chemical muscle composition more or less similar to normal healthy fish.

Keywords

Lake Qaroun, *T. zillii*, *S. aegyptiaca*, Condition Factor, Meat Quality

1. Introduction

Lake Qaroun is one of the most significant environments for fisheries in Egypt's Fayoum governorate. Environmentally significant lake Qaroun supports a significant fishery and is a wetland of global significance for water birds. The lake's biological stability has deteriorated over the 20th century, and numerous publications document the lake's shifting ecosystem [1] [2] [3]. It serves as a reservoir for the province of ElFayoum's agricultural and sewage drainage water. It regularly gets agricultural drainage water, which regulates its area and volume through a network of twelve drains [4] [5].

Human well-being is influenced by issues with the quality of the water [6]. The lake's salt- and heavy-metal-laden drainage water has increased as a result of the governorate of El-Fayoum's increased land reclamation. Heavy metals appeared to be present in high concentrations in water samples from Lake Qaroun. The total concentration of heavy metals in Lake Qaroun's water was 1.42 ppm. [7].

The production of fish focuses not only on increasing quantity but also on improving product quality. All major components (water content, total proteins, total lipids, and carbohydrates) of muscle tissues would change as a result of a change in body weight [8]. In addition, Elghobashy *et al.* [13] found that the Nile tilapia (*Oreochromis niloticus*) fish's muscle total protein and total lipids decreased when their aquatic habitats became less healthy. Regarding, fish respond to heavy metal toxicity, Haggag *et al.* and Zaghloul *et al.* [9] [10] found that toxicants had an effect on chemical muscles composition.

Fish meat quality may be negatively impacted by the bioaccumulation of heavy metals, which can have a significant impact on the growth rate, physiological health, and biochemical state of fish [9] [11]. Metal concentrations can change significantly across different creatures and between different regions of the same organism, as well as from metal to metal and across different organisms, when it comes to the bioaccumulation of metals in tissue [12] [13].

Therefore, degradation of drainage water that is directly discharged into Qaroun lake without prior treatment is regarded as a serious threat to aquatic life and, consequently, to humans. So, the aim of the present study is to recognize the water quality along different sectors of lake Qaroun as well as follow up the biological status of *Solea aegyptiaca* and *Tilapia zillii*, the most common fish, through estimating fish condition factor and meat quality.

2. Materials and Methods

The present field study carried out on water and fish samples collected directly from one of the main Egyptian lakes, Lake Qaroun in El-Fayoum governorate.

Description of the studied sectors along lake Qaroun:

Water and fish samples were collected from three sectors along Lake Qaroun where drainage canals discharged directly without prior treatments as follow:

Sector (1): Northeastern sector of the lake, it lies near the mouth outlet of El

Bats drainage channel.

Sector (2): Eastern sector, it lies four Km of the mouth outlet of El Wadi drainage channel

Sector (3): Western sector, It is an unpolluted area of the lake, where no effluents discharged.

Sampling:

Water and the most abundant fish species (*Tilapia zillii* and *Solea aegyptiaca*) were collected during summer season of 2020 from the aforementioned described sectors of collection along lake Qaroun for the following investigation:

1) Water sampling and analysis:

Water sampling was done based on the standard methods for the examination of water and wastewater according to APHA [14]. Water samples were obtained from each sector (n = 8) in polyethylene containers of two liters. For metal analysis, concentrated nitric acid was added to reduce pH of the collected samples to prevent any microbial reactions.

Physicochemical analysis of water

The water samples collected from different sectors along lake Qaroun subjected to a number of physicochemical analyses as mentioned later:

The parameters of pH, total dissolved salts (TDS) and dissolved oxygen were measured in the field using Corning Checkmate II multi-parameter meter.

- Salinity was measured by using a salinity-conductivity meter (model, YSI 58).
- Total hardness and total alkalinity were measured by titration method according to the American Public Health Association standard methods [14].
- Ammonia (NH_3) was determined colorimetrically using Nessler's solution as described by Sauter and Stoup [15].
- Nitrite concentrations in water samples were measured by ion chromatography (IC) (model DX-600, USA) according to APHA [14].
- Heavy metal (Copper, Lead, and Cadmium) concentrations in water were determined by atomic absorption spectrophotometer (Model, Perkin Elmer-2280) according to APHA [14].

2) Lake Biodiversity and production: Annual trend of catch by fish group from Qaroun lake during the period of 2015 till 2018 was detected from fish statistics year book, 2019 according to Egyptian General Authority for Fish Resources Development.

3) Fish sampling and analysis:

A total number of one hundred and forty four adult fish of both species (24 fish specimens/species/sector) with a body weight range 62 - 110 and 53 - 68 g and a total length range 14 - 19.5 and 17.8 - 19.7 cm for *Tilapia zillii* and *Solea aegyptiaca* respectively were collected from the studied sectors. The fish sampling was about 1 km^2 around the recorded GPS of each site during the summer season (period of maximum evaporation rate) with the help of professional fishermen. Fish were transported to the laboratory of National Institute of Fisheries and Oceanography, El-Fayoum station, in a large plastic container with good aeration conditions using portable oxygen pumps.

Growth parameters:

The condition factor: Body weight was recorded to the nearest gram and total body length to the nearest 0.1 cm, were measured for the different fish species, *Tilapia zillii* and *Solea aegyptiaca* collected form the three studied sectors along lake Qaroun. The condition factor (K) was calculated for individual fish from the formula recommended by Schreck and Moyle [16].

$$K = \frac{W}{L^3} \times 100$$

where:

W: is the wet weight in gm. *L*: is the total length in cm.

Muscle analysis (Meat quality):

Muscle samples were transferred directly after decapitation to weighing bottles and accurately weighed. The bottles were then placed in a drying oven, which was thermostatically regulated at 105˚C, for72 hours. The loss in weight was taken as equivalent to the weight of water of the sample.

- Muscle water content was determined according to Sidwell, *et al.* [17] method.
- Muscle Total protein was determined using the semimicrokjeldahl method as reported by Josyln [18].
- Muscle Total lipids was determined by the standard method reported in A.O.A.C. [19]. The process of extraction was carried out in Soxhlet apparatus using petroleum ether.
- Muscle ash was determined by burning the samples in the muffle furnace for 16 hours 550˚C [17].

Statistical analysis:

The results were statistically analyzed using t-test (between the two studied fish species in each site of collection), analyses of the variance (F-test) and Duncan's multiple range test to determine difference in means among the three studied sectors of collection along lake Qaroun, for each fish species) using Statistical Analyses System, version 6.2 [20].

3. Results and Discussion

The present field investigation is mainly concerned with the study of water deterioration, fish survival and production as a result of main drains effluents discharged directly without prior treatments into lake Qaroun at Fayoum governorate, Egypt. Lake Qaroun represents heavily polluted wild habitat for both studied fish species, *Tilapia zillii* and *Solea aegyptiaca*, the most abundant species.The overall results obtained from the present study could be very useful in identifying the effects of pollution and water quality of three sectors along lake Qaroun (Northeastern sector where El-Bats drain discharge its effluents without prior treatment, eastern sector at four km from the point of El-Bats discharge and unpolluted western sector where no effluents discharged) on fish growth indices, meat quality and the ability of inhabiting fish to resist stressors along the

three studied sectors of lake Qaroun.

The current fieldwork involved investigating water quality with water samples taken directly from three different areas along the shores of Lake Qaroun. The first part is the northeast part of the lake, where the sewage from El-Bats is directly discharged without prior treatment, the east part of the lake is four kilometers away from the direct exit of El-Bats, and the west part is the lake area without pollution sources and sewage discharge.

Water quality indices of the studied aquatic habitats showed highly significant differences in the values of pH, dissolved oxygen, total hardness, total alkalinity, salinity, ammonia and nitrite among the studied sectors of lake Qaroun (**Figure 1**). Values of dissolved oxygen and water salinity were in the following order: Western sector of lake Qaroun > Qaroun eastern sector > Northeastern sector of lake Qaroun. While values of ammonia and nitrite were in the following order: Northeastern sector of lake Qaroun > Qaroun eastern sector > Western sector of lake Qaroun

The agricultural discharge of high amounts of organic compounds, inorganic salts, and heavy metals may be the cause of the decrease in the dissolved oxygen content of the water at the northeastern and eastern sectors of Lake Qaroun. Hypoxia affects fish survival and results in fish death [9] [11] [21]. As previously reported by Fathi and Flower [2] and Elewa *et al.* [22], severe depletion of dissolved oxygen may be caused by the decomposition of organic matter that overflows into water bodies. Additionally, the overgrowth of microorganisms in deteriorated water consumes more oxygen during the respiration process and may be caused by phytoplankton blooming [23].

The agricultural effluents of El-Bats drain, which discharge their effluents straight to the aforementioned sectors, can be blamed for the high levels of water ammonia and nitrite found in the current analysis of water samples taken from the lake's northeastern and eastern sectors. The findings are in line with those of Lim *et al.* [24], who discovered elevated ammonia and nitrite concentrations as a result of the discharge of active pollutants from sewage, agricultural, and industrial effluents that have not undergone sufficient and previous treatment.

Metal accumulation has been linked to the release of agricultural, industrial, and waste disposal in aquatic components, which can harm aquatic life in the province of El-Fayoum. It's important to consider the entire amount of effluents released by all urban activities. Industrial, agricultural, and municipal emissions are typically linked to heavy metal pollution of water [9] [11] [21] [25] [26] [27] [28] [29]. Once in the water column, metals may be absorbed by living things, deposited in sediments, or stay in the water for a while [21].

Because of industrial expansion and the widespread use of pesticides in agriculture, heavy metals are widely dispersed in aquatic systems, as recorded in the present study and showed in **Figure 2**. According to metals [30], organisms [31] and abiotic parameters including pH, water hardness, and temperature, the harmful effects of heavy metals on aquatic creatures varied [32]. Higher concentrations of heavy metals than what fish can tolerate have an adverse effect on fish

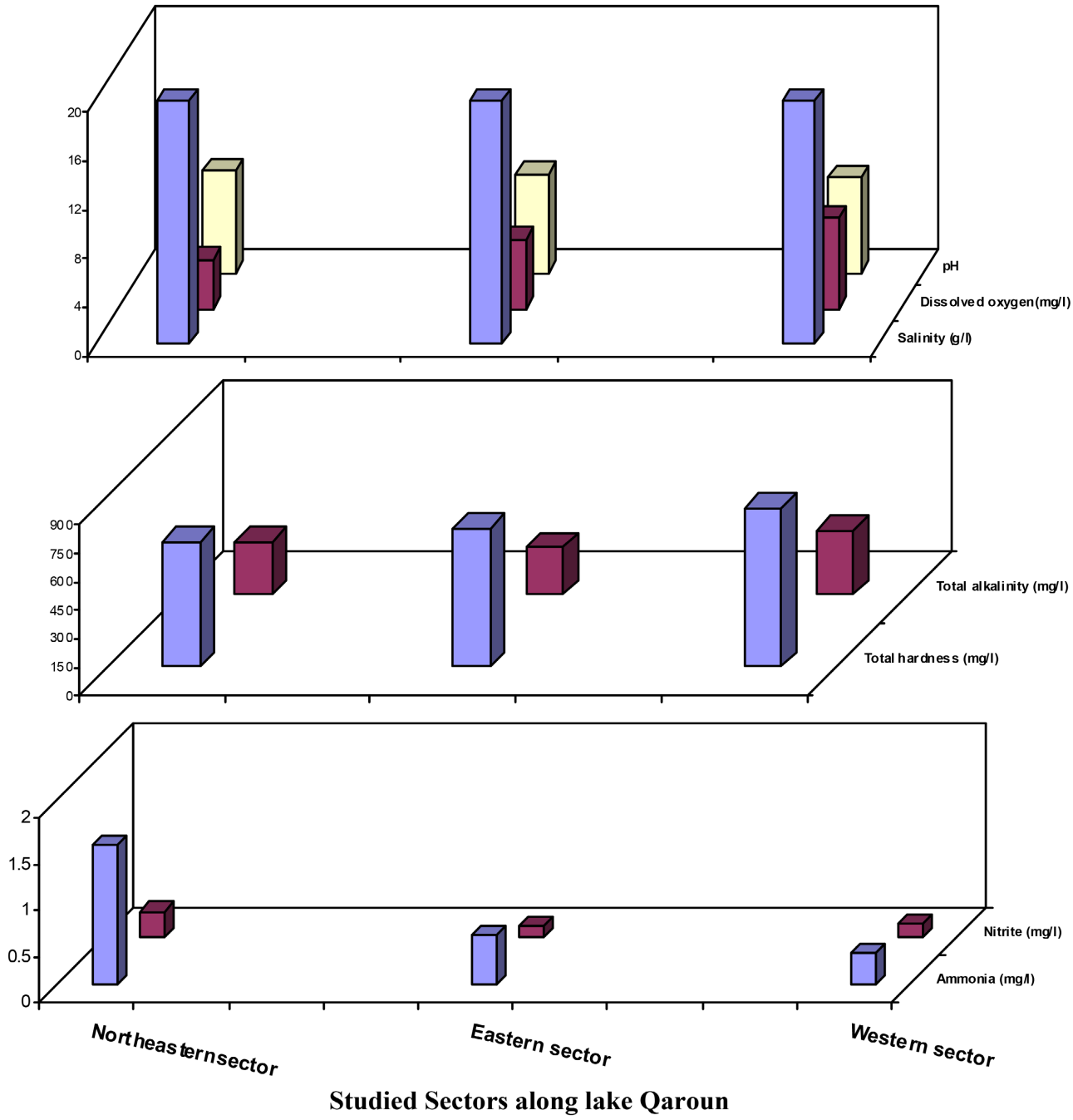

Figure 1. Quality of water collected from three sectors along lake Qaroun.

populations, slowing their growth, diminishing their chance of reproduction, and/or even threat fish life [1] [3] [28] [29] [33] [34]. According to Abdel-Khalek *et al.* [12], Nagdi and Shaker [26], the quality of the industrial and agricultural drainage water, which is rich in fertilizers and chemicals, that feeds the lake, may be to blame for the high copper, lead, and cadmium concentrations in the water collected from the northeastern and eastern sectors of the lake. Comparing the average concentrations of heavy metals in water from the studied sectors, the results revealed the presence of these metals in the following order: Northeastern

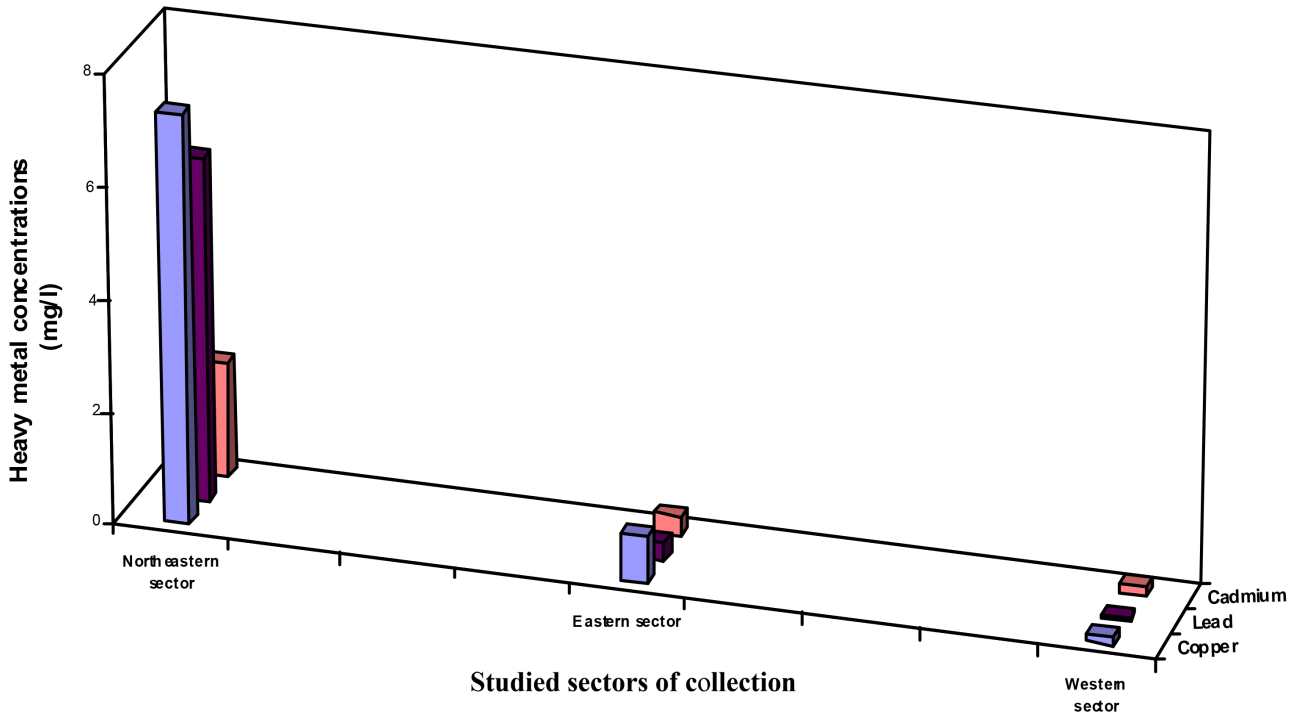

Figure 2. Heavy metal concentrations in water samples (mg/l) collected from three sectors along lake Qaroun at El-Fayoum governorate, Egypt.

sector of lake Qaroun > Qaroun eastern sector > Western sector of lake Qaroun for copper, lead and cadmium.

These results affirm that water collected from the western sector of lake Qaroun where no effluents discharged were lower in concentrations of all the studied heavy metals. However, the highest heavy metals concentrations were detected in the northeastern sector of lake Qaroun where El-Bats drain discharged its effluents followed by the eastern sector. Meanwhile, all measured water heavy metals were above the safe guideline values of the measured heavy metals in water according to WHO [35].

Preliminary survey and annual trend of catch by fish group (Ton) from Qaroun lake was done before this current work during the period from 2015 to 2018 by the General Authority for Fish Resources Development (GAFRD) in 2019. The statistical study carried out by GAFRD (2019) revealed a decrease in the annual catch of fish production from 1124 ton in 2015 to 832 ton in 2018 with the most dominant species, *Tilapia zillii* and *Solea aegyptiaca* along lake Qaroun (**Figure 3**).

Condition factor (CF):

CF values of both selected species; *Tilapia zillii* and *Solea aegyptiaca* collected from the three studied sectors along lake Qaroun are shown in **Table 1**. It is clear that there are highly significant differences in CF values among the studied sectors of the lake (F-values = 467 and 119 for *Tilapia zillii* and *Solea aegyptiaca* respectively). The highest values of CF for both species were observed in fish samples collected from the unpolluted sector of the lake, western sector. Conversely,

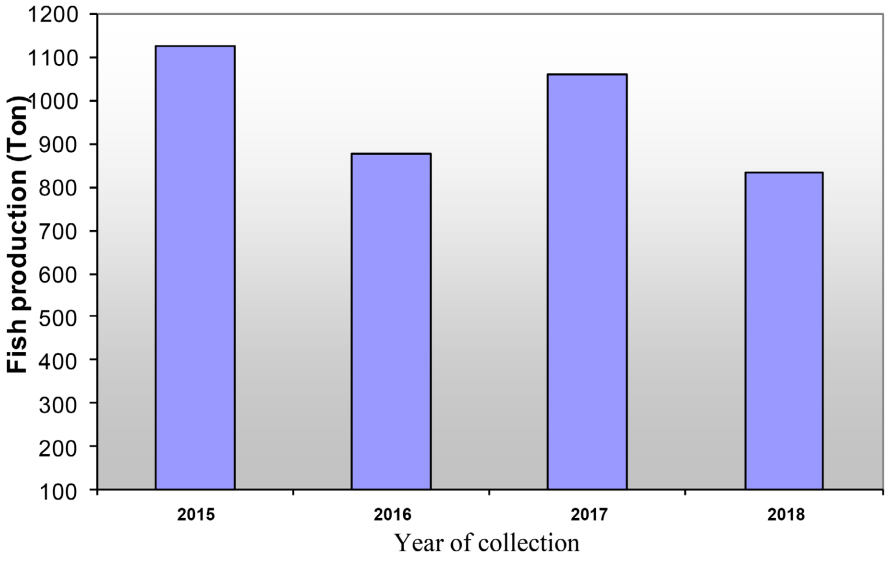

Figure 3. Annual total fish production (Ton) from lake Qaroun according to General Authority for Fish Resources Development (GAFRD, 2019).

Table 1. Condition factor of *Tilapia zillii* and *Solea aegyptiaca* collected from three different sectores along lake Qaroun.

Studied sites of collection	Condition factor "k"		
	T. z.	*S. a.*	*tv*
Northeastern sector (El-Bats drain discharge)	1.57 ± 0.015 B	0.75 ± 0.012 C	**
Eastern Sector (Four Km from El-Bats drain)	1.62 ± 0.027 B	0.87 ± 0.021 B	**
Western sector (Unpolluted site of collection)	2.62 ± 0.037 A	1.13 ± 0.019 A	**
F-values	467**	119**	

Data are represented as means of twenty four samples ± S.E. ***tv* = *t*** test between *Tilapia zillii* (*T. z.*) and *Solea aegyptiaca (S. a.)* for each parameter in each studied site of collection. Means with the same letter for each parameter in the same column are not significantly different, otherwise they do (SAS, 2000). **Highly Significant difference ($P < 0.01$).

fish collected from northeastern sector of lake Qaroun showed the lowest recorded condition values followed by that of fish collected from the eastern sector. The *t* test between *Tilapia zillii* and *Solea aegyptiaca* for condition factor in all studied locations showed highly significant differences.

Fish relative plumpness or health has been measured using length-weight connections. To compare values of the condition factor "k" and determine the effects of changing environmental conditions on fish performance [36] [37]. As a result, changes in "k" may indicate changes in the fish's protein and lipid levels as well as their general health [37].

In the current study, the condition factor of the two chosen fish species, *Tilapia zillii* and *Solea aegyptiaca*, collected from the western, unpolluted sector of

the lake, revealed higher values. On the other hand, fish collected from the northeastern and eastern sectors of Lake Qaroun respectively displayed the lowest reported condition levels. Additionally, *Tilapia zillii* condition factors are higher than that of *Solea aegyptiaca* in all studied sectors. The observed variations in fish k values may be attributed to the feeding rate and to lipid mobilization.

The toxic effects of the various heavy metals recorded in water samples at high concentrations in the present study may be the cause of the lower values of the condition factor "k" of *Tilapia zillii* and and *Solea aegyptiaca* collected from the northeastern and eastern sectors of the lake (**Table 1**). The same finding was previously reported regarding fish that were unable to thrive in contaminated aquatic environments [9] [21] [37]; and/or low densities of both phytoplankton and zooplankton that may have been related to the deterioration in water quality as previously reported by Shaaban *et al.* [38].

Fish collected from the western sector of the lake showed greater "k" values than fish taken from the lake's northeastern, more degraded sector. This supports the findings of Kheir *et al.* [39], who linked the rise in fish condition factor to greater food intake brought on by an accelerated metabolism, reduced oxygen consumption, and an increase in growth hormones.

Additionally, fish would need to detoxicate the metal or enhance the pace at which the deactivated proteins are produced. Both options require more energy, which would cause weight loss. Furthermore, Carvalho *et al.* [40] demonstrated a correlation between decreased fish growth and the activation of metal detoxification mechanisms, such as an increase in metallothionien levels. According to Bonga and Lock [41], water-born toxicants influence the gills by making the gill epithelium more permeable to water and ions and by inhibiting the chloride cells' ability to exchange ions. Reduced growth will ensue from the fish's compensatory responses, which would dramatically increase the energy needed to maintain water and ion balance.

Data obtained from the three studied sectors of Lake Qaroun for the two examined fish species, *Tilapia zillii* and *Solea aegyptiaca*, revealed significant differences (**Table 2**), in fish meat quality (water content, total protein, total lipids and ash). For both species, samples collected from the northeastern part of lake Qaroun had the lowest meat quality with highest water content and ash values. However, fish collected from the lake's western, unpolluted region revealed highest meat quality (lowest water content and ash). Furthermore, fish of the northeastern sector of lake Qaroun had the lowest muscle total protein and total lipids values for both species in comparison with fish samples collected from the lake's western sector, unpolluted region had the highest levels.

Numerous biological, pharmacological, and physiological elements have the potential to significantly affect the metabolic pathways of fish; these elements can be detected using various biochemical processes. Fish responses to stressors, particularly heavy metals, have been evaluated taking into account the effects of toxicants on the chemical makeup of fish muscles [9] [42].

Table 2. Meat quality of *Tilapia zillii* and *Solea aegyptiaca* collected from three different studied sectors along lake Qaroun.

Studied sites of collection	Water content (%)			Total protein (% of wet weight)			Total lipids (% of wet weight)			Ash (%)		
	T. z.	*S. a.*	*tv*	*T. z.*	*S. a.*	*tv*	*T. z.*	*S. a.*	*tv*	*T. z.*	*S. a.*	*tv*
Northeastern sector (El-Bats drain discharge)	81.67 ± 0.56 A	80.5 ± 0.63 A		12.5 ± 0.18 B	12.67 ± 0.21 B		2.03 ± 0.06 B	2.24 ± 0.06 B	**	2.35 ± 0.06 A	2.4 ± 0.03 A	*
Eastern Sector (Four Km from El-Bats drain)	80.7 ± 0.63 A	79.9 ± 0.73 A		12.3 ± 0.22 B	13.3 ± 0.42 B	*	2.17 ± 0.12 B	2.33 ± 0.06 B	*	2.50 ± 0.04 A	2.27 ± 0.06 A	*
Western sector (Unpolluted site of collection)	78.7 ± 0.21 B	76.33 ± 0.60 B	**	17.0 ± 0.37 A	16.5 ± 0.18 A		2.90 ± 0.04 A	3.27 ± 0.09 A	**	1.70 ± 0.04 B	1.93 ± 0.04 B	*
F-values	9.85**	22.3**		98**	49**		13**	38**		97.5**	28**	

Data are represented as means of eight samples ± S.E. ***tv = t*** test between *Tilapia zillii* (*T z.*) and *Solea aegyptiaca (S. a.)* for each parameter in each studied site of collection Means with the same letter for each parameter in the same column are not significantly different, otherwise they do, Duncan multiple range test (SAS, 2000). * Significant difference ($P < 0.05$). **Highly Significant différence ($P < 0.01$)

The meat quality of fish exposed to agricultural effluents in the lake's northeastern sector deteriorated in the current field investigation (Table 2). There were appreciable increases in the muscle's water content and ash, as well as appreciable declines in the total protein and lipid content of the muscle. These findings corroborated those made by Zaghloul [42] and Elghobashy, *et al.* [1], who discovered reductions in the muscle total protein and total lipids of African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*) exposed to high levels of heavy metals.

Exposure of fish gills to deteriorated water saturated with heavy metals may be responsible for the decrease in muscles total protein and total lipids of fish as a result of the agricultural drainage water along the lake. According to earlier research by Reader *et al.* [43], metals induce damage to the gill structure and a decrease in oxygen consumption, both of which result in a dramatic decrease in metabolic rate.

Additionally, tissue hydration happens as a result of the body's contents (muscle total protein and total lipids) being depleted. According to Weatherley and Gill [8], there is an inverse dynamic link between the protein, lipid, and water contents of muscles. El-Sayed, *et al.* [44] demonstrated that the usage of body protein and/or fat as an energy source to satisfy the rising physiological demands was a direct cause of the decrease in body protein and lipids at inappropriate habitat.

The fact that tilapia prefer natural feeding practices may account for their increased dry matter and fat contents in muscles as well as their muscles' minor moisture. The differences in meat quality (chemical muscle composition) of the two studied fish species *Tilapia zillii* and *Solea aegyptiaca*, may also be due to differences in their physiology and ecological requirements [4] [45] [46].

The depletion in protein content reflect the changes in water quality and its deterioration by the stress of pollutants that may critically influence the growth rate and the quality of fish which feed on bottom fauna induced by bioaccumulation of heavy metals. Moreover, Vutukuru [47] reported that depletion in protein content may be attributed to that, it was consumed as an alternative source of energy demand that induced by water pollutants. On the other hand, depletion in muscle lipids content may be due to the activation of toxicity which suppresses the activity of enzymes responsible for lipid transformation ultimately causing disturbance in lipid metabolism [34] [48] [49].

In general, it could be said that fish collected from the lake's western region had growth increment, high meat quality, and safe flesh for human eating. However, drainage water effluents that are directly released, without first being treated, to the northeastern and eastern portions of Lake Qaroun limit fish growth and degrade the quality of its meat, making a threat to humans. The findings of the current study also highlight the need for the relevant authorities to take quick action to solve the issue and to continuously monitor changes in lake conditions in order to help them develop smart management strategies for lake Qaroun.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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