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The Impacts of Climatic Change on Water Quality and Nile Tilapia *(Oreochromis niloticus)* in Burullus Lake, Egypt.

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ABSTRACT

Lake Burullus is the second largest one that is located in the Nile Delta and is connected to the Mediterranean by a narrow outlet. This Lake faces various anthropogenic-induced implications that threat its ecosystem and biodiversity. The prime objective of this study is investigating the impacts of climate change and seasonal variation on water quality and Nile Tilapia fish *(Oreochromis niloticus)* of Lake Burullus, during 2022. Five stations: (1) El-Burullus drain; (2) Bougaz El-Burullus; (3) Drain (7); (4) El-Shakhloba and (5) Mastrou were studied. Surface water samples were collected for assessment water quality from these stations during Four seasons. Also, fish serum and muscles samples were collected for biochemical parameters. Results showed the physicochemical criteria of water quality were attributed with seasonal variation. Salinity % of Lake water was the highest during Winter and Spring seasons especially at Bougaz El-Burullus. Dissolved oxygen (DO) and ammonia (NH_3) were significantly increased during Summer and Autumn. The study showed seasonal changes in the level of total protein, albumin, globulin, AST, ALT in serum of Tilapia fish. These biochemical markers were significantly increased during summer. Besides, Muscles total protein, total lipids and glycogen content were significantly decreased during Summer comparing with other seasons.

In conclusion, Lake Burullus water quality, serum biochemical markers and muscles content of Nile Tilapia fish are affected by climatic changes during seasonal variation and environmental stress particularly at the discharge points which must be monitored and controlled.

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INTRODUCTION:

Burullus Lake environment, the second-largest coastal lagoon in Egypt, has deteriorated as a result of its strategic location within the Nile Delta, where the lake receives the majority of the Nile Delta region's drainage water through several agricultural drains. The drainage water is primarily nutrient-rich freshwater contaminated by heavy metals and agricultural fertilizer (**Hany et al. 2022; Sheta, 2019).** Burullus Lake is rich in phytoplankton and organic matter, whereas the lake is categorized as a hypereutrophic water body with poor and declining water quality based on the trophic state index **(Elsayed et al. 2019).** Twelve Landsat images and two water indices were used to identify spatiotemporal changes in Burullus Lake from 1972 to 2015. The results indicated that the lake's water area had shrunk by about 49% of its surface area **(Mohsen et al. 2018). Mohsen et al. (2021)** stated that the water quality of Burullus Lake is in a critical state due to drain effluents and reclamation activities in the southern part of the lake, according to the spatial distribution of chlorophyll-a, total suspended solid, pH, Fe, Zn, Cr, and NH_4 levels. **Shalby et al. (2020**) showed that the current hydrological, hydrodynamic, and water quality properties of Burullus Lake will likely change as a result of climate change and sea level rise, which will have a significant impact on the ecosystem's health.

Climate change has unquestionably altered lake ecosystems worldwide, and we expect the long-term patterns of change observed in recent decades. Interactions between climate and other aquatic ecosystem stressors will likely lead to unexpected, nonlinear ecological responses, resulting in more severe impacts on aquatic ecosystems than currently observed. Moreover, although the exceedance of temperature thresholds for many aquatic species, as well as regime shifts in the physical environment of lakes are already documented, these will likely become more prevalent in the future and, therefore, have widespread implications for lake ecosystems **(Scheffer, 2009).** The effects of climate change often occur cumulatively and interact synergistically with multiple environmental stressors. Climate change will exacerbate problems with water quantity and quality, the latter including eutrophication, salinization, contamination, and the spread of invasive species, to name a few **(Scheffer and Carpenter 2003).** Long-term changes in the climate, in addition to the increased frequency and magnitude of heatwaves and storms (i.e., that cause rapid nutrient delivery to lakes), as well as land-use changes, can combine to influence lake water quality. For instance, delivering nutrients to surface waters, industry, agriculture, and urbanization has contributed to a well-documented increase in summer phytoplankton blooms (often used as a proxy for poor water quality) in many but not all lakes in recent decades **(Ho et al. 2019, Hou et al. 2022).**

Lakes are also recognized as key sentinels of climate change, which is reflected by a wide range of physical, chemical, and biological responses to climate variations and climate -induced changes within the lake catchment **(Adrian 2009, Williamson 2009).** Surface air temperature is one of the most recognized indicators of climate change, with global observations suggesting that temperatures have risen by more than 1 degree Celsius (°C) since the late twentieth century **(GISTEMP Team 2021).** Higher inland water temperatures may reduce the abundance and distribution of wild fish stocks in lakes by reducing water quality, longer dry seasons, fish mortality, introduction of new predators and pathogens, and changes in the prey abundance for fish. However, the most significant drivers of change in inland aquaculture and fisheries will be the floods and droughts that result from increasing seasonal and annual variability in precipitation. Climate change is already beginning to affect plants and animals that live in freshwater lakes and rivers, altering their habitat and bringing life-threatening stress and disease (**FAO, 2020).** The health of fish can be affected by environmental stress, nutrition as well as by pathogens. Stress in fish may be induced by various abiotic environmental factors such as changes in water temperature, pH, oxygen concentration and water pollutants including pesticides, insecticides **(Meier et al.**

1983 and Lebelo et al. 2001). The abundance and distribution of either of the marine or freshwater fish species is greatly affected by the environmental conditions prevailing at Lake Burullus (**Al Sayes et al. 2007).**

So, the current study was performed to investigate the effect of climatic changes, seasonal variation and environmental stress on water quality and some biochemical parameters of Nile tilapia *(Oreochromis niloticus)* from Lake Burullus, Egypt during 2022.

MATERIALS & METHODS

Study Area:

Lake Burullus (about 420 km2) is shallow slightly brackish water situated along the Egyptian Mediterranean Sea coasts. It lies between longitude 30˚ 30́ and 31˚ 10́ E and latitude 31˚ 21́ and 31˚ 35́ N. It is connected with the sea through a narrow (50 m width) passage called El-Burg inlet or Boughaz El-Burullus. Also, it is subjected to huge inputs of ferruginous material and anthropogenic nutrients from drains discharge, sewage and agricultural runoff as well as reclamation programs.

Five sampling stations were studied at Lake Burullus covering the most area of the lake during Four Seasons, 2022 (Figure 1). Station (1): Located in front of El-Burullus drain. Station (2): Located in front of Bougaz El-Burullus. Station (3): Located in front of drain No. 7. Station (4): Located in the front of both drain No. 8 and drain No. 9 (El-Shakhloba zone). Station (5): Located in the northern side of the lake (Mastrou zone).

2.2. Sampling Strategy:

Water samples (2-3 liters) were seasonally collected from studied stations in clean polyethylene bottles, filtered and kept cool until analysis. Fish Nile tilapia *(Oreochromis niloticus)* samples (20.40 ± 2.31 cm and 150.22 ± 52.64 g) were also collected at the same time, transferred to the laboratory using an ice box within 4-5 hours and kept at -20°C until dissected.

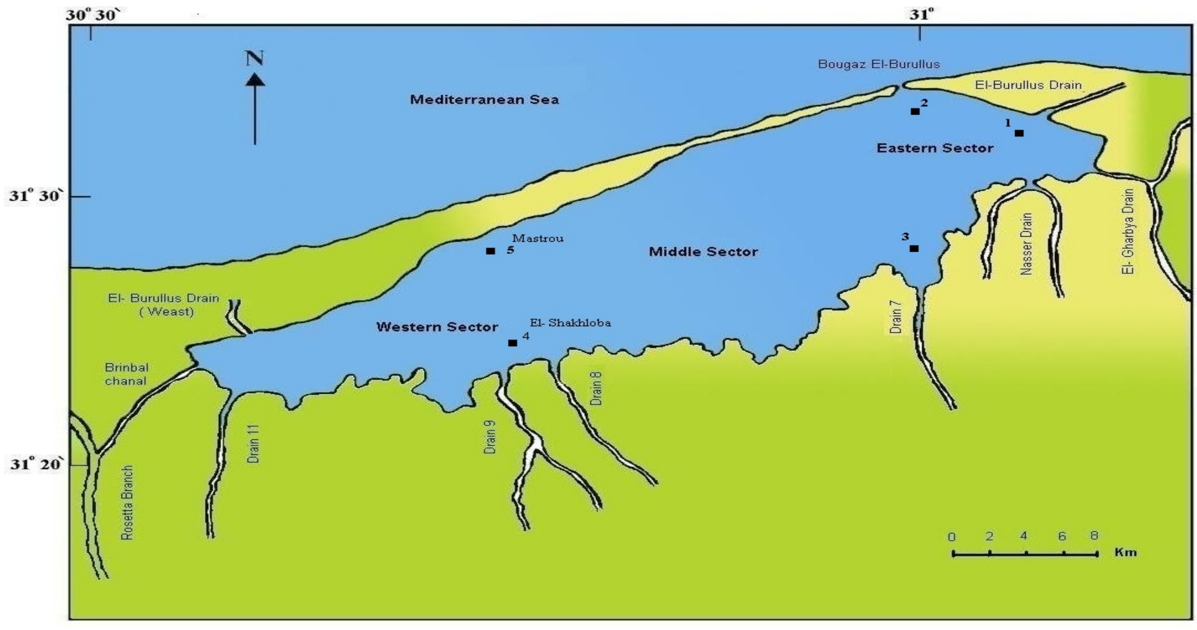

Fig. (1): Lake Burullus Map showing the sampling stations.

2.3. Environmental Stress:

Water temperature was measured using 0.1 °C graduated thermometer, water salinity %, dissolved oxygen (DO) and ammonia (NH_3) were determined according to the standard methods described in **APHA (1989).**

2.4. Biochemical Blood Parameters of Fish:

Blood was withdrawn from un-anesthetized fish by caudal puncture with a non-heparinized injection and collected in sterile closed tubes. Blood samples were left to clot at room temperature, and then kept in the fridge overnight at 4℃. They were centrifuged at 1000 xg for 15 minutes. The supernatant serum samples were kept at -20℃ for biochemical analysis. Total serum protein was determined by the Biuret method **(Weichselbaum, 1946).** Albumin was determined **(Tietz, 1990)** while, globulin was calculated by subtracting serum total protein from serum albumin **(Coles, 1974).** Activities of AST and ALT were determined using clinical kits of Boehringer Mannheim GmbH (Hitachi 706 D/712, USA) method (**Reitman and Frankel, 1957).**

2.5. Biochemical Muscles Parameters of Fish:

Muscle tissue samples (wet wight) for determination of total protein, total lipids and glycogen percentage of *O. niloticus* were taken. Muscle total protein was estimated by Biuret method according to **Gronall, (1949).** Total lipids were estimated according to **Knight et al. (1972).** Muscle glycogen contents were determined by the anthrone method described by **Siefter et al. (1950).**

2.6. Statistical Analysis:

Data obtained were statistically analyzed using SPSS 22 for variance (ANOVA) according to Differences between means were done at the 5% probability level, using Duncan's multiple range test for comparative of means within columns. Correlation coefficient was estimated for all Lake area under investigation.

3. RESULTS

The data obtained revealed that, no significant variations between the water temperature at the different stations in each season, (Table 1).

Water temperature of the lake varied from season to season. The maximum average values of temp. (30.8 ℃) were recorded in summer,

while the minimum one (15.4 ℃) was recorded in winter. In general, the water temperature exhibited a pronounced increase from spring reaching its maximum in Summer.

The salinity of Lake Burullus water differed from one station to the other. The highest values were observed at stations 1, 2 & 3 near to El-Bougaz, that affected greatly by the invasion of seawater in this area, while, the lowest values of salinity were recorded at station 4 (El -Shakhloba) and station 5 (Mastrou). The maximum value of salinity (27.1 %) was recorded at station 2 during Winter, while the minimum (2.1 %) was recorded at station 4 during Spring as shown in Table (2). The highest mean value (8.76 %) was recorded during Winter, while the lowest mean value (5.72 %) was recorded during Summer.

As shown in Table (3), the maximum concentration of dissolved oxygen (19.1 mg/l) was recorded at station 4 during Summer while the minimum (7.9mg/l) was recorded at station 1 during Spring. The highest average value was recorded during Summer (15.88 mg/l), while the lowest one was reported in Winter (10.86 mg/l).

The maximum concentration of ammonia (30.05 µg at/l) was recorded at station 4 during Autumn, while the minimum one (1.16 µg at/l) was recorded at station 5 during Winter (Table 4). On the other hand, the seasonal variation of ammonia exhibited highest average value during Autumn (23.39 µg at/l), while the lowest one (9.82 µg at/l) was determined in Winter.

Table (5) shows the serum AST and ALT activities of tilapia fish samples. The mean value of AST activity ranged from 49.8 U/L during spring to 173.4 U/L during summer. The highest activity of AST (211 U/L) was found in station 3 samples during summer. The mean value of ALT activity ranged from 5.6 U/L during spring to 12.2 U/L during summer. The highest activity of ALT (17 U/L) was found in station 5 during summer. The highest AST and ALT activities were observed during summer compared to other seasons. AST and ALT activities were fluctuated between different stations.

Table (6) shows the mean value of serum total protein level of tilapia fish samples ranging from 2.65 g/dl during spring to 4.32 g/dl during summer. The highest value of total protein was 5.1 g/dl in El-Shakhloba during summer and 3.97 g/dl in Bougaz El-Burullus during winter. The variation in total protein in fish serum was significant ($P \leq 0.01$) during all seasons. As shown in Table (7), the variations in serum albumin level were significant ($P \leq 0.05$) during summer and autumn where the highest total mean of albumin was 2.4 g/dl and 1.9 g/dl at station 4 during summer and autumn respectively. The highest level of total globulin was at stations 2 and 4 (2.9 g/dl) during autumn. Total globulin means values ranged from 1.77 g/dl in spring to 2.54 g/dl during autumn. Total globulin level was significant ($P \leq 0.01$) during all seasons as shown in Table (8).

The obtained data listed in Table (9) showed that the highest mean value was recorded at stations 2 during Four Seasons. The seasonal variation of total protein content in muscle of *O. niloticus* fish was significant ($P \leq 0.01$) during Winter and Autumn. The highest mean value was recorded during Spring (14.5 %), while the lowest one (12.97 %) during Summer. Concerning variations between the different stations in the total lipids in muscles of *O. niloticus* fish during Spring were significant ($P \leq 0.01$), where the highest mean value (2.48 %) was determined at station 5. The maximum value (7.29 %) was estimated during Autumn, on the other hand, the minimum one (1.26 %) was determined during Summer (Table 10). The seasonal variation of total lipids levels in muscles of *O. niloticus* fish showed that, pronounced increase for the mean value during Autumn (5.53 %), while it decreased to (1.58 %) in Summer. There are no significant variations in muscles glycogen content of *O. niloticus* fish between the different stations in each season. The maximum content of glycogen (0.54 %) was determined during Autumn, while the minimum one (0.075 %) was determined during Autumn (Table 11). On the other hand, the seasonal variations of glycogen in muscle of *O. niloticus* fish revealed that, the highest mean value which recorded during Autumn was (0.24 %), while the lowest content of glycogen (0.086 %) was recorded in Summer

Statistical analysis indicated that, a significant positive correlation between salinity percentage and both total protein and glycogen during winter and autumn (Table 12 a). During Four Seasons, there were a significant negative correlation between water temperature and total proteins and while the relation was non-significant between total lipids and glycogen. The relation between salinity percentage and total lipids showed a significant positive correlation. The relation between dissolved oxygen (DO) and total proteins, total lipids and glycogen content in muscles of Nile Tilapia showed non-significant negative correlation. The relation between ammonia and total lipids showed a significant positive correlation while the relation was non-significant between ammonia and glycogen (Table 12 b).

Table 1. Values of water temperature (C° (at the different stations in Lake Burullus during 2022.

	Water Temperature (°C)			
Stations	Winter	Spring	Summer	Autumn
1	15	22	29	24
2	15	23	30	26
3	16	25	32	26
4	16	25	32	24
5	15	22	31	25
Range	15:16	22:25	29: 32	24: 26
Mean	15.4 ± 0.24	23.4 ± 0.68	30.8 ± 0.58	25 ± 0.45

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE).

Table 2. Values of salinity (S %) at the different stations in Lake Burullus during 2022.

	Salinity (S %)			
Stations	Winter	Spring	Summer	Autumn
1	6.1	4.7	4.6	6.2
2	7.1	22.2	10.5	9.5
3	3.8	3.1	6.4	9.2
4	3.9	2.1	3.7	3.7
5	2.9	2.9	3.4	3.2
Range	2.9 :27.1	2.1 :22.2	3.4: 10.5	3.2: 9.5
Mean	8.76 ± 0.79	7 ± 3.82	5.72 ± 1.3	6.36 ± 1.4

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE).

Table 3. Values of dissolved Oxygen (mg/l) at the different stations in Lake Burullus during 2022.

	DO (mg/l)			
Stations	Winter	Spring	Summer	Autumn
1	9.1	7.9	12.9	12.9
2	12	12.1	17.5	11.4
3	10	13.3	18.3	11.8
4	9.1	12.9	19.1	13.8
5	14.1	10	11.6	15.9
Range	9.1: 14.1	7.9 :13.3	11.6: 19.1	11.4: 15.9
Mean ± SE	10.86 ± 0.97	11.24 ± 1.01	15.88 ± 1.52	13.16 ± 0.804

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE).

Table 4: Values of ammonia ((µg /l) at the different stations in Lake Burullus during 2022.

	NH3 (µg /l)			
Stations	Winter	Spring	Summer	Autumn
1	17.33	10.23	26.19	38.9
2	5.29	4.18	7.9	7.15
3	13.82	11.06	6.59	9.99
4	11.52	14.65	8.4	30.05
5	1.16	9.15	7.59	9.88
Range	1.16: 17.33	4.18 :14.65	6.59: 26.19	7.15 :30.05
Mean ± SE	9.82 ± 2.92	9.85 ± 1.69	11.33 ± 3.72	23.39 ± 9.03

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE).

Table 5. Serum AST and ALT (U/L) activities of tilapia (*O. niloticus*) from Lake Burullus during 2022.

St.	AST (U/L)				ALT (U/L)			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	52 ± 1.2^{c}	50 ± 1.2^{c}	210 ± 5.8^{a}	195 ± 5.8^{b}	5 ± 0.9^{c}	4 ± 0.9^{d}	12 ± 1.2^{b}	10 ± 1.2^{b}
2	59 ± 2.3^{b}	45 ± 2.3^{e}	125 ± 2.9^{d}	117 ± 2.9^{e}	10 ± 1.2^{a}	8 ± 1.2^{a}	12 ± 1.2^{b}	7 ± 1.2^{d}
3	52 ± 1.2^{c}	47 ± 1.2^{d}	211 ± 5.8^{a}	210 ± 5.8^{a}	5 ± 0.9^{c}	5 ± 0.9^{c}	12 ± 1.2^{b}	8 ± 1.2^{c}
4	59 ± 1.7^{b}	55 ± 1.7^{a}	134 ± 2.3^{c}	129 ± 2.3^{d}	4 ± 0.6^{d}	7 ± 0.6^{b}	8 ± 1.7^{c}	5 ± 1.7^{e}
5	89 ± 2.3^{a}	52 ± 2.3^{b}	188 ± 1.7^{b}	180 ± 1.7^{c}	7 ± 0.3^{b}	4 ± 0.3^{d}	17 ± 1.2^{a}	12 ± 1.2^{a}
Mean	62.2 ± 3.9	49.8 ± 1.5	173.4 ± 6.4	166.4 ± 2.4	6.2 ± 0.7	5.6± 0.9	12.2± 0.8	8.4 ±1.3
Sig.	***	**	***	**	**	*	***	**

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05); N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01.

Table 6.Serum total protein level (g/dl) of tilapia (*O. niloticus*) from Lake Burullus during 2022.

Total protein in serum (g/dl)				
Stations	Winter	Spring	Summer	Autumn
1	2.79 ± 0.03^{c}	2.29 ± 0.01^{c}	4.1 ± 0.06^{c}	3.8 ± 0.02^{c}
2	3.79 ± 0.01^{a}	3.29 ± 0.01^{a}	4.5 ± 0.3^{b}	4.2 ± 0.03^{b}
3	3.39± 0.052^{b}	2.89 ± 0.022^{b}	3.9 ± 0.23^{d}	3.6 ± 0.20^{d}
4	3.39 ± 0.02^{b}	2.89 ± 0.12^{b}	5.1 ± 0.06^{a}	4.8 ± 0.04^{a}
5	3.4 ± 0.23^{b}	2.9 ± 0.13^{b}	3.7 ± 0.12^{e}	3.4 ± 0.11^{e}
Mean	3.35 ± 0.09	2.65 ± 0.05	4.32 ± 0.16	3.96 ± 0.06
Sig.	***	**	***	***

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE); a, b; Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05); N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01.

Table 7. Serum total albumin level (g/dl) of tilapia (*O. niloticus*) from Lake Burullus during 2022.

Total albumin in serum (g/dl)				
Stations	Winter	Spring	Summer	Autumn
1	1.1 ± 0.12^{d}	0.9 ± 0.01^{bc}	2 ± 0.3^{b}	1.5 ± 0.02^{b}
2	1.68 ± 0.16^{a}	1.13 ± 0.06^{b}	2.1 ± 0.06^{ab}	1.3 ± 0.03^{ab}
3	1.16 ± 0.03^{c}	1.06 ± 0.01^{c}	1.6 ± 0.06^{c}	1.1 ± 0.01^{c}
4	1.27 ± 0.04^{b}	1.17 ± 0.02^{ab}	2.4 ± 0.23^{a}	1.9 ± 0.03^{a}
5	1.27 ± 0.04^{b}	1.20 ± 0.02^{a}	2.1 ± 0.06^{ab}	1.31 ± 0.03^{ab}
Mean	1.29 ± 0.12	1.09 ± 0.05	2.04 ± 0.22	1.42 ± 0.01
Sig.	N.S.	N.S.	*	*

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05);
N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01.

Table 8. Serum total globulin level (g/dl) of tilapia (*O. niloticus*) from Lake Burullus during 2022.

Stations	Total globulin in serum (g/dl)			
	Winter	Spring	Summer	Autumn
1	1.69 ± 0.09[c]	1.39 ± 0.05[e]	2.1 ± 0.23[ab]	2.3 ± 0.03[c]
2	2.11 ± 0.15[b]	2.19 ± 0.10[a]	2.4 ± 0.23[b]	2.9 ± 0.20[a]
3	2.23 ± 0.02[a]	1.83 ± 0.02[b]	2.3 ± 0.17[ab]	2.5 ± 0.13[b]
4	2.12 ± 0.02[b]	1.72 ± 0.02[c]	2.7 ± 0.17[a]	2.9 ± 0.11[a]
5	2.13 ± 0.22[b]	1.7 ± 0.22[bc]	1.6 ± 0.06[c]	2.09 ± 0.04[d]
Mean	2.06 ± 0.07	1.77 ± 0.03	2.22 ± 0.11	2.54 ± 0.08
Sig.	***	**	**	*

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05);
N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01

Table 9. Muscles total protein content (%) of Tilapia (*O. niloticus)* from Lake Burullus during 2022

Stations	Muscles total protein % (wet of weight)			
	Winter	Spring	Summer	Autumn
1	14.16 ± 0.48 a	14.1 ± 0.52 c	13.36 ± 0.36 b	12.76 ± 0.65 c
2	14.31 ± 0.16 a	15.55 ± 0.73 a	13.45 ± 1.05 a	15.31 ± 0.87 a
3	13.02 ± 0.09 b	13.49 ± 0.88 d	11.89 ± 0.81d	12.05 ± 0.09 d
4	13.21 ± 0.43 b	14.51 ± 0.05 ab	13.09 ± 0.99 c	11.90 ± 0.28 e
5	13.02 ± 0.16 b	14.87 ± 0.42 b	13.06 ± 0.3 bc	13.09 ± 0.82 b
Mean	13.54 ± 0.17	14.5 ± 0.34	12.97 ± 0.32	13.14 ± 0.41
Sig.	*	N.S.	N.S.	*

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; %: wet wight; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05);
N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01.

Table 10. Muscles total lipids content (%) of Tilapia (*O. niloticus)* from Lake Burullus during 2022.

Stations	Muscles total lipids % (wet of weight)			
	Winter	Spring	Summer	Autumn
1	2.14 ± 0.07 c	1.57± 0.14 ce	1.26 ± 0.16 e	6.64 ± 0.71 b
2	2.32 ± 0.07 ab	1.59 ± 0.12 e	1.97 ± 0.55 a	7.29 ± 0.82 a
3	2.22 ± 0.07 ab	1.86 ± 0.14 c	1.65 ± 0.01 c	4.18 ± 0.31e
4	2.80 ± 0.29 a	2.03 ± 0.11 b	1.33 ± 0.17 d	4.24 ± 0.32 d
5	2.54 ± 0.23 b	2.48 ± 0.16 a	1.72 ± 0.26 b	4.98 ± 0.36 c
Mean	2.4 ± 0.09	1.91 ± 0.09	1.58 ± 0.13	5.53 ± 0.52
Sig.	N.S.	**	N.S.	N.S.

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; %: wet wight; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05);
N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01

Table 11. Muscles glycogen content (%) of Tilapia (*O. niloticus)* from Lake Burullus during 2022.

	Muscles glycogen % (wet of weight)			
Stations	Winter	Spring	Summer	Autumn
1	0.19 ± 0.023 b	0.19 ± 0.01 c	0.075 ± 0.04 ab	0.31 ± 0.22 b
2	0.22 ± 0.07 a	0.21 ± 0.01ab	0.08 ± 0.01 ab	0.54 ± 0.27 a
3	0.16 ± 0.01 d	0.23 ± 0.01 b	0.09 ± 0.01 b	0.12 ± 0.1c
4	0.18 ± 0.026 ab	0.22 ± 0.03 ab	0.075 ± 0.04 ab	0.08 ± 0.04 d
5	0.178 ± 0.01 ab	0.25 ± 0.024 a	0.11 ± 0.02 a	0.13 ± 0.05 c
Mean	0.187 ± 0.01	0.22 ± 0.006	0.086 ± 0.009	0.24 ± 0.08
Sig.	N.S.	N.S.	N.S.	N.S.

1: El-Burullus Drain; 2: Bougaz El-Burullus; 3: Drain (7); 4: El-Shakhloba; 5: Mastrou; %: wet wight; Values are expressed as mean ± standard error (X ± SE); a, b, Significant difference using Duncan's multiple range test for comparative of means within the same column at (P ≤ 0.05);
N.S: No significant; *, P ≤ 0.05; **, P ≤ 0.01.

Table (12 a): Correlation coefficient between total protein, total lipids, glycogen contents in muscles of *O. niloticus* and some phsico-chemical parameters of Lake Burullus at different stations during each season, 2022.

Winter				
Variables	**Temp.**	**S%**	**DO**	**NH3**
Total proteins	- 0.614	0.976 **	- 0.158	0.182
Total lipids	0.362	- 0.514	0.117	- 0.407
Glycogen	- 0.645	0.836 *	0.203	- 0.293
		Spring		
Total proteins	- 0.419	0.724	0.04	- 0.640
Total lipids	- 0.036	- 0.533	0.074	0.318
Glycogen	0.147	- 0.320	0.371	0.108
		Summer		
Total proteins	- 0.679	0.092	- 0.352	0.411
Total lipids	0.05	0.719	0.088	- 0.639
Glycogen	0.273	- 0.274	- 0.527	- 0.446
		Autumn		
Total proteins	0.493	0.918 *	- 0.321	- 0.543
Total lipids	0.104	0.711	0.379	- 0.187
Glycogen	0.352	0.891 *	- 0.571	- 0.331

**, correlation is significant at (P ≤ 0.01); *, correlation is significant at (P ≤ 0.05).

Table (12 b): Correlation coefficient between total protein, total lipids, glycogen contents in muscles of *O.niloticus* and some phsico-chemical parameters of Lake Burullus at different stations during four seasons 2022.

Variables	Temp.	S%	DO	NH3
Total proteins	- 0.908 *	- 0.486	- 0.651	- 0.442
Total lipids	- 0.043	0.955 *	- 0.047	0.961 *
Glycogen	- 0.508	0.585	- 0.730	0.465

**, correlation is significant at (P ≤ 0.01); *, correlation is significant at (P ≤ 0.05).

DISCUSSION:

Burullus Lake has faced numerous major issues over the last four decades as a result of intensive aquaculture and agriculture activities along with uncontrolled urbanization. These activities have led to increasing pollution and area loss, which have accelerated the deterioration of its entire environmental system, including the water quality of lake **(Hany et al. 2022).** The Egyptian government developed the lake by dredging it, deepening the inlet link between the lake and the Mediterranean Sea, and removing weed (**Zaghloul et al. 2022).**

There was little variation in the water temperature between the sites, and it mirrored the air temperature. Water temperatures vary with changing climatic conditions; this variation in temperature is due to the shallowness and the common mixing of water by wind. In general, the water temperature exhibited a pronounced increase from spring reaching its maximum in Summer (Table 1).

Salinity was gradually decreased from the eastern to the western sector of lake and disturbed in the last few years, due to the invasion of drainage water into the Lake with huge amounts and decreasing of seawater entering the lake, so the salinity of Lake was fluctuated from time to time (Table 2). Also, the increment in salinity may be attributed to evaporation and/or leaching of salts (**Saleh et al. 1988).** These results are in agreement with those obtained by **Eh Rak et al. 2022)** where reported that, the constant flow of drainage water and the influx of seawater from Boughaz are the most significant influences on the TDS contents in the water of Lake. With the greatest values reported in the winter and the lowest in the summer, TDS demonstrated significant spatial variability without temporal variation.

The dissolved oxygen (DO) was seasonal variation in lake and exhibited a considerable degree of fluctuation where the total average of DO range from 15.9 mg/l during summer to 10.9 mg/l during winter (Table 3). These observations cleared that the levels of oxygen in Lake Burullus correlated mainly with the load of organic pollutants discharged from the drains, seasonal climatic variation and the conditions of each station that were further away or near the point of discharge. The highest values of DO in summer were due to the continuous discharges during this season which consume oxygen through biochemical reactions at high temperature. **Abdelhamid (2003)** showed that DO levels were affected negatively by elevating water temperature and salinity. On the other hand, **Radwan (2007)** reported the increase in organic pollution in Lake led to increase in DO levels. **Al-Sayes et al. (2007)** reported that the shallowness of Lake affected DO, water temperature, wind action, photosynthetic activity as well as the oxidation processes of organic matters originating from the discharges into the lake. **Abdel-Satar (2008)** cleared that, the drop in DO may be caused by drainage water where organic wastes and some inorganic compounds exert an oxygen demand upon decomposition that lowers the level of dissolved oxygen below needed by aquatic life. However, a high value of DO in the water system may result from the presence of photosynthetic phytoplankton **(Eh Rak et al. 2022).** Therefore, oxidation–reduction processes along with photosynthetic activity and a load of organic materials discharged into the lake through the drains are the main factors controlling DO distribution **(Khalil, 2018).** It has been observed that there is a significant increase in the average DO value (15.88 mg/L) for this result compared to that of **Hany et al. (2022)** (6.0 mg/L). Generally, most DO values of the sampling sites indicate that the lake is healthy and can sustain aquatic organisms' needs.

Most of the total soluble inorganic nitrogen was found to be NH_4^+-N. As shown in Table (4), the level of ammonia (NH3) in lake water varied according to site and season, (9.82 µg/l during Winter to 23.39 µg/l during Autumn). The highest level was recorded at stations which affected by sewage, fish farms effluents and huge amount of agricultural drainage water that discharged from drains which surrounded by reclaimed lands during the periods of irrigation and not due to the anaerobic condition with depleted oxygen. **Abdelhamid (2003)** mentioned that the toxic level of NH_3 for fish is 0.6 -2.0 mg/l and the critical level of ammonia in water for fish is 2 – 3 mg/l. In addition, NH_3 level is influenced by pH and temperature of water **Abdelhakeem et al. (2002).** The exposure of fish to high levels of ammonia in the environment leads to convulsions due to the increase of ammonia in blood which is turn may limit exercise (**Hillaby and Randall, 1979).**

Climate change-induced extreme temperature events are becoming more intense and frequent. For fish, temperature is the master abiotic factor that controls and limits fish development and physiology at all stages of aquaculture and ecosystem. In fish and other animals, during thermal stress, functional tissues and organ damage release some specific cellular enzymes into the bloodstream and can be used as stress indicators (**Krajnovic-Ozretic & Ozretic, 1987; Roychowdhury et al. 2020).** These agree with our results (Table 5) which indicated that tilapia serum AST and ALT activity was significantly varied between stations and seasons, where it was highest during summer (29: 32℃). Also, the pollution of aquatic media with metals, pesticides and domestic waste, lead to an increase in the serum AST, ALT and LDH enzyme activities of fish (**Borges, et al. 2007).**

Total serum protein is a useful indicator in diagnosis offish disease. The majority of plasma proteins which are synthesized in the liver are used as indicators of liver impairment **(Banaee, 2012 and Salaah et al. 2018).** Also, serum albumin in fish is involved in metabolism and plays an important role in transport functions of exogenous chemicals and endogenous metabolites. Thus, serum albumin is considered as a diagnostic tool which reflects the liver function, metabolic status and stress conditions in fishes **(Vijayan, et al. 2010).** In the present study, highest level of serum total protein, serum albumin of *O. niloticus* fish collected from Lake Burullus were (4.32 g/dl) and (2.04 g/dl) respectively during summer. Serum total protein, albumin and globulin levels were significantly varied between seasons (Tables 6, 7 and 8). The observed hyperproteinemia and hyperalbuminemia in the present study may be due to activation of metabolic systems as a response to pollutants exposure, or the induction of protein synthesis and degradation of the cellular material in the liver caused by liver damage, due to the stressful condition of water pollution **(Al-Attar 2005 and Zaki, et al. 2008).**

Biochemical parameters in blood serum of *O.niloticus* collected from Rosetta branch showed a positive correlation with EC, DO, BOD, COD, TDS, nitrite, nitrate and ammonia in water, that means these characteristics affect and relate to each other (**Salaah et al. 2018).**

Our results indicated the muscles total protein, total lipids and glycogen content of Nile tilapia exposed to environmental stress and pollution in Lake Burullus were varied according to sites and seasons. The highest value of total protein percentage in fish muscles was recorded during Spring, whereas, both total lipids and glycogen were highest during Autumn. Whereas, the lowest percentage of muscles total protein, total lipids and glycogen (12.97 %, 1.58 % and 0.086 %) were recorded in Summer, respectively. **El-Serafy et al. 2005**, indicated the seasonal variations in the content of protein, fat, carbohydrate, water, ash; and found a direct relationship between fat and protein.

The correlation between the water temperature and total protein, total lipids and glycogen content in fish muscles was negatively correlated (Tables 12 a, b). The previous observations were coincided with Rome et al. 1985 who reported that, oxygen content decrease with an increase in temperature due to the reduction of oxygen solubility in water with increase in water temperature, O_2 carrying capacity of the blood reduced leading to a reduction in assimilation of glycogen and total protein. Also, the results observed a positive correlation between salinity % and both total lipids and glycogen, whereas total protein was negatively correlated. **Hillman, 1984**, indicated that salinity plays an important role in the assimilation processes for the content of glycogen, protein and lipids in fish muscles where the activity and swimming capacity is reduced dependent upon the degree to which plasma ion levels become elevated leding to the direct effect on the reduction of hemoglobin oxygen affinity leading to a reduction in oxygen delivery to the muscle and also affect muscle contractile, thus an increase in glycogen content occur. Our results cleared that; Ammonia exhibits insignificant negative correlation with Glycogen content in muscles of fish. These agree with **Ye and Randall (1991)** who reported that, no direct evidence for an effect of elevated ammonia in the environment on muscle contractile and consuming glycogen in muscles, thus the relation was insignificant, while the relation was positive significant with total lipids. Also, DO was nonsignificant negatively correlated with total protein, total lipid and glycogen in fish muscles these may be due to the decomposition of glycogen into glucose which increase in the blood giving a significant positive correlation with DO in the environment. These observations were coincided with **Bashamohideen and Parvatheswararas (1972)** who reported that the DO increases blood glycogen of Tilapia fish especially with the high levels of salinity.

In conclusion, climatic changes and the seasonal variation of the qualitative parameters showed that biochemical parameters in fish serum and muscles changed according to seasons and the source of pollution, where they were significantly correlated with environmental stress. Restricted precautions should be taken to obtain high-quality fish from Lake Burullus. However, studies on the interactive effects of extreme temperature events with other associated environmental stressors are needed across a broader range of species to gain a better understanding of fish response and aquaculture performance during extreme temperature events. Moreover, for fish, studies on alternative species, development of stress-tolerant strains, and the possibilities of nutritional mitigation measures as a potential option to combat extreme temperature stress are promising and should be pursued in future studies.

REFERENCES

Abdelhakeem NF, Bakeer MN, Soltan MA. 2002. "Aquatic environment for fish culture". Deposit No. 4774/2002.

Abdelhamid AM. 2003. "Scientific fundamentals of fish production and husbandry".2nd Rev.ed., Mansoura Univ. Press, Deposit No. 1424/ 2003.

Abdel-Satar AM. 2008. Chemistry of major ions, nutrient salts and heavy metals in the Manzalah Lake system, Egypt. Egyptian Journal of Aquatic Research, 34(2): 130–148.

Adrian R. 2009. Lakes as sentinels of climate change. Limnology and Oceanography (54): 2283–2297

Al Sayes A, Radwan A, Shakweer L. 2007. Impact of drainage water inflow on the environmental conditions and fishery resources of Lake Burullus. Egyptian J. of aquatic research, (33) No (1): 312-351.

Al-Attar AM. 2005. Changes in Hematological Parameters of the Fish, *Oreochromis niloticus* Treated with Sublethal Concentration of Cadmium. Pak. J. Biol. Sci, 8 (3): 421-424.

APHA, American Public Health Association 1989. Standard methods for the examination of water and waste water 17 th Ed. New York, 626p.

Banaee M. 2012. Adverse effect of insecticides on various aspects of *fish's biology and physiology: Insecticides* – Basic and Other Applications Book, Edited by Soloneski, S., Larramendy, M., Published by In Tech, Chapter (6): 101- 126.

Bashamohideen M, Parvatheswararas V. 1972. Adaptations to Osmotic Stress in the Fresh-Water Euryhaline Teleost Tilapia mossambica. IV. Changes in Blood Glucose, Liver Glycogen and Muscle Glycogen Levels. Marine Biology, (16): 68-74.

Borges LV, Scotti D R, Sigueira R, Zanini F, Amaral DF, Juriniz FG, Wassermann S. 2007. "Changes in hematological and serum biochemical values in Jundiai *Rhamdiaquelen*due to sun-lethal toxicity of cypermethrin". *Chemosphere*, (68): 920-926.

Coles EH. 1974. Vet. Clin. Path. W.B. Sounders company. Philadelphia, London and Toronto. 211-213.

Eh Rak A, Abdul Kari Z, Ramli MZ. 2022. The impact of water quality on the Asian clam, *Corbicula fluminea*, distribution in Pergau Lake, Kelantan, Malaysia. Saudi Journal of Biological Sciences, (29): 2348–2354.

Elsayed FA, Okbah MA, El-Syed SM, Eissa MA, Goher ME. 2019. Nutrient salts and eutrophication assessment in Northern Delta lakes: Case study Burullus Lake, Egypt. Egyptian Journal of Aquatic Biology and Fisheries, 23(2): 145–163.

El-Serafy S, Ibrahim S, Mahmoud S. 2005. Biochemical and Histopathological studies on the muscles of the Nile tilapia *(Oreochromis niloticus).* Vet. J., Vol., 9, (1): P: 81-96.

FAO 2020. The ClimeFish project organised the 2020 International Forum on the Effects of Climate Change on Fisheries and Aquaculture, kindly hosted by FAO.

GISTEMP Team. 2021. GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies. NASA. https://data.giss.nasa.gov/gistemp.

Gronall A G, Bardawill C J and David M M. (1949). Cited from (Spectrophotometric and Spectrofluometery Apractical Approach). Bashford, C. L. and Harris, D. A. (eds)1987. IRL Press, Oxford, England.

Hany A, Akl F, Hagras M, Balah A. 2022. Assessment of recent rehabilitation projects' impact on water quality improvement in Lake Burullus, Egypt. Ain ShamsEngineeringJournal, (13):101-492.

Hillaby BA, Randall DJ. 1979. Acute ammonia toxicity and ammonia excretion in rainbow trout (Salmo gairdneri). J. Fish. Res. Bd Can. (36): 621–629.

Hillman SS. 1984. Inotropic influence of dehydration and hyperosmolal solutions on amphibian cardiac muscle. J. comp. Physiol. B (154): 325–328.

Ho JC, Michalak AM and Pahlevan N. 2019. Widespread global increase in intense lake phytoplankton blooms since the 1980s. Nature 57(4): 667–670.

Hou X. 2022. Global mapping reveals increase in lacustrine algal blooms over the past decade. Nature Geoscience (15): 130–134.

Khalil MT. 2018. Physical and chemical properties of Egypt's coastal wetlands; Burullus wetland as a case study. In A. Negm, M. Bek, & S. Abdel-Fattah (Eds.) Egyptian coastal lakes and wetlands: part I. The handbook of environmental chemistry V. (71). Springer.

Knight JA, Anderson S, Rawle JM. 1972. Chemical Basis of the Sulfo-phospho-vanillin Reaction for Estimating Total Serum Lipids. Clinical Chemistry, Vol. (18): 199-202.

Krajnovic-Ozretic M, Ozretic B. 1987. Estimation of the enzymes LDH, GOT and GPT in plasma of grey mullet Mugil auratus and their significance in liver intoxication. Diseases of Aquatic Organisms, (3): 187–193.

Lebelo SL, Saunders DK, Crawford TG. 2001. Observations on the blood viscosity in striped bass, *Morone saxatilis* (Walbaum) associated with fish hatchery conditions. Transaction of the Kansas Academy of Science, 104 (3/4): 183-194.

Meier PG, Fook DC, Lagler KF. 1983. Organochlorine pesticide residues in rice paddies in Malaysia 1981 Bulletin of Environment Contaminants and Toxicology (30): 351-357.

Mohsen A, Elshemy M, Zeidan BA. 2018. Change detection for Lake Burullus, Egypt using remote sensing and GIS approaches. Environmental Science and Pollution Research, (25): 30763–30771.

Mohsen A, Elshemy M, Zeidan B. 2021. Water quality monitoring of Lake Burullus (Egypt) using Landsat satellite imageries. Environmental Science and Pollution Research, (28): 15687–15700.

Radwan AM. 2007. "Impact of pollution on the primary production of phytoplankton in Lake Burullus". African J. Biol. Sci., 3 (1): 35-49.

Reitman S, Frankel S. 1957. A colorimetric method for the determination of serum glutamic oxaloacetic and glutamic pyruvic transaminases. Am. J. Clin. Path., (28):56.

Rome LC, Loughna PT, Goldspink G. 1985. Temperature acclimation: Improved sustained swimming performance in carp at low temperatures. Science 2 (28): 194–196.

Roychowdhury P, Aftabuddin M, & Pati M K. (2020). Thermal stress altered growth performance and metabolism and induced anaemia and liver disorder in Labeo rohita. Aquaculture Research, 51(4): 1406–1414.

Salaah SM, Khalil MT, Gad NS, Ahmed NAM. 2018. PHYSICOCHEMICAL CHARACTERISTICS ANDPHY SIOLOGICAL CHANGESINOREOC HROMIS NILOTICUS FROM ROSET TA BRANCH OF THE RIVER NILE. Eur. Chem. Bull., 2018, 7(2): 63-71.

Saleh MA, Saleh MM, Fouda MA, Saleh MS, Abdellattif Wilson MA. 1988. "Inorganic pollution of the man – made lakes of Wadi El-Raiyan and its impact on aquaculture and wild life of the surrounding Egyptian desert". Arch. Environ. Contam.Toxicol., (17): 391 – 403.

Scheffer M. 2009. Early warning signals for critical transitions. Nature 46 (1): 53–59

Scheffer M and Carpenter SR. (2003). Catastrophic regime shifts in ecosystems: Linking theory to observation. Trends in Ecology and Evolution (18): 648–656.

Shalby A, Elshemy M, Zeidan BA. 2020. Assessment of climate change impacts on water quality parameters of Lake Burullus, Egypt. Environmental Science and Pollution Research, 27(26): 32157–32178.

Sheta BM. 2019. Biodiversity and habitat use of wintering and breeding waterbirds in Burullus Lake (Ramsar site), Egypt. CATRINA, 19(1): 47–54.

Siefter S, Dayton S, Movic B, Mutuler E. 1950. The estimation of glycogen with the anthrone reagent. Arch. Biochem. Biophys. (25): 191 – 192.

Tietz NW 1990. "Clinical Guide to laboratory tests".2nd ed. Philadelphia: WB Saunders, 26-29.

Vijayan MM, Aluru N, Leatherland JF. 2010. Stress response and the role of cortisol in Fish diseases and disorders. Leather land, J.F., Woo, P. T. K. (Eds.), CAB International, Wallingford, (2): 182-201.

Weichselbaum TE. 1946. "An accurate and rapid method for the determination of protein in a small amount of blood serum and plasma". Amer. J. Clin. Path., (7) :40-49.

Williamson CE. 2009. Lakes and reservoirs as sentinels, integrators, and regulators of climate change. Limnology and Oceanography (54): 2273–2282.

Ye X, Randall DJ. 1991. The effect of water pH on swimming performance in rainbow trout (Salmo gairdneri R.). Fish Physiol. Biochem. (9): 15–21.

Zaghloul FA, Hosny S, Faragallah HM. 2022. Preliminary assessment of water quality post-the first phase of the development plans in Lake Burullus, Deltaic coast of the Mediterranean Sea, Egypt. Scientific African, (16): 101-193.

Zaki MS, Sharaf NE, Rashad H, Mostafa SO, Fawzi OM. 2008. Diminution of aflatoxicosis in Tilapia nilotica fish bydietary supplementation with fix in toxin and Nigella sativa oil, Am. Eurasian J. Agric. Environ. Sci., (3): 211-215.