Egypt. J. Bot. **Vol. 62,** No.3, pp. 879-899 (2022)

Egyptian Journal of Botany

http://ejbo.journals.ekb.eg/

Phytoplankton and Bacterial Dynamics Related to the Physico-chemical Characteristics of Manzala Lake Water, Egypt

Abeer M.A. Mahmoud, Nasser S. Flefil#, Seliem M. El Sayed, Usama M. Tahoun, Mohamed E. Goher

National Institute of Oceanography and Fisheries (NIOF), Cairo, Egypt.

MANZALA Lake, the largest Egyptian northern lake, suffers from continuous deterioration as it receives huge amounts of different wastes. This study evaluated the abiotic and biotic conditions of the lake water (e.g., physicochemical variables, bacterial communities, and phytoplankton structures and their biochemical contents) from 11 sites along the lake in winter and summer 2020. The results revealed that the increase in phytoplankton densities and chlorophyll (*a*) in winter combined with increased nutrient contents. The highest concentrations of the biochemical contents of phytoplankton and the highest enumerations of bacterial indicators were recorded during summer. The sites close to the inlets of drains recorded a complete depletion of oxygen and a high ammonia content. The highest phytoplankton standing crop was recorded in the middle sector of the lake. Despite the efforts of the Egyptian government to rehabilitate Manzala Lake since 2017, the results showed an increase in pollution levels at various sites and the continued deterioration of the lake's ecological status. These results confirm the importance of increasing the efforts to restore the environmental health status of the lake, primarily by treating wastewater before it is discharged into the lake.

Keywords: Bacteria, Biochemical composition, Manzala Lake, Physiochemical parameters, Phytoplankton, Pollution levels.

Introduction

The Egyptian Mediterranean coast has six lakes or lagoons situated along the Nile Delta to the east of the Suez Canal: the Mariut, Edku, Burullus, Manzala, Port-Fouad, and Bardawil lakes (Hegab et al., 2020). These six lakes provide about 77% of the harvested fish from the Egyptian lakes (Shabaka, 2018). Because of the increased rate of development along the coastal belt of the Delta region, human impacts cause many environmental problems and intensive pressure. These impacts reduced the available lake volumes and restricted the free hydrodynamic flows within those lakes (El-Naggar et al., 2016). In addition, the aquatic environment has been a major concern because most of our ecological water systems are continuously being contaminated (Reemtsma & Jekel, 2006; Goher et al., 2015).

Among these Egyptian lakes, Manzala Lake is one of the most important sources of inland fisheries in Egypt. It is considered the second major source of natural fisheries after El-Burullus Lake. Moreover, it is estimated to yield about 19.71%, 34.71%, and 41.69% of the annual natural fisheries production, total lakes production, and delta lakes production in Egypt, respectively, in 2020. Also, Manzala Lake produced about 42,000tons of fish in 2016, which rose to 82,541tons in 2020 (CAPMAS, 2021; GAFRD, 2021).

#Corresponding author email: naserflefil@yahoo.com ORCID No: https://orcid.org/0000-0002-7495-3950

Received 16/06/2022 ; Accepted 01/08/2022

DOI: 10.21608/ejbo.2022.145176.2019

Edited by: Prof. Hosam Easa Elsaied, National Institute of Oceanography, NIOF, Egypt.

According to Abd Ellah (2021), Manzala Lake is greatly important locally and internationally. For instance, it is considered one of the most important wintering and nesting sites for many species of migratory birds (Khalil, 1990a; Ayache et al., 2009). It is expected to have a role in relieving the effects of climate change, and it plays a major role in protecting coastal cities from floods and storm inundation. Moreover, Manzala Lake has a high value for the biodiversity in the Mediterranean region (Ali & El-Magd, 2016). Also, it is a natural oxidation basin, which acts as a natural barrier between the Nile Delta and the Mediterranean Sea's drainage system and as a natural buffer zone preventing the intrusion of salty marine water into agricultural lands and groundwater (Shaltout et al., 2017).

However, Manzala Lake is exposed to many challenges, including pollution, illegal aquaculture practices, and a lack of monitoring of fish farms (Zahran et al., 2021). Also, the lake has shrunk over the last few decades because of land reclamation and the conversion of its substantial portions to fish farms, notably in the southern sections. Moreover, large parts of the lake are overgrown with aquatic vegetation, which reduces the open water to nearly half of its total area, speeding up land transformation (Saeed & Shaker, 2008; El-Bana, 2015). In addition, a quite large number of islets of various sizes and shapes play a role in the deterioration of the lake. In a previous study, Abdel Gawad (2018) proved that the lake might turn into a polluted and dead basin because of the modifications and changes inflicted on its environment. In 1900, its area was 1,709km^2, reaching 1,200km^2 in the 1970s. Its area has gradually decreased since the earliest decades of the 20th century. The area of the Lakelake was 904,785km^2 in 1981, as measured by Landsat imagery, while the area of open water was only 699,215km^2 because of the presence of a large number (1022) of islets in the lake (Maclaren, 1981). The total lake area reached 600km^2 in 2010 (El-Mezayen et al., 2018) and 565.91km^2 in 2016 (Abd Ellah, 2021).

This deterioration alarmed the authorities of the potential disappearance of Manzala Lake (Hereher, 2014), which must be rehabilitated in the soonest possible time (Rashad & Abdel-Azeem, 2017). Thus, in 2016, the Egyptian government launched an extensive program for the development of Egyptian lakes, with the maintenance of the aquatic basin of Manzala Lake given a high priority. After these efforts, the total lake area of Manzala Lake extended gradually to 572.41km^2 in 2020, with the open water area increasing to about 75% of the total lake area (Abd Ellah, 2021).

The main water sources of Manzala Lake are wastewater drains (7.7 billion m^3/year) (Dewedar et al., 1995). Hence, pollution from various sources, including sewage, industrial, and agricultural wastes, significantly impacts Manzala Lake. Consequently, the properties and quality of water severely deteriorated, with corresponding undesirable effects on biotic parameters, such as increases in pathogenic bacterial indicators and changes in phytoplankton structures.

The main objective of this work is to study recent phytoplankton and bacterial communities affected by the changes in the physicochemical characteristics of the lake water, especially during the rehabilitation period that started in 2017, to shed light on long-term changes in Manzala Lake during the past decades.

Materials and Methods

Study area

Manzala Lake is a rectangular basin about 60km long and 40km wide, with an average depth of 1.3m. It is located between latitudes 31°10′, 31°40′N and longitudes 31°50′ and 32°25′E (El-Badry, 2016). The lake is connected to the Mediterranean Sea by the straits of El-Gamil, Ashtoum Al-Gamil, Al-Baghdadi, El-Deiba, and, more recently, Al-Burg (at the northwest corner of the lake). The lake is also connected to the Suez Canal through a bit of exploring channel known as Al-Qabouti. These six openings supply the lake with marine water. The western and southern coasts have numerous inlets through which a vast quantity of wastewater is emptied into the lake. The most important drainage ditches are the Bahr El-Baqar, Hadous, Al-Sirw, Abu Garida, and Faraskour drains (Ghanem & Haggag, 2015). Sampling sites were selected to represent different sectors of Manzala Lake during the winter and summer seasons of 2020 (Table 1, Fig. 1).

TABLE 1. Details, longitude and latitude of the sampling locations

Sites	Feature	Latitude	Longitude
1	Boughaz El-Gmail	31°14’49.66” N	32°11’58.78” E
2	Boughaz Ashtoum El-Gmail (New El-Gamil)	31°17’17.97” N	32° 9’53.49” E
3	Boughaz El-Boghdady	31°20’47.80” N	31°59’50.94” E
4	Bahr Kurmullus, in the middle of the lake	31°16’4.88” N	32° 3’42.61” E
5	Bahr El-Hamrah, in the middle of the lake	31°16’31.33” N	32° 0’49.55” E
6	Bahr El-Bashtir 1, In front the new Bahr El Bqar Darin	31°12’2.64” N	32°12’11.01” E
7	Bahr El-Bashtir 2, in the south of the lake	31°11’5.18” N	32° 4’54.62” E
8	Bahr El-junaka (Infront the discharge point of several drains including new Bahr El Bqar Darin)	31°10’24.25” N	3228.71‘4 °” E
9	Bahr Dishdi (El-Mataryia)	31°11’25.20” N	32° 2’21.13” E
10	Bahr El-Diju (El-Serw)	31°15’14.21” N	31°51’29.45” E
11	Bahr El-Zarka	31°22’11.01” N	31°53’17.53” E

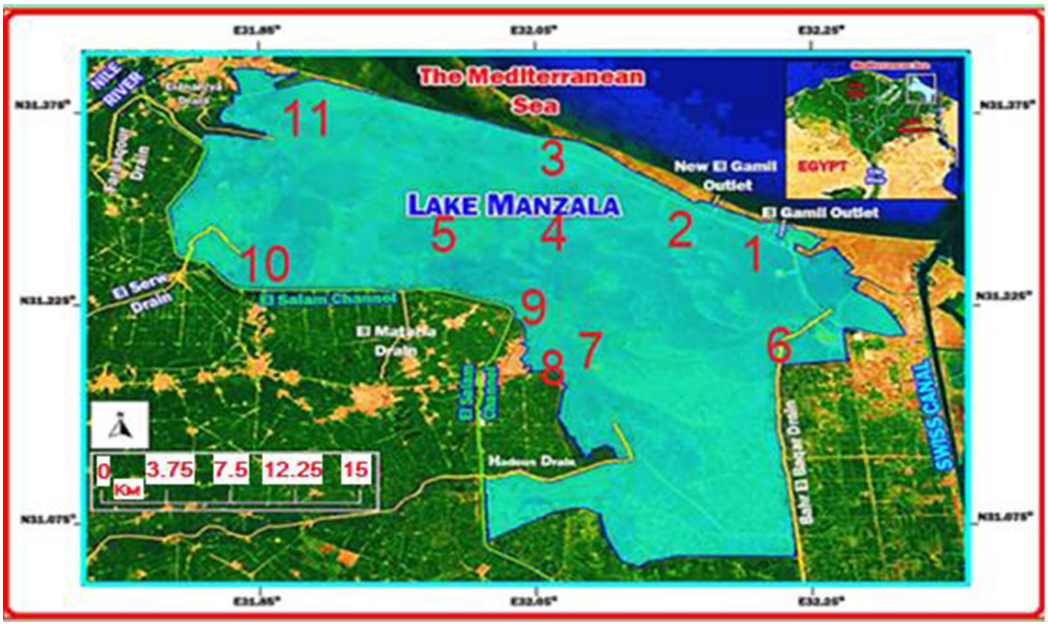

Fig. 1. Map of Manzala Lake showing sampling sites (After: Haroon, 2022)

Sampling program

Subsurface water samples were collected during winter using a 2L Ruttner water sampler (KC Denmark A/S). Ten water samples were collected in the winter of 2020, whereas 11 samples were collected during the summer of 2020. The water samples were kept in polyvinyl chloride plastic bottles and preserved in ice boxes for chemical analysis. Samples of dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected in glass oxygen stoppered bottles with a 300-cm^3 capacity. The samples of DO were fixed immediately by adding 1-ml $MnSO_4$ (40%) and 1-ml alkaline KI solution and mixed well. Meanwhile, the BOD bottle samples were covered with aluminum foil to reflect light. For the bacterial examination, water samples were taken in clean, sterile 1-l glass bottles and transported directly to the laboratories for analysis. The water samples for phytoplankton analysis were stored in polyethylene bottles and immediately preserved using a formalin solution for examination in the laboratory APHA (2017).

Procedures of analysis

The physico-chemical parameters of water samples were determined according to the standard methods (APHA, 2005). In situ, PH, EC, and water temperature were measured using a multiparameter (Hanna HI9829, Woonsocket, RI, USA). Total Dissolved Solids (TDS) were measured by filtering a known volume of a well-mixed sample volume through a glass microfiber filter (GF/C); the filtrate is evaporated to dryness in a weighed dish to constant weight at 180°C. The increase in weight represents the TDS. The modified Winkler method was used to measure DO and BOD. The chemical oxygen demand (COD) was measured using the potassium permanganate method. Carbonate (CO_3^{-2}) and bicarbonate (CO_3^{-1}) alkalinity were determined by titrating using sulphuric (H_2SO_4) acid solution. Nitrite (NO_2^{2}) was determined through formation of a reddish purple azo-dye by coupling diazotized sulphanilamide with N-(1-naphthyl)-ethylenediamine dihydrochloride (NED). Nitrate (NH_4^{+}) was measured as nitrite after reduction using a cadmium column. Ammonia, reactive silicate and Orthophosphate were determined using the phenate method, molybdosilicate and ascorbic acid method, respectively.

Total viable bacterial counts (TVBCs) at 22°C and 37°C were enumerated by pour plate method using nutrient agar media. Enumeration of total coliforms (TC) and faecal coliforms (FC) was determined using the most probable number (MPN) method. MacConkey broth media were used, tubes were incubated at 37°C for 48h for total coliforms and 44°C (in a water bath) for 24h. for faecal coliforms, formation of acid and gas were positive, confirmation tests for positive tubes were streaked on the Eosin Methylene Blue (EMB) agar plates using sterile loop and incubated at 37°C for 24h. MPN of faecal streptococci (FS) was determined using azide dextrose broth at 37°C for 48h; Confirmation test was applied for a positive tube was indicated by dense turbidity and confirmed using ethyl violet azide dextrose broth incubated at 37°C for 24h. The formation of a purple button at the bottom of the tube confirmed the presence of faecal streptococci (APHA, 2005).

For biochemical analysis and chlorophyll (a), a known volume of water samples was filtrated by Whatman GF/F fiber circles. Total protein was determined by the Biuret method (David & Hazel, 1993), and total lipid was determined by Chabrol & Castellano (1961). At the same time, filter papers of chlorophyll (a) were socked in 5 ml acetone (90%) for extracting chlorophyll (a) and preserved under dark and cold conditions overnight. The samples were then shaken well and centrifuged. The clear extract was carefully syphoned and spectrophotometrically measured at 750, 664, 647, and 630nm with a jenway 6800 UV/visible spectrophotometer, UK. The concentrations are calculated according to the trichromatic equation, using 90% acetone as a blank according to APHA (2017).

For phytoplankton investigation, 500ml of the preserved water samples, with 4% neutral formalin and Lugol's iodine solution, were transferred in a glass cylinder. Extra Lugol's iodine solution was added until the colour changed to faint tea colour, covered with aluminium foil, and allowed for five days to settle phytoplankton cells (APHA, 2017). 90% of the supernatant fluid was siphoned off, and the sample volume was adjusted to a fixed volume (50mL) that was transferred to a small plastic vial for microscopic examination. The drop method was applied for counting and identifying phytoplankton species; triplicate samples (2 or 5μL) were taken and examined under an inverted microscope ZEISS IM 4738, with magnification power 40 and 100x. The results of phytoplankton density were presented as a number of units per liter (units/L). The main references used in phytoplankton identification and classification were: Verlencar & Desai (2004), Lee (2008), Bellinger & Sigee (2010, 2015), Munshi et al. (2010). The currently accepted nomenclature of all taxa has been given according to Guiry & Guiry (2022).

Statistical analysis

Spearman's rank correlation analysis was carried out to elucidate relationships between abiotic and biotic parameters. Minimum, maximum, means and standard deviations were done using Excel-Stat software (2019) and were reported when appropriate. One-way ANOVA test was applied to detect the spatial and temporal significant differences for the obtained data using IBM SPSS Statistics 20 software package.

Results and Discussion

Physicochemical parameters

Water quality refers to interrelated properties, including physical, chemical, and biological characteristics related to life's existence, particularly human activity. Predetermined uses are necessary for water quality determination, and each of these uses affects, more or less, the water quality (El-Halag et al., 2013). The water quality in shallow lakes around agricultural lands is influenced by several factors. Extrinsic factors include the frequent loss of fertilizers due to runoff (Hooda et al., 2000), whereas intrinsic factors include sediment aggradation or float (Reddy et al., 1996) and the uptake of hydrophytes or their decomposition (Rectenwald & Drenner, 2000).

The physicochemical characteristics of the water in Manzala Lake are presented in Table 2. The temperature ranged from 20.29°C to 32.45°C, with averages of 16.27°C and 31.17°C during winter and summer, respectively. There were highly significant differences ($P< 0.01$) between seasons. The water in Manzala Lake was within the superior value of 8°C–28°C for fish and aquatic organisms in winter and exceeded the normal value in summer seasons. The temperature was positively correlated with transparency ($r= 0.44$, $n= 21$, $P< 0.05$) but negatively correlated with NH_4 ($r= -0.46$, $n= 31$, $P< 0.05$) and NO_2 ($r= -0.63$, $n= 21$, $P< 0.01$). Transparency was affected by the particulate content of the lake water from suspended matter and floating substances (Haroon et al., 2018). Manzala Lake was characterized by turbid water; the water transparency fluctuated between 10 and 70cm. Meanwhile, the lowest value (10cm) was recorded at sites 6 and 9 during winter because of the heavily polluted effluent loaded with agriculture, industrial, and domestic wastes from the Bahr El-Baqarand Hodous drains, whereas the maximum value was recorded in the east–west of the lake far from the pollution sources. These results agree with those obtained by Goher et al. (2017).

The electrical conductivity showed a noticeable increase northward near El Boghazes and recorded the maximum value of 31.29ms/cm at site 3. In contrast, the value of 1.67ms/cm was recorded at site 9. Noticeably, the electrical conductivity increased in summer (9.02ms/cm on average) compared with that in winter (5.32ms/cm on average) because of the increase in seawater intrusion into the lake. This result agrees with that obtained by Elmorsi et al. (2017). The electrical conductivity increased in sites near the Boghazes entrance (outlets) and decreased in the east and south sectors because of the entrance of brackish water and freshwater via different drains.

The salinity or total dissolved solids (TDS) measures the amount of dissolved salts in water, mainly major anions (CO_3, HCO_3, Cl, and SO_4) and major cations (Na, K, Ca, and Mg). TDS widely varied along Manzala Lake, with a significant spatial difference ($P< 0.05$). The lowest value was 1.16g/L at site 9 (opposite the discharge of domestic wastes), and the highest was 21.9g/L at site 3 (front of Boughaz El-Boghdady). Notably, the TDS was higher in summer (6.32g/L on average) than that in winter (3.81g/L on average). This result may be due to the greater amounts of seawater inflow into the lake than those of brackish water and freshwater discharged into the lake through several drains.

The pH values of the Manzala Lake waters lay on the alkaline side. The pH values ranged from 7.56 to 8.97, with averages of 8.27 and 8.29 during winter and summer, respectively. There were highly significant differences ($P< 0.01$) between sites. Stations 6 and 8 had the lowest concentrations due to decreased phytoplankton activity and sediment bacterial activity, which released methane and hydrogen sulfide and formed organic acids and ammonia in the sediment (Goher et al., 2014). This result was confirmed by the high positive correlations of pH with NH_4 ($r= -0.71$), pH with BOD ($r= -0.77$), and pH with the chemical oxygen demand (COD) ($r = -0.78$) ($n = 21$; $P< 0.01$). Conversely, the maximum pH value was recorded in the middle sector of the lake at site 5, which was accompanied by an increase in photosynthesis activity. According to Yin et al. (2016), intensive photosynthesis would increase the pH. This result was confirmed by the high positive correlation of pH with DO ($r = 0.77$, $n = 21$; $P< 0.01$), which coincides with the results obtained by Elsayed et al. (2019) and Goher et al. (2019).

Carbonate and bicarbonate alkalinities measure the water's ability to neutralize acids. The results pointed to the irregular distribution pattern of carbonate: it was completely depleted at sites 6, 8, and 9 in winter and in sites 6–9 in summer, whereas the highest value (16.8mg/L). was recorded at site 4. The bicarbonate concentrations were much greater than the carbonate contents, ranging between 181.8 and 491.4mg/L. The lowest value was recorded at site 4, whereas the maximum was recorded at site 8, with averages of 230.3 and 378.1mg/L in winter and summer, respectively.

TABLE 2. Minimum, maximum, mean, and ± standard deviation of the water parameters of Manzala Lake, 2020

Parameter	Winter				Summer			
	Min	Max	Average	±SD	Min	Max	Average	±SD
Temp	15.60	16.90	16.27	0.43	29.22	32.45	31.17	1.42
Trans cm	10.00	35.00	15.90	7.34	12.00	67.00	27.50	15.20
EC ms/cm	1.99	12.83	5.32	3.11	1.67	31.29	9.02	9.55
TDS g/l	1.39	8.98	3.72	2.17	1.17	21.9	6.32	6.68
PH	7.62	8.97	8.27	0.48	7.56	8.93	8.29	0.54
DO mg/l	0.70	14.06	7.47	4.24	0.00	14.70	7.51	5.55
BOD mg /l	8.34	76.80	37.51	22.99	8.25	88.60	41.13	26.54
CO_3 mg/l	0.00	16.80	7.32	6.05	0.00	12.00	5.64	5.09
HCO_3 mg/l	181.8	270.9	230.3	34.80	242.1	491.4	378.0	91.00
COD mg/l	19.60	96.80	56.80	25.92	15.80	132.96	60.05	36.20
NH_4 mg/l	0.47	14.62	6.70	5.35	0.10	10.94	2.80	3.72
NO_2 µg/l	53.33	273.96	137.12	67.67	19.74	125.16	54.89	38.14
NO_3 µg/l	112.11	850.36	402.37	246.68	63.75	705.00	207.45	191.97
PO_4 µg/l	24.20	113.30	58.08	29.78	9.90	143.00	34.43	40.15
SiO_2 µg/l	3.20	10.91	6.95	2.97	3.54	7.95	6.25	1.39

CO_3 was positively correlated with pH (r= 0.90, n= 21; P< 0.01) and DO (r= 0.71, n= 21; P< 0.01), whereas it was negatively correlated with BOD (r= −0.66, n= 21; P< 0.01) and COD (r= −0.66, n= 21; P< 0.01). In comparison, HCO_3 was positively correlated with temperature (r= 0.68, n= 21; P< 0.01) but negatively correlated with CO_3 (r= −0.59, n= 21; P< 0.05), NO_3 (r= −0.53, n= 21; P< 0.05), and pH (r= −0.68, n= 21; P< 0.01). At high temperatures, the greater the HCO_3, the lower the pH value. The temperature increase shifts the following equation to the right, increasing the CO_3 to HCO_3 ratio. Also, the (H^+) levels increase, which decreases the pH value.

$$HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$$

DO is considered an important parameter in assessing the degree of pollution in natural water. DO in water is principally sourced directly from the atmosphere through the exposed surface and from the photosynthesis of chlorophyll-bearing plants (El-Sayed, 2015).

The DO results show a wide variation, with decreased DO in the southern section due to the effect of drains. Site 6 showed a noticeable effect of domestic waste from the Bahr El-Baqar drain, which indicates a complete depletion of DO in summer and a low value (0.7mg/L) in winter. In contrast, the maximum value was 14.7mg/L recorded at site 1, with averages of 7.47 and 7.51mg/L during winter and summer, respectively. Meanwhile, DO is negatively correlated with NH_4 (r= −0.68, n= 21; P< 0.01).

BOD measures the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) to oxidize organic matter (El-Sayed, 2011). Analysis of variance (ANOVA) results showed a highly significant difference between sites, with averages of 37.51 and 41.13mg/L during winter and summer, respectively. The minimum value of 8.25 mg/l was recorded at site 10 in summer. The maximum value of 88.6 mg/l was recorded at site 6, which was attributed to the discharge of heavily polluted effluent loaded with agriculture, industrial, and domestic wastes (Hafez et al., 2008). BOD was positively correlated with COD (r = 0.98) and NH_4 (r = 0.89) (n= 21; P< 0.01).

The COD is the total amount of oxygen required to completely oxidize all organic matter in a site to CO_2 and H_2O. The BOD and COD tests are good indicators of water pollution using the organic matter that consumes DO in the aquatic environment (Goher et al., 2018; El Sayed et al., 2020). In the same manner as BOD, the COD increased in the southeast section, which was attributed to the effect of drains. The COD values showed a wide range, with highly significant differences between stations. Site 10 had the lowest COD value of 15.8mg/L in summer, whereas site 6 recorded the highest COD value of 132.96 mg/l, with averages of 56.80 and 60.05 mg/l during winter and summer, respectively. COD was highly positively correlated with NH_4 ($r= 0.79$, $n= 21$; $P< 0.01$).

The nutrient salts include compounds containing nitrogen, phosphorus, or silicate in either available or unavailable forms (Elsayed et al., 2019). Total ammonia includes the toxic non-ionized form (NH_3) and the ionized nontoxic form (NH_4^+) (Bhatnagar & Devi, 2013). Generally, the ammonia contents were in the opposite manner as that of DO. The ammonia concentration had a wide fluctuation with an increase on the southeast side, which may be attributed to major drains such as Bahr El-Baqar, El Matteria, and Hadus (Abu Khatita et al., 2017). The ANOVA results showed highly spatial and temporal significant differences. For instance, Site 10 reported the lowest concentration of 0.103mg/L in summer, whereas site 6 recorded the highest concentration of 14.62mg/L in winter, with averages of 6.7 and 2.8mg/L during winter and summer, respectively. The value of ammonia exceeded the permissible limits for aquatic life of CCME (2017) in most stations, especially in the southern sector.

The nitrite (NO_2–N) values ranged between 19.74 and 273.96µg/L, with a significant difference between seasons. The lowest values were recorded at sites 5 and 6 during summer. The maximum was recorded at site 1, during the same season, with averages of 137.12 and 54.89µg/L during winter and summer, respectively. Generally, the NO_2^{-2} levels were higher than the allowed maximum nitrite concentration of 60µg/L (CCME, 2017). NO_2^{-2} was highly positively correlated with NO_3^- ($r= 0.65$, $n= 21$; $P< 0.01$), indicating that diffuse domestic sources heavily loaded the studied area.

Nitrate is the prime plant nutrient, and raising its content might increase water eutrophication. High nitrate contents may be accompanied by high chloride concentrations in areas of organic pollution (Flemer et al., 1998). In this study, all nitrate levels were much lower than the allowed maximum nitrate concentration of 2.93mg/L (CCME, 2017), where the nitrate values (NO_3–N) ranged from 63.75µg/L at site 3 in summer to 850.36µg/L at site 5 during winter, with averages of 402.37 and 207.25µg/L in winter and summer, respectively. Nitrate was highly positively correlated with phosphate ($r= 0.56$, $n= 21$; $P< 0.01$).

Phosphates do not pose human or health risks except in very high concentrations. In this study, the values of orthophosphate were irregularly distributed and ranged from 9.9µg/L at site 6 during summer to 143µg/L at site 3 in the same season, with averages of 58.8 and 34.43µg/L during winter and summer, respectively. There was a clear indication that Manzala Lake, which is classified as either eutrophic or hypereutrophic based on the amounts of nitrogen and phosphorus, had high levels of nitrogenous salts, which indicate eutrophication. The high concentrations of chlorophyll (a) corroborated these findings (Table 3).

Silica is widespread and always present in surface waters, and it exists in water in dissolved, suspended, and colloidal states. The dissolved forms are represented mostly by silica acid, its dissociation and association products, and organo-silicon compounds (Chapman, 1996). Reactive silicate (SiO_4–Si) respectively ranged from 3.2 to 10.91mg/L at stations 3 and 8 in winter, with averages of 6.95 and 6.25mg/L during winter and summer, respectively.

Bacterial assessment

The bacteriological investigation of the water environment is significant in monitoring the presence of harmful microorganisms for humans and detecting bacterial species that might be transferred to the environments of aquatic organisms such as fish, which might represent health risks and cause deaths. Thus, monitoring serves as a guide to protect human health, fish quality, and aquatic organisms (Abdel-Hamid, 2017).

The bacterial assessments at El-Manzala Lake are shown in Table 4. The numbers of the total bacterial count at 22°C ranged from 2×10^4 to 244×10^4 CFU/ml and 0.4×10^4 to 280×10^4 CFU/mL in winter and summer, respectively. In addition, enumerations of the total count of bacteria at 37°C were similar during winter and summer and ranged from 6×10^4 to 220×10^4 CFU/ml. Furthermore, the highest values of the total count were recorded at sites 9 and 8 during winter and summer, respectively.

TABLE 3. Classification of Eutrophic status according to the leaves of P, N, Ch (*a*), and Secchi depth

Item	Oligotrophic	mesotrophic	Eutrophic	Hyper eutrophic	Present study
Phosphorus µg/L	4.1-9.0	9.0-20	20-43	>96	9.9-143.(46.25)
Nitrogen µg/L	73-157	157-337	337-725	>1558	187.5-15744 (5147)
chlorophyll (a) µg/L	0.82-2.0	2.0-5.0	5.0-12	>31	38.83 - 599.92
Secchi depth (m)	15-7.8	7.8-3.6	3.6-1.6	<0.7	0.1-0.7 (0.22)

TABLE 4. Bacterial assessment at El-Manzala Lake during 2020

Sites	TVBC at 37°C × 10^4 CFUmL^{-1}		TVBC at 22°C × 10^4 CFUmL^{-1}		TC(MPN /100mL)		FC(MPN /100mL)		FS(MPN /100mL)	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1	72	0.2	13	0.4	7×10^{2}	150	7×10^{2}	90	7×10^{2}	300
2	13	1	12	0.5	20	230	20	90	9×10^{2}	23×10^{2}
3	6	92	2	9.8	7×10^{2}	40	4×10^{2}	40	7×10^{2}	11×10^{2}
4	32	75	16	86	3×10^{2}	35×10^{2}	3×10^{2}	15×10^{2}	7×10^{2}	280
5	15	0.6	2	0.7	12×10^{3}	21	75×10^{2}	15	93×10^{2}	90
6	46	180	65	200	21×10^{3}	28×10^{3}	93×10^{2}	21×10^{3}	93×10^{2}	9×10^{3}
7	14	220	7	210	6×10^{2}	110×10^{4}	3×10^{2}	46×10^{4}	21×10^{2}	15×10^{2}
8	52	260	6	280	15×10^{2}	240×10^{4}	9×10^{2}	210×10^{4}	9×10^{2}	16×10^{3}
9	220	7	244	13	46×10^{4}	35×10^{2}	24×10^{4}	15×10^{2}	15×10^{4}	390
10	35	150	22	145	11×10^{2}	1100×10^{2}	7×10^{2}	460×10^{2}	93×10^{2}	4×10^{2}
11	N.C.	124	N.C.	112	N.C.	150×10^{2}	N.C.	28×10^{2}	N.C.	23×10^{2}
Mean	50.5	100.9	38.9	96.1	49.9×10^{3}	33.3×10^{4}	26×10^{3}	23.9×10^{4}	18.4×10^{3}	2.3×10^{3}
Max.	220	260	244	280	46×10^{4}	240×10^{4}	24×10^{4}	210×10^{4}	15×10^{4}	16×10^{3}
Min.	6	0.2	2	0.4	20	21	20	15	7×10^{2}	90
S.D	63.05	94.05	74.4	101.04	14.4×10^{4}	75.9×10^{4}	7.5×10^{4}	63.2×10^{4}	4.6×10^{4}	4.6×10^{3}

N.C.= Not collected sample.

On another note, the enumeration of microbial indicators such as the total (TC) and fecal coliforms (FC) as well as Enterococcus spp. is used internationally on a wide range for water quality evaluations and health hazard assessments of fresh or surface water such as lakes, rivers, and others (Newall et al., 2015; Al-Afify et al., 2019; Goher et al., 2021). In this study, the enumerations of TC, FC, and fecal streptococci (FS) were done using most probable number (MPN) techniques. The numbers of TC fluctuated between 20–46 × 10^4 and 20–240 × 10^4 MPN/100mL during winter and summer, respectively. Moreover, FC bacteria are very good indicators of fecal contamination, and they are harmful microbial contaminants that may cause serious diseases for humans, birds, and animals (U.S. EPA, 2013). The FC results for Lake El-Manzala were enumerated during winter and summer and ranged from 20 to 24 × 10^4 MPN/100mL and from 15 to 210 × 10^4 MPN/100mL, respectively. Likewise, FS was used to detect whether the pollution was caused by human or animal sources. The presence of high numbers of these microorganisms in the water indicates the possibility of pathogen presence. Here, the FS in winter and summer ranged from 7 × 102 to 15 × 10^4 MPN/ 100mL and 90 to 16 × 10^3 MPN/ 100mL, respectively.

The highest enumerations of TC, FC, and FS were recorded at site 9 during winter. In contrast, site 2 recorded the lowest enumerations for TC and FC bacteria. In addition, there were high concentrations of TC, FC, and FS bacteria at site 8 (the discharging point of the new Bahr El-Baqar, Hadous, and Ramsis drains) during summer, indicating high pollution at these locations due to drain discharge water. However, these concentrations exceeded the World Health Organization›s permissible limits, and the results completely agree with those of Tahoun (2016) and Abdel-Hamid (2017).

It must be mentioned that the lowest bacterial populations in the coliforms group recorded at site 5 (the middle of Lake El-Manzala) during the summer of 2020 referred to the enhancement in water quality properties. Also, site 5 is located in the middle sector of the lake, which is comparatively far away from the pollution sources.

Phytoplankton community structure

Undoubtedly, aquatic ecosystems depend largely on phytoplankton density. As the main product of the aquatic environment and the basis of the food web, phytoplankton plays an important role in the nutrient cycle and energy conversion (Suikkanen et al., 2007). Studying the succession of the phytoplankton community is of important theoretical and practical significance. Several research studies have shown that temperature, light, and nutrients are important factors influencing the success of a phytoplankton community (Fleming-Lehtinen & Laamanen, 2012).

Microscopic examinations of phytoplankton samples from the lake during the winter season of 2020 revealed that 90 species belong to six phyla. Its community structure indicated that members of Bacillariophyta were the most common species (31 spp.), followed by Chlorophyta (21 spp.), Cyanophyta (20 spp.), and Euglinophyta (11 spp.), whereas the others belonging to Dinophyta (4 spp.) and Carophyta (3 spp.) occurred less frequently. Meanwhile, phytoplankton samples during the summer season revealed that a total of 93 species belong to seven phyla. Chlorophyta were the most common species (33 spp.), followed by Cyanophyta (23 spp.), Bacillariophyta (18 spp.), and Euglinophyta (9 spp.). In contrast, those belonging to Dinophyta (5 spp.), Carophyta (4 spp.), and Cryptophyta (1 sp.) were less frequent.

The total number of plankton species recorded during the study period was 119 species representing seven major phyla: Chlorophyta (36 sp.); Bacillariophyta (33 sp.); Cyanobacteria (25 sp.); Euglenozoa (13 sp.); Miozoa (dinoflagellates) (7 sp.); Charophyta (4 sp.); and Cryptophyta (1 sp.) (Table 5).

Seasonal variations in phytoplankton densities increased during winter at 83535 × 10^4 units/L standing crop, whereas the least standing crop of phytoplankton was during the summer season (67400 × 10^4 units /L) (Table 6).

Geographically, the minimum phytoplankton standing crops existed in New Boghaz El-Gamil (station 2), which recorded 2630 and 2700 × 10^4 units/L during winter and summer, respectively. This is due to the lack of nutrients in the Boughaz area in comparison with the other sites in the lake. The highest phytoplankton standing crops were recorded in the middle of the lake: station 5 during winter and station 4 during summer. The middle sector of the lake contains sufficient amounts of nutrients and is somewhat far from pollution sources and from severe changes that may occur in many areas within the lake.

TABLE 5. Seasonal variation of phytoplankton phyla density (No. of units ×10^4/L) in Manzala Lake during 2020

Phytoplankton phyla	Winter		Summer	
	Species No.	Count *10^4 unit/L	Species No.	Count *10^4 unit/L
Chlorophyta	21	14045	33	17950
Bacillariopyhta	31	41420	18	16750
Cyanobacteria	20	22120	23	26200
Euglinophyta	11	760	9	1450
Dinophyta	4	3790	5	3000
Charophyta	3	1400	4	750
Cryptophyta	0	0	1	1300
Total	90	83535	93	67400

TABLE 6. Seasonal variations in phytoplankton densities (No. of units ×10⁴/l) in Manzala Lake during 2020

Sites	Winter		Summer	
	Species No.	Count *10^4 unit/L	Species No.	Count *10^4 unit/L
1	40	2785	49	10000
2	36	2630	26	2700
3	28	3970	25	3650
4	38	13150	61	11400
5	40	19050	34	4850
6	31	6250	35	4550
7	52	13000	50	7400
8	34	6850	49	9500
9	36	6050	22	4000
10	44	9800	34	4050
11	-	-	38	5300
Average	8353.5*10^4 unit/L		6127.3*10^4 unit/L	

Chlorophyll (a)

Pigments, an important component of phytoplankton, serve as light harvesters and defenders during photosynthesis (Wang & Moisan, 2020). Phytoplankton pigments absorb sunlight. The resulting photosynthesis and its products, particularly oxygen and organic compounds, depend on the light energy captured by various phytoplankton pigments (Falkowski, 2002; Roy et al., 2011). Chlorophyll (a) is the most important pigment for light harvesting.

During the study period, the results showed noticeable variations in chlorophyll (*a*), which fluctuated between 72.50µg/L at the severely polluted Bahr El-Baqar drain (station 6) and 459.14µg/L at station 5, which is in the middle of the lake during the winter season. This mirrored the results of the phytoplankton counts. In summer, the chlorophyll (*a*) content fluctuated between the lowest value of 38.83µg/L at the nutrient-deficient station 11 in the northwestern part of the lake and the maximum value of 599.92µg/L at station 8, which is a discharging point of drains (Fig. 2). The significant increase in chlorophyll (*a*) content at site 8 may be attributed to the increase in the nutrient levels and the water stagnation and temperature elevation with a marked increase in cyanobacteria content. This finding agrees with those obtained by Flefil (2017). However, based on the seasonal means, chlorophyll (*a*) levels showed a slight increase in winter compared with that in summer. This is similar to the phytoplankton results and coincides with the results of Flefil & Mahmoud (2021) for Qarun Lake.

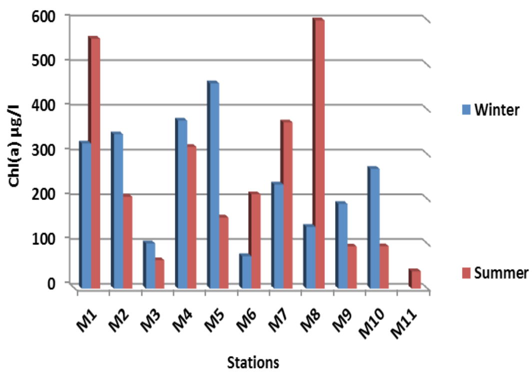

Fig. 2. Chlorophyll (*a*) concentrations in Manzala Lake during 2020

Biochemical contents of phytoplankton

Phytoplankton is the main food source for aquatic animals and is the primary supply of organic matter for a wide range of lake consumers. The importance of phytoplankton as a primary source of nutrition for fish is generally known, and research into phytoplankton and the factors that influence its biomass, nutritional quality, and productivity is essential for fisheries management.

The biochemical content is used to determine the nutritional quality of phytoplankton. Seasonal and regional variations in algal biochemical content are used as biomarkers for a body of water. Several investigations have been conducted concerning the Lake Manzala ecosystem because of its important economic implications. Our study investigated the effects of different environmental factors on the biochemical contents of the phytoplankton community during the winter and summer seasons of 2020.

In winter, the maximum protein content (8.18mg/L) was detected at station 8 (the collection area of the effluents of the new Bahr El-Baqar and Hadous, whereas the minimum value (1.14mg/L) was detected in winter in New El-Gamil (site 2). On another note, the maximum lipid content (0.116mg/L) was detected in the middle of Manzala Lake (site 4), whereas the minimum value (0.001mg/L) was detected at site 8 (Fig. 3). In summer, the maximum protein content (8.41mg/L) was detected at site 6, which is in front of the discharge point of the old Bahr El-Baqar drain, whereas the minimum value (0.68mg/L) was found at site 7. As regards the lipid content, the maximum value (0.256mg/L) was recorded at site 4 in the middle sector of Manzala Lake, whereas the minimum value (0.002mg/L) was detected at site 3 (opposite to the El-Boughdady outlet). According to the ANOVA analysis, the total protein levels were significantly different among stations ($P< 0.05$), whereas the total lipid content showed a high significant temporal difference ($P < 0.001$). Generally, the highest levels of protein and lipid contents were recorded in summer, which may be due to the behavior of some phytoplankton that blooms at high temperatures. This result agrees with that of Abd El-Hady (2008). The total protein constitutes a major part of the biochemical contents of phytoplankton, whereas the total lipid constitutes a minor one. These findings agree with those of Abd El-Karim & Mahmoud (2016).

In light of the current findings, some phytoplankton increases their lipid content to defend themselves from bacteria, whereas others reduce their protein content in response to bacteria. These results agree with Mahmoud et al. (2022) and Newall et al. (2015). Generally, the biochemical composition of phytoplankton could be a good predictor of their nutritional content and a good integrator with the surrounding ecosystems where they develop (Sabae & Mahmoud, 2021). Also, the biochemical composition of phytoplankton is affected by the bacterial load, nutrient concentration, physicochemical parameters, and discharged contaminants and drainage water.

Correlation analyses indicated that the total protein content was negatively affected by nitrate salts (NO_3) ($r= -0.9, P<0.01$) but positively affected by ammonium-nitrogen (NH_3) ($r= 0.45, P< 0.05$). The total lipid content was negatively affected by phosphate salt (PO_4) ($r= -0.83, P< 0.01$), but positively correlated with chlorophyll, ammonium-nitrogen, bicarbonate, and FS bacteria (r= 0.9, 0.78, 0.7, 0.47, and 0.46, respectively). In the examined regions of Lake Manzala, the biochemical compositions, pigments, and bacterial load responses to variations in nutrient concentrations varied depending on location and physicochemical characteristics. Many other parameters associated with nutrients, such as photic conditions, zooplankton grazing pressure, lake morphometry, and phytoplankton species composition can cause disparities in the phytoplankton biomass and biochemical composition response to different nutrient sources (Bucka & Wilk-Wozniak, 2003). Also, Komárek & Perman (1978) found that other variables that can affect phytoplankton community growth may explain the changes in the phytoplankton response to nutrients. Variations in temperature, light, and metal content are likely to cause changes in microalgae biochemical compositions (Anonymous, 2007). Both seawater intrusion and treated/untreated polluted fresh water drained into Lake Manzala are thought to significantly affect the phytoplankton composition, distribution, and dominating functional groupings (Abd El-Karim, 2008).

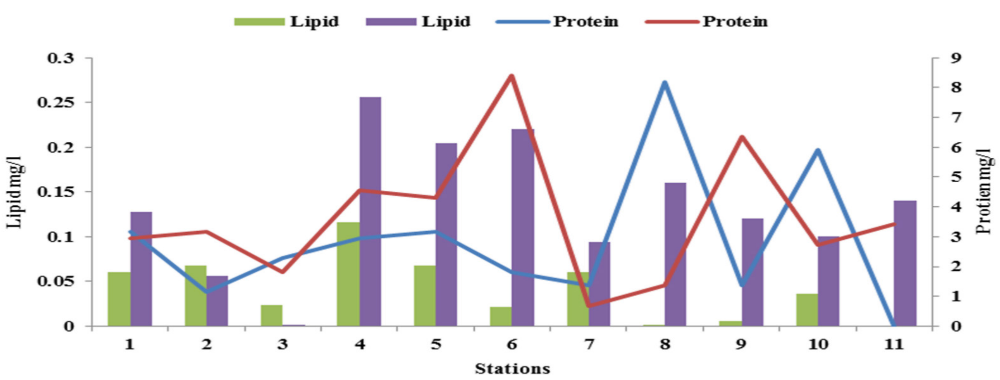

Fig. 3. Biochemical contents of phytoplankton in Lake Manzala

Long-term assessments are very important in understanding changes in aquatic environments and water bodies. These are also used to interpret and identify trends, cycles, and nonrecurring events, which are very important for complex systems (Burt et al., 2014). Regarding Manzala Lake, the salinity noticeably recorded wide fluctuations during the last decades, where the average value recorded (17.24‰) in 1967, and deceased to (5.37‰) in 1975, and (2.53‰) in 2001, whereas it gradually increased to 4.26‰ in 2015 and 5.02‰ in 2020. Although there is a noticeable spatial difference in the DO values in previous studies, the lake is generally oxygenated, except for the areas close to the inlets of different wastewaters, where the DO is completely depleted. Table 7 shows that COD and BOD have remarkably increased in the last decade. Meanwhile, the nutrient results have fluctuated through time. Generally, the long-term changes in the physicochemical characteristics of the Manzala Lake water confirmed the spatial and temporal differences of most parameters according to the quantities and quality of the different wastes discharged into the lake, in addition to the amounts of seawater that enter the lake through boughazes.

Table 8 shows the long-term changes in the bacterial indicators in Manzala Lake water, considered a suitable approach for comparing the present data with previous studies. Briefly, the data show a gradual increase in coliforms groups at the lowest and highest readings starting from 1999 till 2014, indicating a gradual increase in the pollution rate during this period. Meanwhile, the data on the total bacterial count showed irregular variations over several years, which may be attributed to different factors such as the variation of the amounts and types of pollutants discharged into the lake continuously through the years.

Most previous studies showed that the lowest numbers of the bacterial indicators were recorded at sites opposite the Boghazes (which feed the lake with saline water from the Mediterranean Sea), whereas the greatest bacterial indicators were found mostly at the sites close to the discharge points of polluted and untreated water via the drains. This data interpretation agrees with the results obtained by Tahoun (2016), Zaky & Ibrahim (2017), and El-ghannam et al. (2020).

The diversity of phytoplankton in Manzala Lake varied over time. For instance, diatoms were the most prevalent group during the past 35 years, where they prevailed from 1985 to 1993 (Ibrahim, 1989; Khalil, 1990a; El-Sherif & Gharib, 2001). Then, Chlorophyceae predominated from 2003 to 2007 (Ramdani et al., 2009; Abd El-Karim, 2008, 2009). Thereafter, diatoms returned to the fore again from 2010 to 2013 (Khairy et al., 2015; Yassin et al., 2020). From 2014 to 2019, Cyanophyceae prevailed (Abdel Monem et al., 2017; Flefil, 2017; Deyab et al., 2019, 2020) before the diatoms returned to the fore again in 2020 (Table 9).

The dominating diatoms appear to be functional surrogates because they can successfully exhaust inorganic nutrient accumulations over the winter and produce bloom-level biomass that contributes to vertical organic matter export. However, the group has extremely diverse sedimentation patterns, and the water floor in different sub-basins has varying abilities to mineralize the settled biomass. Moreover, diatoms sink swiftly out of the euphotic zone. Thus, the diatom dominance directly impacts both the midsummer nutrient pools of the water column and the organic matter input to the sediment, although in opposite directions (Spilling et al., 2018), where environmental changes during winter from rain and wind play a major role in forming diatom clusters in this environment (Shibabaw et al., 2021).

Meanwhile, the increase in Chlorophyta and Cyanobacteria in the lake was due to the increase in nitrogen and phosphorous concentrations and the organic load received from many domestic, agricultural, and industrial drains. When the water flow slows, Cyanobacteria become dominant instead of Chlorophyta and vice versa. The dominance of phytoplankton changed from Chlorophyta to Cyanobacteria in the abundance of nutrients from sewage and industrial effluents in surface waters (Wang et al., 2015; Hou et al., 2018).

TABLE 7. Long-term changes of a physicochemical parameters in the water of Manzala Lake

Date	Temp.	Salinity ‰	pH	NO_3 µg/L	NO_2 µg/L	NH_4 mg/L	PO_4 µg/L	DO mg/L	BOD mg/L	COD mg/L	References
1967		17.24									Youssef (1973)
1985		5.37									El-Araby (1990)
1986			7.6-8.8								Khedr (1989)
1985-1986	12-30.1	0.4-36	7.34- 10	Nd -21.7	ND- 1.76	ND-5.88	ND -1.8	2.4-15.0			Khalil (1990b)
1993	20.7± 8.3		8.2 ±0.6					6.85 ±6.8	3.66 ±3.2	26.0 ±16.6	Badawy et al. (1995)
1994							0.233-4.033		1.16-10.66		Zyadah (1995)
1997		2.13-39.13	7.6-8.8					0 -9.8			Dewidar & Khedr (2001)
1999	17.6--30.5		6.69-8.8	2-830	0.009-0.43	1.13-20.35	0. 249-1.4	0.0-5.9	1.4-60	2.7-55.0	Abdel-Satar (2001)
2000-2001			6.84-8.86					1.0-10.5	2.05- 9.45	1.5 - 18.10	El-Enani (2004)
2000-2001								0.51-14.30	0.13-9.47	2.53-15.80	Yacoub et al. (2005)
2001	12.35-29.14	2.53	7.7-7.8	1.81-17.7	1.18-4.61	0.64-10.61	1.24-4.89	6.27-10.78			Shakwer (2005)
2004		1,1-22.5	7.45-8.9	27-660	0.003-0.222	0.2-7.23	0.1-0.98	0 -10.2		10-31.2	Ali (2008)
2012	12.2-33	0.55-36	7.2-8.8	14-64	0.003-0.193.2	0.005 -0.337	0.017-0.13	2.6- 14.3			EL-Saharty (2014)
2011	12.7-30.6		7-9.4	10-1290			0.1-0.9	0- 14.56	0.58-218.7	6.4- 660.3	Elshemy (2016)
2015	14-27.5	1.1-17.3	7.7-8.88	89-3460	36.5-211.4	0.098-3.49	52-343	1.6-11.8	5.2-56.8		Elmorsi et al. (2017)
2017-2018	14.3-35.5		7.68-9					0.7- 12.4	6.8-9.6	24.1-240	Behary et al. (2019)
2020	15.6-23.45	1.39-21.9	7.62-8.93	63.75-850.36	19.74-273.96	0.1-14.62	9.9-143.0	Nd – 14.7	8.34-88.6	19.6-132.96	Present study

ND: Not detected

TABLE 8. Long-term changes of bacterial flora in Lake El-Manzala

Date	Season	Parameters					Reference
		TVBC at 22 °C(CFU mL^{-1})	TVBC at 37 °C(CFU mL^{-1})	TC (MPN/ 100mL)	FC (MPN/ 100mL)	FS (MPN/ 100mL)	
1999	-	255- 79×10^5	65 - 5×10^4	0 - 15×10^2	0 -1000	0-790	Mostafa et al. (2003)
2004-2005	Autumn 2004 -Summer 2005	-	10^2- 10^4	0 - 4000	0 -38×10^2	-	Mansour et al. (2006)
2008-2009	9- 2008 to12-2009	-	$(0.9 - 17.9)\times10^5$	-	0 - 45×10^2	-	Hamed et al.(2013)
2014	Spring	1000 - 8.5×10^6	1000 - 30×10^6	300 -110×10^3	300 - 35×10^3	30 – 1.5×10^3	Tahoun, (2016)
	Summer	6000 - 680×10^4	1000 - 540×10^4	40 - 110×10^3	30 -15×10^3	9 - 300	
	Autumn	3000 – 8.5×10^4	200 - 9.2×10^4	$(1.1-110)\times10^3$	400 - 110×10^3	20 -300	
2015	Winter	3500 - 30×10^4	1000 - 22×10^4	200 - 46×10^3	40 - 24×10^3	70- 24×10^3	
	Spring	$(6 – 380)\times10^4$	1000 -156×10^4	40 - 110×10^3	30 - 24×10^3	360-110×10^3	
2016	Autumn	-	3×10^4 -6.7×10^4	$(0.13-4)\times10^4$	200 -12.67×10^3	-	Abdel-Hamid (2017)
2020	Winter	$(2 – 244) \times10^4$	$(6 -220)\times10^4$	20 - 46×10^4	20 - 24×10^4	700 - 15×10^4	Present study
	Summer	4000 - 280×10^4	2000 - 260×10^4	21 - 240×10^4	15 - 210×10^4	90 - 16×10^3	

TABLE 9. The historical status of the dominant phytoplankton groups assemblies in Manzala Lake

Date	Dominant class	Dominant species	References
1985-1986	Bacillariophyceae	Synedra sp.	Khalil (1990a)
1986-1987	Bacillariophyceae	Cyclotella menenghiniana and Nitzschia closterium	Ibrahim (1989)
1992-1993	Bacillariophyceae	-	El-Sherif & Gharib (2001)
2003-2004	Chlorophyceae	-	Ramdani et al. (2009)
2004	Chlorophyceae	Dictyosphaerium pulchellum, Cyclotella menenghiniana and Microcystis aeruginosa	Abd El-Karim (2008)
2007	Chlorophyceae	Scenedesmus sp. and Dictyosphaerium pulchellum	Abd El-Karim (2009)
2010-2011	Bacillariophyceae	-	Khairy et al. (2015)
2013-2014	Bacillariophyceae	-	Yassin et al. (2020)
2014-2015	Cyanophyceae	Microcystis aeruginosa	Abdel Monem et al. (2017), Flefil (2017)
2017	Cyanophyceae	-	Deyab et al. (2019)
2019	Cyanophyceae	-	Deyab et al. (2020)
2020	Bacillariophyceae	Achnanthidium minutissimum	Present study

Conclusion

Manzala Lake is the second largest lake in Egypt after Nasser Lake, with an area of proximately 572.41 km^2 in 2020. It is a very important source of inland fisheries in Egypt: it produced about 80038 tons of fish in 2020, which represented 20.1%, 36.26%, and 46.63% of the annual natural Egyptian fisheries, annual total lakes, and Egyptian Delta Lakes production, respectively. However, despite the great importance of Manzala Lake, it has been subjected to continuous environmental degradation as it receives more than 7 billion m^3 of various untreated wastewater annually. Therefore, the Egyptian government began rehabilitating the lake and improving its water quality in 2017 by removing encroachments inside the lake. This is in addition to dredging operations, especially in front of the *boughazes*, which were done to increase the flow of seawater into the lake.

This study analyzed and monitored the water quality characteristics of Manzala Lake by determining its physicochemical properties, bacterial distributions and structures, biochemical contents, and the structures of phytoplankton communities in 2020. The lake was classified as a eutrophic–hypertrophic water body, where it receives a large amount of nitrogenous and phosphorus salts, in addition to increasing levels of chlorophyll (*a*). Considerable variations in the spatial and temporal distributions of most parameters were detected. The results indicated that the water discharged to the lake directly and continuously from the surrounding drains without any previous treatments negatively affects the lake environment. In addition, the results showed high pollution levels due to the increased contents of ammonia, BOD, COD, and TC and FC bacteria, especially at the sites close to the drains.

This study recommends increasing the efforts to restore the safe conditions of the lake by combining all efforts of government organizations, responsible institutions, civil society organizations, and stakeholders with the continuous and enhanced environmental awareness of the residents around the lake. Also, this study emphasizes the great importance of treating wastewater before its discharge into the lake, especially at the Bahr al-Baqar drain. These should be done in conjunction with continuous scientific follow-ups on the ecological status of the lake to determine the extent of the development and improvement in the water quality and all environmental systems of the lake.

Conflict of interests: The authors declare no conflict of interest.

Authors' contributions: Abeer M.A. Mahmoud: Conceptualization, Methodology, Data visualization, Writing; Nasser S. Flefil: Conceptualization, Methodology, Data visualization, Writing, Editing; Reference Editing; Seliem M. El Sayed: Sampling, Methodology, Writing; Usama M. Tahoun: Methodology, Writing; Mohamed E. Goher: Project administration, Methodology, Writing, Editing, supervision.

Ethical approval: Not applicable.

References

Abd El-Hady, H.H. (2008) Effect of environmental factors and different pollutants on biochemical contents of phytoplankton in Lake Manzala, Egypt. *Egyptian Journal of Aquatic Research,* **34**(2), 168-178.

Abd Ellah, R. (2021) An extensive nationwide program for developing the Egyptian lakes, Lake Manzalah: From an ambiguous to a bright future. *Egyptian Journal of Aquatic Research,* **47**, 337–343.

Abd El-Karim, M.S. (2008) Monthly variations of phytoplankton communities in Lake Manzala. *Global Veterinaria*, **2**(6), 343-350.

Abd El-Karim, M.S. (2009) Present and long-term changes of phytoplankton communities in hypertrophic mediterranean lagoon, Lake Manzala, Egypt. *American-Eurasian Journal of Agricultural & Environmental Sciences,* **5**(2), 171-178.

Abd El-Karim, M.S., Mahmoud, A.M.A, (2016) Phytoplankton nutrition quality and chlorophyll a- nutrient relationships in Lake Nasser, Egypt. *International Journal of Fisheries and Aquatic Studies*, **4**(2), 463-473.

Abdel Gawad, S.S. (2018) Concentrations of heavy metals in water, sediment and mollusk gastropod, *Lanistes carinatus* from Lake Manzalah, Egypt. *Egyptian Journal of Aquatic Research,* **44**(2), 77–82.

Abdel Monem, A.M., Gharieb, M.M., Hussian, A.M. Flefil, N.S. (2017) Sensitivity of phytoplankton to the wastewater quality discharging at Lake Manzala, Egypt. *International Journal of Oceans and Oceanography*, **11**(2), 231–247.

Abdel-Hamid, E.A. (2017) Assessment of some water quality characteristics and bacterial contamination in water, sediments and some fish species of El-Manzala Lake, *Egyptian Journal for Aquaculture*, **7**(1), 55-75.

Abdel-Satar, A.M. (2001) Environmental studies on the impact of the drain effluent upon the southern sector of Lake Manzalah, Egypt, *Egyptian Journal of Aquatic Biology and Fisheries,* **5**(3), 17-30.

Abu Khatita, A.M., Shaker, I.M., Shetaia, S.A. (2017) Water quality assessment and potential health risk of Manzala Lake-Egypt. *Al-Azhar Bulletin of Science,* Vol. 9th., *Conf.,* March 2017, pp. 119-136.

Al-Afify, A.D.G., Tahoun, U.M., Abdo, M.H. (2019) Water quality index and microbial assessment of Lake Qarun, El-Batts and El-Wadi Drains, Fayoum Province, Egypt, *Egyptian Journal of Aquatic Biology and Fisheries,* **23**(1), 341 -357.

Ali, E.M., El-Magd, I.A. (2016) Impact of human interventions and coastal processes along the Nile Delta coast, Egypt during the past twenty-five years. *Egyptian Journal of Aquatic Research*, **42**(1), 1–10.

Ali, M.H.H. (2008) Assessment of some water quality characteristics and determination of some heavy metals in Lake Manzalah, Egypt, *Egyptian Journal of Aquatic Biology and Fisheries,* **12**(2), 133-154.

American public Health Association (APHA) (2005) "*Standard Methods for the Examination of Water and Wastewater*", 21th ed. American Public Health Association, Washington, D.C.

American Public Health Association (APHA) (2017) "*Standard Methods for the Examination of Water and Wastewater*". 23rd ed. Washington: 1546p.

Anonymous (2007) Ecological studies on Lake Manzala. *Report of National Institute of Oceanography and Fisheries*, 93p.

Ayache, F., Thompson, J.R., Flower, R.J., Boujarra, A., Rouatbi, F., Makina, H. (2009) Environmental characteristics, landscape history and pressures on three coastal lagoons in the southern Mediterranean region: Merja Zerga (Morocco), Ghar El Melh (Tunisia) and Lake Manzala (Egypt). *Hydrobiologia,* **622**(1), 15–43.

Badawy, M.I., Wahaab, R.A., Abou Waly, H.F. (1995) Petroleum and chlorinated hydrocarbons in water from Lake Manzala and associated canals. *Bulletin of Environmental Contamination and Toxicology,* **55**, 258–263.

Behary, S.M., Saleh, E., Seraga, M.S. (2019) Water quality and monitoring of some pollution indicators in Lake Manzala, Egypt. *Advances in Environmental Biology*, **13**(6), 7-12.

Bellinger, E.G., Sigee, D.C. (2010) "*Fresh Water Algae: Identification and Use as Bioindicators*". 1st ed. by John Wiley and Sons, Ltd, 284p.

Bellinger, E.G., Sigee, D.C. (2015) "*Freshwater Algae: Identification, Enumeration and Use as Bioindicators*". John Wiley & Sons, Ltd, 275p.

Bhatnagar, A., Devi, P. (2013) Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Science*, **3**(6), 1980-2009.

Bucka, H., Wilk-Woźniak, E. (2003) Morphology and ecology of selected coccal green algae occurring in different types of water bodies. *Biologia, Bratislava,* **58**, 483-487.

Burt, T.P., Howden, N.J.K., Worrall, F. (2014) On the importance of very long-term water quality records. *WIREs Water*, **1**, 41–48.

CAPMAS, (2021) Statistical Yearbook 2020" (Issue no. 111) produced by Central Agency for Public Mobilization and Statistics. https://www.capmas.gov.eg/HomePage.aspx

CCME (Canadian Council of Ministers of the environment) (2017) Canadian water quality guidelines for the protection of aquatic life: CCME water quality index, user's manual 2017 update. *Canadian Council of Ministers of the Environment,* Winnipeg.

Chabrol, E., Castellano, A. (1961) SPV method for estimation of total serum lipid. *Journal of Laboratory and Clinical Medicine,* **57**, 300.

Chapman, D. (1996) "*Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*". 2nd ed., Chapman and Hall Ltd., London, 651p. http://dx.doi.org/10.4324/noe0419216001

David, J.H., Hazel, P. (1998) "*Analytical Biochemistry. Hand book*", 3rd ed., Pearson Education, England, 497p.

Dewedar, A., Diab, A.M., Zaky, M.M. (1995) The Distribution of Bacterial Pollution Indicators in Lake Manzala, Egypt. *German Egyptian Conference Proceeding. Pesticides and Environmental Contaminants in Water and Food, Ismailia*, 288-297.

Dewidar, K.H., Khedr , A. (2001) Water quality assessment with simultaneous Landsat-5 TM at Manzala Lagoon, Egypt. *Hydrobiologia*, **457**, 49–58.

Deyab, M.A., Abu Ahmed, S.E., Ward, F.M.E. (2019) Comparative studies of phytoplankton compositions as a response of water quality at North El−Manzala Lake, Egypt. *International Journal of Environmental Science and Technology*, **16**(12), 8557–8572.

Deyab, M., Abu Ahmed, S., Ward, F. (2020) Seasonal patterns in phytoplankton growth, composition, and predominance in relation to water quality at Northwest El-Manzala Lake, Egypt. *Water Supply*, **20**(8), 3341-3357.

El-Araby, A. (1990) The occurrence and biological characteristics of marine fishes in Lake Manzalah at the area of the lake sea connection. *M.Sc. Thesis.* Fac. Sc. Alex. Univ., 104p.

El-Badry, A.E.A. (2016) Distribution of Heavy Metals in Contaminated Water and Bottom Deposits of Manzala Lake, Egypt. *Journal of Environmental and Analytical Toxicology*, **6**(1), 344-351.

El-Bana, M.I. (2015) Gravel pads of powerline towers as human-made habitats for ruderal vegetation in some Mediterranean wetlands of Egypt: Implications for management. *Egyptian Journal of Aquatic Research,* **41**(1), 83–91.

El-ghannam, M.G., Hanora, A., Abdulla, H.M., Zaky, M. (2020) Evaluation of bacterial quality of *Oreochromis niloticus* samples of Lake Manzala, Egypt. *Alfarama Journal of Basic and Applied Sciences,* **1**(2), 60-77.

El-Halag, R.S.F., Shaker, I.M., Mehanna, S.F., Othman, M.F., Farouk, A.E. (2013) Impact of some environmental condition on water quality and some heavy metals in water from Bardawil Lake. *New York Science Journal*, **6**(11), 5-13.

El-Enani, H.R. (2004) Ecological and biological studies on Lake El-Manzalah with special reference to their water quality and sediment productivity. *M.Sc. Thesis*, Fac. Sci., Al Azhar Univ., 358p.

El-Mezayen, M.M., Rueda-Roa, D.T., Essa, M.A., Muller-Karger, F.E., Elghobashy, A.E. (2018) Water quality observations in the marine aquaculture complex of the Deeba Triangle, Lake Manzala, Egyptian Mediterranean coast. *Environmental Monitoring and Assessment,* **190**, 436. https://doi.org/10.1007/s10661-018-6800-6

Elmorsi, R.R., Hamed, M.A., Abou-El-Sherbini, K.S. (2017) Physicochemical properties of Manzala Lake, Egypt. *Egyptian Journal of Chemistry*, **60**(4), 519-535.

El-Naggar, N.A., Rifaat, A.E., Khalil, M.K. (2016) Numerical modelling on water flow in Manzalah Lake, Nile Delta, Northern Egypt. *International Journal of Contemporary Applied Sciences*, **3**(4), 28–44.

EL-Saharty, A.A. (2014) Seasonal Variation of Water Physicochemical Parameters and Trace Metals in Lake Manzala, Egypt. *Journal of King Abdulaziz University, Marine Science,* **25**(1), 37-58.

Elsayed, F.A., Okbah, M.A., El-Sayed, S.M., Eissa, M.A., Goher, M.E. (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-Sayed, S.M.M. (2011) Physicochemical studies on the impact of pollution up on the Nile River branches, Egypt. *M.Sc Thesis* Faculty of Science, Benha University, Egypt.

El-Sayed, S.M.M. (2015) Physico - chemical studies of water and sediment quality of Ismailia canal, River

Nile, Egypt, for its evaluation and protection from some hazard heavy metals. *Ph.D. Thesis*, Fac. of Sci., Al-Azhar Univ., Egypt.

El Sayed, S.M., Hegab, M.H., Mola, H.R.A., Ahmed, N.M., Goher, M.E. (2020) An integrated water quality assessment of Damietta and Rosetta branches (Nile River, Egypt) using chemical and biological indices. *Environmental Monitoring and Assessment,* **192**, 228. https://doi.org/10.1007/s10661-020-8195-4

Elshemy, M. (2016) Water Quality Assessment of Lake Manzala, Egypt: A Comparative Study. *International Journal of Scientific Research in Environmental Science*, **4**(6), 196-207.

El-Sherif, Z.M., Gharib, S.M. (2001) Spatial and temporal patterns of phytoplankton communities in Manzalah Lagoon. *Bulletin Institute of Oceanography and Fisheries,* **27**, 217–239.

Falkowski, P.G. (2002) The ocean's invisible forest. *Scientific American*, **287**(2), 54-61.

Flefil, N.S. (2017) Phytoplankton as bioindicator and bioaccumulator for drained pollutants in Lake Manzala, Egypt. *Ph.D. Thesis,* Faculty of Science, Menoufia University. Egypt.

Flefil, N.S., Mahmoud, A.M.A. (2021) The Seasonal Fluctuations of Phytoplankton Diversity and its Biochemical Components in Lake Qarun. Egypt. *Egyptian Journal of Aquatic Biology & Fisheries,* **25**(5), 131-145.

Flemer, D.A., Lores, E.M., Bundrich, C.M. (1998) Potential sediment denitrification rates in estuaries of Northern Gulf of Mexico. *Journal of Environmental Quality*, **27**, 859 - 868.

Fleming-Lehtinen, V., Laamanen, M. (2012) Long-term changes in Secchi depth and the role of phytoplankton in explaining light attenuation in the Baltic Sea. *Estuarine, Coastal and Shelf Science*, **102–103**, 1-10.

GAFRD, (2021) The General Authority for fishery resources development: Summary production statistics. Cairo, Egypt.

Ghanem, A., Haggag, M. (2015) Assessment of the feasibility of using filter made of rice straw for treating aquaculture effluents in Egypt. *Resources and Environment,* **5**(5), 135–145.

Goher, M.E., Hassan, A.M., Abdel-Moniem, I.A., Fahmy, A.H., El-sayed, S.M. (2014) Evaluation of surface water quality and heavy metal indices of Ismailia Canal, Nile River, Egypt. *Egyptian Journal of Aquatic Research*, **40**(3), 225–233.

Goher, M.E., Abdo, M.H., Mangood, A.H., Hussein, M.M. (2015) Water quality and potential health risk assessment for consumption of *Oreochromis niloticus* from El-Bahr El-Pharaony Drain, Egypt. *Fresenius Environmental Bulletin*, **24**(11), 3590-3602.

Goher, M.E., Abdo, M.H., Bayoumy, W.A., El-Ashkar, T.M. (2017) Some heavy metal contents in surface water and sediment as a pollution index of El- Manzala Lake, Egypt. *Journal of Basic and Environmental Sciences*, **4**, 210-225.

Goher, M.E., El-Rouby, W.M., El-Dek, S.I., El-Sayed, S.M., Noaemy, S.G. (2018) Water quality assessment of Qarun Lake and heavy metals decontamination from its drains using nanocomposites. *IOP Conference Series: Materials Science and Engineering,* **464**(1), 012003. https://doi.org/10.1088/1757-899X/464/1/012003

Goher, M.E., Mahdy, E.M., Abdo, M.H., El Dars, F.M., Korium, M.A., Elsherif, A.A. (2019) Water quality status and pollution indices of Wadi El-Rayan Lakes, El-Fayoum, Egypt. *Sustainable Water Resources Management*, **5**(2), 387-400.

Goher, M.E., Napiórkowska-Krzebietke, A., Aly, W., El-Sayed, S.M., Tahoun, U.M., Fetouh, M.A., et al. (2021) Comprehensive Insight into Lake Nasser Environment: Water Quality and Biotic Communities—A Case Study before Operating the Renaissance Dam. *Water*, **13**(16), 2195. https://doi.org/10.3390/w13162195

Guiry, M.D., Guiry, G.M. (2022) AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. https://www.algaebase.org.

Hafez, A., Khedr, M., El-Katib, K., Gad Alla, H., Elmanharawy, S. (2008) El-Salaam Canal project, Sinai II. *Chemical Water Quality Investigations*, **227**(1-3), 274–285.

Hamed, Y.A., Abdelmoneim, T.S., ElKiki, M.H., Hassan, M.A., Berndtsson, R. (2013) Assessment of heavy metals pollution and microbial contamination in water, sediments and fish of Lake Manzala, Egypt. *Life Science Journal*, **10**(1), 86-99.

Haroon, A.M. (2022) Review on aquatic macrophytes in Lake Manzala, Egypt. *Egyptian Journal of Aquatic Research*, **48**(1), 1-12.

Haroon, A.M., Hussian, A.E.M., El-Sayed, S.M. (2018) Deviations in the biochemical structure of some macroalgal species and their relation to the environmental conditions in Qarun Lake, Egypt. *Egyptian Journal of Aquatic Research*, **44**, 15-20.

Hegab, M.H., Ahmed, N.M., Kadry, S.M., ElSayed, R.A., Goher, M.E. (2020) Impact of heavy metals on the food web in the Mediterranean lagoon, Lake Burullus, Egypt. *Oceanological and Hydrobiological Studies,* **49**(3), 215-229.

Hereher, M.E. (2014) The Lake Manzalah of Egypt: An ambiguous future. *Environmental Earth Sciences,* **72**(6), 1801–1809.

Hooda, P.S., Edwards, U.A.C., Anderson, H.A., Miller, A. (2000) A review of water quality concerns in livestock farming areas. *Science of the Total Environment,* **250**, 143–167.

Hou, Z., Jiang, Y., Liu, Q., Tian, Y., He, K., Fu, L. (2018) Impacts of Environmental Variables on a Phytoplankton Community: A Case Study of the Tributaries of a Subtropical River, Southern China. *Water,* **10**(2), 152. https://doi.org/10.3390/w10020152

Ibrahim, E.A. (1989) Studies on phytoplankton in some polluted areas of Lake Manzala. *Bulletin of the National Institute of Oceanography and Fisheries*, **15**(1), 1-19.

Khairy, H.M., Shaltout, K.H., El-Sheekh, M.M., Eassa, D.I. (2015) Algal Diversity of the Mediterranean Lakes in Egypt. *International Conference on Advances in Agricultural, Biological & Environmental Sciences (AABES-2015), London (UK)*.

Khalil, M.T. (1990a) Plankton and primary productivity of Lake Manzala, Egypt. *Hydrobiologia,* **196**, 201–207.

Khalil, M.T. (1990b) The physical and chemical environment of Lake Manzalah, Egypt. *Hydrobiologia,* **196**, 193- 199.

Khedr, A.A. (1989) Ecological studies on Manzala Lake. M. Sc. Thesis, Botany Department, Faculty of Science, Mansoura University.

Komárek, J., Perman, J. (1978) Review of the genus *Dictyosphaerium* (Chlorococcales). *Algological Studies/Archiv für Hydrobiologie,* **20**, 233-297.

Lee, R.E. (2008) "*Phycology*". 4th ed. Cambridge University Press, New York. 547p.

Maclaren (Engineers, Planners and Scientists) (1981) Lake Manzalah study. EGY/76/001-07. Draft Report to Arab Republic of Egypt. Ministry of Development and New communities and UNDP Scientists, Inc. Toronto, Canada, 12 Vols.

Mahmoud, A., Sabae, S., Hamza, W. (2022) Environmental assessment of bacterial load, epiphytic algae, and their biochemical contents after and before flooding in Lake Nasser, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, **26**(2), 473-488.

Mansour, F.A., Ismail, A., Abou-Dobara, M.I., Zaky, M.M. (2006) Studies on bacterial pollution in lake Manzala. *Arab Universities Journal of Agricultural Sciences*, **14**(1), 105-119.

Mostafa, S., Hewedy, M., Touliabah, H., Ashour, S., Abdallah, S. (2003) Comparative Study among Microflora in El-manzala Lake Water and Rashid (Rosetta) Estuary of Nile River, Egypt. *Pakistan Journal of Biological Sciences*, **6**, 671-679.

Munshi, J.D., Roy, S.P., Munshi, D. (2010) "*Manual of Freshwater Biota*". Narendra Publising House, Delhi; pp. 1–455.

Newall, E.R., Nguyen, T.H., Quynh, L.T., Sengtaheuanghoung, O., Ribolzi, O. (2015) A short review of fecal indicator bacteria in tropical aquatic ecosystems: knowledge gaps and future directions. *Frontiers in Microbiology*, **308**(6), 1-15.

Ramdani, M., Elkhiati, N., Flower, R.J., Thompson, J.R., Chouba, L., Kraiem, M.M., Ayache, F., Ahmed, M.H. (2009) Environmental influences on the qualitative and quantitative composition of phytoplankton and zooplankton in North African coastal lagoons. *Hydrobiologia,* **622**, 113–131.

Rashad, H.M., Abdel-Azeem, A.M. (2017) Lake Manzalah, Egypt: A bibliography. *Microbial Biosystems Journal,* **2**(2), 1–5.

Rectenwald, L.L., Drenner, R.W. (2000) Nutrient Removal from Wastewater Effluent Using an Ecological Water Treatment System. *Environmental Science and Technology*, **34**(3), 522–526.

Reddy, K.R., Flaig, E.G., Graetz, D.A. (1996) Phosphorus storage capacity of uplands, wetlands and streams of the Lake Okeechobee watershed, Florida. *Agriculture, Ecosystems and Environment*, **59**(3), 203–216.

Reemtsma, T., Jekel, M. (2006) "*Organic Pollutants in the Water Cycle: Properties, Occurrence, Analysis and Environmental Relevance of Polar Compounds*", John Wiley & Sons, 368p. https://doi.org/10.1002/352760877X

Roy, S., Llewellyn, C.A., Egeland, E.S., Johnsen, G. (Eds.) (2011) "*Phytoplankton Pigments: Characterization, Chemotaxonomy and Applications in Oceanography*". Cambridge University Press.

Sabae, S., Mahmoud, A. (2021) Structure and Biochemical Analysis of Phytoplankton in the Wadi El-Rayan Lakes, El-Fayoum, Egypt. *Egyptian Journal for Aquaculture,* **11**(2), 17-32.

Saeed, S.M., Shaker, I.M. (2008) Assessment of heavy metals pollution in water and sediments and their effect on *Oreochromis niloticus* in the northern delta Lakes, Egypt. *8th International Symposium on Tilapia in Aquaculture*, pp. 475-490.

Shabaka, S.H. (2018) Checklist of seaweeds and seagrasses of Egypt (Mediterranean Sea): A review. *Egyptian Journal of Aquatic Research,* **44**(3), 203–212.

Shaltout, K., El-Bana, M., Galal, T. (2017) Coastal Lakes as Hot Spots for Plant Diversity in Egypt. *Egyptian Coastal Lakes and Wetlands: Part II – Climate Change and Biodiversity,* **72**, 129–146.

Shibabaw, T., Beyene, A., Awoke, A., Tirfie, M., Azage, M., Triest, L. (2021) Diatom community structure in relation to environmental factors in human influenced rivers and streams in tropical Africa. *Plos One*, **16**(2), e0246043.

Spilling, K., Olli, K., Lehtoranta, J., Kremp, A., Tedesco, L., Tamelander, T., Klais, R., Peltonen, H., Tamminen, T. (2018) Shifting Diatom—Dinoflagellate Dominance During Spring Bloom in the Baltic Sea and its Potential Effects on Biogeochemical Cycling. *Frontiers in Marine Science*, **5**, article 327, 1-17. https://doi.org/10.3389/fmars.2018.00327

Suikkanen, S., Laamanen, M., Huttunen, M. (2007) Long-term changes in summer phytoplankton communities of the open northern Baltic Sea. *Estuarine Coastal and Shelf Science,* **71**(3-4), 580–592.

Tahoun. U.M. (2016) Biosorption of some heavy metals using resistant bacterial strains from El-Manzala Lake, Egypt. *Ph.D.Thesis*, Fac. Sci., Al Azhar Univ.

U.S. Environmental Protection Agency (2013) Drinking Water Contaminants. National Primary Drinking Water Regulations. Washington, D.C.: U.S. Environmental Protection Agency.

Verlencar, X.N., Desai, S. R. (Eds.) (2004) "*Phytoplankton Identification Manual*". National Institute of Oceanography, Dona Paula. 35p.

Wang, G., Moisan, J. (2020) Remote Sensing of Phytoplankton Pigments. In: "*Plankton Communities*", L. Pereira, & A. M. Gonçalves (Eds.), *IntechOpen.* https://doi.org/10.5772/intechopen.95381

Wang, X., Liu, X., Qin, B., Gu, Z., Wu, Z., Xu, H., Zhu, H., Cheng, G., Liu, H. (2015) Green algae dominance quickly switches to cyanobacteria dominance after nutrient enrichment in greenhouse with high temperature. *Journal of Ecology and Environment*, **38**(3), 293-305.

Yacoub, A.M., Siliem, T.A., Kadry, S.M., Mabrouk, D.B. (2005) Effect of drainage water on the chemical characteristics of Lake Manzalah waters, Egypt. *Journal of the Egyptian Academy of Environmental Development (D- Environmental Studies)*, **6**(1), 133-152.

Yassin, H.T., Madkour, F.F., Deyab, M.A., Abu Ahmed, S.E. (2020) List of phytoplankton species of the northeastern part of Lake Manzala, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, **24**(7), 1097 – 1114.

Yin, X.L., Zhang, J., Hu, Z., Xie, H.J., Guo, W.S., Wang, Q.S., Ngo, H.H., Liang, S., Lu, S.Y., Wu, W.Z.

(2016) Effect of photosynthetically elevated pH on performance of surface flow-constructed wetland planted with *Phragmites australis*. *Environmental Science and Pollution Research,* **23**, 15524–15531.

Youssef, S.F. (1973) Studies on the biology of family Mugilidae in Lake Manzalah. *M.Sc. Thesis.* Fac. Sci. Cairo Univ.

Zahran, E., Elbahnaswy, S., Mamdouh, A., El-Matbouli, M. (2021) Xenosteroids in aquaculture with special consideration to Lake Manzala (Northern delta lake, Egypt): Types, sources and mechanism of action. *Aquaculture Research*, **52**, 5962–5977.

Zaky, M., Ibrahim, M. (2017) Screening of bacterial and fungal biota associated with *Oreochromis niloticus* in Lake Manzala and its impact on human health. *Health*, **9**, 697-714.

Zyadah, M.A. (1995) Environmental impact assessment of pollution in Lake Manzalah and its effect on fishes. *Ph. D. Thesis*, Fac. Sci. Damietta, El Mansoura Univ. 127p.

علاقة نظم الهائمات النباتية والبكتيريا بالخصائص الفيزيوكيميائية لمياه بحيرة المنزلة، مصر

عبير محمد محمود، ناصر سليمان فليفل، سليم محمود السيد، أسامة محمد طاحون، محمد الشريف جوهر
المعهد القومي لعلوم البحار والمصايد– القاهرة– مصر.

تعاني بحيرة المنزلة، أكبر البحيرات الشمالية بمصر، من التدهور البيئي المستمر حيث تستقبل كميات هائلة من مياه الصرف المختلفة. تهتم هذه الدراسة بتقييم الظروف البيئية والحيوية لمياه البحيرة من حيث الخواص الفيزيوكيميائية، والمجتمعات البكتيرية، وتوزيع الهائمات النباتية ومحتوياتها البيوكيميائية. وقد تم تجميع العينات من 11 موقعًا على طول البحيرة في موسمي الشتاء والصيف عام 2020. أوضحت النتائج زيادة كثافة الهائمات النباتية وكلوروفيل (أ) في فصل الشتاء مع زيادة تركيز الأملاح المغذية. على الجانب الأخر تم تسجيل أعلى تركيزات للمحتويات البيوكيميائية للهائمات النباتية وكذلك أعلى تعداد للمؤشرات البكتيرية خلال فصل الصيف. لم يتم تسجيل أي وجود للأكسجين بالمواقع القريبة من مداخل المصارف، بينما تم تسجيل أعلى تركيزات من الأمونيا بهذه المواقع. وقد لوحظ أن القطاع الأوسط من البحيرة يحتوي على أعلى تجمع للهائمات النباتية. وعلى الرغم من جهود الحكومية المبذولة لإعادة تأهيل بحيرة المنزلة والتي بدأت منذ عام 2017، فقد أظهرت الدراسة زيادة في مستويات التلوث في العديد من المواقع المختلفة مع استمرار التدهور البيئي للبحيرة. وتؤكد الدراسة على ضرورة زيادة الجهود المتضافرة لاستعادة البحيرة للوضع البيئي الصحي قائماً بشكل رئيسي على معالجة مياه الصرف المختلفة قبل تصريفها إلى البحيرة.