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Eutrophication assessment using TRIX and Carlson's indices in Lake Mariout Water, Egypt.

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ABSTRACT

Eutrophication of coastal waters is considered one of the major threats in marine ecosystems. Therefore, continuous monitoring is urgently needed to define potential risk zones. The present study is an attempt to test the applicability of the trophic state indices (TRIX) and Carlson's indice for scaling the eutrophication status of Lake Mariout in concert with a number of physicochemical descriptors aimed to select the most relevant of their ecological quality directed to increase fish production. Water samples were investigated seasonally during 2014. The range and annual average values of Physicochemical parameters were 18-27.5°C (23.20±0.52°C) for Temperature; 0.28-7.40‰ (3.70‰±1.69‰) for Salinity; 7.84-8.84 for pH; 0.60 - 5.24meq/l (1.97 ±0.43meq/l) for Total alkalinity; 0.14–10.71mg/l (4.91±2.98mg/l) for DO; 0.01-2.6mg/l (1.35±0.32mg/l) for BOD; 3.2-134.4mg/l (56.35±27.89 mg/l) for OOM; and 16.30–161.00 mg/l (63.80±24.70) for Total suspended solids;. The results of nutrient salts range and mean concentration (μM) were from 0.20 to 118.30 (15.61±15.46) for Ammonium; from 0.05 to 22.48 (3.43±3.38) for Nitrite; from 0.14 to 66.67 (13.50±7.78) for Nitrate; from 0.39 to 157.26 (39.28±43.79) for DIN; from 0.32 to 123.55 (33.64±18.77) for total nitrogen; from 0.10 to 45.30 (8.27±10.28) for reactive phosphate; from 0.04 to 49.60 (7.98±6.93) for total phosphorus; and from 2.14 to 226.16 (39.97±21.85) for silicate. Chlorophyll-a ranged from 3.95 to 130.3µg/l (28.51±21.99µg/l). According to seasonally calculated TRIX and Carlson's trophic state indices values, the sites are ranked in a descending order from very high to moderate eutrophic level for most stations, revealing the existence of anthropogenic stress.

INTRODUCTION

Eutrophication has become a significant worldwide problem which catastrophically affects aquaculture and local economies (Richlen *et al*. 2010). Water eutrophication can be greatly accelerated by human activities that increase the rate of nutrient input in a water body, as rapid urbanization, industrialization, and intensifying of agricultural production. For lake aquatic ecosystems, human activities in the watershed can lead to loss of dominant species and functional groups, high nutrient turnover, low resistance, high porosity of nutrients and sediments, and the loss of productivity (Liu and Qiu 2007). Lake Mariout, for a long time, represents a source of fish production in Egypt. Currently, some parts of the lake are used in aquaculture activities. It is one of the most heavily populated urban areas in Egypt (Mateo 2009; Saad *et al*. 2017). The lake has been subjected to various anthropogenic activities. Lake Mariout acts as a receptor for agricultural drainage and domestic wastewater. The main drains and canal are Qalaa drain, El-Umum drain, and Nubaria canal. The water inflow to the lake comes mainly from these sources plus those from the East and West treatment plants began in 1993 to treat Alexandrian waste water. Both are primarily treatment plants and they discharge their final effluents into the lake, and from the petrochemical area. Domestic sewage from the Wastewater Treatment Plant at the north and El-Qalaa drain are discharging in the main basin of the lake body. The *Tilapia* species is of considerable importance in fisheries of Lake Mariout as it represents about 90% of the total catch in the lake (Bakhoum 1994). Outflow from the lake is only released by El-Max pumping station. Thus, Lake Mariout has changed from being the most productive fisheries resource of the four major Egyptian brackish water lakes to the least productive in a couple of decades. Degradation of water quality due to land-based pollution is a major problem in the Mediterranean coastal areas (Arab Republic of Egypt, Ministry of State for Environmental Affairs 2009). Many investigators had studied the hydrographical and chemical characteristics of Lake Mariout water and sediments as well as phytoplankton standing crop; (Ahdy 1982; Saad *et al*. 1982; Saad 1985; Okbah *et al*. 1996; Okbah and Tayel 1997; Okbah *et al*. 1997; Saad *et al*. 2017)

The present work is aimed to study eutrophication status and assessment of potential ecological risks of Lake Mariout water in concert with a number of physicochemical parameters. This study will be a useful tool for helping decision makers and authorities in charge of sustainable marine management to increase fish production.

MATERIALS AND METHODS

Area of study and sampling:

Lake Mariout is one of the main fishing grounds of Alexandria located between longitude 29° 47.1′ to 29° 50.4′ E and latitude 31° 7.5′ to 31° 9′ N (Saad *et al*. 2017). The Lake is a shallow brackish water basin, its water depth ranges from 60 to 150 cm. It lies at the north of the Nile Delta, southeast of Alexandria; the lake is divided by artificial embankments into four basins (Fig. 1). In recent years, Lake Mariout was considered as an oxidation pond for Alexandrian waste water and agricultural wastes, discharged to it by the newly constructed plant stations. In order to evaluate the lake's water quality, 10 surface water samples from the Lake beside Qalaa, El-Umum drains, and Nubaria canal were collected seasonally in winter, spring, summer, and autumn 2014 (Fig. 1). Water samples were taken manually by attaching a cleaned 1L-polyethylene bottle immersing to a depth 20-cm below the surface water.

Methods of Analysis

Water temperature was measured using a thermometer sensitive to 0.1°C; water pH and salinity were measured using a pocket pH meter (model 201/digital pH meter) and a Beckman salinometer (Model NO.R.S.10), respectively. Total alkalinity was determined according to standard Methods (APHA 1995).

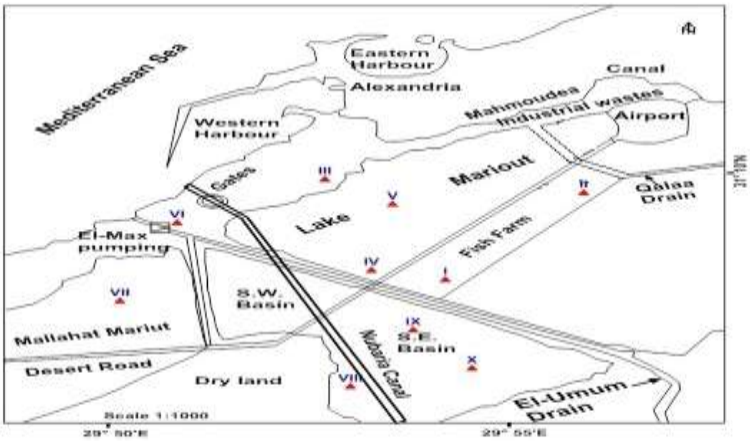

Fig. 1: Map of Lake Mariout showing the sampling sites

Dissolved oxygen and biological oxygen demand (BOD) were determined according to the classical Winkler's method modified by Grasshoff (1976). Oxidizable organic matter (OOM) was determined using permanganate values test (FAO 1975). Water samples for nutrient salts (NO_2/N, NO_3/N, PO_4/P, and SiO_4) were immediately filtered through Whatman GF/C filters and kept frozen until analysis. Water samples for ammonium (NH_4/N) were fixed in the field without filtration. Nutrient salts were determined according to Grasshoff (1976). Total nitrogen (TN) and total phosphorus (TP) were determined in unfiltered samples using the method described by Valderrama (1981). Nutrient salts were measured using a Shimadzu double beam spectrophotometer UV-150-02. Chlorophyll-*a* in water samples was extracted with 90% acetone and measured spectrophotometrically using the SCORE UNESCO equation given by Jeffrey and Humphrey (1975).

Statistical analysis

Ecological risks of nitrogen and phosphorus were evaluated by using the following equation of the trophic index (TRIX) (Vollenweider *et al*. 1998; Peng *et al*. 2015):

TRIX = (LOG (Chl-a × [%DO] × DIN × SRP+1.5))/1.2

Chl-a, DIN and SRP are the concentrations of chlorophyll-a, dissolved inorganic nitrogen, and soluble reactive phosphorus, respectively. %DO is the absolute value of oxygen saturation deviation and is calculated as [100- %DO].

Carlson's trophic state index: The trophic state index (TSI) of Carlson is based on the interrelationships of secchi depth reading, Chlorophyll-a concentration, and total Phosphorus (Carlson 1977). TSI calculation was done as following:

CTSI = [TSI (TP) +TSI (CA) +TSI (SD)]/3

The formulas for calculating TSI values from TP, SDT and Chl-*a* are:

a- TSI for Chlorophyll-a (CA) TSI = 9.81ln Chlorophyll-a (µg/L) +30.6

b- TSI for Secchi depth (SD) TSI = 60-14.41ln Secchi depth (Meters)

c- TSI for Total phosphorus (TP) TSI = 14.42 ln Total phosphorous (µg/l) + 4.15

Where; ln is Natural logarithm.

RESULTS AND DISCUSSION

Physicochemical parameters

Water Temperature, pH, Total Alkalinity and Salinity:

Water temperature has a direct and an indirect impact on fish productivity; warm water is much less capable of holding oxygen gas in solution than colder water, which consequently may hamper fish production (Francis-Floyd 2003). The growth of Tilapia in Lake Mariout may be acceptable between 20 and 35 °C (El-Sherif and El-Feky 2009). As shown in Fig. 2, water temperature fluctuated between 18.00 ºC at station IV in winter and 27.50 ºC at station III and Qalaa drain in summer with an annual average of 23.20 ± 0.52 ºC (Table 1). This range of temperature in Lake Mariout water is suitable for Tilapia growth and is in agreement with the measured temperature obtained by Saad *et al*. 2017 (15.1-32.6) °C.

Table 1: The seasonal range, mean ±SD and annual mean of physicochemical parameters of Lake Mariout Water during 2014.

Parameter	Unit	**Winter**	**Spring**	**Summer**	**Autumn**	**Annual mean**
Temp.	**ºC**	18.00-21.00 (19.58±0.93)	24.50-26.6 (25.98±0.68)	25.10-27.50 (26.47± 0.73)	19.80-21.40 (20.69± 0.54)	18.0-27.5 (23.20 ± 0.52)
Salinity	**‰**	0.39 -5.66 (3.02 ± 1.54)	0.39-7.40 (3.60 ± 2.06)	2.11- 7.12 (3.86 ±1.57)	0.43 - 7.00 (3.79 ± 2.24)	0.39-7.4 (3.70 ± 1.69)
Alkalinity	**meq/l**	0.98 - 4.43 (2.25±1.08)	2.02-5.24 (3.49±1.10)	0.60-1.61 (0.90± 0.34)	0.98-1.94 (1.39 ±0.38)	0.60-5.24 (1.97 ± 0.43)
DO	**mg/l**	0.14 - 6.36 (3.13 ± 2.31)	0.17-10.58 (5.43 ± 4.01)	0.21-9.77 (5.15 ± 3.78)	0.29 -10.71 (6.11 ±3.6)	0.14 – 10.71 (4.91 ± 2.98)
BOD	**mg/l**	0.03 -1.00 (0.31±0.33)	1.22 -2.40 (2.07± 0.62)	1.29-2.60 (2.67 ±0.83)	0.01-0.86 (0.32 ±0.32)	0.01 – 2.60 (1.35 ± 0.32)
OOM	**mg/l**	16.00-105.60 (52.9± 27.29)	12.80-102.40 (47.09 ±32.28)	3.20 -115.20 (52.48± 42.71)	22.00- 134.40 (73.76± 37.85)	3.20-134.40 (56.35 ± 27.89)
TSM	**mg/l**	16.30-149.00 (70.37±51.19)	25.00-138.00 (67.07 ±39.62)	33.70 -68.00 (50.72 ±12.28)	26.00-161.00 (70.40± 43.08)	16.30-161.00 (63.80 ± 24.70)
NH_4^+/N	**µM**	0.19-70.03 (18.16±26.99)	1.85-118.29 (30.55 ± 43.55)	1.34-54.77 (15.70± 19.77)	7.47-33.52 (16.40 ±10.26)	0.19-118.29 (15.61 ± 15.46)
NO_2^-/N	**µM**	0.05-11.50 (2.00 ± 3.91)	0.05-4.50 (1.03 ± 1.59)	0.12 -22.48 (6.00 ± 7.70)	0.10-19.83 (6.52 ± 6.60)	0.05 – 22.48 (3.43 ± 3.38)
NO_3^-/N	**µM**	0.14-44.71 (6.54 ± 15.04)	0.26-34.46 (13.98 ± 12.65)	1.22 -20.36 (8.26 ± 6.64)	5.00- 66.67 (31.97 ± 20.47)	0.14-66.67 (13.50 ± 7.78)
DIN	**µM**	0.39-126.24 (26.70 ± 45.94)	2.19-157.26 (45.56± 57.79)	2.68-97.61 (29.96 ±34.11)	12.57-120.02 (54.89± 37.33)	0.39-157.26 (39.28± 43.79)
TN/N	**µM**	1.25-90.48 (29.93 ± 34.44)	0.32-63.35 (17.28 ± 23.43)	15.43 -75.14 (38.24 ± 22.41)	25.42-123.55 (57.67 ± 30.10)	0.32 – 123.55 (33.64 ± 18.77)
PO_4^{3-}/P	**µM**	0.10-41.60 (10.89 ± 16.82)	0.10- 15.40 (4.06 ±5.56)	0.30 -15.20 (4.64 ± 4.90)	1.15- 45.30 (13.80 ± 16.32)	0.10-45.30 (8.27 ± 10.28)
TP/P	**µM**	0.04-15.05 (5.10 ±5.77)	0.61-17.34 (4.23 ± 5.53)	1.10 -17.70 (7.78 ± 5.67)	1.74-49.60 (16.04 ± 17.46)	0.04-49.60 7.98 ± 6.93)
SiO_4^-	**µM**	8.63-64.91 (26.12 ± 21.08)	4.58-226.16 (73.64 ± 74.39)	4.50 -105.73 (49.13 ± 27.99)	2.14-24.63 (9.83 ± 7.87)	2.14 – 226.16 (39.97 ± 21.85)
Chl-a	**µgl/l**	3.95-75.84 (29.12 ± 26.07)	6.90-127.50 (31.45 ± 39.18)	6.10 -38.56 (24.26 ± 11.40)	7.80-130.30 (32.68 ± 39.82)	3.95-130.30 (28.51± 21.99)

Salinity plays an important role in biological processes affecting algal blooms, fish movements, shellfish productivity, and aquaculture. Different Tilapia species can be adapted according to water salinity in the range of 5-49‰ (Abdel-Fattah 2006). Decrease in water salinity enhances the flourishment of macrophytes to cover wide areas of the Lake (Mamdouh *et al*. 2001). The present data revealed wide variation in the level of salinity content (Table 1). Minimum salinity values were 0.39 followed by 0.43 at Nubaria drain (drinking water canal) in spring and autumn seasons respectively. The maximum salinity values were 7.4‰ followed by 7.12‰ at station VII in spring and summer seasons (Fig. 2). The salinity annual average was 3.70‰ ± 1.69‰ (Table 1). Generally, these low salinity values indicate that; the water content in Lake Mariout was mainly fresh water during 2014. This may be due to human activities and the quantity and quality of drainages run off on the Lake.

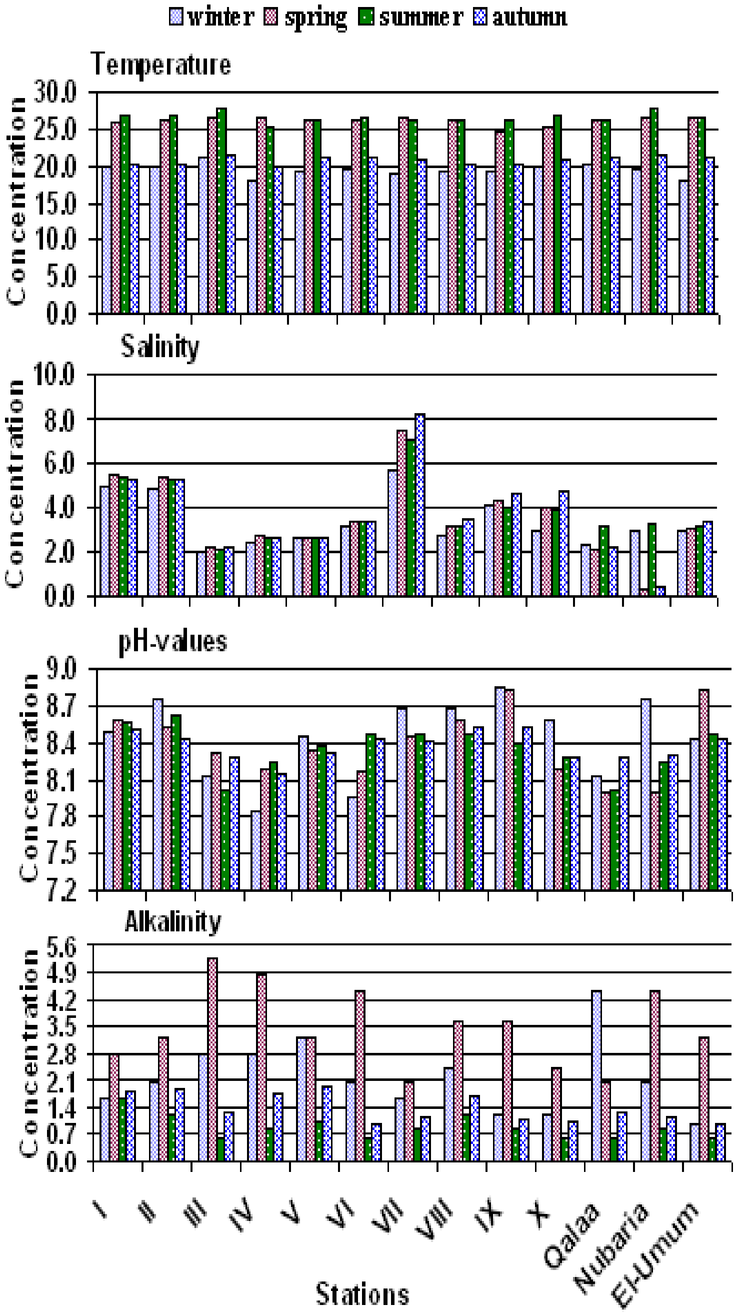

Fig. 2: Spatial and temporal variations of water temperature (°C), salinity, pH and total alkalinity (meq/l) in Lake Mariout water during 2014.

Hydrogen ion concentration (pH-value) plays an important role in the biological processes of almost all aquatic organisms, for safe level of pH, for a normal range fish productivity (5.0 –9.0), and for maximum productivity, pH values should range from 6.5 to 8.5 (Phang 1991). As for Tilapia species, to ensure high production, the optimum level of water pH should be between 5 - 8.5 (Rachman and Adi 2005). Standard range according to Law 48/1982 is from 7.0 to 8.5. The pH-values in Lake Mariout water differed between a minimum of 7.84 at station IV and a maximum of 8.84 at station IX in winter followed by 8.83 at both stations IX and Umum drain in spring (Fig. 2), indicating that the water of the lake is slightly alkaline (Table 1). These values are slightly higher than those reported by Saad *et al*. (2017) (7.16-8.6) and compatible with that recorded by Mateo (2009) (7.5-8.9). The variation may be due to photosynthetic activity of algal organisms as well as by the amount of discharged sewage and watershed run off.

Total alkalinity of water refers to the total concentration of bases expressed as mg/L equivalent calcium carbonate (mg/L $CaCO_3$). Fish generally show better growth in those areas of moderate alkalinities exceeding 50 mg/L of $CaCO_3$ (Lazur, 2000). The optimum alkalinity level of water suggested for Tilapia production ranges between 50-100 mg/L of $CaCO_3$ (Rachman and Adi 2005). In the present study; alkalinity ranged between 0.60meq/l at stations VI&X beside Qalaa and El-Umum drains in summer and 5.24meq/l at station III in spring with an annual average of 1.97 ± 0.43meq/l (Table 1 and Fig. 2). Natural alkalinities fall within a general range of (0.40 to 4.00 meq/l). Relatively high alkalinity was reported in some stations during spring as a result of the presence of fresh water source may rich in Ca and Mg carbonate. There can be long-term changes in the alkalinity of water in response to human disturbances (Kaushal *et al*. 2013). The higher of alkalinity values of the lake is the greater in resistance to the pH changes.

Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Oxidizable organic matter (OOM), Chlorophyll-a (Chl-a), and Total suspended matter (TSM):

Dissolved oxygen is one of the most important water variables affecting fish production. The lowest dissolved oxygen concentrations were recorded at station III in all seasons (0.14-0.29 mg/l), Qalaa drain in all seasons except spring, and El Umum drain and station VI in spring. These lowest values may be due to the increasing rate of sewage discharge and consequently the decomposition of organic matter. Generally, it was argued that the optimum oxygen concentration should be above 5 mg/l at all times for good fish growth (Lazur 2000). For Tilapia species, the recommended optimum dissolved Oxygen level of water should exceed 3 mg/l (Rachman and Adi 2005).

According to Law 48/1982, standard level should exceed 4 mg/l. The decrease in oxygen supply in the water showed a negative effect on the fish and other aquatic life. The highest value of dissolved oxygen (10.71 mg/l) was observed at station IX in autumn. The annual mean value was 4.91 ± 2.98 mg/l (Table 1 and Fig. 3). DO concentrations evaluated from the present study during 2014 were higher than that obtained by Saad *et al*. (2017) (2.14-5.63) mg/l during 2014-2015, reflecting the fluctuation of organic load subjected to the Lake.

Biological Oxygen Demand (BOD) refers to the quantity of oxygen consumed in the course of aerobic processes of decomposition of organic materials, caused by microorganisms (ReVelle and ReVelle 1988). BOD therefore provides information on the biologically-convertible proportion of the organic content of water samples. Therefore, a low BOD is an indicator of good water quality, while a high BOD indicates polluted water. BOD is stated in mg/l of oxygen and is usually measured within a period of 5 days (BOD_5). The obtained data of BOD fluctuated between 0.01mg/l at station V during autumn season and 2.4 mg/l at station VII and Qalaa drain followed by 2.6 mg/l at stations III and IV in summer season. Relatively, the high BOD values were observed during summer season coincided with a high level of pollution in this season. The annual average was 1.35 ± 0.32 mg/l (Table 1 and Figure 3).

It is noticed that the lowest TSM values were observed in summer season, while the highest values were observed in autumn season 2014, as that was observed with the oxidizable organic matter values which may indicate the high load of discharged water into Lake Mariout during this season. The annual average of TSM value was 63.80±24.70mg/l (Table 1).

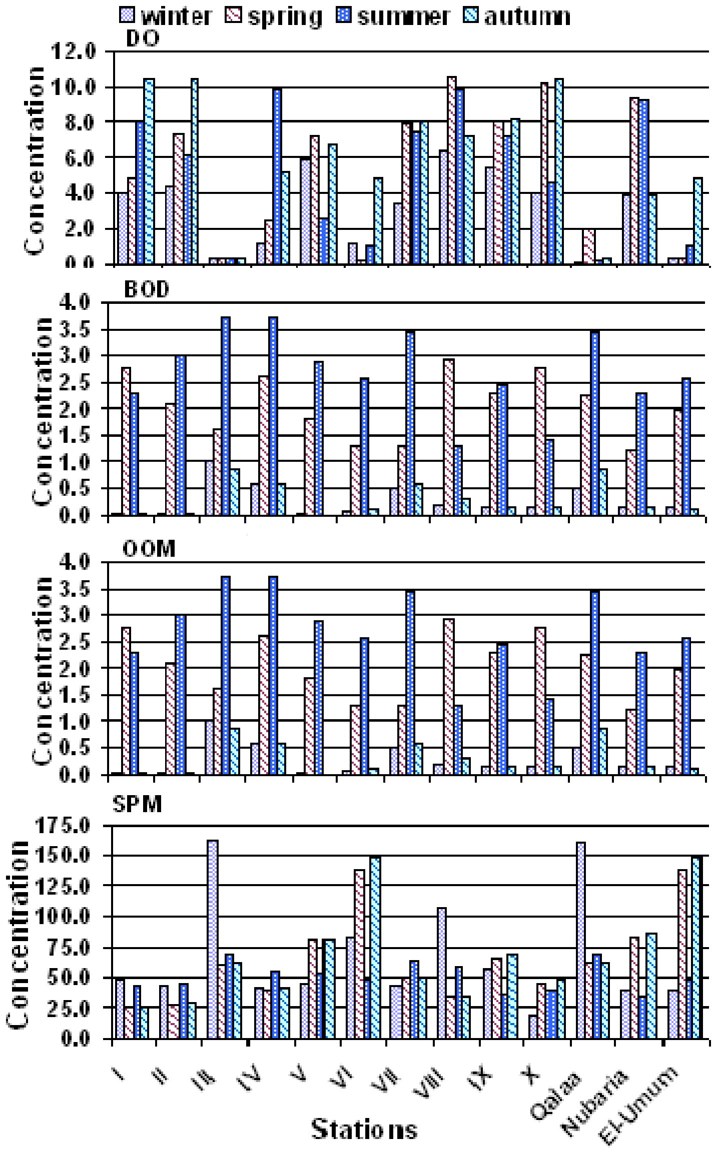

Fig. 3: Spatial and temporal variations of DO, BOD, OOM and SPM (mg/l) in Lake Mariout water during 2014.

Nutrient salts

Nutrients from anthropogenic pollution can degrade water quality and alter the balance of marine food webs. Quick responses to nutrient changes in the water can have repercussions throughout both pelagic and benthic food webs, and thus they serve as a good bio-indicator of water quality (Moritsch *et al*. 2010). Nutrient concentrations determine the magnitude of phytoplankton growth, which relates to total fish production. Hence, for obtaining maximum fish production, it is necessary to maintain the nutrient status of the pond to an optimum range (Brunson *et al*. 1999).

Dissolved inorganic nitrogen (DIN: NH_4^+/N, NO_2^-/N and NO_3^-/N) and Total Nitrogen (TN):

Ammonium (NH_4^+/N): Normally, warm water fish are more tolerant to ammonium toxicity than cold water fish, so NH_3-N concentrations should be held below 0.05 mg L^{-1} and total ammonia nitrogen (TAN) concentrations below 1.0 mg L^{-1} for long-term exposure (Timmons *et al*. 2002). The regional and seasonal distribution of ammonium content (NH_4^+/N) in Lake Mariout waters varied from near depletion at stations I, VIII, and X followed by 0.19 µM at station II in winter and 118.29 µM at station III and Qalaa drain in spring 2014 (Fig. 4). Ammonium content in Lake Mariout is higher than that recorded by (Okbah and El Goharry 2002) in Lake Edku in spring (9.10 ± 3.20µM) but lower than those recorded by Saad *et al*. (2017) who stated that ammonium differed from 87.0 to 234.7 µM in 2014-2015. The annual mean content of ammonium was 15.61 ± 15.46 µM (Table 1).

Nitrite (NO_2^-/N): A minor constituent of DIN represents from 0.04 to 8.99% of DIN and is characterized as intermediate compound which could be derived either from the oxidation of ammonium or reduction of nitrate and can be removed from solution during nitrogen assimilation by phytoplankton. It is recommended for the highest production of Tilapia that NO_2^-/N concentration in water should not exceed 0.06 mg/l (0.02 mg/l of NO_2^- form) (Rachman and Adi 2005). According to the obtained data of nitrite concentration, it is noticed that most stations are not suitable for Tilapias production. Nitrite concentrations differed between near depletion (0.05µM) followed by 0.08, 0.1µM at station X in all seasons of 2014, and 22.48 µM followed by 19.83 µM at station V in summer and autumn, respectively (Fig. 4). Annual nitrite average was 3.43±3.38 µM (Table 1). The lowest nitrite concentrations values were observed in winter, while the highest values were noticed in autumn followed by summer season. This is mostly due to the high rate of nitrification processes where the level of NH_4^+ concentration was inversely proportion to this relation during this period of study.

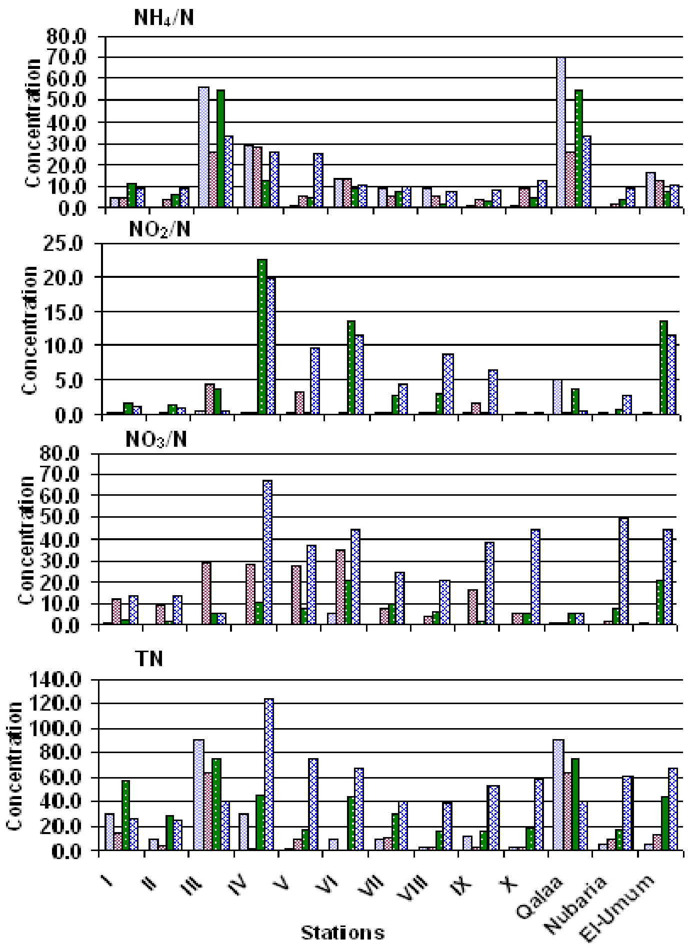

Fig. 4: Spatial and temporal variations of NH_4/N, NO_2/N, NO_3/N and TN (µM) in Lake Mariout water during 2014.

Nitrate (NO_3^-/N): The most stable and predominant inorganic nitrogen compound form in oxygenated water. Nitrate is relatively non-toxic to tilapia, but exposing tilapia to elevated levels of nitrate for a long time could decrease the immune response and induce mortality (Abdel-Fattah 2006). Nitrate concentrations fluctuated between a minimum value 0.14 µM at stations IV and VII, followed by 0.17 µM at station X in winter and maximum value 66.67 µM at station IV in autumn (Fig. 4). The annual average nitrate concentration was 13.50 ± 7.78 µM (Table 1). It is noticed that; nitrate concentration showed the lowest values in winter followed by summer; while the maximum nitrate values were observed in autumn season accompanied by the highest oxidizable organic matter concentrations; this may indicate the relative increase in agricultural discharge in autumn 2014. These obtained values are much higher than those obtained by Saad *et al*. (2017); (7.4- 11.1) µM.

Dissolved inorganic nitrogen (DIN): It represents the sum of (NH_4^+/N, NO_2^-/N, and NO_3^-/N) which is assimilated by aquatic organisms. The present results showed that; the average of NH_4^+/N, NO_2^-/N, and NO_3^-/N concentrations were 15.61, 3.43, and 13.50 µM, respectively (Table1). These mean values represented 51.90, 9.25, and 38.79% from the total dissolved inorganic nitrogen, respectively. From the average percentage values of different N ions relative to DIN, it can be indicated that NH_4^-/N is the abundant form followed by NO_3^-/N, while NO_2^-/N is the least constituent. This observation reflects that; the rate of denitrification is the major one followed by nitrification process. Based on these results, the abundance of inorganic nitrogen species in the study area are principally in the order NH_4-N> NO_3-N >> NO_2-N. These results were deviated from those obtained by (Faragallah *et al*. 2009 and Hermine *et al*. 2016).

Total nitrogen (TN):

It ranged between 0.32 µM at station VI in spring and 123.6 µM at station IV in autumn 2014 (Fig. 4). The annual average of TN was 33.64 ± 18.77 µM. Generally, spring season showed the lowest TN value, while the highest TN value was observed in autumn season. The highest values of TN were accompanied by the highest nitrate, nitrite, and oxidizable organic matter concentration which indicated the high agricultural discharge during autumn 2014. Generally, the present study showed lower rate of content of TN, it was decreased 10 folds in comparison with those reported for Lake Mariout, by El Rayis (2005), which might be as a result of processes of water treatment (west treatment plant). Total nitrogen concentration obtained from the present study was much lower than that recorded by Alnagaawy *et al*. 2018 in Lake Mariout during 2015 (615.71+31.57) µM.

Reactive Phosphate (PO_4^{-3}/P) and Total phosphorus (TP):

Phosphorus plays a major role in biological metabolism; it is an essential nutrient element, which plays an important role in photosynthesis and other processes in plants and algae. Phosphorus as P_2O_5 is the most important nutrient for tilapia in ponds (Brunson *et al*. 1999). Phosphorus has been regarded as the most important nutrient in waste from aquaculture, followed by ammonia, and it is an important limiting factor for the primary productivity in most aquatic environments (Beveridge 2004). However, the eutrophying effects reported in the literature are usually more related to phosphorus than to nitrogen compounds or to organic matter (Sara 2007). The previous work indicates that; only 32% of phosphorus is used for the fish metabolism, and the remainder is transferred to the environment and may induce eutrophication state (Penczak, *et al*. 1982; Wetzel 2001). Alves and Baccarin (2007) reported that; 66% of phosphorus deposited by intensive feeding goes to the sediment.

Reactive Phosphate concentrations fluctuated between 0.10 µM followed by 0.15 µM at station II in spring and winter, respectively. High level was recorded at station V (14.30 µM) in autumn. Very high value of 45.3 µM was observed at stations III and Qalaa drain in autumn season (Fig. 5). Most phosphate concentrations of the present study agreed with the range obtained by Saad *et al*. 2017. The annual average was 8.27±10.28 µM (Table1). The highest phosphate concentrations were observed in autumn, while the lowest values were noticed in summer season. The highest phosphate values confirm the high agricultural discharge during autumn 2014; they were also accompanied by the highest nitrate, nitrite, total nitrogen, and oxidizable organic matter concentration values.

In the present study, total phosphorus fluctuated between 0.04 µM at station II in winter to 49.60 µM at stations III and Qalaa drain in autumn (Fig. 5). The maximum values of total phosphorus in autumn matched with the highest values of reactive phosphate, nitrate, nitrite, total nitrogen, and oxidizable organic matter content.

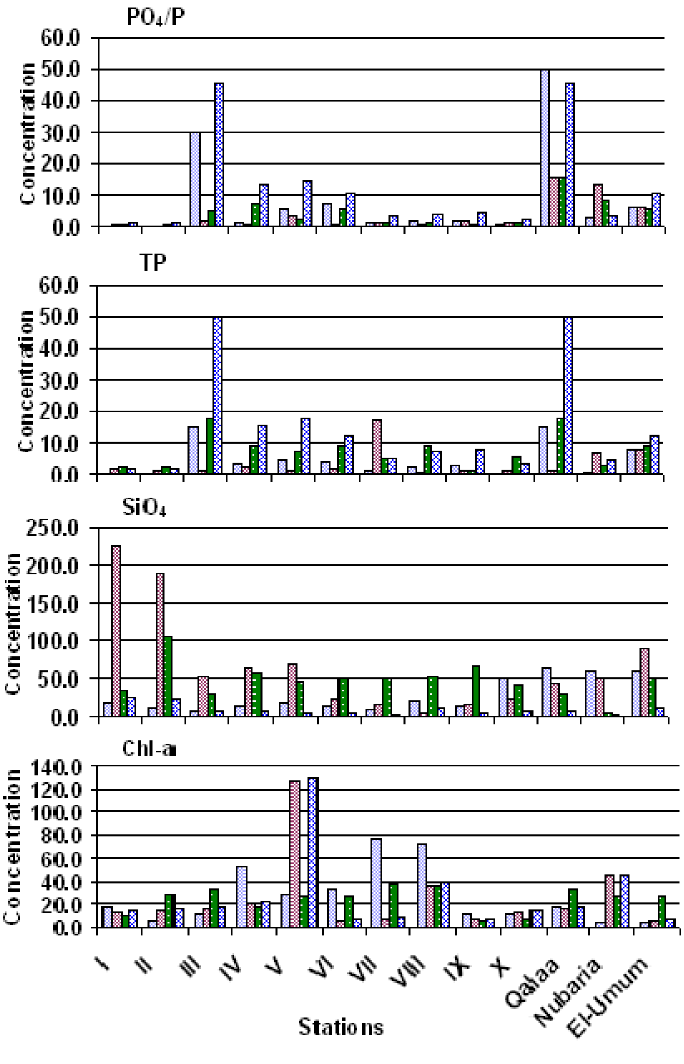

Fig. 5: Spatial and temporal variations of PO_4/P, TP and SiO_4 (µM) and Chl-a (µg/l) in Lake Mariout water during 2014

These results confirm the high agricultural discharge during autumn 2014. Generally, minimum TP concentrations were observed in spring followed by winter, while maximum TP values were observed in autumn. The annual average of TP content was 7.98 ± 6.63 µM (Table1). The average of the present study was less than that obtained by Alnagaawy *et al*. 2018 in Mariout lake during 2015 (32.32+1.16) µM.

Reactive silicate (SiO_4^-):

Silicate is one of the major constituents in the aquatic environment. It is a good indicator of fresh water dispersion and of the potential for diatom (Fahmy *et al*. 1999). The principal source of silicon for Lake Mariout is agricultural drainage (Masoud *et al*. 1984). In the present study, SiO_4^- fluctuated between 2.14 µM at station VII in autumn and 226.16 µM at station I in spring (Fig. 5). These results agreed with those obtained by (Saad *et al*. 2017), who found that silicate concentration was in the range 14.60- 221.90 µM. Generally, the minimum values were observed in autumn followed by winter seasons, while maximum SiO_4^- values were observed in spring season. Probably, in autumn and winter the rate of chemical precipitation of silicate occurred and retained to the sediment faster than the diffusion to the water column. But during summer and spring, the dissolution of diatom skeletons by increasing temperature is responsible for the relative high level of silicate content. The annual mean concentration of SiO_4^- was 39.97 ± 21.85 µM (Table1). This annual mean is higher than that of the other nutrient salts, indicating that SiO_4^- is not a limiting factor in Lake Mariout. The data were markably higher than those recorded by Dorgham *et al*. (2004) in the western Harbor (9.03 µM), Abdel Aziz *et al*. (2001) in Abu Qir Bay (16.74 µM), and Abdel Aziz *et al*. (2006) in El-Dekhaila harbour (49.52 µM). Although the drainage waters have been reported as the principal source of silicate in the Lake and play a significant part in its spatial and temporal distribution, it was found that phytoplankton growth was actually regulating the silicate level (Dorgham *et al*. 2004). The calculated ratio of DIN/SiO_4^- in the different parts of the study area varied between 0.2 at stations II and 2.68 at station III.

Chlorophyll- a (Chl-a):

Chlorophyll- a (Chl-a) is considered as the main pigment that can be used for the determination of phytoplankton biomass (Carlson 1977), and it is used as a trophic state indicator. Chl-a reflected the water quality in the Nile's tilapia aquacultural ecosystem (Ahmed 2015). Chlorophyll-a ranged between 3.95µg/l at Nubaria drain in winter and 130.3 µg/l at station V in autumn (Fig. 5). Near average values were observed during all seasons. Generally, minimum average Chl-a values were observed in summer while maximum average concentrations were observed in winter 2014. The annual average of Chl-a content was 28.51 ± 21.99 µg/l (Table 1). In general, the high values of chlorophyll-a in the investigated area are undoubtedly due to the rich supply of DIN, reactive silicate, and reactive phosphate, these nutrient salts contribute in the growth of phytoplankton expressed in high levels of Chl-a which lead to the eutrophication process in the Lake. The levels of DIN, PO_4^{3-} and chlorophyll-a indicated that the Lake is under eutrophic condition.

By comparing the results showed from Table 1, it was noticed that; the highest average values of alkalinity, NH_4^+, and SiO_4^- were observed in spring season. The highest average of water temperature, BOD and salinity were reported in summer season, while DO, OOM, NO_2^-, NO_3^-, and PO_4^{3-} were recorded in autumn season. Meanwhile; the lowest DO, BOD, NO_3^-, and salinity were observed in winter 2014; alkalinity and NH_4^+ were observed in summer season, OOM and PO_4^{-3} and SiO_4^- were found in spring and autumn, respectively.

Statistical analysis

N/P ratio

Dissolved inorganic nitrogen (DIN) and PO_4/P are the main forms of N and P that are readily bioavailable for the growth of phytoplankton. Based on the data of the present study, the N/P ratios varied from 3.08 at station 8 to 20.37 at station 1. The ratios of N/P fluctuated between 3.08 and 8.67 and maximum variations were observed only for both stations 1 and 2 (20.37, 12.97, respectively), this may be due to the richness of the fish farm with nutrients at stations 1 and 2. Total average N/P ratio was 4.92; this means it is near to 5:1 ratio.

The N/P ratio in the present study is significantly lower than the assimilatory optimal N/P=15/1 and N/P=16/1 ratio reported by Redfield *et al*. (1963). According to previous studies, Smith (1979) found that phytoplankton yield depends mainly on N/P ratio; ratio > 15-17:1 indicates that phosphorus was the critical controlling factor, from < 9-10:1 indicates that the yield varied with nitrogen, and > 21 shows that phosphorus was the primary controlling factor. Extreme variation of N/P ratio is common along the Egyptian Mediterranean coast, particularly at areas exposed to land based runoff (Dorgham *et al.* 2004). The results recorded by Chiaudani and Vighi (1978) found that marine algae are P-limited at N: P ratio > 6 and N – limited at ratio < 4.5; in range of 4.5 – 6, the two nutrients are near their optimal assimilative proportion.

In the present study, N/P ratio ranged between low value > 3 (N-limited) and very high values 20.4 (P-limited). Very low values of N/P ratio were recorded at most periods of the study, this consideration showed that nitrogen is a limiting factor in the Lake. Also, the ratio average value in the study region (4.92) indicates that nitrogen and phosphorus are removed from water at almost constant proportions. This observation was true by the studies carried out by Aboul-Kassim (1987) and Faragallah (1995) in the Eastern Harbor.

The results recorded by Saad *et al*. (2017) showed that the N/P ratios were decreased from 90.3 during autumn to 13.1 during winter reaching a minimum value during spring (12.0). Summer showed N/P ratio being 15.5 which was close to the normal one.

In general, nitrogen is the limiting factor for Lake Mariout, while phosphorus is an important source of eutrophication, and it originates from domestic and industrial waste water.

<u>Trophic indices</u>

Trophic index (TRIX)

Water quality index provides a convenient means of summarizing complex water quality data. In order to identify the trophic condition of Lake Mariout, the water quality TRIX index was calculated (Vollenweider *et al*, 1998). It is a linear combination of four state variables related to primary production (chlorophyll-a and oxygen) and nutritional condition (dissolved inorganic nitrogen, inorganic phosphorus) (Melaku *et al*. 2003). This index was calculated as follows: Trophic index levels were defined as: low trophic level with TRIX < 4, moderate trophic level with 4 < TRIX < 5, high trophic level with 5 < TRIX < 6, and very high trophic level with TRIX > 6 which revealed high nutrient levels, low transparency, and recurrent hypoxia/anoxia in bottom waters (Peng *et al*. 2015). This scale was compared to the 5-category scale (excellent, very good, good, fair, and poor) for water quality state (Moncheva *et al*. 2002).

Carlson's trophic state index

One of the standard water quality indices used by limnologists and lake managers is the trophic status index (TSI; Carlson 1977). The basis of the TSI is to quantitatively describe the trophic continuum based on the relationships between total phosphorus, water clarity (Secchi depth), and chlorophyll *a*. Further analyses of the TSI can be used to determine potential limiting factors of algal growth (Carlson and Havens 2005). While trophic indices are useful for this purpose, they are based on empirical relationships for a subset of lakes and are restricted to trophic assessment. It is still desirable to have a tool that can be tailored to assess specific nutrient targets for a water body and to expand the definition of water quality to include variables other than phosphorus, Secchi depth, and chlorophyll-*a*.

In accordance with the definition of trophic state, the trophic state index (TSI) of Carlson (1977) uses algal biomass as the basis for trophic state classification. Carlson's Trophic State Index (TSI) is a common method for characterizing a lake's trophic state (Table 2). Three variables are used to estimate algal biomass (Chlorophyll-a, Secchi depth, and Total phosphorous). The range of the index between 40 and 50 is usually associated with mesotrophy (moderate productivity); values greater than 50 are associated with eutrophy (high productivity); values less than 40 are associated with oligotrophy (low productivity). Application of TSI to Lake Mariout under study revealed that the lake has an Index above 60 and is considered to be hypereutrophic. There is dominance of blue green algae, formation of algal scums, and extensive macrophytic problems.

Table 2: Carlson's trophic state index values and classification of lakes

TSI	Trophic	Attributes
< 30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes will become anoxic during the summer
40- 50	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
50-60	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency, warm-water fisheries only
60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems
70-80	Eutrophic	Heavy algal blooms possible throughout the summer
>80	Eutrophic	Algal scum, summer fish kills, few macrophytes

According to seasonally calculated TRIX and Carlson's trophic state indices values, the sites are ranked in a descending order from very high to moderate eutrophic level in most stations as shown in (Figs. 6 and 7); revealing the existence of anthropogenic pressure.

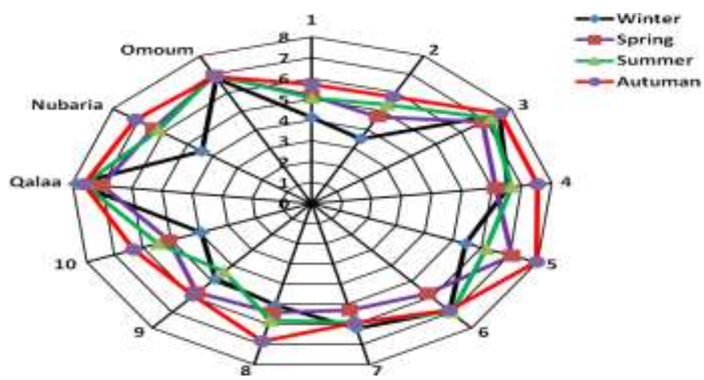

Fig. 6: Radar Chart representative of TRIX Index

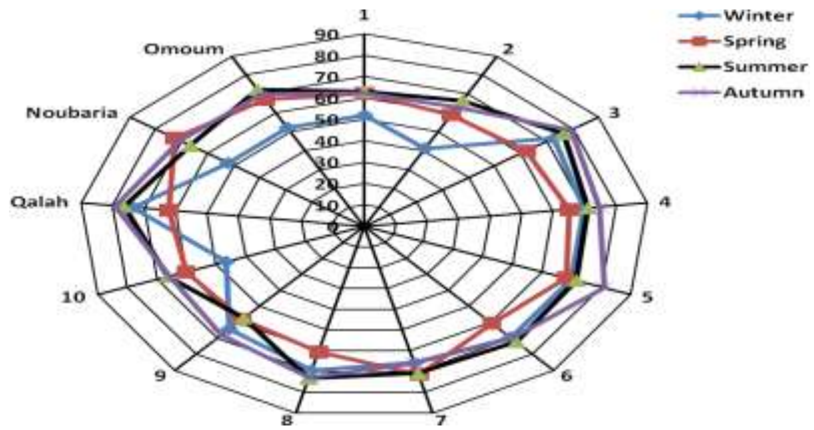

Fig. 7: Radar Chart representative of Carlson Trophic State Index

Conclusions

Because of the different pollution problems in Delta lakes increasing with time following the successive increase in population, the following principal proposals and measures are strongly recommended for better protection, conservation, and management of these wetlands in order to increase the opportunities of the socioeconomic development of the country:

1. Sewage, agricultural and industrial wastes dumping into Mariout Lake must be treated, at least by limiting the amounts of nutrients;
2. Industries affecting Mariout Lake should adopt low- and non-waste technologies at all stages of production;
3. New agricultural technologies could be used to decrease fertilizers in agriculture for the reduction of nitrogen and phosphorus inputs into Lake Mariout.

The selected parameters readily discriminating among sites could be considered as indictors of ecological quality. The results could contribute to further efforts for defining typology and mapping WQ based on harmonized, unified descriptors and indicator categories to help decision makers implement strategies to Lake Mariout's development.

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REFERENCES

Abdel Aziz, N.E.M.; Fahmy, M.A. and Dorgham, M.M. (2001). Hydrography, nutrient levels and plankton abundance in Abu-Qir Bay, Egypt. Mediterranean Marine Science, 2 (2): 13-17.

Alnagaawy A. M.; Sherif M. H.; Assy M. G. and Shehata A. S. 2018 Impact of industrial pollutants on some water quality parameters of Edku, Mariout lakes and the Nile River International Journal of Environment,7:1-15.

Abdel Aziz, N.E.M.; Fahmy, M.A. and Dorgham, M.M. (2006). Water quality observations on the Dekhaila Harbour, Alexandria, Egypt. Egyptian Journal of Aquatic Research, 32 (2): 167-182

Abdel-Fattah, M. E. (2006). Tilapia Culture in Salt Water: Environmental Requirements, Nutritional Implications and Economic Potentials. En: Editors: L., Elizabeth Cruz Suárez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto López, David A. Villarreal Cavazos, Ana C. Puello Cruz y Armando Garcia Ortega. Avances en Nutrición Acuicola VIII. VIII Simposium Internacional de Nutrición Acuicola. 15-17 November. Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, México. ISBN 970-694-333-5.

Abdelfattah, S.S.; Magdy, A. M.; Ranya, A. A. and Mohamed, A. Gh. (2017). Assessment of the Physico-chemical Characteristics and Water Quality Analysis of Mariout Lake, Southern of Alexandria, Egypt. Journal of Environmental and Analytical Toxicology, 7(421): 1-19, doi: 10.4172/2161-0525.1000421

Aboul-Kassim, T. (1987). Cycles of carbon, nitrogen and phosphorus in the marine environments of Alexandria region. MSc. Thesis, Faculty of Science, Alexandria University, 233p.

Ahdy, H.H. (1982). Distribution of heavy metals in Lake Mariout and Nozhe Hydrodrome and their accumulation in fish. MSc. Thesis, Department of Oceanography, Alexandria University.

Ahmed, M. E. (2015). Evaluation of the physicochemical and chlorophyll-a conditions of a subtropical aquaculture in Lake Nasser area, Egypt. Beni-Suef University of Basic and Applied Sciences, 4(4): 327-337.

Alnagaawy A. M.; Sherif M. H.; Assy M. G. and Shehata A. S. 2018. Impact of industrial pollutants on some water quality parameters of Edku, Mariout lakes and the Nile River International Journal of Environment,7:1-15.

Alves, R.C.P. and Baccarin, A.E. (2007). Efeito da produção de peixes em tanques-rede sobre sedimentação de material em suspensão e de nutrientes no córrego da Arribada (UHE Nova Avanhandava, baixo rio Tiête, SP). In NOGUEIRA, M.G., HENRY, R. and JORCIN, A. (Eds.). Ecologia de Reservatórios: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos, Rima: 329-347.

American Public Health Association, APHA. (1995). Standard methods for the examination of water and wastewater. 12th edition, New York. 769p.

Arab Republic of Egypt, Ministry of State for Environmental Affairs, Egyptian Environmental Affairs Agency; Alexandria Integrated Coastal Zone Management. Project (AICZMP) Environmental and Social Impact Assessment, (2009).

Bakhoum, S.A. (1994). Comparative Study on Length Weight relationship and Condition Factor of the Genus Oreochromis in Polluted and Non-polluted parts of Lake Mariout Egypt, Bulletin of The National Institute of Oceanography and Fisheries, 20 (1): 201-282.

Beveridge, M.C.M. (2004). Cage Aquaculture, (3rd edition), Blackwell Science, Oxford, UK, pp 164–182.

Brunson, W.; Stone, N. and Hargreaves, J. (1999). The effects of plankton on Tilapia growth using organic and inorganic fertilizers and what causes phytoplankton bloom to "crash". Fertilization of Fish Ponds. PR SRAC Publication No. 471 SRAC Publication No. 471. 4 Pages.

Carlson, R. E. and Havens, K. E. (2005). Simple Graphical Methods for the Interpretation of Relationships between Trophic State Variables, Lake and Reservoir Management, 21(1): 107-118, DOI: 10.1080/07438140509354418.

Carlson, R.E. (1977). A trophic state index for lakes. Limnology and Oceanography, 22 (2): 361-369.

Chester, R. (2000). Marine Geochemistry, 2nd Edition. Block Well Science Ltd, 493pp.

Chiaudani, G. and Vighi, M. (1978). Metodologia standard di saggio algale per lo studiodella contaminazione delle acque marine, Quad. Instituto di Ricerca Sulle Acque (IRSA), 39: 120-130.

Darwin, L.; Sorensen, M.M.; McCarthy, E.; Joe, M. and Donald, B.P. (1977). Suspended and dissolved solids effects on freshwater biota: A Review. Ecological research series. Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Corvallis, Oregon 97330. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161. Alaska Resources Library & Informaticin Services Anchorage, AK, 65p.

Dorgham, M.M.; Abdel-Aziz, N.E.; El-Deeb, K.Z. and Okbah, M.A. (2004). Eutrophication problems in the Western Harbor of Alexandria, Egypt. Oceanologia, 46 (1): 25–44.

El-Rayis, O.A. (2005). Impact of Man’s Activities on a Closed Fishing-Lake, Lake Maryout in Egypt, as a Case Study. Mitigation and Adaptation Strategies for Global Change. 10: 145–157.

El-Rayis, O.A.; El-Sabrouti, M. and Hanafi, H. (1994). Some Hydro-Chemical Observation from Lake Mariout prior to Diversion of Sewage of Eastern Districts of Alexandria, 1st Arab Conf. Mar. Environ. Protec., Arab Maritime Transport Academy, Alexandria, 5(7): 191–204.

El-Sherif M.S.; El-Feky A.M. (2009). Performance of Nile tilapia O. niloticus fingerlings. II. Influence of different water temperatures. Int. J Agric. Biol., 11:301-305.

Fahmy, M.A.; Beltagi, A.I. and Abbas, M.M. (1999). Nutrient salts and Chlorophyll-a in the Egyptian Mediterranean coastal waters. MEDCAST 99- EMECS99 Joint conferences, Land-Ocean Interactions: Managing Coastal Ecosystems, 9-13 November, Antalya, Turkey.

FAO. (1975). Manual of methods in aquatic environment research. FAO Fish. Tech. Paper No. 137- 238 pp.

Faragallah, H. M.; Tadros, H. R. Z. and Okbah, M. A. (2009). Nutrient salts and chlorophyll-a during short term scale in the Eastern Harbour, Alexandria (Egypt), Egyptian Journal of Aquatic Research, 35(3): 243-250.

Faragallah, H.M. (1995). Sediment-water interface chemistry in the Eastern Harbour, Alexandria, Egypt. MSc. Thesis, Faculty of Science, Alexandria University, 277p.

Francis-Floyd and Ruth. (2003). Dissolved Oxygen for Fish Production, Fact Sheet FA 27, The Department of Fisheries and Aquaculture, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, February 2003. http://edis.ifas.ufl.edu/FA002#FOOTNOTE_1, Accessed 11, January, 2008.

Grasshoff, K. (1976). Methods of seawater analysis, Verlag Chemie Weikeim, New York.

Hermine, R.Z.T.; Galila, H.I.; Gehan, M.El-Z. and Okbah, M.A. (2016). Multivariate analysis to investigate the organization of physicochemical parameters in the Eastern Harbour Alexandria, Egypt. International Journal of Contemporary Applied Sciences, 3(3): 33-58.

Jeffrey, S.W. and Humphrey, G.F. (1975). New spectrophotometric equations for determining chlorophylls *a*, *b*, c_1 and c_2 in higher plants, algae and natural phytoplankton. Biochemie und Physiologie der Pflanzen, 167 (2): 191-194.

Kaushal, S.S.; Likens, G.E.; Utz, R.M.; Pace, M.L.; Grese, M. and Yepsen, M. (2013). "Increased river alkalinization in the Eastern U.S". Environmental Science & Technology, 47 (18): 10302–10311, doi: 10.1021/es401046s.

Lazur, A.M. (2000). Management Considerations of Fish Production in Cages, Bulletin FA-36, Department of Fisheries and Aquatic Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu/FA048#FOOTNOTE_1, Accessed 06, January, 2008.

Liu, W. and Qiu, R.L. (2007). Water eutrophication in China and the combating strategies. Journal of Chemical Technology and Biotechnology, 82(9): 781–786, doi: 10.1002/jctb.1755.

Mamdouh, M.A.; Shakweer, L.M. and Youssef, D.H. (2001). Ecological and Fisheries management of Edku Lake, 1. Hydro-Chemical characters of Edku Lake. Bulletin National Institute of Oceanography and Fisheries, A.R.E. 27: 65-93.

Massoud, A.H.S.; El-Rayis, O.A. and Ahdy, H.H. (1984). Status of nutrients in Lake Mariout, a delta lake in Egypt suffering from intensive pollution. Marine Pollution Bulletin, 15 (11): 408-411.

Mateo M. A. (2009). Lake Mariut: An ecological assessment. WADI project water demand integration; INCO-CT-2005-015226.

Melaku, C.D.; Solidoro, C. and Umgiesser, G. (2003). Modelling the response of the Lagoon of Venice o variations in physical forcings. Ecol. Model, 170: 265–289.

Moncheva, S.; Dontcheva, V.; Shtereva, G.; Kamburska, L.; Malej, A. and Gorinstein, S. (2002). Application of eutrophication indices for assessment of the Bulgarian Black Sea coastal ecosystem ecological quality. Water Science Technology, 46: 19–28.

Moritsch, M.; Szendrenyi, A.; Leger, Ch. and Frossard, B. (2010). Associations among Plankton Abundance, Water Quality and Sediment Quality in the San Francisco Bay: Nitrogen and Phosphorus Berkeley Scientific Journal, 14 (1): 45-54.

Okbah, M.A. and El-Gohary, S.El. (2002). Physical and Chemical Characteristics of Lake Edku Water, Egypt Medit. Mar. Sci., 3(2): 27-39.

Okbah, M.A. and Tayel, F.T.R. (1997). Chemical availability and transformation of trace metals (Fe, Mn, Zn, Co and Ni) in Lake Maryut sediments, Alexandria, Egypt. Chemistry and Ecology, 14: 55-67.

Okbah, M.A.; El-Deek, M.S. and El-Attar, H.A. (1996). Distribution of Cu, Zn, Pb and Cd in some recent molluscan shells from Lake Maryut sediment. Pakistan Journal of Marine Sciences, 5(2): 105-112.

Okbah, M.A.; Kaloosh, A.A.M.; El-Deek, M.S. and El-Attar, H.A. (1997). Trace metals (Cu, Zn, Pb, Cr and Cd) concentration of three subfractions of organic matter (nonhumic, humic acid and fulvic acid) from Lake Maryut sediments, Egypt. Pakistan Journal of Marine Sciences, 6 (1& 2): 14-26.

Osman, A.El-R.; Fatma, E. El-N. and Daniel, H. (1998). Existing environmental conditions in Lake Maryout South of Alexandria, Egypt: 1-Water Quality. Proceedings of the 8th International Conference on: “Environmental Protection is A Must”, 5-7 May 1998.

Penczak, T.; Galicka, W.; Molinski, M.; Kusto, E. and Zalewski, M. (1982). The enrichment of a mesotrophic lake by carbon, phosphorus and nitrogen from the cage aquaculture of rainbow trout, Salmo gairdneri. Journal of Applied Ecology, 19: 371–393.

Peng, S. (2015). The nutrient, total petroleum hydrocarbon and heavy metal contents in the seawater of Bohai Bay, China: Temporal–spatial variations, sources, pollution statuses, and ecological risks. Marine Pollution Bulletin, 95(1): 445-51.

Phang, S-M. (1991). Role of Algae In Livestock-Fish Integrated Farming Systems, Integrated Livestock-Fish Production System, Proceedings of the FAO/IPT Workshop on Integrated Livestock-Fish Production Systems, 16–20 December 1991, Institute of Advanced Studies, University of Malaya, Kuala Lumpur, Malaysia http://www.fao.org/DOCREP/004/AC155E/AC155E07.htm Accessed 11, January, 2008

Rachman, B. and Adi, S. (2005). Practices for Carp and Tilapia Grow Out in Cages, Sukabumi Research Water Aquaculture Development Center, Department of Fisheries and Marine Affairs, West Java, Indonesia.

Redfield, A.C.; Ketchum, B.H. and Richards, F.A. (1963). The influence of organisms on the composition of seawater. In the Sea, Ed. M.N. Hill. Wiley Interscience, New York, pp. 26- 79.

ReVelle, P. and ReVelle, C. (1988). The Environment: Issues and Choices for Society, 3rd ed. Boston: Jones & Bartlet, 749 p.

Richlen, M.L.; Morton, S.L.; Jamali, E.A.; Rajan, A. and Anderson, D.M. (2010). The catastrophic 2008–2009 red tide in the Arabian Gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides. Harmful Algae, 9: 163–172.

Saad, M.A.H.; Abu-Elamayem, M.; El-Sebae, M. and Sharaf, I. (1982). Occurrence and distribution of chemical pollutants in Lake Mariout, Egypt. I. Residues of organochlorine pesticides. Water, Air and Soil Pollution, 17: 245-252.

Saad, A.S.; Massoud, R.A. and Ghorab, M.A. (2017). Assessment of the Physico-chemical Characteristics and Water Quality Analysis of Mariout Lake, Southern of Alexandria, Egypt. J Environ Anal Toxicology, 7(1): 1-19. doi: 10.4172/2161-0525.1000421.
https://www.researchgate.net/publication/312585833.

Saad, M.A.H. (1985). Influence of pollution on Lake Mariout, Egypt. II. Nutrient salts. Rev. Int. Oceanogr. Med, 79-80, 50-63.

Sara, G. (2007). A meta-analysis on the ecological effects of aquaculture on the water column: dissolved nutrients. Marine and Environmental Research, 63: 390–408.

Shreadah, M.A.; Masoud, M.S.; Khattab, A.M. and El Zokm, G.M. (2014). Impacts of different drains on the seawater quality of El-Mex bay (Alexandria, Egypt). Journal of Ecology and the Natural Environment, 8 (8): 287-303.

Smith, V.H. (1979). "Nutrient dependence on primary productivity in lakes". Limnology and Oceanography, 24: 1051-1064.

Timmons, M.B.; Ebeling, J.M.; Wheaton, F.W.; Sommerfeld, S.T. and Vinci, B.J. (2002). Recirculating Aquaculture Systems, 2nd Edition. Cayuga Aqua Ventures, Ithaca, NY 14850, USA. 800 p. NRAC. Publication No. 01-002.

Valderrama, J.C. (1981). The simultaneous analysis of total nitrogen and total phosphorus in natural waters. Marine Chemistry, 10: 109-122.

Vollenweider, R. A.; Giovanardi, F.; Montanari, G. and Rinaldi, A. (1998). Characterization of the trophic conditions of marine coastal waters, with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics, 9: 329- 357.

Wetzel, R. (2001). Limnology: Lakes and Rivers Ecosystems. Academic Press, San Diego, CA, USA. pp. 226-237.

ARABIC SUMMARY

تقييم الاثراء الغذائى باستخدام مؤشرات Trix و Carlson بمياه بحيرة مريوط – مصر

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معمل الكيمياء البحرية، شعبة البيئة البحرية، المعهد القومى لعلوم البحار والمصايد بالاسكندرية-مصر

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يمثل الاثراء الغذائى أحد أهم التهديدات الرئيسية فى نظم البيئة البحرية. لذلك ، يوجد حاجة ملحة إلى رصد مستمر لتحديد مناطق الخطر المحتملة. تعتبرالدراسة الحالية هي محاولة لاختبار قابلية تطبيق مؤشرات قياس الحالة الغذائية (مؤشرات Trix و Carlson) لتدرج الحالة الغذائية ببحيرة مريوط مع بعض الخواص الفيزيوكيميائية بهدف إختيار الأكثر ملائمة من حيث الجودة البيئية الموجهة لزيادة انتاج الأسماك. فحصت عينات المياه بشكل موسمي خلال عام ٢٠١٤. وكان المدى المتوسط والقيم السنوية للمعاملات الفيزيوكيميائية ١٨-٢٧.٥□م (٢٣.٢٠±٠.٥٢ □م) بالنسبة لدرجات الحرارة، ٠.٢٨±٧.٤٠‰ (٣.٧٠‰±١.٦٩‰) بالنسبة لدرجة الملوحة، ٧.٨٤-٨.٨٤ للأس الهيدروجينى، ٠.٦٠-٥.٢٤ مللى مكافئ/لتر (١.٩٧±٠.٤٣ مللى مكافئ/لتر) للقلوية الكلية، ٠.١٤-١٠.٧١مجم/لتر (٤.٩١±٢.٩٨مجم/لتر) للأكسجين الذائب، ٠.٠١-٢.٦مجم/لتر (١.٣٥±٠.٣٢مجم/لتر) للأكسجين المطلوب بيولوجيا، ٣.٢٠-١٣٤.٤٠مجم/لتر (٥٦.٣٥±٢٧.٨٩ مجم/لتر) للمواد العضوية القابلة للأكسدة، و١٦.٣٠-١٦١مجم/لتر (٦٣.٨٠±٢٤.٧٠) لمجموع المواد الصلبة العالقة. تتراوح نتائج الأملاح المغذية (ميكرومول) بين ٠.٢٠ الى ١١٨.٣٠ (١٥.٦١±١٥.٤٦) للأمونيا، من ٠.٠٥ الى ٢٢.٤٨ (٣.٤٣±٣.٣٨) للنيتريت، ٠.١٤ الى ٦٦.٦٧ (١٣.٥٠±٧.٧٨) للنيترات، من٠.٣٩ الى ١٥٧.٢٦ (٣٩.٢٨±٤٣.٧٩) للنيتروجين غير العضوى الذائب، من ٠.٣٢ الى ١٢٣.٥٥ (٣٣.٦٤±١٨.٧٧) للنيتروجين الكلى، من ٠.١٠ الى ٤٥.٣(٨.٢٧±١٠.٢٨) للفوسفور النشط، من ٠.٠٤ الى ٤٩.٦٠ (٧.٩٨±٦.٩٣) للفوسفور الكلى ومن ٢.١٤ الى ٢٢٦.١٦ (٣٩.٩٧±٢١.٨٥) للسيليكات. الكلوروفيل-أ تراوح بين ٣.٩٥ الى ١٣٠.٣ ميكروجرام/لتر (٢٨.٥١±٢١.٩٩ميكروجرام/لتر)

ووفقًا لقيم مؤشر TRIX و Carlson للتغيرات المحسوبة موسمياً ، يتم تصنيف المواقع بترتيب تنازلي من مستوى تحفيزي مرتفع إلى معتدل في معظم المحطات ، مما ينبىء عن وجود ضغوط بشرية على البيئة المائية للبحيرة.