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Elucidation of the Phytoplankton Distribution at an Egyptian Ramsar Site (Burullus Lake, Egypt) using Alpha Diversity Indices Supported with RS and GIS Maps

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ABSTRACT

This study was conducted to detect the effect of nutrients on the microscopic count of phytoplankton and chlorophyll-a concentration. Water samples were collected from nine selected stations in Lake Burullus, Egypt in October 2020. Integration of remote sensing (RS) data was assessed to estimate and determine the distribution of the phytoplankton groups in the lake during two different periods. Results showed high levels of nutrients and chlorophyll (indication to trophic levels), especially behind the drains' outlets according to the count of phytoplankton species. Changes in nitrates (NO_3) and phosphates (PO_4) were the most effective on the phytoplankton count and chlorophyll-a concentration in the lake. On the other hand, the concentrations of chlorophyll a, nitrate and phosphate are marked gradients with high values recorded near the drains and originated from the inputs released into the lake. In general, nitrates and phosphates were limiting factors as well as silicate (SiO_4) which correlated with the blooming of diatoms. GIS maps of alpha diversity indices revealed that the Shannon index value was high near El-Shaklouba area (indication to pollution). The regression model for the estimation of the groups of phytoplankton species indicates interrelation of Euglenophyceae group, with band ratios of red and infrared (R^2=0.7). In addition, a predicted distribution map was made for the Euglenophyceae group in the year 2021 in the summer season according to the correlation between the retrieved phytoplankton group of Euglenophyceae with the same bands of Landsat image of 2021 (R^2=0.98).

INTRODUCTION

Phytoplankton is free-floating uni-cells and colonies photoautotrophically growing in the aquatic environment. Phytoplankton plays an important role in the primary production and global nutrient cycles of the earth **(Daniel, 2001)**. It represents the main producer in any aquatic system **(Biddanda & Benner, 1997)**. It flourishes at the upper part of the water and down depending on the limit of light penetration. Phytoplankton abundance and the microscopic high counts are related to the nutrients status of each water ecosystem. In lakes, the phytoplankton is determined by the changes in many abiotic and biotic parameters in time and space. Among abiotic parameters, the most important are nutrients availability and hydrological conditions. Fertile water is usually distinguished by a higher share of Euglenophyceae and Cyanophyceae **(Grabowska *et al*., 2014)**. The phytoplankton species in the lake water are exposed to rapid changes in the levels of nutrient salts (NO_3, PO_4, SiO_4,) and other hydrochemical parameters that may have pronounced effects on the phytoplankton species numerically and may cause changes in phytoplankton pigment (chl-a) as well **(Bellacicco *et al*., 2016)**. Nutrient availability is also an important variable driving phytoplankton production. Not only do nutrients impact cell division rates and algal density, but nutrients availability can also impact the cellular pigment (chl-a). In general, cellular chlorophyll-a density increases with added nutrients to facilitate the flourish and increase the cell numbers and the photosynthetic demand **(Burt *et al*. 2018)**. Researchers showed a decrease in chlorophyll-a density following a reduction in nitrate level **(Jakobson & Markager, 2016)**. Attempts have been made over the past several decades to predict the occurrence of a high count of phytoplankton based on nutrient concentration, particularly nitrate and phosphate as well as the cellular pigment **(Smayda & Renolds, 2001)**. While, other studies reported that the aquatic low salinity system, and phosphate limited with the determination are generally based on nutrients levels **(Hecky & Kilham, 1988)**.

In this research, a light was shed on the changes recorded in the microscopic count of phytoplankton as biomass and cellular pigment (chlorophyll-a), acting as a universal indicator of the total count of phytoplankton with the changes in nutrient levels in Lake Burullus at the different stations. In addition, the current study aimed to evaluate the fluctuation in the nutrient availability affecting both chlorophyll-a and phytoplankton density at each station in the lake. Early studies focused on the relationship between phytoplankton-nutrient and chlorophyll-a to manage strategies mitigating cultural eutrophication in the lakes **(Paerl *et al*. 2016)**. The influence of nitrate and phosphate on the microscopic count is well established, and the current evidence strongly supports N and P co-limitation of the primary productivity in most lakes and the synergistic responses of phytoplankton to dual (P and N) nutrient enrichment **(Allgeir *et al*. 2011; Bracken *et al*. 2015)**. In addition, previous studies have demonstrated that regional landscape characteristics can modify chlorophyll a and phosphate relationship in lakes. In this context, **Jones *et al.* (2011)** showed that the levels of chlorophyll-a concentrations were positively correlated with the total phosphorous among lakes. On the other hand, **Filstrup *et al.* (2014)** assessed regional maximum chlorophyll-a level under high phosphate conditions. Additionally, **El-Amier *et al.* (2021)** recommended removing unwanted aquatic plants and enhancing the treatment of wastewaters before discharge in Lake Burullus.

The main aim of this study was to understand the interrelationship between phytoplankton species with the distribution of nutrients using diversity alpha indices supported with Landsat data and GIS maps.

MATERIALS AND METHODS

1- Study Area

Lake Burullus is a shallow (not exceeding one meter as an average) aquatic system bordered from the north by the Mediterranean Sea with an area of 453 Km^2 and surrounded by agricultural lands and fish farms. Nine stations were selected to cover the whole area of the lake. Stations 1, 2, and 3 were selected from the eastern sector; stations 4, 5, and 6 were chisen from the middle sector, and stations 7, 8, and 9 were those of the western sector. The water samples were collected from the subsurface (30cm below) (Table 1 & Fig. 1).

St No.	Station Name	Latitude (N)	Longitude (E)
1	El-Boughaz (outlet)	31° 34` 7.59``	30° 59` 10.73``
2	In front of El-Burullus drain (east)	31° 33` 29.9``	31° 04` 25.3``
3	In front of drain 7	31° 27` 56.1``	30° 56` 17.5``
4	Mastrouh	31° 29` 09.0``	30° 45` 24.4``
5	El-Tawillah	31° 27` 53.3``	30° 47` 10.0``
6	El-Shakhloubah	31° 24` 46.9``	30° 45` 54.9``
7	Abou Amer	31° 26` 47``	30° 42` 36.87``
8	El-Hoks	31° 23` 15.5``	30° 36` 15.3``
9	In front of Brimbal Canal	31° 24` 22.90``	30° 35` 32.67``

Table 1. Latitude and Longitude of sampling stations in Lake Burullus

The samples were collected for different chemical analyses with the phytoplankton samples at the same time. The chemical variables are water temperature, pH, TDS, NH_4, NO_2, NO_3, PO_4, and DO, which were determined according to **APHA (1989)**. Chlorophyll-a concentration was calculated following the methods of **Strickland and Parsons (1972)**.

2- Qualitative and quantitative analyses of phytoplankton

The qualitative and quantitative analyses of phytoplankton species were carried out using a binocular research microscope model (XSZ-10 BN Germany-NO. 009707). Sedimentation technique was used for phytoplankton community study **(Ütermohl, 1936)** and determined as units per liter. The phytoplankton was identified and confirmed according to the identification and description of **Vinard (1974)**, **Bold and Wynn (1978)** and **Prescott (1978)**. The procedure of phytoplankton count was carried out using a hemocytometer. The speciecs number in a unit of litre was calculated according to the following equation:

$$\text{No of species in L} = \text{No of counted species (average of 4 square)x concetration factor x } (1000/0.4)$$

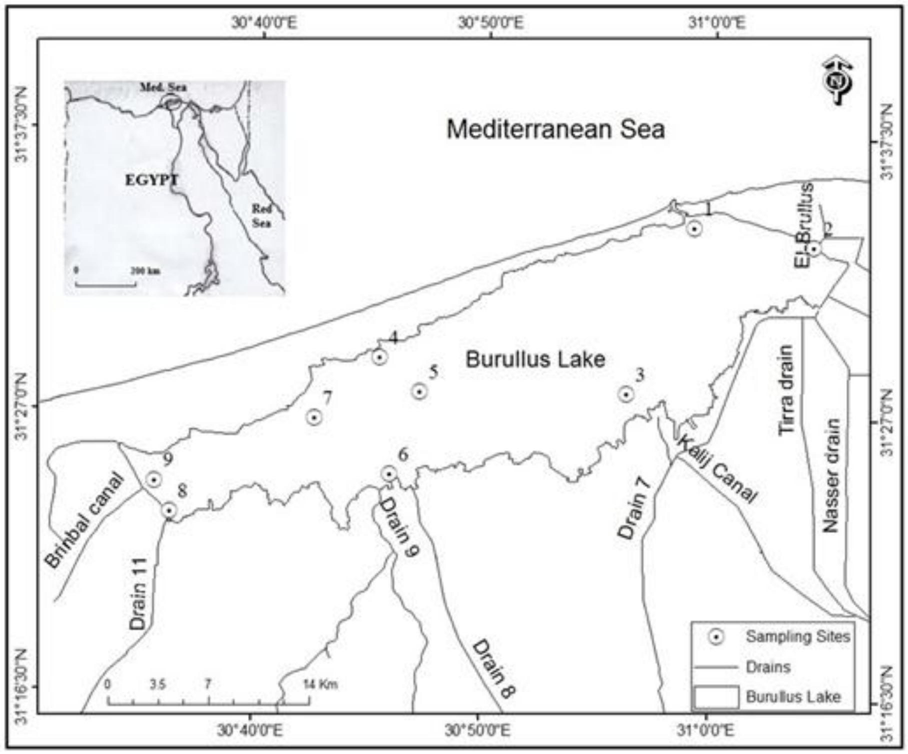

Fig. 1. A map of Lake Burullus showing the sampling stations

3- Phytoplankton alpha diversity indices Analyses

The dominance of phytoplankton species was calculated according to **Zhao and Zhou (1984)**:

$$\text{Dominance} = (n_i/N) * f_i$$

Where, n_i: abundance of species; N: total abundance; f_i: the frequency of species occurrence, and the dominance value is ≥ 0.02 **(Xu & Chen, 1989)**. The index of Shannon (H´) was computed in **Shannon and Weaver (1949)** as follows:

$$H' = \sum_{i=1}^{n} n_i/N \text{ x } \ln(n_i/N)$$

The species Evenness (J`) was estimated according to **Heip (1974)** as follows:

$$J` = H/\ln(S)$$

Where, H´: diversity index; S: number of species, and Ln: normal logarithm.

4- Remote sensing data processing

Two different Landsat OLI_8 images were downloaded from the site of (*http://earthexplorer.usgs.gov*) for September 2020 and July 2021 periods. The path and raw of the study area were 177 and 38, respectively. The two images were subjected to radiometric correction to obtain an image of reflectance using the QGIS 3.16 program. Then, different processes were performed to extract the band values of these two images in the sampling location for further processing.

5- GIS mapping method

ArcGIS program version 10.5 (graduated color item under proprieties of layer tool) was used to obtain graduated distribution maps for alpha diversity indices.

RESULTS AND DISCUSSION

The distribution of nitrate, phosphate, chlorophyll-a and the total count of phytoplankton at the different stations showed variance from one station to another. Nitrates varied between 29.8 µg/l and 56.8 µg/l at stations 1 and 6, respectively, while a higher concentration of nitrate was observed at stations 2 and 6 in the eastern and middle sectors of the lake, respectively. The higher values of nitrate were recorded in front of the discharges from the drains (Table 2). Phosphate in the lake ranged between 22.9 µg/l and 113.9 µg/l. The maximum value was at station 2 in front of the El-Burullus drain. The relatively high nutrients concentrations at the station near the point of discharges from the drains indicate strong nutrient loading in the lake originated from the drains. These observations coincide with those of **Radwan (2007)** who reported that the load of nutrients in Lake Burullus originates mainly from the drains. Chlorophyll-a concentration reached a peak of 405.2 µg/l at station 6, while the lowest one was measured at station 1 at El-Boughaz outlet. The stations near the drains recorded high values of chlorophyll-a, which are associated with the high count of phytoplankton numbers due to the high levels of nutrient enhancing the flourishness of phytoplankton. This finding concurs with that of **Chen *et al*. (2003)**.

This study discussed the effect of nutrients inputs discharged from the drains on the phytoplankton numbers and chlorophyll-a content as it represents a universal indicator of the primary productivity of phytoplankton at any aquatic ecosystem **(Scott *et al.*, 2020)**. The different phytoplankton classes and species are listed according to their dominancy at each station, where four groups of phytoplankton were identified in the lake; namely, Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae (Appendix 1).

In the present study, the phytoplankton population was more productive due to the pronounced increase of classes and species which were mainly affected by the nutrient levels of water, originated from the drains where the highest levels of nutrients were measured with high phytoplankton counts, especially NO_3 and PO_4 at station 6. This observation agrees with that of **Burt *et al.* (2018)** and **Radwan *et al*. (2018)** who reported that the numbers and productivity of phytoplankton increased with the addition of nutrients (NO3) which facilitated rapid cell division. When comparing the flourishing of phytoplankton classes at the different stations with high and low nutrients, Bacillariophyceae (diatoms) dominated at station 2 in front of El-Burullus drain (39% from the total count of phytoplankton) due to the high concentration of silica (3176 µg/l), another high count of diatoms observed at station 6 (34.7% from the total count of phytoplankton) was associated with a high record of nutrients. This result coincides with the observation of **Scott *et al*. (2020)**. On the other hand, the higher share and high count of the euglenoids at stations 6 and 8 were aligned with the increase in nutrients. This observation agrees with that of **Granbowska *et al.* (2014)** who pointed out that, the increased number of euglenoids due to the availability of nutrients in addition to the fertility of water is usually distinguished by a higher share of euglenoids. Another observation was recorded at station 2 (in front of El-Burullus drain), where the increase in the diatoms numbers at this station was attributed to the high concentration of PO_4 and SiO_4. This finding agrees with that of **Cloern and Dufford (2005)** who reported that diatoms do not thrive in phosphate depletion, besides inorganic phosphate; diatoms development may be inhibited by the lack of silica (Appendix 1 & Table 2). On the other hand, the results presented here give a more robust description of microscopic count with nutrients, where the highest numbers of phytoplankton were recorded at stations characterized by high levels of nutrients, including silicate, NO_3, and PO_4 in particular, which coincides with the study of **Badylak *et al*. (2004)** who attributed the high counts of phytoplankton taxa to nutrients concentration. Diatoms dominated the phytoplankton community at station 2 due to the abundance of species. Cyclotella Meneghiniana and Cyclotella kutzingiana, recording 230×10^3 and 188×10^3 cells/l, respectively, represent the main productive diatoms at this station influenced by the high levels of nitrate, phosphate, and silicate. The current finding and explanation coincide with the observation of **Ozuem *et al.* (2014)** who associated the flourishness of Cyclotella spp. with TDN and TDP in the aquatic system. From the present study, Chlorophyceae was the dominant class at station 4 (Mastarouh), representing about 83.8% from the total count of phytoplankton; on the other hand, other peak was observed with respect to this class at station 9 (Brimbal), constituting about 51.3% from the total count. The first dominant genus among the genera belonging to Chlorophytes at station 4 was *Pediastrum* and *Scenedesmus,* while *Scnedesmus* and *Ankistrodesmus* were the dominant genera at station 9 (Brimbal). The flourishing of these genera were correlated mainly with low salinity, the well oxygenated water and concentration of phosphate which were favorable for the bloom of these genera as shown in Table (2). This observation coincides with that of **Radwan *et al.* (2019)** who stated that, the occurrence of these genera in high numbers were in the localities of Idku Lake , which is known for the lowest values of salinity and well oxygenated water as well as the high levels of phosphate, all of which enhance the growth of these genera and their species.

Nutrient enrichment typically stimulates phytoplankton growth in lakes and increases the microscopic count and the changes in the phytoplankton structure **(Chen *et al.*, 2008)**. It is important to understand the links between the nutrient concentration and the phytoplankton numbers, which are important for the eutrophication management. Phosphorous (P) and nitrogen (N) are often considered as the principal limiting nutrients for the aquatic algal production **(Jin *et al.*, 2011).** Overloading of phosphate is usually considered as the primary causative, which leads to bloom, forming blue-green algae domination due to the flourishness of genus *Microcystis* **(Jin *et al*., 2011)**. This observation agreed with our study where the dominancy of blue-green (Cyanophyceae) at station 5 in Lake Burullus was due to the flourish of *Microcystis aeriogenosa* with a high level of phosphate (66.46 µg/l) in addition to the filamentous forms such as *Oscillatoria formosa* coincided with **Alex and Linda (2008).**

Table 2. The water samples data during October 2020 and One-way ANOVA analysis of these data (P < 0.05).

Parameter	Eastern Side				Middle Side				Western Side				P-Value
	El-Boughaz	El-Burullus Drain	Infront of Drain 7	Mean	Mastrouh	El-Tawillah	El-Shakhlouba	Mean	Abu-Amer	El-Hoks	Brinbal Canal	Mean	
T°C	27.50	28.00	29.20	28.23[b]	30.00	29.80	29.30	29.70[a]	30.00	31.00	30.00	30.33[a]	0.018*
TDS	9530.00	5370.00	4960.00	6620.00[a]	1480.00	1350.00	1370.00	1400.00[b]	1160.00	463.00	221.00	614.67[b]	0.005**
NH_4	169.00	2069.00	251.00	829.67[a]	183.00	173.00	2046.00	800.67[a]	193.00	2002.00	929.00	1041.33[a]	0.952[ns]
NO_2	19.80	44.80	23.70	29.43[a]	27.90	25.40	29.60	27.63[a]	26.80	24.60	21.20	24.20[a]	0.732[ns]
NO_3	29.80	54.90	51.90	45.53[a]	42.70	31.80	56.80	43.77[a]	41.80	47.90	36.80	42.17[a]	0.935[ns]
PO_4	22.90	113.90	22.05	52.95[a]	30.63	66.46	84.50	60.53[a]	21.75	50.23	33.08	35.02[a]	0.679[ns]
SiO_4	3835.00	3991.00	4130.00	3985.33[a]	3682.00	2579.50	2082.50	2781.33[ab]	3290.00	1652.00	710.50	1884.17[b]	0.073[ns]
DO	7.90	9.90	8.90	8.90[a]	9.10	9.90	11.70	10.23[a]	8.30	8.50	10.00	8.93[a]	0.310[ns]
pH	8.00	7.70	8.44	8.05[a]	8.06	8.33	8.57	8.32[a]	8.44	8.31	8.26	8.34[a]	0.385[ns]
Chl-a	23.90	399.70	237.30	220.30[a]	307.60	155.60	405.20	289.47[a]	199.60	203.40	168.70	190.57[a]	0.659[ns]
T-phyto	2890.00	18500.00	12620.00	11336.67[a]	14510.00	10730.00	30790.00	18676.67[a]	12390.00	13710.00	9780.00	11960.00[a]	0.481[ns]

Abbreviations: T°C: temperature, TDS: total dissolved solids, NH_4: ammonia, NO_2: nitrite, NO_3: nitrate, PO_4: Phosphate, SiO_4: silicates DO: dissolved oxygen, pH: hydrogen ion concentration, Chl-a: chlorophyll a and T-phyto: total count of phytoplankton species.

phytoplankton numbers are important in the efforts for eutrophication management. Phosphorous (P) and nitrogen (N) are often considered as the principal limiting nutrients for aquatic algal production **(Jin *et al.* 2011).** Overloading of phosphate is usually considered as the primary causative, which leads to bloom, forming blue-green algae domination due to the flourish of genus Microcystis **(Jin *et al*. 2011)** this observation agreed with our study where the dominancy of blue-green (Cyanophyceae) at station 5 in Lake Burullus was due to the flourish of *Microcystis aeriogenosa* with a high level of phosphate (66.46 µg/l) in addition to the filamentous forms such as *Oscillatoria formosa* coincided with **Alex and Linda (2008).**

In the present study, the results obtained cleared that the high count of phytoplankton recorded at stations 2 and 6 were associated with high levels of chlorophyll a, phosphate, and nitrate coincided with Dokulil et al., (2006) who stated that a positive correlation between TN and chlorophyll-a as well as chlorophyll-a increased with phosphorus and nitrogen. The need to control the water quality of lakes and other aquatic environments in countries and regions is increasing; it is valuable to grasp the global functional relationship between phytoplankton count, phosphorous, nitrogen, and the other nutrient in the lake's ecosystem. Chlorophyll a is the most widely used measure of phytoplankton counts in lakes. The relationship between chlorophyll-a, phosphate, and nitrate in the lakes has been intensively studied **(Søndergaard *et al.* 2011)** who showed that the concentration of TP and TN together or in isolation affects the concentration of chlorophyll-a. Most previous studies pointed out that the microscopic count of phytoplankton was TP limited **(Arvola *et al*. 2011)**, while others reported that TN is a limiting factor **(Trevisan and Forberg, 2007).** In general, the levels of nitrate and phosphate were limiting factors for the development of phytoplankton and chlorophyll-a content at the stations near to the drains, while not clear at stations further away from the effects of the drains.

The one-way ANOVA analysis as in the previous Table (2) showed non significance between nutrients level in the lake (NH_4, NO_2, NO_3, PO_4 and SiO_4), DO, pH, chlorophyll a and total count of phytoplankton. While between the three different sectors of lake, the ANOVA statistical analysis showed low Significance ($P = 0.018$) for temperature and moderate significance for total dissolved solids ($P = 0.005$), as the lake distinguish between saline water type in the north eastern side to brackish and fresh water types in the southern and western sides.

Understanding the diversity patterns of phytoplankton assemblages in coastal waters is important to managing water **(Stefanidou *et al.* 2020)**. The Shannon diversity index may refer to pollution conditions in the lake surface water (Soeprobowati et al. 2019). It is varied between 2.4 at Brinbal canal to the highest value in the El-Shaklouba area with a value of 3.7. **Dorgham *et al*. (2019)** recorded high Evenness values with those sites of low salinities. The results of this research showed similar observations. As higher values were recorded nearby Drain7 and lower were recorded nearby El-Boughaz and East El-Burullus Drain. **Hossain *et al.* (2017)** stated that the index of Margalef Richness has no limit value and it shows a variation depending upon the number of species. The lowest value at Drain 7 and its highest value were obtained nearby the El-Shaklouba area. Other different indices were also obtained as in Table 3. The spatial distributions of diversity indices are as shown in Figure 2. The correlation between extracted band values and the phytoplankton groups only indicate a significant correlation between the Euglenophyceae group and infrared to red band ratio (r = 0.715) (Table 4), according to the linear regression analysis as follow:

$$\text{Euglenophyceae percentage \% of presence} = -1.59 + 9.15 * (B_5/B_4), R^2 = 0.51$$

Where: B5: near-infrared and B4: Red.
This is may be that group Euglenophyceae characterized by the grass-green color of the water that makes absorption to radiance in the areas of red and near-infrared bands of operational Landsat imager sensor.

The spatial distribution of retrieved Euglenophyceae species presence according to this relation is as Figure (3). But other groups showed no significance with extracted band values. To make a predicted estimation for the presence of a spatial distribution of Euglenophyceae along the period of summer (7/2021), a correlation matrix (Table 5) between the retrieved values of presence percentage of Euglenophyceae and bands and band ratios of the OLI image of 2021 to make a predicted map according to the correlation and regression model which follow the following equation:

$$\text{Euglenophyceae percentage \% of presence} = -4.76 + 29.14 * (B_5) + 2.99 * (B_4/B_5) + 3.58 * (B_5/B_4), \text{adjusted } R^2 = 0.98$$

Table 3. Alpha diversity indices values for phytoplankton species in different locations

Index / Station	1	2	3	4	5	6	7	8	9
Taxa_S	15	26	18	29	21	50	25	25	24
Individuals	289	1850	1307	1451	1073	3008	1296	1457	1671
Dominance_D	0.099	0.068	0.073	0.049	0.060	0.031	0.050	0.052	0.196
Simpson_1-D	0.901	0.932	0.928	0.951	0.940	0.969	0.95	0.948	0.804
Shannon_H	2.492	2.890	2.748	3.184	2.910	3.676	3.051	3.076	2.384
Evenness_e^H/S	0.806	0.692	0.868	0.833	0.874	0.790	0.845	0.867	0.452
Brillouin	2.387	2.853	2.711	3.132	2.859	3.631	3.001	3.030	2.348
Menhinick	0.882	0.605	0.498	0.761	0.641	0.912	0.694	0.655	0.587
Margalef	2.471	3.323	2.369	3.846	2.866	6.118	3.349	3.295	3.099
Equitability_J	0.920	0.887	0.951	0.946	0.956	0.940	0.948	0.956	0.750
Fisher_alpha	3.358	4.283	2.953	5.135	3.702	8.518	4.393	4.287	3.97
Berger-Parker	0.201	0.124	0.144	0.114	0.103	0.077	0.069	0.110	0.419
Chao-1	15	26	18	29	21	50	25	25	24

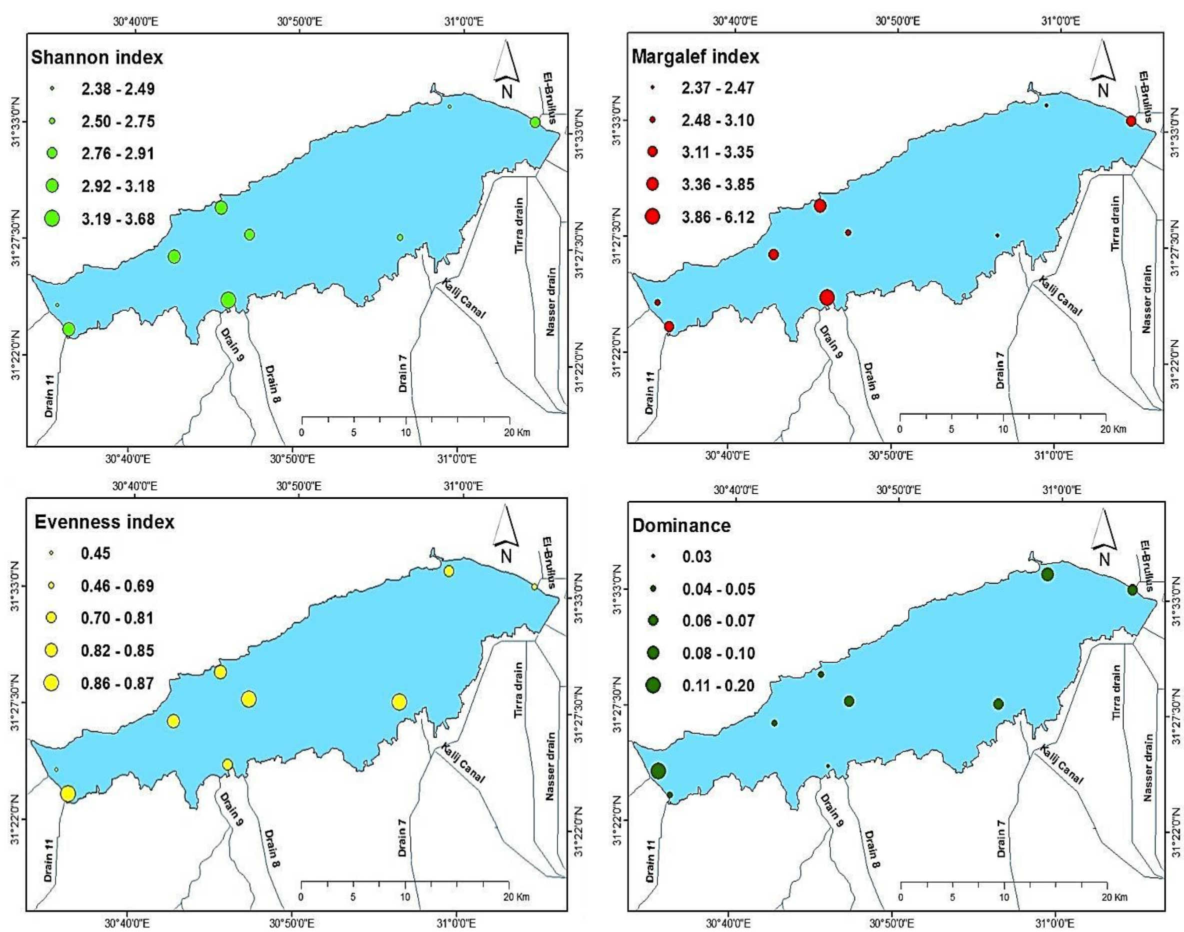

Figure 2. Distribution of diversity indices of phytoplankton species within Burullus Lake

Table (4): matrix correlation between bands and band ratios of Landsat image of 9/2020

Bands and Band Ratios	Phytoplankton Groups			
	Bacillariophyceae	Cyanophyceae	Chlorophyceae	Euglenophyceae
B5	-0.217	-0.233	-0.193	0.629
B2/B3	-0.255	-0.256	0.072	0.450
B4/b5	0.037	0.553	-0.095	-0.615
B5/b4	-0.286	-0.233	-0.213	**0.715***
B4/b3	0.006	-0.066	0.150	-0.056
B3/b4	0.096	0.040	-0.179	0.034
B3/b2	0.285	0.220	-0.076	-0.426
B2/b5	0.043	0.476	-0.144	-0.482

**Correlation is significant at the 0.01 level (2-tailed) (*Correlation is significant at the 0.05 level (2-tailed).

Table (5): matrix correlation between bands and band ratios of Landsat image of 7/2021 and retrieved presence of Euglenophyceae

Var.	Eug	B2	B3	B4	B5	B2/B4	B3/B4	B3/B2	B4/B3	B4/B5	B5/B4
Eug	1										
B2	-0.578	1									
B3	-0.491	0.953**	1								
B4	-0.474	0.986**	0.976**	1							
B5	**0.986****	-0.502	-0.440	-0.403	1						
B2/B4	0.111	-0.546	-0.770*	-0.646	0.141	1					
B3/B4	0.478	-0.937**	-0.855**	-0.938**	0.408	0.441	1				
B3/B2	-0.130	0.536	0.765*	0.632	-0.158	-0.998**	-0.410-	1			
B4/B3	-0.446	0.939**	0.847**	0.939**	-0.366	-0.410	-0.997**	0.38	1		
B4/B5	**-0.818****	0.604	0.651	0.584	-0.857**	-0.544	-0.565	0.543	0.504	1	
B5/B4	**0.988****	-0.641	-0.577	-0.550	0.985**	0.232	0.546	-0.245	-0.509	-0.878**	1

**Correlation is significant at the 0.01 level (2-tailed) (*Correlation is significant at the 0.05 level (2-tailed). Var.: variable, Eug: Euglenophyceae, B: Band

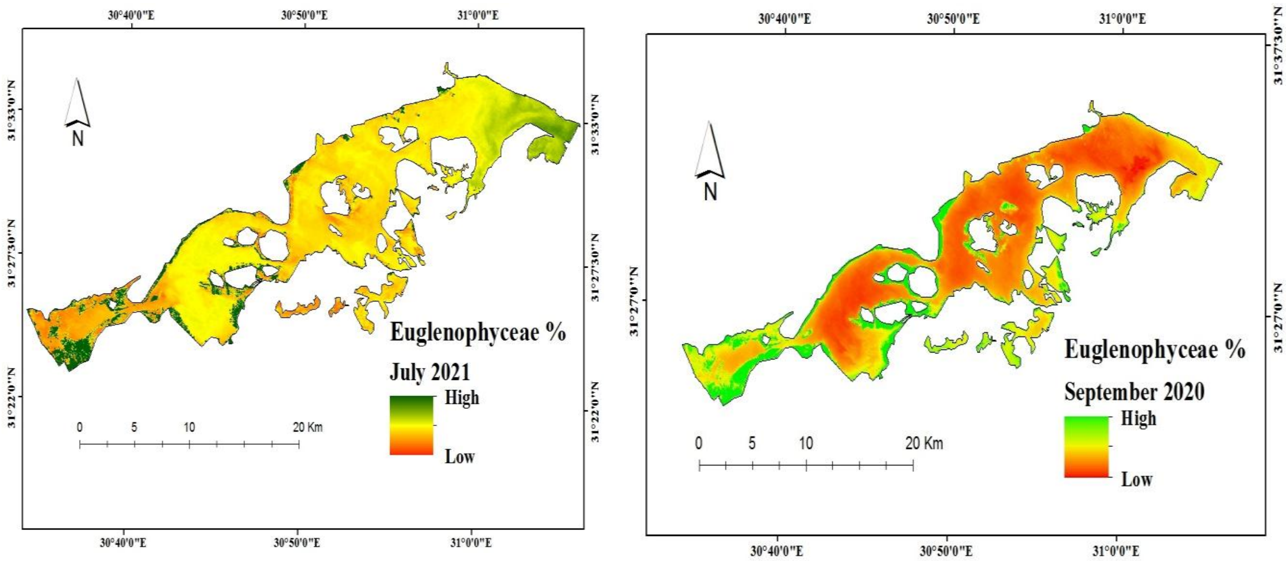

Figure 3. The percentage values of Euglenophyceae that were retrieved from Landsat images in two different periods (September 2020 and July 2021).

The retrieved spatial distribution map of Euglenophyceae group in July 2021, that is as shown in Figure (3). Where the values range were obtained from predicted maps in September 2020 and July 2021 (0 to 71 %) and (2.74 to 47%), respectively. The high percentage of the Euglenophyceae distripution was at nearby El-Hox and El-Shaklouba areas, while the lowest distripution is at the central part of the lake and nearby El-Boughaz.

Figure 4 (A-C) indicate the validation models between perventage of precence of Euglenophyceae group and those retrivied from satelite image close to the time of sampling and predicted from satelite image at summer 2021.It is indicated a significance from the linear equation as; (A) between the euglenophyceae presence and the retrievied at september 2020 (R^2= 0.5105), (B) the relation between euglenophyceae presence and the retrievied at July 2021 (R^2=0.48) and (C) between both the retrivied at september (2020) and July (2021).

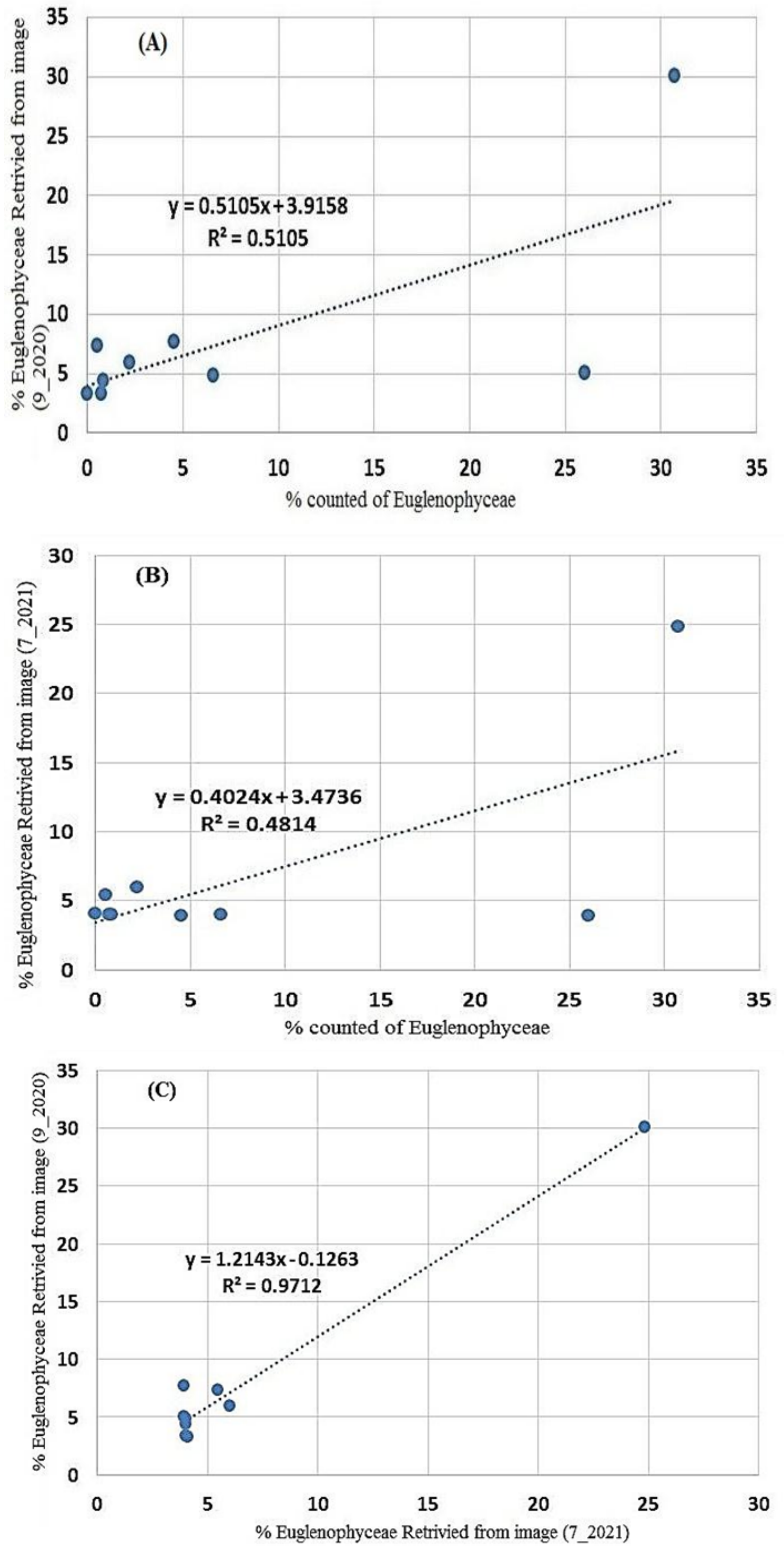

Figure 4(A-C). Validation models between % counted of Euglenophyceae and those retrieved from satellite images (A and B), and between the % Euglenophyceae retrieved from two satellite images (C) at different times.

CONCLUSION

In the present study, the variations in the microscopic count of phytoplankton species and chlorophyll-a content due to the effects of nutrient levels and other environment variables can be concluded: The variance in phytoplankton species abundance at all stations was due to the levels of nutrients that play an important role in the flourish of phytoplankton as well as dissolved oxygen and salinity where the discharge of fresh water into the lake from the drains displayed high phytoplankton numbers and chlorophyll-a content. The results illustrated that Bacillariophyceae (Diatoms) were dominated at station 2 in front of El-Burullus drain affected by the levels of silica as limiting factor, other peaks of diatoms were detected at station 6 associated with nutrient levels. Class Chlorophyceae were dominant at stations 4 (Mastarouh) and 9 (Brimbal) affected by the water salinity and favorable level of NO_3 and PO_4. Class Cyanophyceae were abundant at station 5 (El-Tawillah) associated with the PO_4 level. another peak was observed at station 7 (Abou-Amer) attributed to the high level of NO_3, while the flourish of euglenoids at stations 6 and 8 was mainly due to the high levels of NO_3 and PO_4 as well as the high load of organic matters in front of the drains. This is supported by the presence of pollution resistance phytoplankton species such as *Phacus spp* and *Euglena spp* at station 6. Using Landsat data aid in making prediction maps for phytoplankton groups that make alterations in water color due to absorbance of radiance for different image bands.

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