SEASONAL DYNAMICS OF PHYTOPLANKTONIC GROUPS IN DAMIETTA BRANCH, RIVER NILE, EGYPT

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Abstract:

The distributions of major phytoplankton groups were quantified to estimate the relative contribution of different groups to spatiotemporal dynamics in the northern part of Damietta branch, River Nile, Egypt, in response to a complex of physical and chemical conditions. The study was based on seasonal sampling over one year (summer 2015 to spring 2016) conducted at 6 freshwater and 6 marine sites. Limnological parameters, including electrical conductivity, alkalinity, orthophosphate, reactive silicate, nitrite, nitrate and ammonium, were simultaneously measured to determine the possible factors affecting the phytoplankton composition. Individuals within each phytoplankton groups were expressed as count ($\times 10^5$) per liter. Distinct variations in EC were detected between fresh and estuary habitats, however, other parameters shown spatiotemporal fluctuations. The phytoplankton communities were dominated by five common groups including Bacillariophyta, dominant in both habitats, Chlorophyta and Cyanophyta dominant in freshwater, Pyrrophyta and Euglenophyta dominant in estuary, different abundance contributions were detected between groups depending on seasons and sites. Thus, in River Nile, a complex of physical, chemical and biological factors that affected by natural and anthropogenic activities is responsible for the ecological determinants of the phytoplankton population.

Key words: Freshwater, Estuaries, Phytoplankton, Spatiotemporal, Anthropogenic, River Nile.

Introduction

Phytoplankton are the largest group of primary producers in marine and fresh aquatic ecosystems, its free-floating behavior give the opportunity to the community-composition to changing in response to environmental conditions **(Pinckney *et al.* 1998; Arrigo 1999; Hare *et al.* 2007)**. Currently, increases in anthropogenic activities, i.e. industrial, urban and agricultural discharges, near to aquatic ecosystem cause changes to phytoplankton productivity by affecting a

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complex of factors including physical e.g. (temperature and retention time of solutes), chemical (e.g. nutrient inputs) and biological (e.g. grazing and filter feeding) symptoms **(Bouvy *et al*. 1999; Chen *et al*. 2003; Hare *et al*. 2007)**.

The Nile river is the life artery of Egypt and represents the main freshwater resource needed for nearly all drinking and irrigation water demands **(Ali *et al*. 2014)**. the Nile passing for about 950 km beginning from downstream high Aswan dam to upstream delta at Mohammed Ali's barrage, El- Kanater city, where the river split into the Rosetta branch (about 236 km, West) and Damietta branch (about 242 km, East) each branch runs separately to the Mediterranean Sea, where the delta region is located between both branches **(Zaghloul and Elwan 2011)**. The Nile ecosystem is exposed to a complex interaction of natural and anthropogenic activities. Such anthropogenic sources include agriculture (e.g. nutrients, pesticides, and herbicides inputs), urban sewages (from all towns and villages of Egypt that drain either directly or indirectly into the River), industrials, and technological development such as constructions of Aswan Dam from 1902, High Dam from 1965, Faraskour barrage near the end of Damietta branch, Edfina barrage near the end of Rosetta branch. All those activities are influencing the hydrological characters of the river Nile and estuary, and subsequently, influence the floral and faunal compositions **(El-sheekh 2009; El-Amier *et al*. 2015).** Extreme anthropogenic activates may increase nutrient loading in water, which cause an increase in primary production leading to eutrophication. Eutrophication can have positive or negative effects on ecosystem, where, increasing nutrient inputs can stimulate primary producers, resulting in higher food availability for grazers and filter-feeders. However, increasing of organic nutrients, for instance, is harmful to some fauna and may cause oxygen depletion due to the high decomposition rates **(Grall and Chauvaud 2002; Smucker *et al.* 2013)**.

Building dams across Nile river is a necessity due to the rare precipitation and excessive population growth in Egypt, however, dams impounding water behind it and leading to profound changes in the limnological regime of the waterbody, these may include chemical and physical changes, in turn affecting the flora and fauna of the regulated waterbody **(Gharib and Abdel-Halim 2006)**. The aim of the present study was to investigate the impact of Faraskour dam, as a boundary between fresh and marine habitats, on the dynamics of major phytoplanktonic groups in Damietta branch, river Nile, Egypt.

Materials and Methods

1. Study area

The Nile River runs from Lake Tanganyika in Tanzania (3° S) to the Mediterranean Sea (31° 15' N) over ca. 6625 km length. At Cairo, the river splits into two branches, Damietta and Rosetta. The study area (about 30 km) is mainly located in the main stream of the Damietta Branch of the River Nile and starts at Faraskour city to Ras El-Bar (*Ellesan*) region, passing through Damietta governorate, and includes fresh, brackish-marine and marine habitats (Fig. 1).

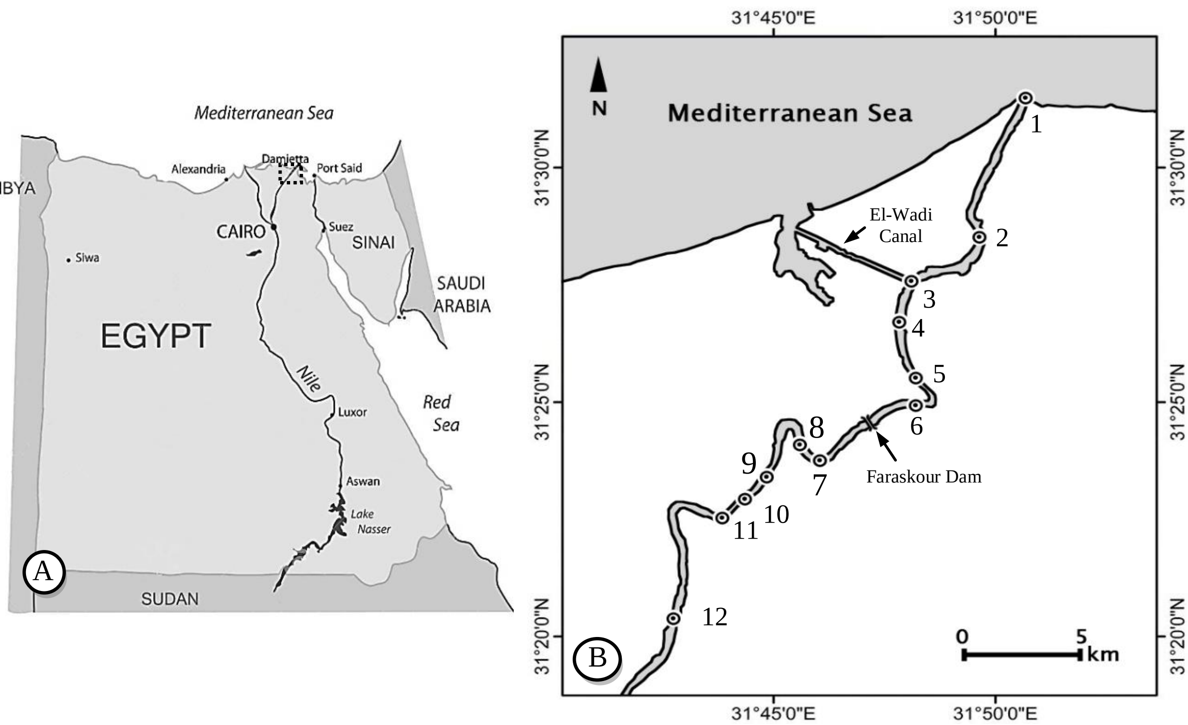

Fig.1: (A) Map of Egypt showing the study area (dashed-line area). (B) Detailed view of the study area at the northern part of Damietta branch showing the location of selected sites.

The branch is cut off by Faraskour impoundment to two different area freshwaters southern the dam and saline water northern the dam. The area from Faraskour city to barrage (fresh water area) is exposed to heavy anthropogenic activities including agriculture fields and villages that discharging the wastes in the Nile, in addition to the presence of high number of fish cages, electrical power plant and water plant. The Faraskour impoundment has six gates, these gates open randomly and rarely to release freshwater to Damietta estuary. The length of the Damietta estuary is ca.13 km and it is completely isolated from the Nile further upstream by the Faraskour dam.

2. Water Sampling and Analyses

Water samples and ambient physical and chemical data were examined at twelve sites (coded as 1-6 marine and 7-12 freshwater sites) in the northern part of Damietta branch (Figure 1B). Samples were collected seasonally from summer 2015 through spring 2016. Water sampling and analysis were carried out according standard method for examination of water and wastewater (**APHA, 2012**).

2.1. Electrical Conductivity (EC)

It was measured by the conductivity meter HANNA instrument (model HI991301). Results were expressed as (µmhos/cm)

2.2. Chemical properties

Alkalinity was determined by using the titration method (0.02 N H2SO4 with phenolphthalein and methyl orange as indicator). Ammonium (NH_4^+) was measured using ammonia selective electrode, ORION model 95-12 attached to bench top ion analyzer, ORION model EA940 with built-in stirrer, Germany. Reactive silicate (SiO_2) was determined by using molybdosilicate method. Orthophosphates (PO_4), nitrites (NO_2) and nitrates (NO_3) were measured using Ion Chromatography (IC) model DX-500 chromatography system.

3. Quantification of phytoplanktonic groups

Phytoplankton cells were collected from the twelve sites by filtering 30 liter in 15 µm mesh plankton net. The samples were kept in ice box and transported to the lab, then samples were preserved by adding 4% formalin (**Sourina 1981**) for further investigations. Phytoplankton were counted using a 1 ml Rafter counting chamber, each count was repeated 3 times and the results were expressed as count

($\times 10^5$) of unites per liter (**APHA, 2012**). Diatoms (Bacillariophyta) preparation was according to (EN 15708 2009) standardization.

Results and Discussion

The present study was carried out at the end part of Damietta branch and its estuary at Damietta governorate in four seasons (from summer 2015 to spring 2016), to study the structure and dynamics of planktonic groups in relation to environmental factors. The sampling represents different habitat fresh, in section of Nile, brackish and marine in estuary.

A. Physico-chemical parameters

1. Electrical Conductivity

Generally, distinct variations in EC were detected between fresh and estuary habitats. The highest value of 58000 µmhos/cm was recorded in estuary part during autumn at site 1, while lowest value of 28500 µmhos/cm was recorded during summer at site 6, while in fresh habitat, the heights value of 562 µmhos/cm was recorded at site 12 during winter and the lowest value of 359 µmhos/cm in site 11 during summer (fig.2A). At estuary, the highest values that recorded at winter may be due to the turbulence of sea water occurred during season, and work on movement of saline water along the estuary, the phenomena was a field personal observation, and agree with the observation of **Abdel-Baky (2006).** In addition to sea water effects, exposure to pollutants resulting from anthropogenic activities (i.e. industrial, urban and agricultural discharges) cause increasing in electrical conductivity **(Abdel-Hamid *et al*. 1992; Aziz *et al.* 1996; Ezzat *et al*. 2012**). In freshwater habitat, rises in electrical conductivity may be related to lowering of water level in the river Nile during drought period which leads to concentrate the dissolved mineral in the water (**Elsayed 2009**).

2. Carbonate and bicarbonate (alkalinity):

Seasonal and spatial variations in alkalinity were detected. The maximum alkalinity values of 385 mg/l were found during winter at site 2 within estuary part, as compared with the minimum values of 134 mg/l, which observed during spring at site 12 within fresh part (fig.2B). These variations could be explained by the photosynthetic activity of algae and the quality of the discharged water (**Abdel-Baky 2006; Abd El-kader 2015**). The results showing the dominance of HCO3 over CO3 which undetectable during the entire period of investigation. The bicarbonate revealed increased in autumn and winter over summer and spring, this could be related to decrease in air and water temperatures during cold seasons leading to decrease in the reaction rate of carbonate direction and vice versa **(Abdo 2004**). Also, the decomposition of dead phytoplankton during cold seasons may be cause liberation of CO_2 which dissolves in water and accelerates the formation of HCO_3^- (**Goldman and Horne 1983**).

3. Orthophosphate (PO_4^{3-})

Orthophosphate is the only bioavailable form of phosphorus that autotrophs (i.e. algae and plants) can assimilate, it is also known as soluble reactive phosphorus (**Yousif 2011**). the high concentration value of PO_4^{3-} (0.45 mg/l) was recorded at site 5 during autumn season, could be related to reduced uptake rates by phytoplankton (**El-Kassas et al. 2016**); and raw human and animal faces (**Davies *et al*. 2009**). However, the minimum value of 0.03 mg/l was recorded in site 4 during winter (fig. 2C).

4. Reactive silicate:

Silicate is the abundant form of silicon, it is the great indispensable nutrient for diatoms, which forms the valves and cell walls and constitutes from 10 to 30% of their dry weigh (**Paasche 1980; Robards *et al*. 1994)**. The maximum value of 9.98 mg/l was recorded during summer season at site 12, while the minimum value of 0.2 mg/l was recorded during winter season at sites 6, 9, 11 and 12 (fig.2D).The decrease in silicate concentrations during cold season is related to the low flow discharge of Nile's water in addition to uptake by diatoms blooms, fungi, phyto- and zooplanktons (**Abdo and El-Nasharty 2010**). The increase in silicate concentration during hot seasons especially summer may be related to increase the solubility of silicon with elevation of temperature and/or to degradation of dead diatoms (**Shabana 1999**). Furthermore, agricultural activities and industrial wastes of furniture factories increase the silicon content in water (**Jüttner *et al.* 1996; El-Sheekh *et al.* 2010**).

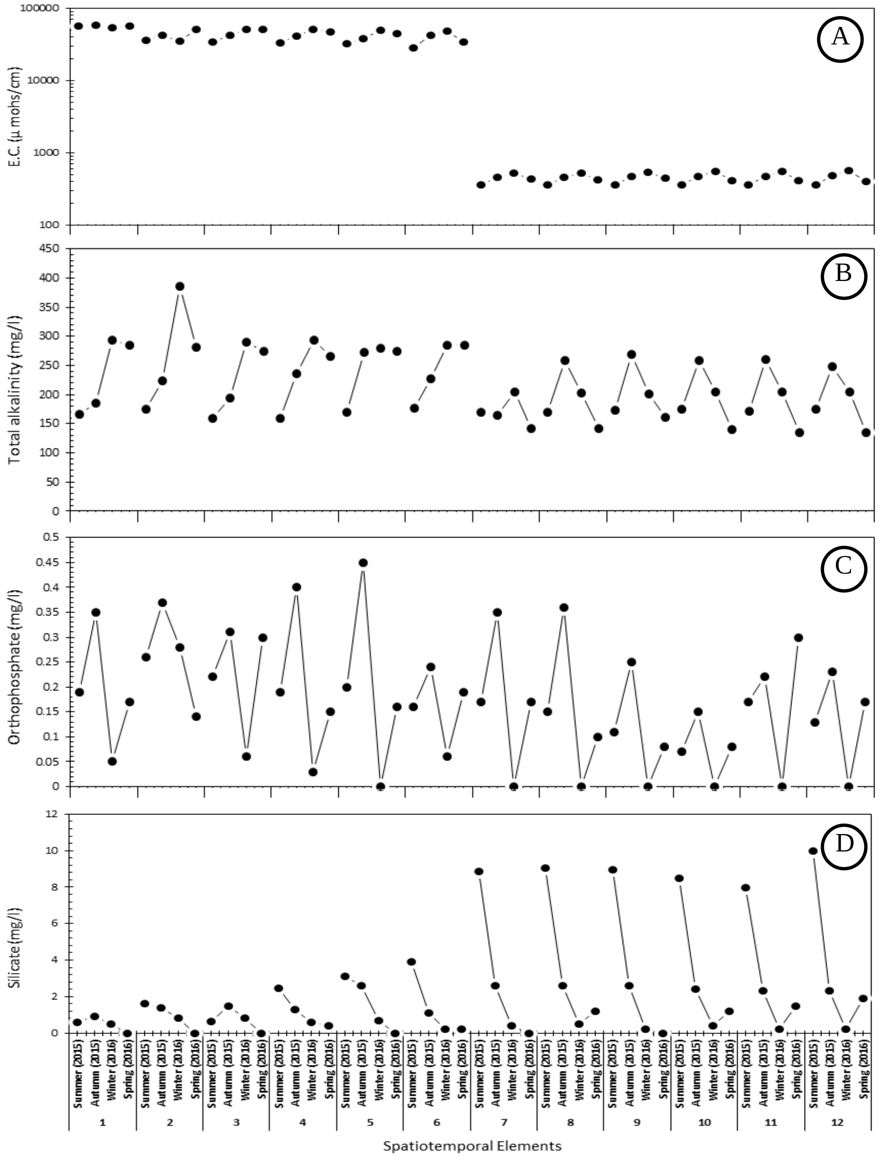

Fig.2: Chemical properties of study sites at different seasons. (A) Electrical conductivity (μ mohs/cm). (B) Total alkalinity (mg/l). (C) Orthophosphate (mg/l). (D) Silicate (mg/l).

5. Nitrite

Nitrite is an intermediate oxidation state between ammonia and nitrate; i.e. it can appear as a transition in the oxidation of ammonia and reduction of nitrate. Nitrite is an essential nutrient to plants and other microorganisms **(Ghallab 2000; El-Enany 2004**). The nitrite values fluctuated between 0.004 mg/l during summer at sites 9 and 0.665 mg/l during autumn, at site 5 (fig. 3A).

The lower values of nitrite during different seasons may be related to a complex of biological processes including the acceleration of nitrite (NO_2^-), as unstable form of nitrogen, into nitrate (NO_3^-) by nitrifying bacteria or into ammonia (NH_3) by denitrifying bacteria **(Sabae and Abdel-Satar 2001; Abdo and El-Nasharty 2010**).

6. Nitrate

Nitrate is an essential nutrient for synthetic autotrophies, and can be considered as a nutrient limiting growth resource. The more stable oxidized form comprises 42.6% of dissolved inorganic nitrogen, and 12.8 % of the total dissolved nitrogen (**Greensberg *et al.* 1992**). The results of the present investigation showed that, nitrate varied between 0.06 mg/l during summer at site 1 and 0.5 mg/l during winter season at site 10 (fig. 3B). Rises in nitrate and nitrite levels in water may result from a complex of natural and anthropogenic activities, for instance, excessive application of fertilizers or leaching of wastewater or other organic wastes into surface water and ground water **(Jüttner *et al.* 1996; WHO 1997; Pratiksha *et al.* 2013**), or naturally by the oxidation of ammonia (NH_4^+) to nitrate (NO_3^-) and nitrite (NO_2^-) by aerobic bacteria through the nitrification process (**El-Bahnasawy 2013**), or due to low consumption rates by phytoplankton, especially during cold seasons (**Macdonald *et al.* 1995**). On the contrary, decrease in nitrate content could be mainly due to its consumption by algae as well as reduction by the denitrifying bacteria (**Yusoff *et al*. 2002**).

7. Ammonium

Ammonium (NH_4^+) is a biologically active cation existing in nature as a biological degradation product of the nitrogenous organic compounds and hydrolysis of urea. Throughout this study, NH_4 concentrations showed a spatiotemporal variation (fig. 3C), where maximum value was recorded at site 9 during winter (7.85 mg/l), this might be due to the leaching of domestic, sewage and agricultural wastes containing high amount of nitrogenous organic matter (Ma et al. 2009). However, the minimum value of (0.73 mg/l) that recorded at site 8 during autumn may be due to the biological consumption of ammonia by organisms (Abdel-Baky 2006).

B. Quantification of phytoplanktonic groups

Quantitative analysis of the phytoplankton groups reflects the productivity and nutritional capacity of the ecosystem, where, results revealed that phytoplankton community at Damietta section of the river Nile and its estuary, mainly represented by four common groups including Bacillariophyta, Chlorophyta, Cyanophyta, Pyrrophyta and one rare group of Euglenophyta.

1. Cyanophyta

Cyanophyta reveled distinct seasonal trends (fig. 4A). The highest number of 13.63×10^5 unite / L was recorded during spring at site 8 and the lowest number of 0.45×10^5 unite / L were recorded during winter season at site 7. Concerning the spatial distribution, fresh water habitat supported a higher number of Cyanophyta individuals than estuary habitat. The dominance of Cyanophyta group in most sites located in freshwater habitat during spring season due to the availability of nutrients and other favorable environmental conditions such as light and temperature (**Gao and Song 2005**). In addition to, lack of competition with diatoms that thrive in cold seasons or with other groups that may inhibited by increases in cyanotoxins concentration (**Leland *et al.* 2001**).

Generally, Cyanophyta was rare in the sites influenced with sea water, due to the high salinity levels and other associated chemical properties **(Yusoff *et al.* 2002**). The exceptions at some marine sites, that recorded relatively high numbers of Cyanophyta, were due to the exposure to freshwater discharges (i.e. agricultural drainage canals), field observation.

2. Chlorophyta

Generally, Chlorophyta was recorded as the most division of phytoplankton in freshwater habitat, especially, at spring. The highest population density of 23.4×10^5 unite / L was recorded in site 7 during spring, while the lowest value of 3.68×10^5 unite / L was recorded in the same site during autumn.

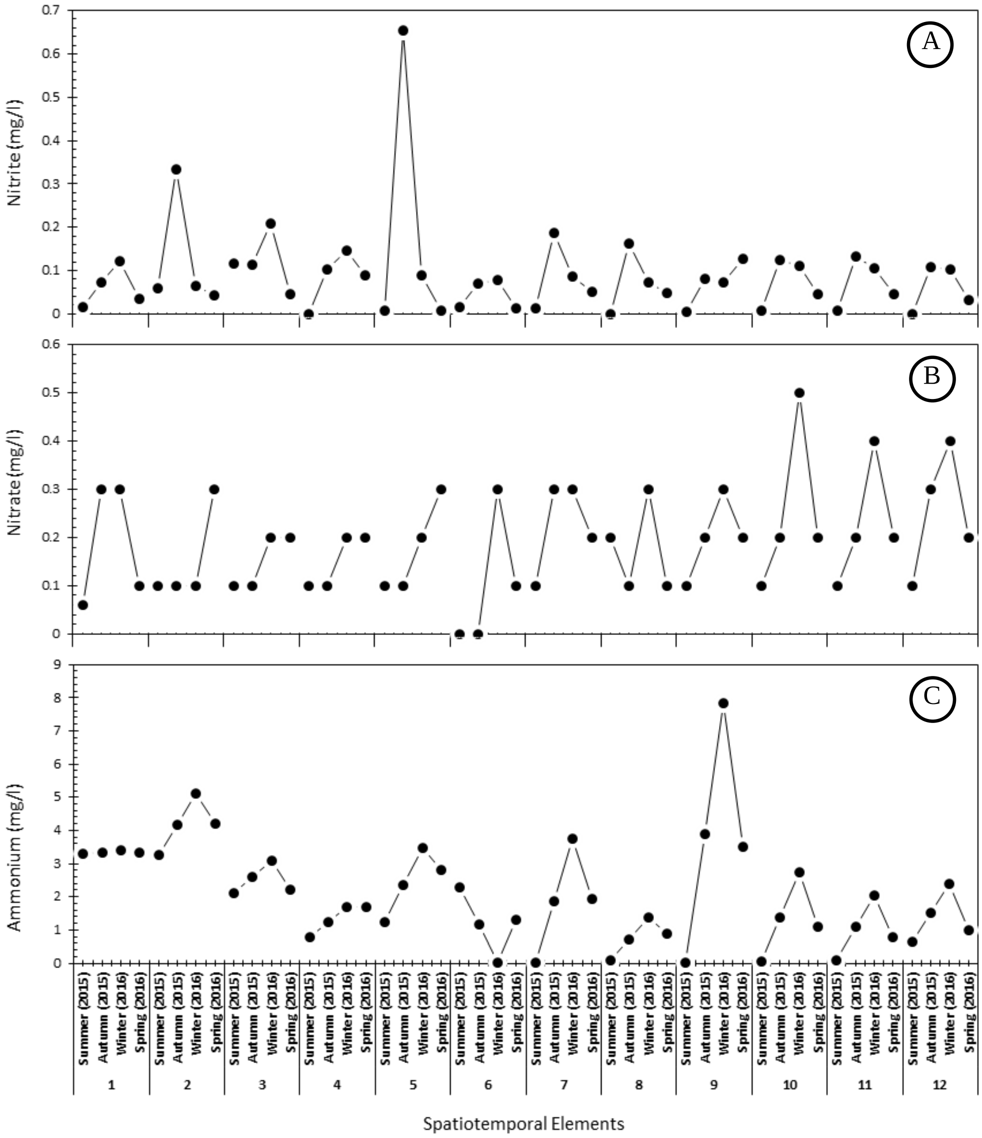

Fig. 3: Chemical properties of study sites at different seasons. (A) Nitrite (mg/l). (B) Nitrate (mg/l). (C) Ammonium (mg/l).

In estuary habitat, Chlorophyta represented by the lowest counts, this may be due to the harmful effects of salinity stress, or represented by relatively small numbers of individuals the comes with discharging of freshwater.

3. Bacillariophyta

The phytoplankton population was mainly dominated by Bacillariophyta, which remarkably recorded in both fresh and marine habitats, due to their ability to resist many environmental stress conditions **(Tien 2004**).The highest count of 125.1×10^5 unite / L was recorded at site 6 within estuary habitat at summer season, while the lower count of 1.1×10^5 unite / L occurrence in site 2 during autumn season.in freshwater habitat, the highest values were recorded in autumn at all sites, the maximum population density of 33.79×10^5 unite / L was recorded at site 12 during autumn season while the minimum of 1.21×10^5 unite / L was during summer season at site 7 (fig. 4C). Bacillariophyta was occupied the first arrangement in phytoplankton groups of Damietta estuary in accordance with **Shaaban-Dessouki *et al.* (1994)** and **Abdel-Baky (2006).** Correspondingly, the results of Shaaban-Dessouki and Baka (1985), related to the distribution of phytoplankton in Damietta branch, showed that the summer density peak was mainly represented by Cyanophyta and Chlorophyta individuals, while autumn peak was mainly represented by Bacillariophyta. In general, most investigators on phytoplankton community of the river Nile, e.g. **Ahmed *et al*. (1986), Abdel-Baky (2006),** recorded that, Chlorophyta occupied the second dominance group after Bacillariophyta, while Cyanophyta was the third dominant group, which agree with results of the present study.

4. Pyrrophyta

Individuals of this division were rarely existed at fresh water habitat, however, the maximum population density of 0.808×10^5 unite / L was recorded in site 7 during autumn, while the minimum of 0.0505×10^5 unite / L was recorded during spring at site 12. In estuarine habitat, Pyrrophyta was extensively exist, where, the maximum population of 11.7×10^5 unite / L occurred during summer at site 2, meanwhile the minimum population of 0.2×10^5 unite / L recorded at site 6 at summer and site 1 at autumn (fig. 5A).

At most sites within estuary habitat, Pyrrophyta was in the second rank of dominance after Bacillariophyta, however, in few sites, where alternate the dominance with diatoms, was due to the toxic effect of the extra cellular metabolites lead to the dominance of Pyrrophyta **(Abdel-Hamid *et al.* 1992; Calliari *et al*. 2005; Abdel-Baky 2006**).

5. Euglenophyta

Euglenophyta were scarcely recorded in the study area compared with other phytoplankton divisions, i.e. it was completely absent at many sites. The maximum population density of 0.65×10^5 unite / L was recorded during summer season at site 3, while the minimum number of 0.05×10^5 unite / L was recorded in site 8 during spring (fig. 5B). Euglenophyta, in compare with previous investigations, was represented by low number of cells, due to sampling from subsurface only, where, a relatively high frequency of Euglenophyta was recorded within near bottom waters, e.g. (**Deyab 1987; Abdel-Baky 2006**). **Shaaban-Dessouki *et al.* (2004)** reported that, Euglenophytes disappeared from surface water through high sunlight intensity periods. However, the Eugleniodes were barely and occasionally present in Nile water and, generally, showed an irregular distribution (**Baka 1980; Abdel-Hamid 1991; Touliabah 1996**).

Conclusion and prospective

Changes in environmental conditions due to natural and anthropogenic activities can influence phytoplankton population dynamics in aquatic habitats in the northern part of Damietta branch, River Nile, Egypt. A complex of physical, chemical and biological factors is responsible for the ecological determinants of the phytoplankton population. Phytoplankton is an ecologically and biologically important element in River Nile ecosystem due to their role as primary producers in food webs and contributes between 50 to 85 percent of the oxygen in aquatic habitats and atmosphere. However, phytoplankton may be harmful to the ecosystem when growing as explosion-blooms. Therefore, it still remains to be determined how changes in natural conditions and extreme rise in anthropogenic activities will affect phytoplankton abundance as aquatic biological resources.

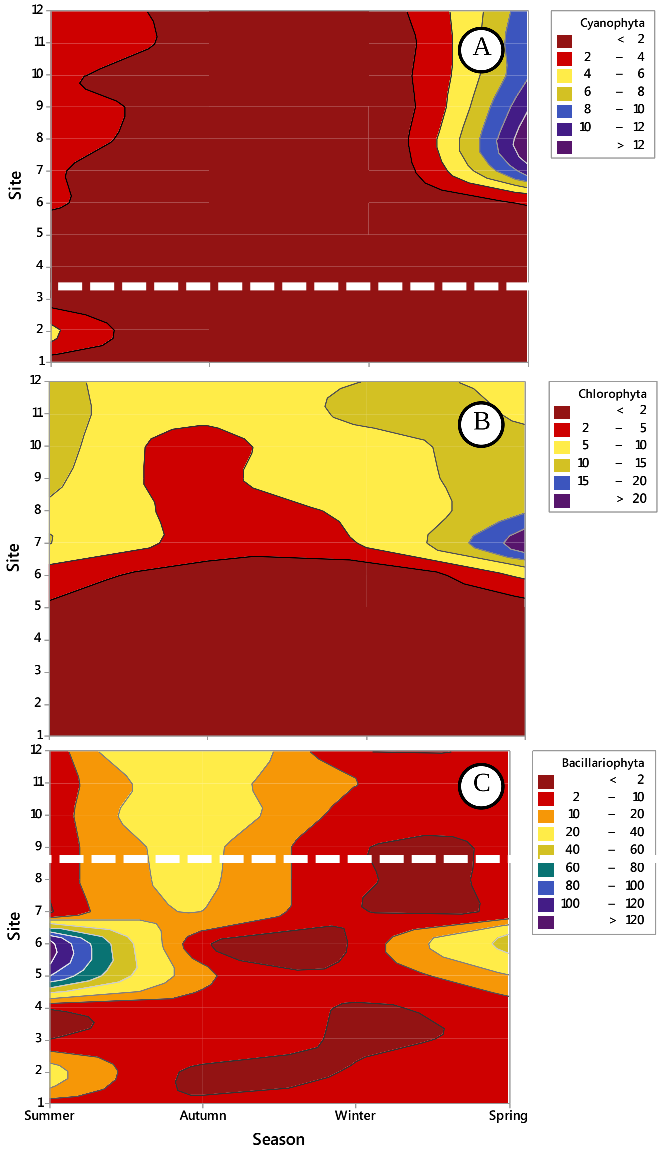

Fig.4: Spatiotemporal contour plots of phytoplankton groups represented by count ($\times 10^5$cell L^{-1}). Dashed line represents the location of Faraskour dam, as a boundary between fresh and marine habitats.

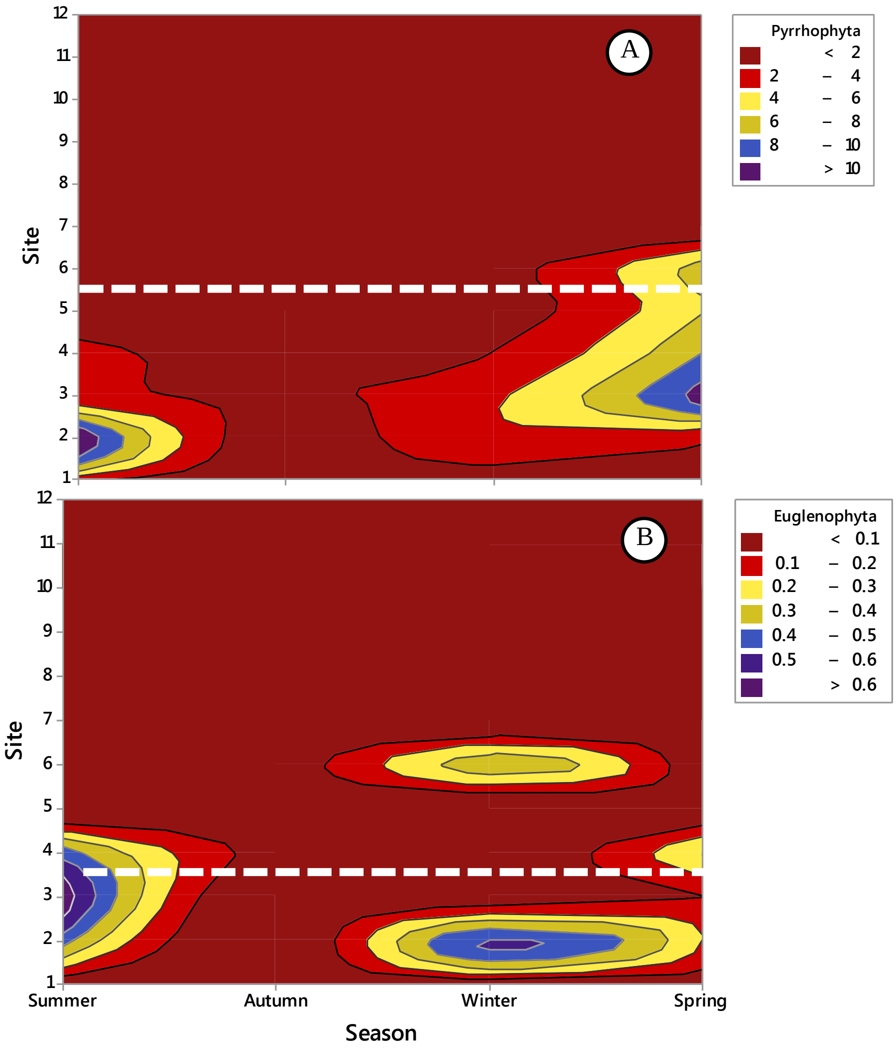

Fig.5: Spatiotemporal contour plots of phytoplankton groups represented by count ($\times10^5$cell L^{-1}). Dashed line represents the location of Faraskour dam, as a boundary between fresh and marine habitats.

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التغيرات الموسمية لمجموعات العوالق النباتية في فرع دمياط، نهر النيل، مصر

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أجريت هذه الدراسة على فرع دمياط نهر النيل – مصر، لمدة اربع مواسم من صيف 2015 الى ربيع 2016 لدراسة التغيرات الزمانية والمكانية التي تحدث في مجموعات العوالق النباتية الرئيسية والمساهمة النسبية لهذه المجموعات استجابة للعوامل الطبيعية والكيميائية المختلفة. ولقد تمت الدراسة على 12 محطه، منهم ستة من النهر و ستة من المصب. شملت الدراسة قياس بعض الخواص الطبيعية والكيميائية للمياه، بما في ذلك التوصيل الكهربائي والقلوية والفوسفات والسيليكات والنتريت والنترات والأمونيوم لتحديد العوامل المحتملة التي تؤثر على تكوين العوالق النباتية. تم التعبير عن عدد الأفراد داخل كل مجموعة من العوالق النباتية ($\times10^5$) لكل لتر. اظهرت النتائج اختلاف واضح في قيم التوصل الكهربائي بين النهر والمصب بالاضافه الى التغيرات في باقي العوامل. كانت السيادة في مجتمع العوالق النباتية لخمس مجموعات ممثلة في الدياتومات حيث كانت سائده في كل من النهر والمصب، والطحالب الخضراء والطحالب الخضراء المزرقه حيث كانت سائدة في المنطقه العذبه والطحالب البيرية والطحالب اليوجيلينه والتي كانت سائدة في منطقة المصب فقط. تم الكشف عن السياده بين المجموعات اعتمادا على المواسم والمواقع. وخلصت الدراسة الى وجود مجموعة من العوامل الفيزيائية والكيميائية والبيولوجية، التي تتأثر بالأنشطة الطبيعية والأنشطة البشرية تلعب دورا هاما في تحديد توزيع ووفرة العوالق النباتية.