Spatial and Temporal Variations of Phytoplankton Communities and Environmental Conditions Along the Coastal Area of Alexandria

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Abstract: This paper studied the spatial and temporal variations of phytoplankton communities and environmental conditions. This study focuses on the Spatio-temporal distribution of phytoplankton community structure and environmental conditions (physical conditions, and nutrient availability) along Alexandria coastal area (from Abu Qir in the east to eastern harbor in the west) over one year 2013-2014. The study results gave a signal of the area is light to moderate polluted and emphasized the need of use phytoplankton community as index of water quality. A total of 153 phytoplankton taxa were identified belonging to73 genera (6 Classes); Bacillariophyceae, Dinophyceae, Cyanophyceae, Chlorophyceae, Euglenophyceae and Silicoflagellata. Bacillariophyceae recorded the main bulk, while the others were limited and showed an indication of pollution. The total average density (60.7x10^{3} units l^{-1}) was mainly a reflection of the trends in counts of Bacillariophyceae (58.03x10^{3}units l^{-1}). Species diversity (H') ranged between 0.21 and 3.59. The most obvious impact of the previously described physical and chemical features is on the distribution of phytoplankton biomass derived from Chl-a concentration (ranged; 0.92-4.27µgL^{-1}). The concentrations of the nutrient salts displayed significant seasonal variation. The results revealed that the values of salinity, DO, temperature and pH were in the ranges: from (35.34 to 38.28 ‰), (4.77 and 11.13 mgL^{-1}), (18.20 and 27.5 °C), and (7.53 to 8.12), respectively In general, the results indicated that the amounts of ammonia decreased as follows: winter < spring < autumn < summer (ranged; 0.14-5.16 µM), while nitrate were as follows: spring < autumn < summer < winter (ranged; 3.69 -19.66 µM), and the PO_{4}-P content were arranged as follows: spring < autumn < winter < summer (ranged; 0.13 -0.79 µM).

Keywords: Alexandria Coastal Water, Phytoplankton, Diversity Indices, Nutrients, Chlorophyll-a

1. Introduction

Alexandria is an Egypt's largest city on the Mediterranean coast, and is one of the most important industrial centers, comprised 100 large factories and about 260 smaller ones [1], to cover about 40% of the nation's industry. It is also the main summer resort in Egypt; about 4 million citizen and two million summer visitors [2]. The Alexandria coastal zone is about 42 km long, extending from El-Dekhaila in the west to Abu Qir in the east, and consists of pockets and embayment beaches morphology. Alexandria coastal zone is one of the most important areas along the Egyptian coast of Egypt, including several beaches.

In recent years, there is an appearance of interest in the phytoplankton diversity of the Mediterranean Sea, which is undergoing rapid succession under the pressure of pollution, climate change, ship traffic, introduced species and changes in the distribution of autochthonous species [3]. Research has primarily emphasized the changes in phytoplankton community structure that may have important implications for the entire ecosystem through the food web and
biogeochemical cycles.

Generally, the water quality was detected and measured by chemical-physical analysis, but in dynamics environment the monitoring using phytoplankton needs to be done, because phytoplankton community analysis will describe clearer figurine the existence of the pollutant impact the community structure in the waters [4,5]. Physico-chemical characteristics and species composition of the phytoplankton community are important indicators of water quality. The differences of phytoplankton distribution and biomass concentrations are expressed in terms of diversity, relative abundance of species, size class, as well as seasonal succession. Variability of phytoplankton assemblages are explained by several factors; nutrients availability; light variation; and mixing conditions [6, 7]. The distribution of species within these assemblages is dependent on the degree of stability and nutrient concentrations [8, 9]. Nutrient inputs can be of natural origin or anthropogenic origin [10]. In the last decades, numerous investigations have been conducted on the structure and dynamics of phytoplankton communities along the coastal area of Alexandria [11-21]. These earlier studies have helped improve knowledge on the spatio-temporal dynamics of phytoplankton assemblages in coastal area.

This study focuses on the Spatio-temporal distribution of phytoplankton community structure and environmental conditions (physical conditions, and nutrient availability) along Alexandria coastal area (from Abu Qir in the east to eastern harbor in the west) over one year 2013-2014.

2. Material and Methods

2.1. Study Areas

Ten surface water samples were collected seasonally from the coastal zone of Alexandria using plastic Rottener Sampler of 2 liters capacity. Trips for sampled collection were carried out on a boat. Sampling periods were performed in June, September, December 2013, March and June 2014. Sampling stations were chosen covering the different locations of the costal area (Figure 1).

2.2. Seawater Analysis

The water temperature was measured with an ordinary thermometer. The pH value was measured using a pocket pH meter (model 201/digital pH meter). Water salinity was measured using Bechman salinometer (Model NO. R.S.10). Dissolved oxygen was estimated according to the Winkler method. Samples for nutrient salts were immediately filtered through Whatman GF/C filters and kept frozen until analysis. Samples of ammonium were fixed in the field without filtration. Dissolved inorganic nitrogen compounds DIN (NH₄-N, NO₂-N and NO₃-N), reactive phosphate (PO₄-P) and reactive silicate (SiO₄) were determined according to Grasshoff (1976) [22]. Chlorophyll-α in the surface water was extracted with 90% acetone and measured spectrophotometrically using the SCORE UNESCO [23]. The measurements of dissolved nutrient salts (PO₄-P, NH₄-N, NO₂-N, NO₃-N and SiO₄) and Chlorophyll-α were performed using a Shimadzu double beam spectrophotometer (UV UV-150-02), after centrifugation. Absorptions at 630, 647, 664 and 750nm were measured and Chl-a concentration was calculated.

Estimation of the phytoplankton density was carried out by the sedimentation method; the sample was preserved in 4% neutral formalin. The different species were counted and the results expressed as unit per liter (Cyanobacteria and Chlorophyta contain filament, coenobia and colonies). Various key books and taxt were consulted for identification of phytoplankton species. Diversity H' (Shannon–Wiener index) was used to describe the numerical structure of the phytoplankton community.
3. Results Discussion

3.1. Hydrographic Conditions

3.1.1. Physical Parameters

Water temperature, the values of pH of the investigated area, and Water salinity were studied, the hydrographic conditions varied widely during the study period (Figures 2, 3, 4). Water temperature variation was in the range (18.20 - 27.5 °C) (Table 1). The values of pH of the investigated area lie on the alkaline side, its values ranged from 7.53 to 8.19.

The results of pH values at most of stations decrease than that normal pH value of seawater (8.20) observed during June, September 2013 and March 2014 due to wastewater inputs (Table 1). The salinity is an important factor which reflects the changes caused by the mixing of fresh water, drainage water and seawater. The variation of water salinity was recorded in Table 1. The lowest value (35.34 PSU) was recorded at station IX, while the highest one (38.28 PSU) was recorded at station VII. The low mean value of salinity recorded in December 2013 and June 2014 (36.01 ± 0.41 PSU), it was decreased than that reported in the other season. The results are similar to those reported by Fahmy, et al. (1997) [24].

3.1.2. Chemical Parameters

The results of DO value varied between 4.77 and 11.13 mgL⁻¹ in the study area (Table 1), which the lower value was recorded at station X in June 2014 while the highest value was recorded at station I in December 2013. Generally, the increasing of water temperature leads to the decreasing of DO.

| Parameter | Summer | Autumn | Winter | Spring | Summer |
|-----------|--------|--------|--------|--------|--------|
| pH        | 7.76-8.12 | 7.75-7.98 | 7.84-8.19 | 7.53-7.85 | 7.66-8.12 |
| Salinity(PSU) | 37.68-38.22 | 37.44-38.28 | 35.34-36.66 | 36.00-38.00 | 35.34-36.66 |
| Temper.(°C) | 37.91±0.52 | 37.94±0.31 | 36.01±0.43 | 37.50±0.53 | 36.01±0.43 |
| NO₂(Na)(µM) | 25.20-27.10 | 26.20-27.50 | 18.20-20.01 | 19.80-20.60 | 23.80-24.30 |
| DO, mgL⁻¹ | 26.00-20.60 | 26.98±0.45 | 19.81±0.57 | 20.16±0.35 | 24.08±0.19 |
| NO3(Na)(µM) | 6.35-8.90 | 6.35-7.94 | 6.35-11.13 | 5.10-9.63 | 4.77-8.90 |
| NH₄(Na)(µM) | 7.40±0.81 | 7.24±0.76 | 8.55±1.54 | 8.14±1.40 | 6.71±1.37 |
| PO₄(P)(µM) | 0.07-0.90 | 0.10-0.96 | 0.93-1.82 | 0.01-0.47 | 0.36-1.22 |
| SiO₄(Si)(µM) | 0.26±0.26 | 0.50±0.27 | 1.36±0.24 | 0.25±0.15 | 0.76±0.25 |
| NH₄/N(µM) | 1.51-8.97 | 1.16-7.55 | 0.10-0.45 | 0.27-0.80 | 0.57-1.34 |
| NO₃/N(µM) | 5.16±2.36 | 3.98±2.19 | 0.14±0.11 | 0.53±0.16 | 0.81±0.11 |
| NO₂/N(µM) | 2.50-7.27 | 2.36-11.99 | 9.04-33.21 | 2.58-4.64 | 2.95-11.08 |
| PO₄/P(µM) | 0.01-0.64 | 0.01-0.69 | 0.01-0.90 | 0.01-0.48 | 0.17-1.63 |
| CHL-a(µg/l) | 4.27±1.59 | 2.32±1.38 | 0.92±0.49 | 2.32±1.38 | 4.27±1.59 |

3.1.3. Nutrient Salts and Chlorophyll-a (Chl-a)

Ammonium is the major nitrogenous product of the bacterial decomposition of organic matter containing nitrogen, and is an important excretory product of invertebrates and vertebrates. As for the utilization of nitrogenous materials, ammonium is the preferred inorganic source because of its ease uptake and incorporation into amino acids (N-assimilation). The present study showed that, winter2013, spring and summer 2014 (Table 1) have low levels of NH₄/N (<1.00 µM). Faragallah (1995)[25] observed low concentration of NH₄/N during winter in the eastern harbor (3.37 µM) and respect this to promotion of nitrification due to violation of the water as a result of wave and wind action prevailing in this season. Also, Madkour et al. (2007) [26] pointed out that March has the lowest value of NH₄/N during 2002. As shown in Figure 3, NH₄/N concentration in the period of summer and autumn 2013 revealed high levels of NH₄/N (ranged; 3.98 - 5.16 µM). Madkour et al. (2007) [26] respect this to the stratification and the effect of the rise in water temperature which may induce the mineralization from the sediment, decomposition rate of sewage and other organic wastes. Nitrate form is generally considered as the most stable and predominant inorganic nitrogen compound in oxygenated sea water. Nitrate concentration ranged between 2.50 and 33.21 µM. The distribution of NO₃/N (Figure 3) showed that the concentration during June2013 is similar to that of June 2014. Also the distribution of NO₃/N through the study period is mostly similar to that of NH₄/N. These refer to the fact that the rate of nitrification is mostly similar to that of denitrification, or due to the oxidation of ammonia to nitrite.
and nitrate either chemically or biologically. The mean concentration of PO\textsubscript{4}-P (Table 1) revealed that, the lowest value (0.01 µM) was recorded at station II in all seasons except winter (December 2013) and the highest concentration of PO\textsubscript{4}-P in the study area was recorded in summer 2014 (1.63 µM) and (1.37 µM) at stations VII and X, respectively. Silicate is one of the major constituents in the sea water. It is a good indicator of fresh water dispersion and of the potential for diatom [27].

Silicate is one of the major constituents in the sea water. It is a good indicator of fresh water dispersion and of the potential for diatom [27]. The seasonal distribution of silicate concentration in the area of study water showed a wide range of variation (Table 1). It ranged from 0.78 µM in June 2013 (station IV) to 30.43 µM in December (Station VIII). The highest mean content of silicate was found in winter 2014 (20.15 ± 5.49 µM) and decreases to lowest level in autumn (7.00 ± 4.07 µM). The lower silicate was recorded during summer, autumn, spring 2013 and summer 2014 (Figure 4); this may be due to the high level of phytoplankton growth (Chl-a was 3.28 ± 1.13; 4.27± 1.59 µg l\textsuperscript{-1} in summer 2013 and 2014 and 2.06 ± 1.67 µg l\textsuperscript{-1} in spring 2014, respectively). The present results are the opposite than that reported by Faragallah \textit{et al.} (2009) [25] in the eastern harbor. The data was similar to those recorded by Dorgham \textit{et al.} (2004) [28] (9.03 µM), in the western Harbor, and it was markedly lower to that reported by Abdel Aziz \textit{et al.} (2001) [29] (16.74 µM) in Abu Qir bay and 49.52 µM in El-Dekhaila harbor [30]. Although the drainage waters have been reported as the principal source of silicate in the area and play a significant part in its spatial and temporal distribution, it was found that phytoplankton growth was actually regulating the silicate level [28]. The results showed relationship between phytoplankton and silicate content, this is confirmed with the negative correlation between silicate and Chl-a concentration (r = - 0.342). The same observation was found by Abdel-Halim and Khairy (2007) [31]. The regional variations of silicate content were related to the amounts of drainage water discharged.

![Figure 2: Seasonal variations of pH values, Temperature and DO along the Coastal Area of Alexandria (2013-2014).](image)

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![Figure 3: Seasonal variations of Ammonium (NH\textsubscript{4}-N), Nitrite (NO\textsubscript{2}-N) and Nitrate (NO\textsubscript{3}-N) along the Coastal Area of Alexandria (2013-2014) Su: Summer, Au: Autumn, Wi: Winter, Sp: Spring.](image)
Chlorophyll-a concentration is considered as a good indicator of the phytoplankton biomass [27], it is used as a trophic state indicator. The mean concentration of Chl-a (Figure 4) was exhibited lower value in autumn 2013 (0.38 µg l\(^{-1}\)), while the highest value in June 2014 (6.96 µg l\(^{-1}\)). The results revealed high concentration of Chl-a in hot seasons. Faragallah et al. (2009) [25] showed that most days during autumn and winter mainly had levels of Chl-a lower than that recorded during spring and summer. The present data of Chl-a was in agreement with that of phytoplankton biomass collected from the same sites [33]. Also, the results indicated relatively high concentration of Chl-a in Alexandria coastal zone comparing with that reported by Ignatiades et al. (1992)[34] in the north and eastern Mediterranean sea (0.01-0.15 µg l\(^{-1}\)) and higher than that recorded in Aegean Sea; 0.10-0.80 µg l\(^{-1}\) [23].

3.2. Biological Parameters

3.2.1. Phytoplankton Community

The Phytoplankton community in the investigated area during the period of this work was not only productive but also diversified. A total of 153 phytoplankton taxa were identified belonging to 73 genera represented by six groups (Table 2). In a previous study 135 taxa recorded at some coastal area of Alexandria [19], in this study, Bacillariophyceae comprised the highest abundance (97.46 %) to the total counts represented by 85 species belonging to 44 genera, while Dinophyceae 1.37 % comprised 31 species, an average value attained about 838.6 x 10\(^3\) unit l\(^{-1}\) [19] (Hussein 2000); a total of 92 taxa were identified at the same coastal area of Alexandria [20]; and a total of 162 phytoplankton species were identified in the EH and 110 species in the KB [21].

In this work Bacillariophyceae comprised the highest number of taxa, (94 species belonging to 40 genera), with relative frequency 95.55 % of the total numerical abundance (Table3). Dinophyceae contributing about 3.04% of the total counts (34 species, 12 genera), while Euglenophyceae, Cyanobacteria, Chlorophyceae, Silicoflagellata were rarely recorded contributing all together about 1.41 % to the total counts (Table 3). The Phytoplankton counts attained an average value about (60.7 x 10\(^3\) unit l\(^{-1}\)), which is lower than that recorded previously (236.4 x 10\(^3\) unit l\(^{-1}\)) [35]; and lower than that recorded at the same coastal area of Alexandria (680, x 10\(^3\) unit l\(^{-1}\)) [20]; and (1387.0 x 10\(^3\) unit l\(^{-1}\)) in the EH and (108 x 10\(^3\) unit l\(^{-1}\)) in the KB [21].

The highest numerical abundance of phytoplankton appeared during Autumn 2013 (227.3 x 10\(^3\) unit l\(^{-1}\)) and Spring 2014 (37.5 x 10\(^3\) unit l\(^{-1}\)) represented by Six groups most of them belonging to class Bacillariophyceae (Table3), while the lowest one detected during Summer 2014 (8.4 x 10\(^3\) unit l\(^{-1}\)) (Table3). The Phytoplankton numerical abundance ranged between (1.2 x 10\(^3\) unit l\(^{-1}\)) of St.VIII, summer 2014 and 2.2 x 10\(^3\) unit l\(^{-1}\) of St.I, autumn (Table 4).

Dinophyceae represented by 34 species and 12 genera, with abundance 3.04% from the total counts, with an average about 1.8 x10\(^3\) unit l\(^{-1}\) (Table3). On the other hand, Euglenophyceae, Cyanobacteria, Chlorophyceae and Silicoflagellates were rare or scarce forms. Euglenophyceae represented by 5 species, 4 genera and attained its maximum record (2.1 x 10\(^3\) cell.l\(^{-1}\)) of St.VII, summer 2013, represented by 2 species belonging to 2 genera. Cyanobacteria represented by 8 species, 5 genera reached its maximum count (1.9 x 10\(^3\) unit l\(^{-1}\)) of St.IV, Summer 2014, it was represented by 2 species belonging to 2 genera, while Chlorophyceae represented by 10 species, 10 genera attained its maximum record (6.4x 10\(^3\) unit l\(^{-1}\)) of St. I, Winter 2013 represented by 4 species belonging to 4 genera (Table3).
Silicoflagellates was scarcely occurrence and represented by 2 species, and 2 genera which appeared during summer and autumn 2013 at Stations I and II respectively (Table 3).

3.2.2. Distribution and Seasonal Variations of Phytoplankton Abundance

The abundance and species composition of phytoplankton varied strongly at the successive seasons and between stations in the study area. The average phytoplankton counts reached (60.7 x 10^3 units.1^-1) long Alexandria coastal water (Table 3 and Figure 5). They varied widely from 1.2 x 10^3 unit 1^-1 in summer 2014 (St.VIII) to 218.72x 10^3 unit 1^-1 in autumn 2013 (St.I) (Table 4 and Figure 5) as a result of good nutritional conditions caused by continues discharge of allochthonous nutrients and organic load from sewage. Community composition of all stations was dominated by Bacillariophyceae, which constituted the main abundance (95.55%) from the total counts. The seasonal variations showed heavy blooms during autumn 2013 at station I, and spring 2014 at station III. Bacillariophyceae reaches (449.3 x 10^3 unit 1^-1; 35.9 x 10^3 unit 1^-1), respectively, (Table2). Dinophyceae attained an average (1.85 x 10^3 unit 1^-1), with abundance 3.04% to the total counts Table 3 and Figure 6). The lower values of the phytoplankton counts were observed during summer and winter due to decrease in nutrient, low temperature and light which considerably limited the phytoplankton production.

### Table 2: Distribution of Phytoplankton Classes (units l^-1) at all stations along Alexandria Coastal Water (2013-2014).

| Classes                  | St. I         | St. II        | St. III       | St. IV        | St. V         | St. VI        | St. VII       | St. VIII      | St. IX        | St. X         | Total | Aver. | %     |
|--------------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--------|-------|-------|
| Total Bacill              | 449340        | 9968          | 35904         | 7022          | 8588          | 11586         | 16104         | 6941          | 17556         | 17302        | 58031  | 58031 | 95.55 |
| Total Chloro             | 1420          | 250           | 64            | 132           | 126           | 20            | 120           | 395           | 380           | 180           | 3087   | 309   | 0.52  |
| Total Cyano              | 452           | 268           | 230           | 488           | 274           | 280           | 96            | 91            | 220           | 200           | 2599   | 260   | 0.43  |
| Total Dino               | 1884          | 5110          | 1936          | 2154          | 1493          | 1552          | 807           | 704           | 1614          | 1226          | 18480  | 1848  | 3.04  |
| Total Eugle              | 140           | 110           | 132           | 94            | 302           | 226           | 621           | 509           | 376           | 230           | 2740   | 274   | 0.45  |
| Total Scilico            | 20            | 70            | 0             | 0             | 0             | 0             | 0             | 0             | 0             | 0             | 90     | 9     | 0.01  |
| Total phyto              | 453256        | 15777         | 38266         | 9890          | 10783         | 13664         | 17748         | 8640          | 20146         | 19138         | 60730  | 60731 | 100   |

Total Bacillariophyceae: Total Bacill; Total Chlorophyceae: Total Chloro; Total Cyanobacteria: Total Cyano; Total Dinophyceae: Total Dino; Total Euglenophyceae: Total Eugle; Total Silicoflagellate: Total Scilico; Total phytoplankton: Total phyto

### Table 3: Seasonal and Taxonomic composition and proportional representation of the phytoplankton groups (units l^-1) along the coastal area of Alexandria (2013-2014).

| Phytoplankton groups | 2013 | Aver. | | 2014 | Aver. | | Genus | No. of Species | %     |
|----------------------|------|-------|-------|------|-------|-------|-------|----------------|-------|
|                      | Summer | Autumn | Winter | Spring | Summer | Aver. count | Genus | No. of Species | %     |
| Total Bacill          | 9539  | 22565  | 14858  | 35906  | 4199   | 5803 x10^-3 | 40    | 94             | 95.6  |
| Total Dino            | 3023  | 1195   | 536    | 1000   | 3487   | 185 x10^-3  | 12    | 34             | 3.04  |
| Total Chloro          | 344   | 178    | 828    | 110    | 84     | 0.31 x10^-3 | 10    | 10             | 0.52  |
| Total Cyano           | 256   | 122    | 289    | 131    | 502    | 0.26 x10^-3 | 5     | 8              | 0.43  |
| Total Eugle           | 477   | 88     | 311    | 360    | 134    | 0.27 x10^-3 | 4     | 5              | 0.45  |
| Total Scilico         | 17    | 28     | 0      | 0      | 0      | 0.01 x10^-3 | 2     | 2              | 0.01  |
| Total phyto           | 13655 | 227264 | 16822  | 37507  | 8406   | 60.7 x10^-3 | 73    | 153            | 100   |

Total Bacillariophyceae: Total Bacill; Total Chlorophyceae: Total Chloro; Total Cyanobacteria: Total Cyano; Total Dinophyceae: Total Dino; Total Euglenophyceae: Total Eugle; Total Silicoflagellate: Total Scilico; Total phytoplankton: Total phyto

### Table 4: Seasonal variations of the total phytoplankton counts (units l^-1) at different stations along Alexandria coastal water (2013-2014).

| Seasons Stations | Summer | Autumn | Winter | Spring | Summer | Average |
|------------------|--------|--------|--------|--------|--------|---------|
|                  | 2013   | 2014   | 2013   | 2014   | 2013   | 2014    | 2013   | 2014   | 2013   | 2014   | 2013   | 2014   | 2013   | 2014   |
| I                | 13300  | 21872  | 41900  | 13000  | 10880  | 453256  |
| II               | 13354  | 17280  | 8650   | 16200  | 23400  | 15777   |
| III              | 5070   | 11000  | 18770  | 147700 | 8790   | 38266   |
| IV               | 9600   | 6300   | 5110   | 18140  | 10300  | 9890    |
| V                | 2695   | 5320   | 11750  | 27310  | 6840   | 10783   |
| VI               | 22320  | 5700   | 8500   | 26600  | 5200   | 13664   |
| VII              | 3700   | 11700  | 3440   | 62400  | 7500   | 17748   |
| VIII             | 22030  | 4850   | 4600   | 10500  | 1219   | 8640    |
| IX               | 27040  | 6840   | 32900  | 29220  | 4730   | 20146   |
| X                | 17440  | 16450  | 32600  | 24000  | 5200   | 19138   |
| Average          | 13655  | 227264 | 16822  | 37507  | 8406   | 60731   |
3.2.3. Distribution and Seasonal Occurrence of the Recorded Species

I. Bacillariophyceae distribution and seasonal variations

The abundance of phytoplankton groups in the present study exhibited clearly different counts in the dominant species. Phytoplankton counts was attained an average value about (60.7x10^3 unit 1^-1), the highest counts recorded during autumn 2013 (227.3x10^3 unit 1^-1) and Spring 2014 (37.5x10^3 unit 1^-1) represented by Six groups, most of them belonging to class Bacillariophyceae, 99.29 %, 95.73% respectively. (Table 4). Bacillariophyceae attained its maximum count at station I during autumn (2187.3 x 10^3 unit 1^-1), with abundance 99.29%, comprised 69 species, dominated by Thalassiosira rotula meunier (93.46 % from the total phytoplankton community). On the other hand, the lowest count recorded at St. VIII (0.9 x 10^3 unit 1^-1) during summer 2014 as shown in (Figure5).

![Figure 5: Temporal and Spatial Variation of Total Phytoplankton along Alexandria Coastal Water (2013-2014).](image5)

The most dominant diatoms species during the period of this study contributed 49.3% to the total phytoplankton count in summer 2013, represented by (Skeletonema costatum (Grev.) Cl., Cyclotella meneghiniana Kutz., Grammatophora marina, Leptocylindrus danicus Cleve, Leptocylindrus minimus Grun., Licmophora gracilis, Navicula cryptocephala Kutz, Pseudonitzschia seriata Cleve); and decreased to 33.9% to the total community in summer 2014, represented by (cocconeis placenta, Cyclotella meneghiniana Kutz., Licmophora gracilis, Melosira granulataV.angustissima Muller, Navicula cryptocephala Kutz, Navicula spectabilis, Nit. longissima, Nit. microcephala Grun, Rhizosolenia delicatula cleve.. The abundance cycle of this group exhibited high level in the cells number of one specie in autumn 2013 (93.5%) to the total phytoplankton count; Thalassiosira rotula Meunier; in winter 2013 represented 64.3% (Chaetoceros affinii, Coscinodiscus centralis Ehr., Cyclotella meneghiniana Kutz., Melosira granulataVangustissima Muller, Navicula lanceolata (Agar)Kutz., Skeletonema costatum (Grev.) Cl., Synedra acus, Synedra ulna(Nitzsch.)Ehr., Thalassiosira rotula Meunier; in spring 2014 were represented 74.2% by number to the total phytoplankton count (Chaetoceros affinii, Chaetoseros didymus Her., Leptocylindrus danicus cleve., Leptocylindrus minimus Grun., Skeletonema costatum (Grev.)Cl.).

II. Dinophyceae distribution and seasonal variations:

While it was considered as rare from planktonic group throughout the Period of investigation, it ranked the second group. It attained an average count (1.85x10^3 unit 1^-1), with abundance (3.04 %) from the total community (Table3). Dinophyceae was represented by 12 genera including 34 species, attained its maximum count at station II (5.1x10^3 unit 1^-1), dominated by Prorocentrum cordatum(Osten.)Abae (0.71%), Protoperidinium minutum (Kofoid) Balech (0.44 %), Protoperidinium trochoidium(Stein) Lemm (0.30%) (4.2x10^3 unit 1^-1; 2.6x10^3 unit 1^-1 and 1.8x10^3 unit 1^-1), during summer season 2013 -2014, respectively. The phytoplankton community was more diverse in Alexandria coastal area (153 species), however, the species composition revealed irregular distribution between the sampling stations along the study area (Table 2 and Figure 6). Bacillariophyceae and Dinophyceae groups appeared to be the major phytoplankton groups; its relative percentage ranged from 49.9(summer 2014) to 99.3%(autumn 2013) for Bacillariophyceae and from 0.5 (autumn 2013) to 41.5% (summer 2014) for Dinophyceae to the total phytoplankton community, the two groups represented 94 species and 34 species, respectively. On the other hand, freshwater represented mainly by Chlorophyceae (10 species), Cyanophyceae (8 species) and Euglenophyceae (5 species), the relative percentage to the total phytoplankton community for the three groups ranged from1.0 to 4.9% for Chlorophyceae; from 0.05 to 6.0% for Cyanophyceae and from 0.04 to 3.5% for Euglenophyceae. The freshwater taxa showed almost low count, constituting collectively 0.53% of total phytoplankton in spring 2014 and reached to 2.86% in summer 2014.

![Figure 6: Seasonal distribution of phytoplankton groups along Alexandria coastal area (2013-2014).](image6)

3.2.4. Species Diversity: Diversity Index of Phytoplankton Community

Diversity index usually illustrates the distribution of the different species within the community. It reflects the pollution status of aquatic habitats, Species diversity is reliable parameter in biology to determine how healthy an environment [36].There are several numerical attempts to
express degrees of oligotrophy and eutrophy from a consideration of species complements rather than from nutrient levels [37]. In this investigation the species diversity of the phytoplankton was estimated according to the equation of Shannon and Weaver (1963) [38]. The estimated diversity reflects an inverse relationship to the degree of dominance of the main species recorded rather than to the number of species or the magnitude of the phytoplankton counts. In the present study, the diversity index were relatively high most of the time fluctuated between 0.21 and 3.59 (Table5). The abundance and species composition of phytoplankton varied strongly at the successive months and between stations in the study area (Table5), it ranged between a minimum (St.III) 0.21 (H) in Autumn season 2013 with the dominance of *Thalassiosira rotula* (97%) to total phytoplankton counts, accompanied by a higher phytoplankton counts (60.7 x 10^3 unit.l^{-1}) and a maximum of (St.II) 3.59 (H) in Autumn season; with the dominance of 3 species namely *Skeletonema costatum* (41 %) in Summer 2013 and Spring 2014 and *leptocylindrus minimus* (35 %) in Spring 2014 and *Chaetoceros affinis* (42%) in Spring 2014 (The annual average was 2.16%), it ranged between a minimum(0.21) at St.I during Autumn 2013 (30 taxa were recorded) dominated by *Thalassiosira rotula* (97.11%) from the total phytoplankton counts,accompanied by a high phytoplankton counts (2187.2 x 10^3 unit.l^{-1}), and a maximum of (3.59) at (St.II)during the same season(48 taxa), with the dominance of more than one species, *Pseudonitzschia seriata* Cleve 6.77%, *Navicula cryptocephala* Kutz.6.25%, *Leptocylindrus danicus* Cleve.5.72%, *Leptocylindrus minimus* Grun.5.21% accompanied by a low phytoplankton counts (17.3 x 10^3 unit l^{-1}) Also the diversity index showed low value at St.III (0.83) during winter, where 15 taxa were recorded dominated by *Navicula lanceolata* (Agar.) Kutz 83.11%, and phytoplankton counts reached 18.8 x 10^3 unit l^{-1}.

### Table 5: Seasonal Variations of Phytoplankton Diversity at different stations along Alexandria Coastal water (2013-2014).

| St. | Summer | Autumn | winter | Spring | Summer | average |
|-----|--------|--------|--------|--------|--------|---------|
| I   | 2.43   | 0.21   | -2.79  | 2.25   | 2.87   | 0.99    |
| II  | 2.97   | 3.59   | 2.23   | 2.17   | 2.18   | 2.63    |
| III | 2.72   | -3.42  | 0.83   | 2.06   | 2.47   | 0.93    |
| IV  | 3.35   | 3.15   | 2.51   | 2.67   | 2.43   | 2.82    |
| V   | 2.5    | 3.02   | -2.56  | 2.56   | 2.77   | 1.66    |
| VI  | 2.71   | 2.4    | -2.13  | 1.73   | 2.24   | 1.39    |
| VII | 1.6    | 2.74   | 2.3    | 1.43   | 2.39   | 2.09    |
| VIII| 2.6    | 3.09   | 2.4    | 1.5    | 2.01   | 2.31    |
| IX  | 3.07   | 2.67   | 2.31   | 2.57   | 2.61   | 2.53    |
| X   | 2.23   | 3.42   | 2.55   | 1.47   | 2.72   | 3.91    |
| Average | 2.64 | 2.08 | 0.77 | 2.75 | 2.41 | 2.13 |

### 3.3. Statistical Analysis

Correlation coefficient of phytoplankton counts, its main groups and physicochemical properties of Alexandria seawater showed that; the data revealed high positive correlation between temperature and total Dinophyceae content (R^2= 0.66).This reflects the important role of temperature in the activity of Dinophyceae growth. Total Chlorophyceae group was highly positive correlated with dissolved silicate concentration (R^2= 0.90), also the total Bacillariophyceae showed highly positive correlated with dissolved silicate (R^2= 0.95 n=50, P < 0.05). The total phytoplankton and dissolved silicate content revealed good relationship (R^2= 0.95 n=50, P < 0.05). The two most common parameters used to recognize the composition of wastewater are the biochemical oxygen demand (BOD) and the chemical oxygen demand (COD). BOD5 is a measure of how much dissolved oxygen is consumed by aerobic bacteria in 5 days at 20°C. It is the broad measure of the strength of the organic matter in a waste stream, the relationship between the BOD and COD was high (r=0.72). The type of wastewater discharge can be determined according to BOD/ COM (ECPH, 1975). 1: 1 ratio reveals well-purified water; the biodegradable matter has a ratio ≤ 2: 1. Finally the ratio that ranged between 2:1 and 4:1 is specific to crude domestic sewage. The ratio of BOD/ COM in the investigated area is less than one during the period of study, ranged from 0.15 to 0.81. Temperature can affect ammonia toxicity to aquatic species, as well, and pKa is a function of temperature. As temperature increases, the pKa value will increase, resulting in an increased percentage of un-ionized ammonia, the data showed high positive correlation between temperature and ammonia (R^2= 0.72 n=50, P < 0.05). Nitrate and nitrite values showed a good relation between them through the study period, this observation may be reflecting the distribution similarity for the two forms (R^2= 0.59 n=50, P < 0.05).

### 4. Conclusion

The continuous land run off into the Mediterranean coast caused massive development of algal blooms and the coastal current allows such blooms to extend along the shore line, and so water quality creates on the long run nuisance and aesthetic problems in the recreational beaches. The results can be concluded as the following:

- Euglenophyceae, Cyanobacteria, Chlorophyceae and Silicoflagellates were rare or scarce forms.
- The data revealed high positive correlation between...
temperature and total Dinophyceae content ($R^2=0.66$). This reflects the important role of temperature in the activity of Dinophyceae growth.

- Total Chlorophyceae group was highly positive correlated with dissolved silicate concentration ($R^2=0.90$), also the total Bacillariophyceae showed highly positive correlated with dissolved silicate ($R^2=0.95$ n=50, $P < 0.05$).

- The results showed that the highest density of phytoplankton community recorded at Abu-Qir (St.I) (453.3x10^3 units l-1), while Shatby (St.VIII) showed the lowest density (8.6x10^3 units l-1).

- The estimated diversity reflects an inverse relationship to the degree of dominance of the main species recorded rather than to the number of species.

- A signal of the area is light to moderate polluted and/or recycled before discharge into this natural aquatic body.

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