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Marine Protozoa composition, distribution and abundant species at Egyptian Coast of the Mediterranean Sea

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ABSTRACT

The Mediterranean Sea receives several kinds of untreated pollution resulting from intensive human activities which affect zooplankton distribution along the sea. For this reason, the present work aimed to study the spatial and temporal distribution of zooplankton communities along the Egyptian coast of the Mediterranean Sea, with some lights shed on their diversity and abundance. To achieve this target, four seasonal cruises were carried out at three stations along the study site. The area's environmental parameters and protozoan community were seasonally addressed in 2020. A total of 94 protozoan species were identified, belonging to Foraminifera (57 species), tintinnids (33 species) and Amoebozoa (4 species). The numerical density of protozoans was high over the whole area, with annual averages of 11458 Individuals/m^3. Summer and autumn were the most productive seasons for protozoans, while spring was the lowest. The recorded values of physicochemical parameters including transparency (0.9-2 m), temperature (19.2-33.9 ^{o}C), depth (4-6 m), salinity (30-45 ‰), water pH (6.8-8.6) and dissolved oxygen (2.15-7 mg/l) fluctuated throughout studied seasons.

INTRODUCTION

Protozoans represent an important biotic component in the aquatic ecosystem, particularly ciliates, which act as predators of bacteria, provide nutrition for organisms at higher trophic levels **(Sikder *et al.*, 2020)**. In addition, they increase mineralization and make nutrients more available to other organisms **(Vickerman, 1992)**. They also play a crucial role in food chains as biomonitors and/or water quality indicators **(Charubhun & Charubhun, 2000)**. Simultaneously, it was proved that Protozoa stimulates the rates of carbon and nitrogen cycling **(Yang *et al.*, 2021)**. In aquatic environments, zooplankton plays an important role in transferring energy from the primary producers to the higher level in the food chain **(Nour El-Din, 1987)**. Furthermore, the favorite food items for many animals include economic fish; great numbers of ciliates feed mostly on bacteria and not on dissolved organic material and compete with other ciliates and rotifers for different bacteria (**El-Rashidy, 1987**).

Protozoa and Chromista have a cosmopolitan distribution and play an integral role in the decomposition of organic matter, nutrient cycling, and maintenance of energy flow within terrestrial and aquatic ecosystems **(Pournou & Pournou, 2020)**. They can be of low abundance, but they widespread in environments that only marginally suit their survival or can rapidly colonize and exploit microenvironments that more optimally satisfy their needs **(Anderson, 1988)**. Although relatively little is known about the potential ecological significance of protozoan assemblages in hydrothermal vent environments, many protozoans can tolerate reducing conditions and are likely candidates for survival in these marine ecosystems **(Kouris *et al*., 2007)**. Most free-living marine ciliates are widely distributed and dominate in both species' numbers and numerical densities. In addition, protozoan organisms play a vital role in the microbial food web **(Lee & Choi, 2000)**. Besides, they are known for their high tolerance against extreme environmental conditions such as heavy metals and sewage pollution **(Forge *et al*., 1993)**.

Several studies on zooplankton abundance, composition and seasonal variations have been carried out in the coastal water of Alexandria, such as **El-Maghraby and Halim (1965)**, **Dowidar and El-Maghraby (1970a, b)**, **AboulEzz (1975)**, **El-Zawawy (1980)**, **Dowidar *et al*. (1983)**, **Khalil *et al*. (1983)**, **AboulEzz *et al*. (1990)**, **AboulEzz and Zaghloul (1990)** and **Abdel Aziz (1997)**. The near-shore waters west of Alexandria have attracted the attention of some investigators such as **Hussein (1997)**, who studied the zooplankton standing stock and community structure in relation to the impact of waste discharge in El-Mex Bay **and Abdel Aziz (2000)** who studied zooplankton community at El-Dekhelah Harbor. The impact of water circulation and discharged wastes on zooplankton dynamics in the Western Harbor of Alexandria have been studied by **Abdel Aziz (2002)**. On the other hand, water quality and zooplankton distribution in the Eastern Harbor were studied by **Dowidar *et al*. (1983a)**, **Aboul Ezz (1990)**, **Zakaria (2006)**, **El-Gindy *et al*. (2007)**, **Mansour *et al*. (2020)** and **Heneash *et al*.** (**2022**).

Protozoon plankton constitutes a significant proportion of total zooplankton biomass in various aquatic environments **(Stoecker & Pierson, 2019)**. Studies on the distributional patterns of these smaller consumers and their spatial and temporal relationships with major hydrological features along the coastal water of Alexandria are those of **Hussein (1977)**, **Abdel Aziz (1997)**, **Abdel Aziz *et al*. (2011)**, **Hussein (1997)**, **Abo-Taleb (2010, 2014)**, **Abou Zaid *et al*. (2014)** and **Aboul Ezz *et al*. (2014)**.

The present work was conducted to analyze the species composition of Chromista and Protozoa, determine their abundance along the coastal water of Alexandria and assess the impact of different environmental factors on their distributional pattern in order to use it as bio-indicator for the environmental conditions potentially.

MATERIALS AND METHODS

Samples were collected from the Egyptian coast of Mediterranean Sea in 2020 from three stations; Station I stands for the Montazah area east of the coast of Alexandria; Station II is at the Eastern Harbor and station III: El- Max Bay (Fig. 1).

Fig. 1. The location of sampling stations along the coast of Alexandria

Zooplankton abundance

Zooplankton samples were collected during 2020 from three stations using a standard plankton net (No. 25) of a 55µm mesh size by filtering $0.2m^3$ from the water surface. The zooplankton organisms retained in the net were then transferred into a small glass bottle and preserved in a 5% neutralized formalin solution, and the sample volume was then adjusted to 100ml. The samples were examined under a binocular research microscope. The identification was undertaken at species levels. To estimate the standing crop, sub-samples of 5ml were transferred to a counting chamber (Bogorov chamber) using a plunger pipette. This operation was performed three times, and the average of the three counts was taken, and the standing crop was calculated and estimated as organisms per cubic meter according to the following formula of **Santhanam and Srinivasan (1994**):

$$N= (n * v) / (V * c)$$

$$V= \pi r^2.d$$

Where,

N: Total number of zooplankton per cubic meter; **n:** average number of zooplankton in one ml of the sample; **v:** volume of concentrated sample (100 ml); **V:** volume of total filtered water (m^3); **r:** radius of the net opening; **d:** length of the net traction (30 m), **c**: subsample volume (one ml), and **π** is constant (3.14).

Identification of the species

Identification of different Protozoa species was carried out according to **Jörgensen, (1924)**, **Tregouboff and Rose (1957)**, **Marshall (1969)** and **Paulmier (1997)**.

Physicochemical parameters

Water temperature was directly measured by usual thermometers (0.1 ºC), while water transparency was measured using a white enameled Secchi disc with a diameter of 30cm, and the water salinity was measured by a refractometer. Determination of the dissolved oxygen was carried out according to Winkler's method **(Strickland & Parsons, 1972)**, and the pH values of the water were measured in the field using a pocket digital pH meter (model Oyster, inspected 82738, Extech instruments, Germany).

Statistical analysis

All collected data in the present study were tabulated, and appropriate graphs were illustrated to determine the biodiversity and distribution of fauna through the year among the different inspected stations which were computed by Microsoft Excel 365.

RESULTS

The visibility of coast water fluctuated between a minimum of 0.9m at station III during autumn and a maximum of 2m) at station I during winter. The average water temperature varied seasonally and ranged from 19.43±0.32°C during winter to 31.73±1.90 °C during summer. The minimum temperature (19.2 °C) was recorded at station I during winter and increased to a maximum value (33.9 °C) at station II during summer. On the other hand, the maximum average depth was 5.13±0.25 m at station I, and the minimum average depth was 4.88±0.85 m at station III (Tables 1, 2).

Water salinity varied from a minimum of 30 ‰ at station III during winter to a maximum of 45 ‰ at station II during summer. The average pH varied seasonally, ranging from 7.4±0.55 during summer to 8.17±0.58 during winter. The minimum pH value (6.8) was recorded at station III during summer and increased to a maximum value (8.6) at station II during winter. Additionally, the dissolved oxygen (D.O.) showed wide variations, fluctuating between 2.15mg/ L at station III during summer and 7mg/ L at station I during winter (Tables 1, 2).

Table 1. Characteristics of the the Egyptian Mediterranean water at the study sites during different seasons in 2020 (SD: Standard deviation)

Variable		Winter	Spring	Summer	Autumn
Visibility (m)	Mean ± SD	1.5±0.45	1.37±0.37	1.47±0.40	1.33±0.45
	Range	1.1-2	1.1-1.8	1.1-1.9	0.9-1.8
Temperature ºC	Mean ± SD	19.43±0.32	29.03±0.95	31.73±1.90	28±1
	Range	19.2-19.8	28.1-30	30.3-33.9	27-29
Depth (m)	Mean ± SD	4.83±0.28	5.5±0.5	4.5±0.5	5.27±0.64
	Range	4.5-5	5.0-6.0	4.0-5.0	4.8-6
Salinity (‰)	Mean ± SD	34.33±3.78	37.33±2.30	37.67±7.02	36.33±5.13
	Range	30-37	36-40	31-45	32-42
pH	Mean ± SD	8.17±0.58	7.8±0.36	7.4±0.55	7.43±0.32
	Range	7.5-8.6	7.4-8.10	6.8-7.9	7.2-7.8
DO (mg/l)	Mean ± SD	5.33±2.08	4.05±1.36	3.71±1.35	4.86±0.26
	Range	3.0-7.0	2.50-5.09	2.15-4.57	4.6-5.12

Table 2. Spatial distribution of water characters in the Egyptian Mediterranean water during 2020

Variable		I	II	III
Visibility (m)	Mean ± SD	1.88±0.10	1.3±0.14	1.08±0.13
	Range	1.8-2	1.1-1.4	0.9-1.2
Temperature ºC	Mean ± SD	26.8±5.34	27.45±5.80	26.9±5.10
	Range	19.2-31	19.8-33.9	19.3-30.3
Depth (m)	Mean ± SD	5.13±0.25	5.08±0.65	4.88±0.85
	Range	5-5.5	4.5-6	4.0-6.0
Salinity (‰)	Mean ± SD	36.25±0.96	40.75±3.77	32.25±2.63
	Range	35-37	36-45	30-36
pH	Mean ± SD	8.05±0.26	7.8±0.61	7.25±0.31
	Range	7.8-8.4	7.2-8.6	6.8-7.5
DO (mg/l)	Mean ± SD	5.34±1.15	4.55±1.49	3.58±1.21
	Range	4.4-7	2.5-6	2.15-4.6

During the study period, Protozoa represented an average of 11459 organisms/m^3. The total number of species recorded in the study area was 94, divided into three major phyla belonging to 9 classes, 13 orders and 37 families under 47 genera. The three phyla were: Ciliophora, represented by 3 classes, 3 orders, 11 families, 14 genera and 33 species. Amoebozoa is represented by 1 class, 1 order, 2 families, 4 genera and 4 species. While, Foraminifera is represented by 5 classes, 9 orders, 24 families, 29 genera and 58 species. Table (6) represent the most dominant protozoan species (relatively 14 % of the total Protozoa).

The spatial distribution of protozoan species throughout the study period (Tables 3, 4) shows that the highest density was recorded at station I (13000 organisms/m^3), with the highest number of species (43), followed by station III recording 11625 organisms/m^3 and diversity being 39 species. On the other hand, the lowest station density was II (9750 organisms/m^3), with the lowest number of species (39) (Fig. 2).

Regarding the seasonal distribution, the maximum density of protozoan species was recorded during summer (21000 organisms/m^3), with high diversity (52 species). In comparison, the lowest densities were recorded during spring and winter (4333 and 5167 organisms/m^3), respectively, with species diversity of 11 and 18 species (Tables 3, 4 & Fig. 3).

Table 3. Spatial distribution of Protozoa (organisms/m^3) in the Egyptian Mediterranean water during 2020

Abundance	I	II	III	Average
Winter	5000	8500	2000	5167
Spring	3500	5000	4500	4333
Summer	21000	16500	25500	21000
Autumn	22500	9000	14500	15333
Average	13000	9750	11625	

Table 4. Spatial diversity of Protozoa in the Egyptian Mediterranean water during the year 2020

Diversity	I	II	III	No. of Sp.
Winter	7	10	2	18
Spring	4	6	3	11
Summer	21	15	26	52
Autumn	17	11	14	39
No. of Sp.	43	39	39	

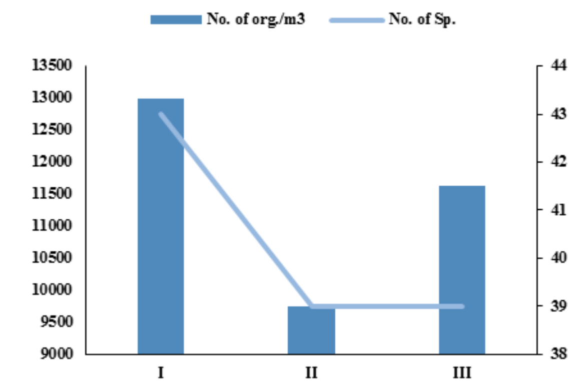


Fig. 2. Spatial distribution of collected protozoans

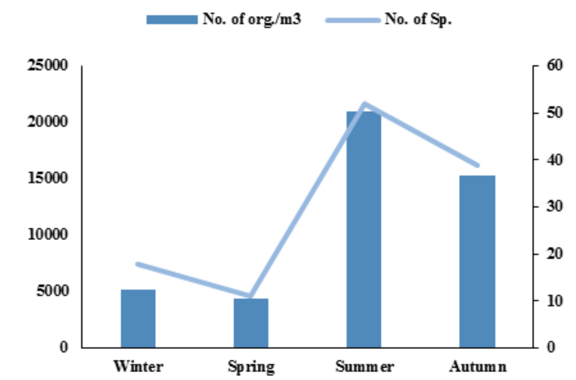


Fig. 3. Temporal variations in total species and individual numbers of collected protozoans

Table 5. List of the recorded protozoan species

Protozoa	*Globigerina depressa* d'Orbigny, 1903
Phylum: Amoebozoa	*Globorotalia truncatulinoides* d'Orbigny, 1839
Arcella Costata Ehrenberg, 1843	*Globotruncana fareedi* El-Naggar, 1966
Arcella discoides Ehrenberg, 1843	*Globotruncana fornicata* Plummer, 1931
Centropyxis aculeata Ehrenberg, 1832	*Globotruncana lapparenti* Brotzen, 1936
Centropyxis Spinosa Cash, 1905	*Lagena hexagona* Williamson, 1848
Phylum: Ciliophora	*Lamarckina scabra* Brady, 1884
Ascampbelliella tortulata Jorgensen, 1924	*Miliolina angulata* Silvestri, 1896
Ascampbelliella urceolata Ostenfeld, 1899	*Operculina ammonoides* Gronovius, 1781
Bursaopsis punctatostriata Daday, 1887	*Planispirina exigua* Brady, 1879
Coxliella annulata Daday, 1886	*Planorbulina acervalis* Brady, 1884
Coxliella bolivari Tafall, 1941	*Planorbulina Larvata* Parker & Jones, 1865
Coxliella laciniosa Brandt, 1907	*Planorbulina lobatula* Walker & Jacob, 1798
Coxliella longa Kofoid & Campbell, 1929	*Planorbulina mediterranensis* d'Orbigny, 1826
Cyttarocylis brandti Kofoid & Campbell, 1929	*Planorbulina rubra* d'Orbigny, 1826
Valid name: *Cyttarocylis* (*ampulla*) *f. brandti* Bachy et al., 2012	*Planorbulina wuellerstorfi* Schwager, 1866
Ephelota gemmipara Hertwig, 1875	*Quinqueloculina bicarinata* d'Orbigny, 1878
Ephelota gigantea Noble, 1929	*Quinqueloculina dubia* d'Orbigny, 1852
Epiplocylis blanda Kofoid & Campbell, 1939	*Quinqueloculina eborea* Schwager, 1866o
Epiplocylis constricta Kofoid & Campbell, 1929	*Quinqueloculina peregrina* d'Orbigny, 1846
Epiplocylis mucronata Zacharias, 1906	*Quinqueloculina rugosa* d'Orbigny, 1852
Epiplocylis undella Jörgensen, 1927	
Epistylis anastatica Linnaes, 1767	

Epistylis anastylis	*Quinqueloculina subcarinata* d'Orbigny, 1878
Epistylis sp	*Quinqueloculina vulgaris* d'Orbigny, 1878
Eutintinnus apertus Kofoid & Campbell, 1929	*Rosalina soldanii* d'Orbigny, 1826
Favella aciculifera Kofoid & Campbell, 1929	*Rotalia perlucida* Heron-Allen & Earland, 1913
Favella adriatica (Imhof, 1886) Jörgensen, 1924	*Rotalina semimarginata* d'Orbigny, 1850
Favella azorica (Cleve, 1900) Jörgensen, 1924	*Sphaeroidina dehiscens* Parker & Jones, 1865
Favella campanula (Schmidt, 1901) Jörgensen, 1924	*Spirillina decorata* Brady, 1884
Favella ehrenbergii Claparède & Lachmann, 1858	*Spirillina limbata papilosa* Brady, 1879
Favella ehrenbergii forma *Coxliella* laval-Peuto, 1981	*Spirillina tuberculata* Brady, 1878
Favella panamensis Kofoid & Campbell, 1929	*Spirillina vivipara* Ehrenberg, 1843
Favella serrata (Möbius, 1887) Jörgensen, 1924	*Spiroloculina acutimargo* Wiesner, 1916
Metacylis jorgensenii Kofoid & Campbell, 1929	*Spiroloculina depressa* d'Orbigny, 1826
Metacylis mereschkowskii Kofoid & Campbell, 1929	*Spiroloculina perforate* d'Orbigny, 1832
Tintinnopsis magna Merkle, 1909	*Spiroloculina tenuimargo* Cushman, 1917
Undella hyalina Daday, 1887	*Spiroloculina terquemiana* Fornasini, 1900
Undellopsis marsupialis Brandt, 1906	*Streblus compactus* Hofker, 1964
Zoothamnium Bory de St. Vincent, 1824	*Textularia acuta* Costa, 1856
Phylum: Foraminifera	*Textularia agglutinans* d'Orbigny, 1839
Ammodiscus intermedius Hoglund, 1947	*Textularia flintii*
Ammodiscus Tenuis Brady, 1881	*Textularia gracillima* Hoglund, 1947
Ammonia Convexidorsa Zheng, 1978	*Textularia semialata* Cuchman, 1913
Ammonia crebera Shchedrina, 1984	*Thalamophaga incerta* Rhumbler, 1911
Ammonia Moroensis Hofker, 1978	*Tournayella discoidea* Dain, 1953
Asterigerinata mamilla Williamson, 1858	*Tretomphalus bulloides* d'Orbigny, 1839
Candeina nitida d'Orbigny, 1839	*Triloculina circularis* Bornemann, 1855
Cornuspira carinata Costa, 1856	*Triloculina Schreiberiana* d'Orbigny, 1839
Cornuspira Involvens Reuss, 1850	*Truncatulina wuellerstorfi* Schwager, 1866
	Vertebralina insignis Brady, 1884

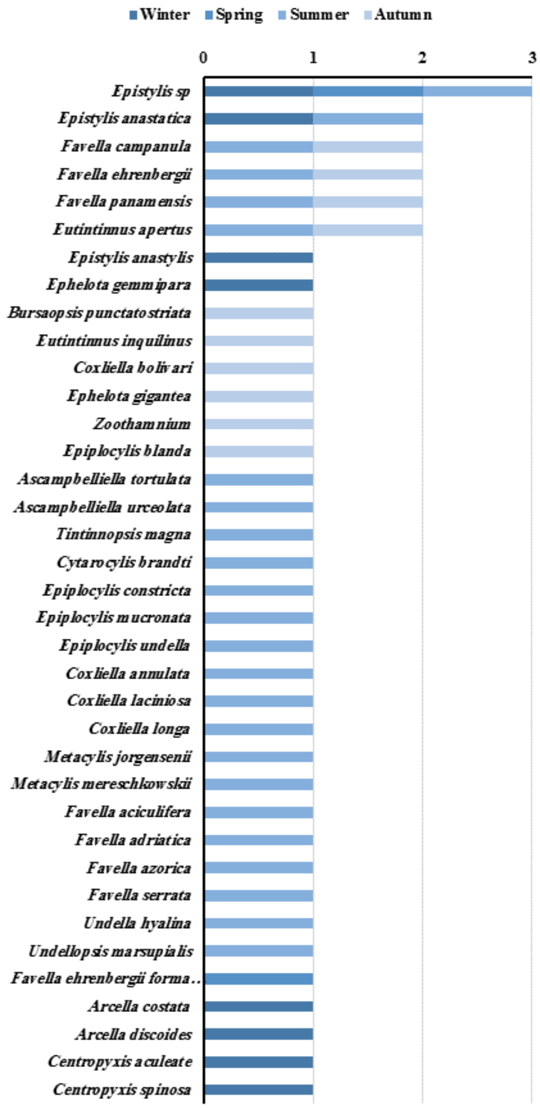
Favella ehrenbergi is represented the most dominant protozoan species, forming 4.36 %, followed by *Tretomphalus bulloides, Epistylis* sp. and *Textularia semialata* constituted 3.27 %, 3.27 % and 2.91 %, respectively, of total protozoan counts. While, *Favella panamensis, Planorbulina lobatula* and *Ammodiscus tenuis* represented 2.55 % for each (Table 6).

Table 6. The most dominant protozoan species (organisms/m3) and their percentages to total Protozoa

Species	Average (organisms/m^3)	% of total Protozoa
Favella ehrenbergii	500	4.36
Tretomphalus bulloides	375	3.27
Epistylis sp	375	3.27
Textularia semialata	333	2.91
Favella panamensis	292	2.55
Planorbulina lobatula	292	2.55
Ammodiscus tenuis	292	2.55
Planorbulina wuellerstorfi	250	2.18
Epiplocylis undella	250	2.18
Quinqueloculina vulgaris	250	2.18
Spiroloculina tenuimargo	250	2.18

Results of occurrence and distribution of protozoan species displayed in Figs. (4, 5) show that, three species occurred at three seasons (represents 75 %); namely, *Epistylis* sp., *Ammodiscus tenuis* and *Spiroloculina tenuimargo.* On the other hand, 17 species were recorded in two seasons with an occurrence 50 % during the study period; they were: *Epistylis anastatica, Favella campanula*, *F. ehrenbergii, F. panamensis, Eutintinnus apertus, Cornuspira carinata, C. involvens, Textularia semialata, Tretomphalus bulloides*, *Planorbulina lobatula*, *P. mediterranensis, P. acervalis, P. larvata*, *Spirillina tuberculata, S. vivipara, S. limbata papilosa* and *Quinqueloculina vulgaris*. In comparison, the remaining species (74) were recorded only in one season (representing 33 %).

Figs. (6, 7) represent the spatial distribution of Protozoa, the occurrence of protozoan species varied with station during the entire study period, where the highest percentage of occurrence (100 %) was recorded for three species in the three stations; *Epiplocylis undella*, *Textularia semialata* and *Ammodiscus tenuis*. While, twenty species occurred only in two stations, representing 67 % of the study period, they are; *Epistylis anastatica*, *Cytarocylis brandti*, *Favella azorica*, *F. panamensis*, *F. serrata*, *F. ehrenbergii*, *F. ehrenbergii forma Coxliella laval, Epistylis sp*, *Centropyxis aculeate, Planorbulina lobatula*, *P. acervalis*, *P. larvata*, *P. exigua, Tretomphalus bulloides, Spiroloculina tenuimargo, Cornuspira carinata, Quinqueloculina vulgaris, Rosalina soldanii, Streblus compactus* and *Cornuspira involvens*. The remaining 71 species showed the lowest percentage of occurrence (33 %), and they were presented only in one station during the study period.



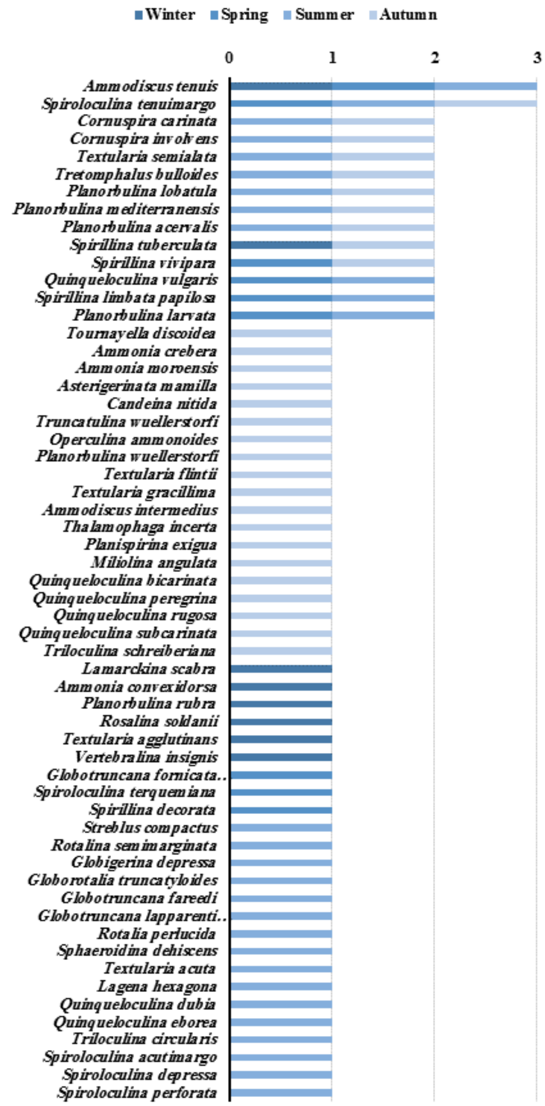


Fig. 4. Histogram showing the frequency of occurrence of protozoan species (Ciliophora and Amoebozoa).

Fig. 5. Histogram showing the frequency of occurrence of protozoan species (Foraminifera).

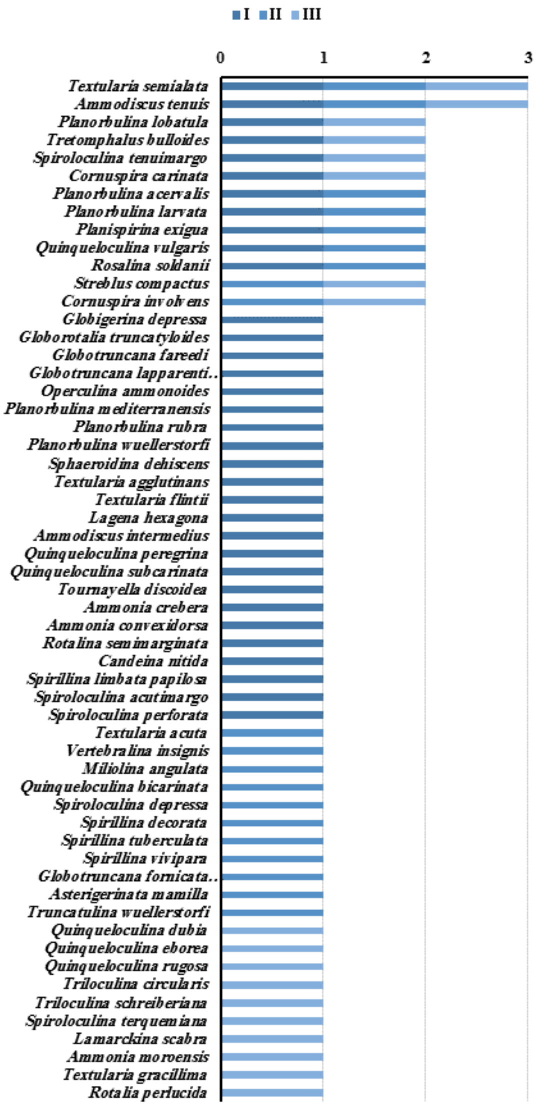


Fig. 6. Histogram showing the frequency of occurrence of protozoan species (Foraminefra).

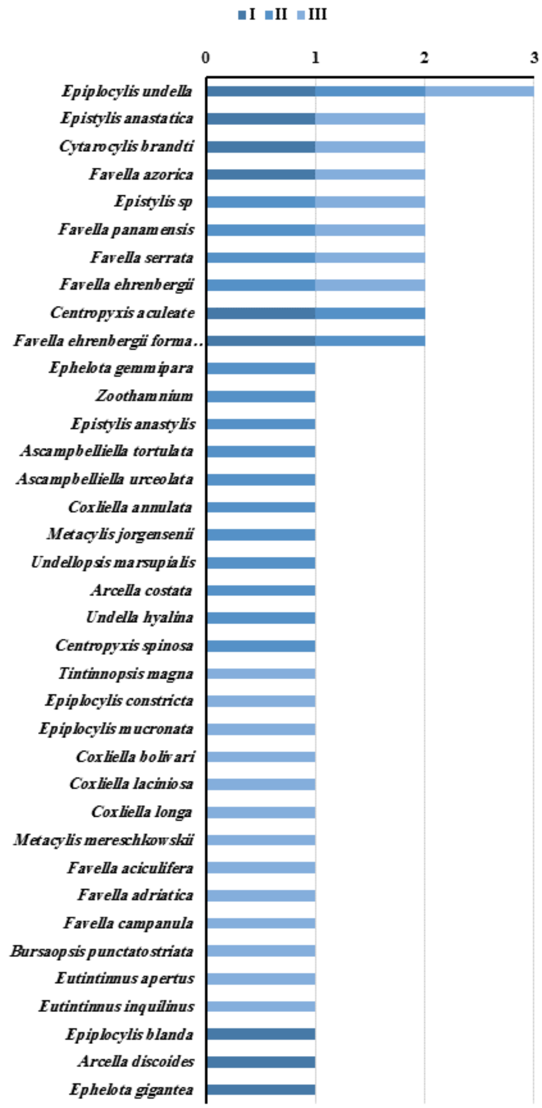


Fig. 7. Histogram showing the frequency of occurrence of protozoan species (Ciliophora and Amoebozoa).

DISCUSSION

In aquatic environments, ciliated protozoan assemblages are important components of the microplankton fauna and are considered primary mediators of energy transfer from pico- and nanoplankton production to higher trophic levels in the functioning microbial loop **(Dolan & Coats, 1990; Sime-Ngando *et al.*, 1995; Jiang *et al.*, 2013)**. Remarkably, there are several advantages for using ciliated Protozoa to assess water quality. As a result of their short life cycles and semipermeable external membranes, they may react more rapidly to environmental changes than many other eukaryotic organisms. Furthermore, many forms can inhabit environments unsuitable to metazoan organisms **(Cairns *et al*., 1972; Franco *et al.*, 1998; Corliss 2002; Madoni & Braghiroli, 2007; Jiang *et al*., 2007)**.

Ciliates feed mostly on bacteria and not on dissolved organic material; bacteria and flagellates compete for dissolved nutrients, while ciliates compete with other ciliates and rotifers; due to the controlled human activities, the environmental parameters showed quite aerobic conditions, moderate nutrient levels and efficient protozoan growth **(Galal, 2013)**.

Ciliated Protozoa are considered bioindicators. The absence of these organisms indicates the presence of toxic substances, such as phenols, cyanide, and heavy metals **(Chandarana & Amaresan, 2022)**. The presence of these organisms indicates oxygen deficiency, system overload and putrefaction. An increased number of several different bacteria, the presence of Cyanophyta, Zooflagellata and Ciliata, is an indication of water overloaded with organic matter, i.e., an indication of polysaprobic processes and oxygen deficiency **(El Raey & Abo-Taleb, 2019)**. Some protozoan species are indicators of pollution with sewage pathogens, such as the genera *Euplotes, Centropyxis* and *Difflugia*. All the studies' results indicate that zooplankton's potential as a bioindicator is very high. Other countries can develop these concepts to monitor water quality **(Ferdous & Muktadir, 2009)**.

Several environmental conditions appear to control the regional and seasonal distribution of protozoa, including the prevailing physicochemical conditions like temperature and salinity **(Palit *et al*., 2022)**. Many authors observed that the maximum protozoa abundance is associated with high salinity **(Verity, 1987)**. **Zakaria *et al.* (2007)** found the influence of salinity variations on the zooplankton community in El-Max Bay and stated that Protozoa was the second most important group after rotifers in the bay.

Protozoa is characterized by many specific structural and functional features; it presents an important ecological assemblage in aquatic ecosystems and plays a crucial role in the function of microbial food webs in addition to its role as indicator of water quality **(Xu *et al.*, 2008)**. In the investigated area, the optimum temperature for nourishing of Protozoa ranged between 19.2 & 33.90°C and the optimum salinity fluctuated from 30 - 45 ‰, which agree with the findings of **Hendy (2013)** and **Abo Taleb (2015)** who found that, temperature ranged between 16.22 & 31.2°C, and salinity ranged between 15.32 & 30.34 ‰; they added that these conditions were favorable for the growth and high abundance of rotifers. On the other hand, low temperatures (during winter) and salinity were unfavorable for developing Protozoa assemblages.

The Protozoa community in the waters of the Egyptian coast of the Mediterranean Sea is pronounced affected by the dispersion pattern of discharged waters. Higher values were particularly observed during summer (21000 organisms/m^3), while spring displayed lower densities (4333 organisms/m^3). Protozoa reached the maximum density at station III during summer (25500 organisms/m^3). **El- Sherif (2006)** stated that Protozoa was the highly diversified group in the western part of Alexandria; it was represented by 63 species (48.46% of the total number of the recorded zooplankton species), classified into 40 tintinnid species, 11 foraminifera and 12 species of freshwater ciliates. All tintinnid species are marine forms, while some Foraminifera species belong to freshwater forms, such as *Elphidium* sp., *Ammonia beccarri* and *Quinqluliculina* sp. The pronounced occurrence of these species and the freshwater ciliates could be considered indicators of the freshwater discharge to the area. El-Max Bay had the highest tintinnid densities during the study period, which was dominated by *Tintinnopsis beroidea*, which coincide with the result of **Nour El-Din (2001)**. Protozoa occupied the 2nd order of abundance among zooplankton groups in El-Max Bay, contributing 15.6 % of the total zooplankton counts (averaged 1440 organisms/m^3), predominated by ciliates **(Abo Taleb, 2015)**. **Galal (2016)** reported that, the average total ciliate densities were 4695, 2542 and 2220/L in western Alexandria, El-Hammam and Sedi A. Rahman, respectively, which means that ciliate numerical densities increased in the east-west direction of the Mediterranean Sea, which is more or less similar to the results of **Pitta *et al*. (2001)**.

Parallel to the data obtained by **Dorgham *et al*. (2013)**, human activities along a coastal region have caused drastic changes in the environment, expressed by a salinity decrease, frequent low and slightly moderate oxygenated conditions and elevated nutrient levels. These changes are reflected in the structure and abundance of the protozoan community in the studying area. According to **Yang *et al*. (2020)**, the quantitative dominance of oligotrich ciliates was found to be related to the oligotrophic status of the studying area. The differences in the community composition of tintinnid ciliates suggest that ciliated protozoan communities in the east and central Mediterranean are more diverse regarding the number of species and species evenness **(Li *et al*., 2023)**. Variations in the present data could be attributed mostly to the illegal sewage discharge at the adjacent Alexandria sampling station and/or due to the predation influence of certain animals such as crustaceans, insect larvae and rotifers **(Dolan *et al*., 1999; Pitta *et al*., 2001)**.

Many ships transport heavy industrials like metals, including iron products and others; these ships discharge the ballast water directly into the sea, including many invading organisms from different regions and origins. Ballast water is considered one of the primary transport vectors for the transfer to introduce non-indigenous zooplankton **(DiBacco *et al*., 2012)**. It may also be due to the prevailing northeastern current on the Egyptian Mediterranean coast that can bring the open water organisms into the shallow areas.

CONCLUSION AND RECOMMENDATIONS

Sea water quality was low based on the quality measurements detecting an excess in water nutrients. This bad condition enhanced the flourishing of protozoan species, consequently the densities and abundance of protozoans could be used as pollution bio-indicator. On the other hand, the following recommendations are necessary: 1- To control the discharge of drainage and sewage water into El- Umoum Drain, Mariout Lake and El-Max Bay, 2- and establish a management information system to store all previous information and data which would help in future development, management and restoration of the Alexandria coastal zone.

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