Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(2): 197 – 216 (2022)
www.ejabf.journals.ekb.eg

Short-Term Scale Observations on Zooplankton Community and Water Quality in the Eastern Harbor of Alexandria, Egypt

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ARTICLE INFO
Article History:
Received: Nov. 8, 2021
Accepted: Feb. 19, 2022
Online: March 21, 2022

Keywords:
Eastern harbor,
Physicochemical parameters,
Weekly distributions,
Zooplankton,
Community structure

ABSTRACT

Physicochemical parameters and zooplankton composition in addition to abundance were studied weekly for a year at a fixed station in the Eastern Harbor (EH), a semi-closed basin in Alexandria. The recorded values of physicochemical parameters included temperature (16.4-31.4 ^{o}C); salinity (32.3-35.9 ‰), dissolved oxygen (3.5-9.3 mg/l), and water pH (7.43–8.76). The following nutrient salts were determined: nitrate (0.3-32.1 µM), nitrite (0.35-7.34 µM), ammonium (0.95 -5 µM), silicate (7.01-56.3 µM) and total phosphorus (5.76 -73.9 µM). The annual average of zooplankton was 49405 ind. /m^3. The number of zooplankton species was 65 recorded in the eastern harbor, with the dominance of Protozoa (32 species), followed by Copepoda (17 species). Phosphorus concentration as an environmental variable showed a positive correlation with the Copepoda and Ostracoda and the dominant group. Cladocera performed a significant positive relationship with ammonia. Cluster analysis illustrated three zooplankton community alignments with each other. Interestingly, the information and observation of this research would be very useful in formulating policies and regulatory frameworks for sustainable management of the Eastern Harbor.

INTRODUCTION

Egypt's Mediterranean coastline is in the Mediterranean's south-eastern region. The eastern Mediterranean Sea is one of the world’s most oligotrophic aquatic areas **(Alprol *et al.*, 2021a)**. The Eastern Harbor (EH) is one of the most historically significant maritime areas in the world for it once contained thousands of ancient Egyptian antiquities **(Khairy *et al.*, 2014)**. The EH is a popular spot for fishing, yachting, boat building and entertainment. Pollution in marine habitats has proven to be one of the most bothersome issues, spreading throughout the marine natural life system **(Khairy & Gharib, 2017)**. For the ease of exchange, a huge majority of the projects on the planet are in the water bodies of countries, particularly in major commercial harbors, which adds to serious pollution **(Ghoneim *et al.*, 2014)**. The Eastern Harbor of Alexandria (Egypt) became a highly eutrophic basin due to the continuous discharge of untreated domestic, industrial and agricultural wastewater **(Khairy *et al.*, 2014)**. The Eastern Harbor contains an abnormally heavy plankton, high chlorophyll-a and a low diversity index **(Zaghloul 1996)**. The growth of the human population has been linked to the intensification of human activities, which has resulted in an increase in nutrient enrichment in the Eastern Harbor **(Dorgham *et al*., 2004)**. As a result, an increase was detected in eutrophication over the last three decades, either directly or indirectly. The problem of eutrophication in Alexandria's Eastern Harbor has been documented for more than 30 years. These issues arose as a result of the continuous addition of nutrients from various sources. The harbor's ecosystem went through several phases of profound changes in environmental and biological characteristics over the second half of the twentieth century. The first phase occurred prior to completion of the High Dam in 1964, when the Nile flood in late summer caused significant dilution of the harbor's water. The second phase occurred after the cessation of the Nile flood, with an increasing effect of the sewage pollution (96.5 x 103 m^3/ day), reaching the harbor indirectly (263 x 10^3 m^3/day) from KayetBey sewer **(Aboul-Kassim 1987)** and directly through eleven submersible outfalls **(Zaghloul & Halim, 1990)**. Due to these conditions, the harbor's water has become eutrophic, with high levels of plankton production practically year-round **(Ismael 1993)**. After 1993, all sewers of the harbor were closed, except those of KayetBay and EL-Selsela, due to the diversion of sewage discharge into Lake Mariout **(Awad 2004)**. In aquatic environments, zooplankton plays an important role in transferring the energy from primary producers to the higher levels in the food chain. Moreover, they represent preferred food items for numerous animals comprising economic fishes **(El-Naggar *et al*., 2019)**. In this respect, the investigation of zooplankton organisms in any marine environment is necessary regarding the information about the production and diversity in that specific environment **(El-Damhougy *et al.*, 2017)**.

Recently, numerous studies have been carried out on the physical, chemical and biological characteristics of the Eastern Harbor of Alexandria as documented by **Zaghloul *et al*., (2020)**, **Tadros *et al*. (2016)**, **Khairy *et al*. (2014)**, **Faragallah (2009a)** and **Madkour *et al*. (2007)**. **Awad *et al.* (2004)** postulated that, variable environmental conditions have a significant impact on changing the water quality of the harbor. **Mansour *et al*. (2020)** recorded 87 species and other immature forms belonging to 19 groups, with an average annual density of 4984.31 ind. /m^3 in the Eastern Harbor. They added that, copepods (39 species) followed by Foraminifera (12 species), tintinnides (10 species), rotifers (5 species), and other groups showed rare occurrence. On the contrary, **El-Gindy *et al*. (2007)** recorded 5 groups and 19 species of zooplankton and zooplankton community depending on the environmental factors in the Eastern harbor. Furthermore, the study of **Zakaria (2006)** was based on a quantitative estimation of zooplankton in the Eastern Harbor. Therefore, this study demonstrated the value of environmental monitoring, combined with statistical treatment to better understand a complex water system. In addition, the current work aimed to study the water quality of various physicochemical data of the Eastern Harbor after the sewage outlets were closed, at weekly intervals, in relation to analogous changes in some environmental factors, and assess the diversity, abundance, community composition and toxicity of the water.

MATERIALS AND METHODS

2.1. Study area

The Eastern Harbor is a shallow semi-circular and semi-closed bay, with an area of about 2.8 Km^2. It is located along the central part of Alexandria, with an average depth of 6.5 m and water volume of 16.44 ×106 m^3 at longitudes $29^{o}53^{\backslash}$- 29^{o} $54^{\backslash}$ E and latitudes $31^{o}12^{\backslash}$ - 31^{o} $13^{\backslash}$ N (Fig. 1). The harbor is isolated from the open sea by an artificial break water of concrete blocks, except two openings in the middle and the eastern side of the break water, which allow active water exchange between the harbor and the open sea.

Fig. 1. Location map of the Eastern Harbor of Alexandria and sampling site

2.2. Samples collection and processing

Weekly surface water samples were taken from the fixed presentative location in Alexandria Eastern Harbor from June 2011 to May 2012. During the study period, parallel studies on the physicochemical conditions were conducted in the Eastern Harbor.

Zooplankton collections were obtained from 00-11.00 AM and collected with a 55 mm mesh Nansen net (30 cm diameter) by vertical hauls at a speed of 0.5 m s^{-1} from near-bottom to the surface. The net collections were kept in a 2.5 % formaldehyde-seawater solution for preservation. The number of individuals per cubic meter was used to calculate abundances (ind. m^{-3}). The volume of all samples was concentrated to 100 mL, and the whole sample was examined in a Petri dish under a research binocular microscope. For zooplankton count, two aliquots (2 mL of well-shaken suspension) were removed from each example utilizing a graduated pipette, set in an including chamber, and the number of individuals of every species was enumerated. The average number of duplicated assessments for each example was assessed, and enumerations were communicated as the number of organisms per cubic meter. The organisms were identified and counted. The total number of zooplankton present in a cubic meter (m^3) of water sample was calculated according to the following equation no. (1):

$$N= n (v/V) - 1000 \qquad (1)$$

Where, N = total number of zooplankton per cubic meter of filtered water; n = average number of zooplankton in 1 mL of zooplankton sample, v = volume of zooplankton concentrates (ml), V = volume of total water filtered (L).

The Nansen bottle was used for the collection. The samples were instantly transferred to ascertain the chosen environmental parameters. A regular thermometer was used to test the temperature of the seawater (0-50). Beckman digital pH meter model 3560 was used to determine the pH of the water samples. The primary chemical characteristics of seawater were measured using five parameters. The conventional Winkler's method was modified by **Parsons and Strickland (1972)** to determine dissolved oxygen. Nutrient salts' samples were filtered immediately via Whatman GF/C filters and kept refrigerated until analysis. Ammonium samples were collected in the field and fixed without filtration **(Koroleff, 1969)**. Dissolved inorganic nitrogen compounds DIN (NH_4/N, NO_2/N and NO_3/N), reactive phosphate (PO_4/P) and reactive silicate (SiO_4) were determined according to **Grasshoff *et al*., (1999)** and **El-Feky *et al*., (2018)**.

RESULTS AND DISCUSSION

3.1. Hydrographic conditions

The EH and neighboring marine environment are under risk of discharged waste waters released from both drains and ballast water. These pollutants cause dysfunctions in the food web that might lead to a total ecosystem imbalance, especially because of the low water exchange rate with the open sea **(Heneash *et al*., 2015)**.

As seen in Fig. (2), the water pH ranged between a low value of 7.43 in July and a high value of 8.21 recorded in October 2012. The pH values of 2012 were within the normal pH range, which could reflect the redox potential and productivity level of the Eastern Harbor aquatic ecosystem. Additionally, these data differ slightly from those acquired in front of NIOF, where the pH fluctuated between 7.53 and 8.70 in 2004-2005 **(Faragallah *et al*., 2009b)**. Whereas, values ranged from 8.025- 8.415 during 2011-2012 **(Hermine *et al*., 2016)** due to the presence of ammonia, domestic sewage and agricultural run-off that are usually alkaline. Moreover, the pH increase could be caused by algae photosynthetic activity as well as the runoff from the watershed. In general, the key distinguishing feature of eutrophic and mesotrophic water bodies is the alkaline pH **(Seetha & Chandran, 2020)**.

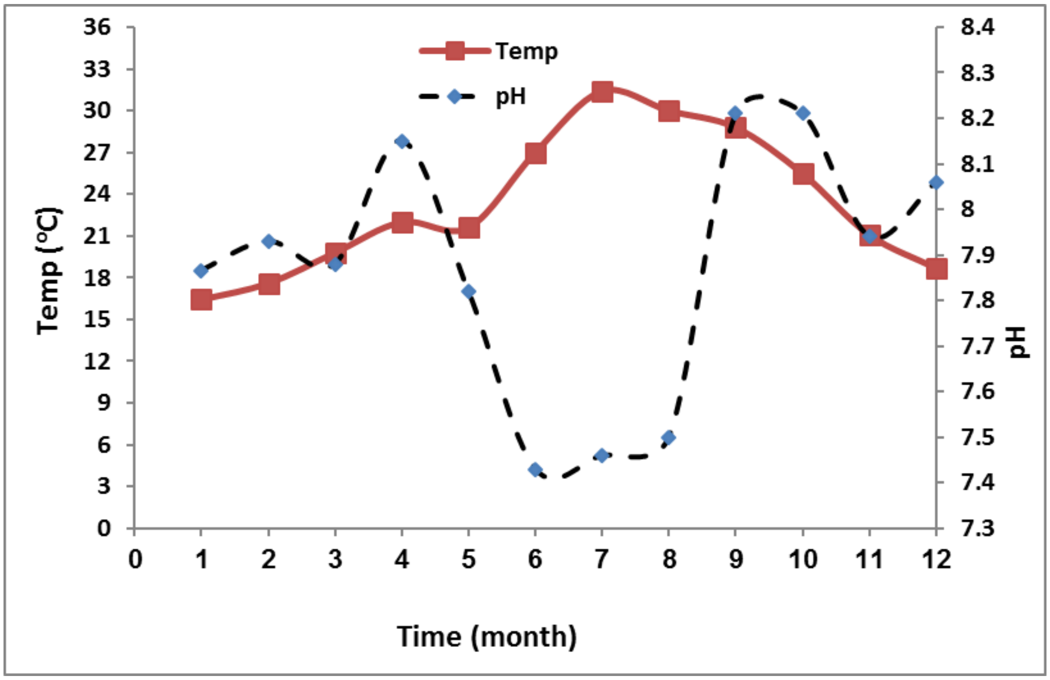


Fig. 2. Variations of Hydrogen ion concentration (pH) and temperature factors in water during the study (1: January, 2: February, 3: March, 4: April, 5: May, 6:June, 7: :July, 8: August, 9: September, 10: October, 11: November, 12:December).

Remarkably, temperature has an influence on the pH, alkalinity and DO concentration in water **(Alprol *et al*., 2021)**. Water temperature was at its minimum (16.42^{o}C) in January and its maximum (31.4^{o}C) in July as presented in Fig. (2). **Zaghloul *et al*. (2020)** reported that, the temperature of the water in the Eastern Harbor increased over time, recording 7.2°C during the years of 2004/2005 as reported in the study of **Abdel Halim and Khairy (2007**. While, it reached a degree of 14.4°C during 2009 **(Khairy *et al*., 2014)** and 15.6°C during the period of 2011/2012 **(Tadros *et al*., 2016)**. Changes in air temperature (climatic changes) and the shallowness of the Eastern Harbor water account for all these changes.

The average DO range was between 3.5 mg/l during June and 9.3 mg/l during March, with a total average of 6.26 mg/l (Fig. 3). Fig. (3) displays the strong relation between DO and pH. Dissolved oxygen is one of the most significant parameters for identifying distinct water masses and evaluating the degree of pollution, particularly with organic chemicals that cause oxygen reduction or depletion in fish and other marine organisms **(Alprol *et al*., 2021a)**. The dissolved oxygen concentrations in this study almost agree with those of **Khairy *et al*. (2014)**, who reported ranges between 3.5 and 10.1 ml/l. However, values differed from those collected from the front side of NIOF during the period of 2007-2008, with recorded DO values between 5.84 and 15.01mg/l and an annual average of 8.44mg/l as reported in the study of **Nessim *et al*. (2014)**. The effect of turbulence in Eastern Harbor seawater over the winter season is responsible for the high value in DO concentrations in March. Furthermore, the highest dissolved oxygen level in most times represent the change of organic load subjected to the study area **(El Zokm *et al*., 2008)**.

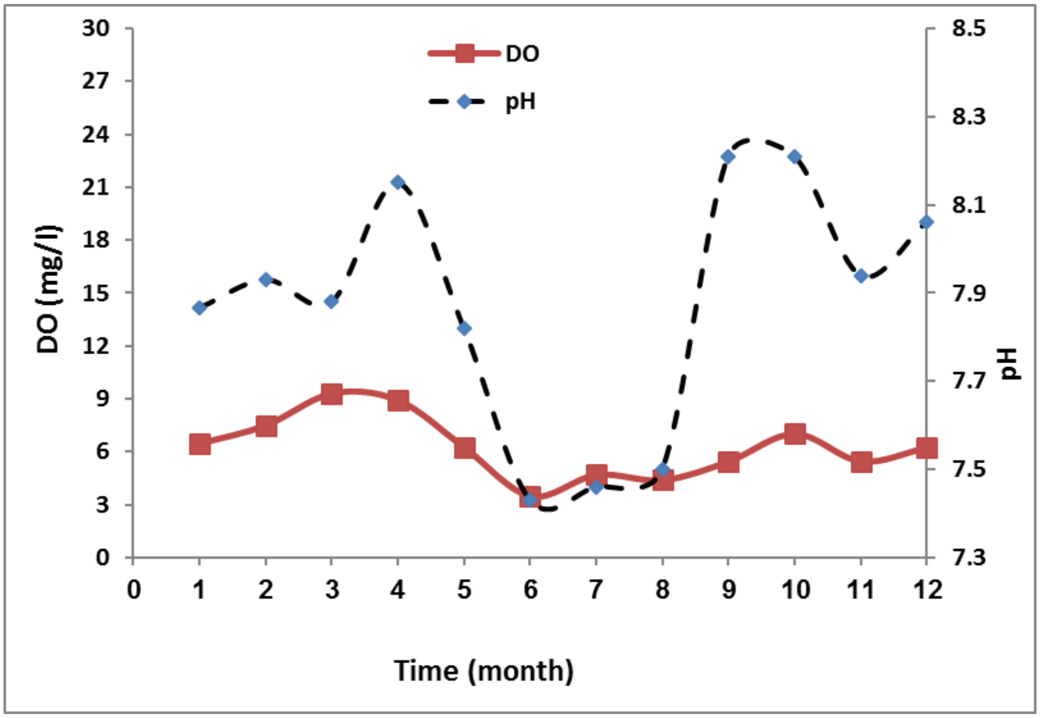


Fig. 3. Monthly variations of dissolved oxygen parameter in water during the study

The salinity fluctuated between 32.3 and 35.9 ‰, recording an average of 34.7 ‰ as shown in Fig. (4). This value is lower than the open water (39.4 ‰) diluted by sewage effluents and discharged into the coastal area by KayetBey pump station. Low salinity (32.55‰± 0.35) was recorded for a few weeks in February, whereas higher salinity (35.9 ±0.56) was reported in the second week of May. The amount of sewage water discharged into Eastern Harbor, as well as the rate at which the Harbor water exchanges with the surrounding open seawater through its two ports control the salinity of the harbor in El-Boughaz and El-Silsila **(Abdelsalam *et al*., 2015)**.

On the other hand, **Ahmad and Abdullah (1979)** noted that during the winter and summer seasons, coastal seawater enters the Harbor through El-Boughaz, resulting in extra amounts of filthy water from KayetBey's primary sewage outfall, reaching the Harbor and decreasing salinity during these seasons.

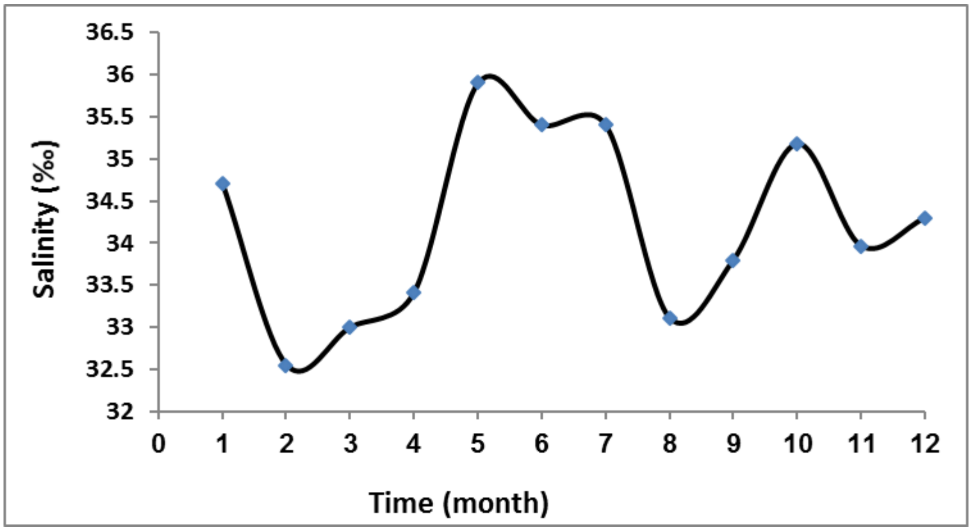


Fig. 4. Histogram showing monthly variation of salinity (‰) of seawater in the Eastern Harbor, Alexandria

Ammonia (NH_4) attained an annual average of 2.30 µM, varying from a minimum of 0.95 µM during September to a maximum of 5 µM during July. Most weeks of May, September and December sustained the lowest values, while other months showed markedly high concentrations (Fig. 5). Ammonium is a major nitrogenous product of bacterial decomposition of nitrogen-containing organic materials, and it is a significant excretory product of invertebrates and vertebrates. Its easiness of absorption and integration into amino acids made NH_4^+/N the preferred inorganic supply of nitrogen - containing materials (N-assimilation) **(Heneash & Alprol, 2020)**. **Khairy *et al*. (2014)** recorded 0.03-23.49 µM with total average of 3.57µM. In addition, **Abdelsalam *et al*. (2015)** reported that the average of NH_4^+ during summer 2012 was 4.31µM.

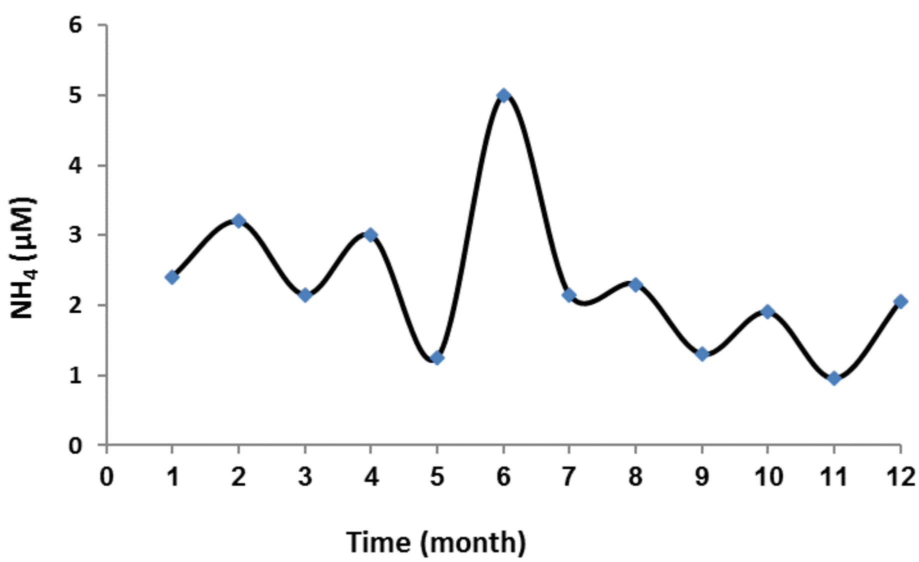


Fig. 5. Histogram displaying monthly variations of ammonia parameter in water during the study period

Nitrate (NO_3^-) had a varied weekly distributional pattern, fluctuating between 0.3 µM (29 April) and 32.1 µM (25 September), but it fluctuated dramatically over the year as shown in Fig. (6). In oxygenated seawater, the nitrate form is the most stable and abundant inorganic nitrogen compound. The average of 9.32 µM reported in the study of **Nessim *et al*. (2014)** indicates that the wastewater discharges in the Eastern Harbor seawater are greater than those recorded in the current study.

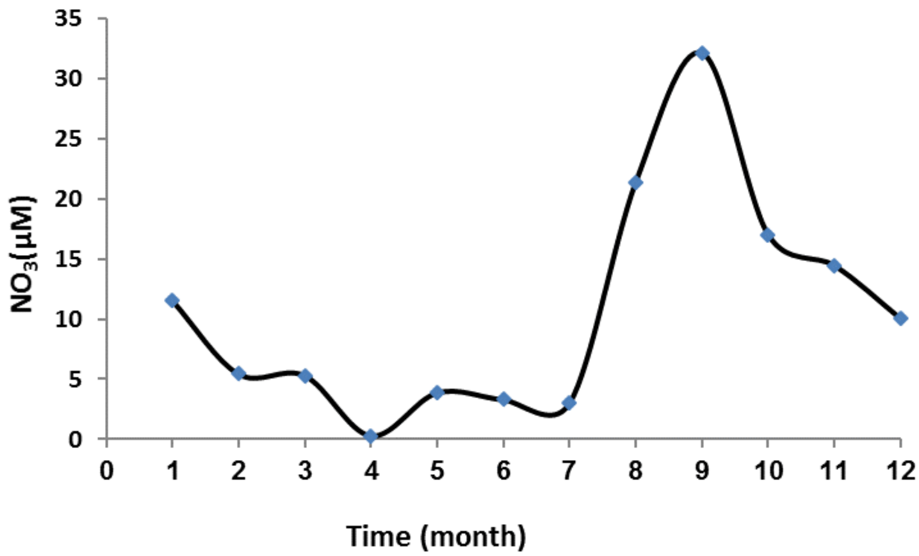


Fig. 6. Histogram showing variations of nitrate parameter in water during the study period

Nitrite (NO_2^-) concentration fluctuated between 0.35 µM (26 June) and 24 µM (4 December), with annual average 2.02 µM. The highest average concentrations were noticed during December 2012 (Fig. 7). This is mostly owing to the high rate of denitrification processes, which resulted in a high level of NH_4^+ concentration during the study period.

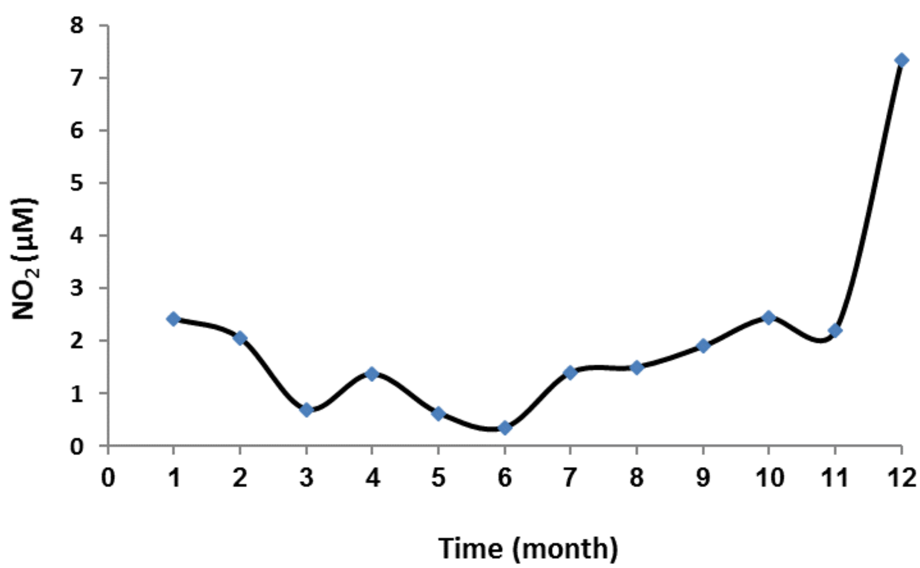


Fig. 7. Variations of nitrite parameter in water during the study period

Phosphate ranged between 5.76 µM (May) and 73.9 µM (August), recording an average of 10.65 µM (Fig. 8). Lower $PO_4^{3-/}P$ concentrations were observed during May, confirming the phosphorous preferentially uptake in photosynthetic process.

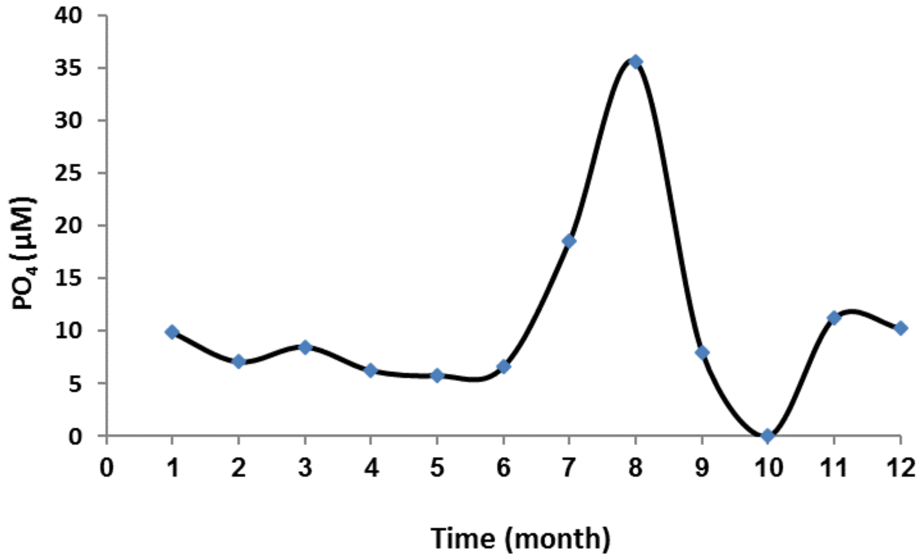


Fig. 8. Variations of phosphorus parameter in water during the study period

One of the major constituents of seawater is silicate. It is a good indicator of diatom potential and freshwater dispersal. The concentration of silicate ranged from 7.01 to 56.3 µM, with an annual average of 26.03 µM (Fig. 9). Moreover, the highest value for silicate was recorded in March, while the lowest value was reported on the 25th of October. Silicate in the Eastern Harbor indicates that the source of silicate is not all achthonous from drains, but rather autochthonous from the synthesis of biogenic silicate from diatoms, resulting in silicate content distribution preservation **(Verschuren *et al*., 1998)**.

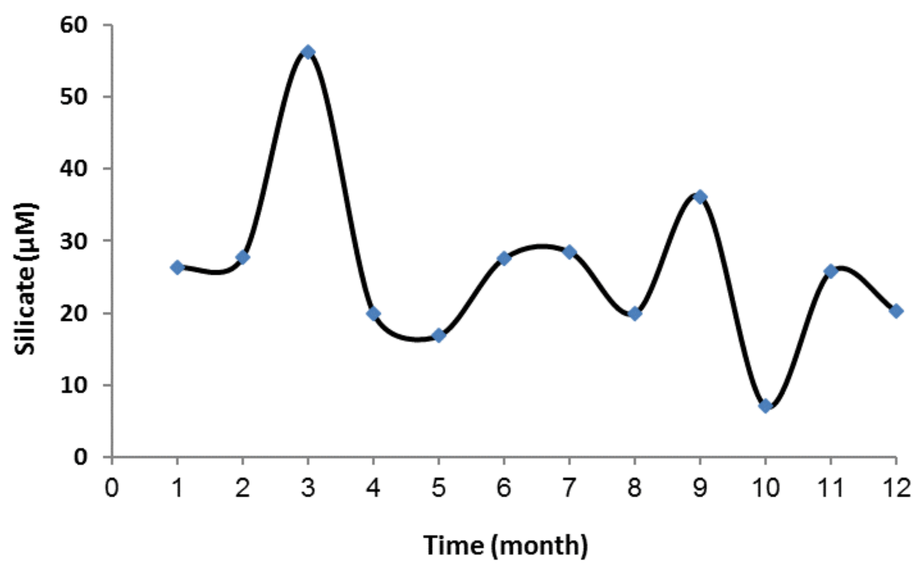
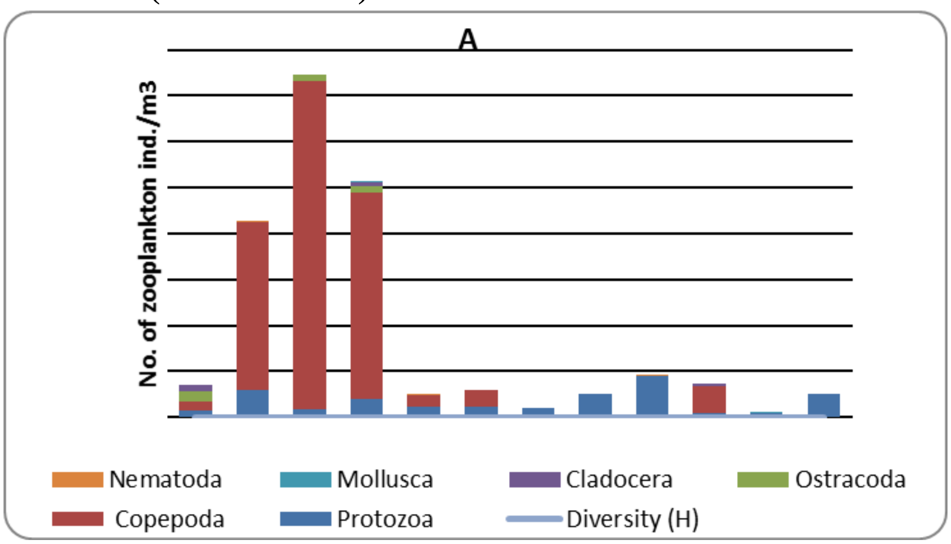


Fig. 9. Histogram exhibiting variations of silicate in water during the study period

3.2. Composition and population of zooplankton

In total, 65 zooplankton species were identified, including the larval stages of different groups. Most of them were protozoans (32 species: 3 species of non- tintinnid ciliates, 18 species of tintinnids and 11 species of Foraminifera). Copepods formed 17 species, rotifers 6 species and Annelida 2 species. This result coincides with those of **Aboul Ezz (1990)** and **El-Gindy *et al.* (2007)**. In addition, both the studies of **Dowidar *et al*. (1983)** and **Mansour *et al.* (2020)** showed that the dominant groups were those of copepod and rotifer (6 species and metamorphosis of rotifer). In terms of the number of species, Tintinnids were dominated by Tintinnopsis (8 species) and Favella (3 species), while Copepoda was dominated by *Acartia* (3 species). Other zooplankton groups like Rotifera, Cladocera, Decapoda, Mollusca, Annelida and Cnidaria were represented by a few species. Moreover, zooplankton larvae were represented by the following Ostracoda, Cirripedia and Nematoda. The zooplankton density demonstrated marked weekly fluctuations from 3825 to 306000 ind./m^3 (Fig. 10). It attained an annual average of 49405 ind./m^3. In addition, two exceptionally high counts were recorded on the 12th of October (207650 ind./m^3) and the 25th of October (306000 ind./m^3).



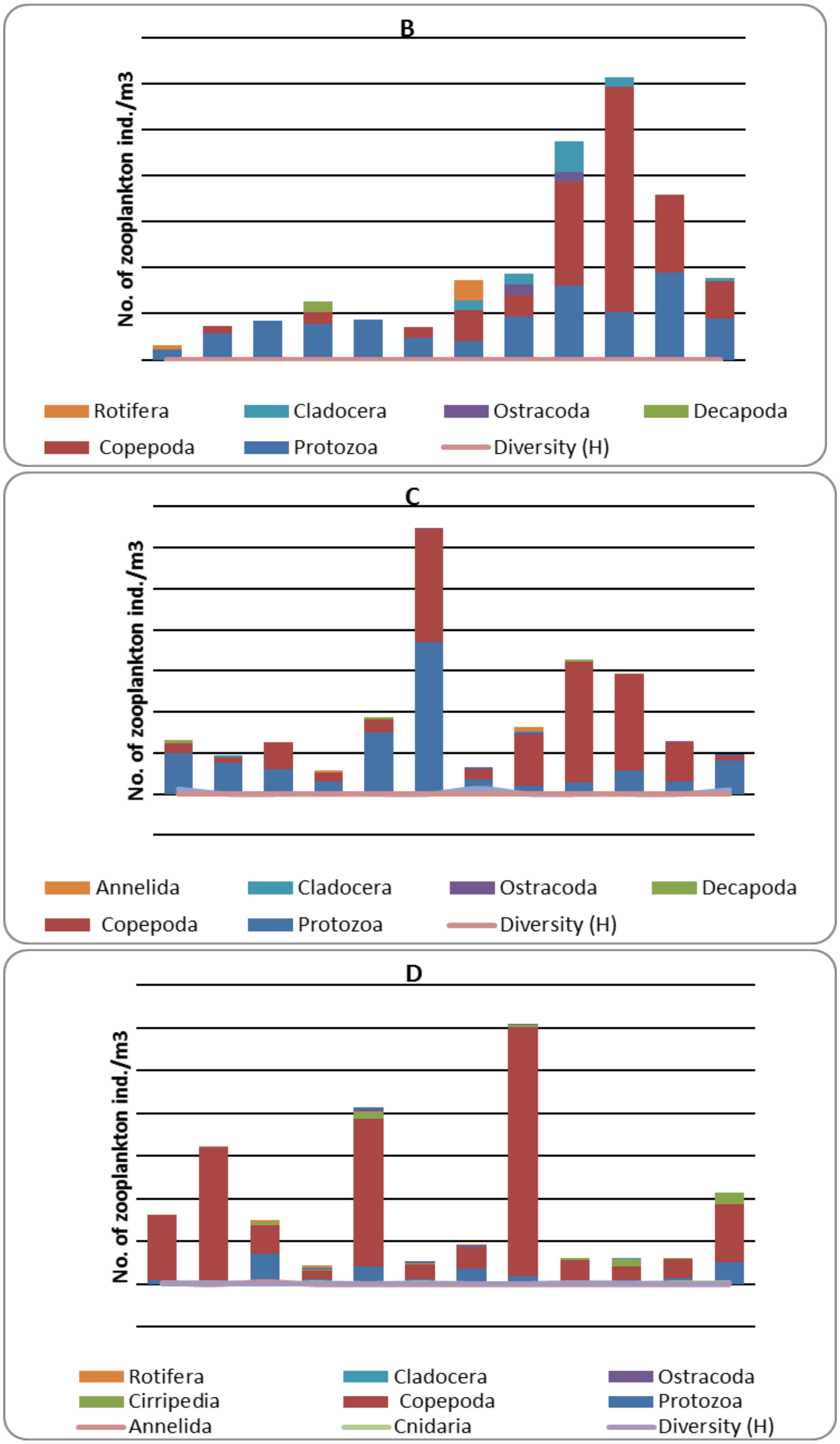


Fig. 10. Seasonal variations of zooplankton in eastern harbor at different season (A) Winter, (B) Spring, (C) Summer and (D) Autumn.

3.4. Weekly occurrence of zooplankton community

In this study, the highest count of zooplankton species seems of the harbor, the highest appearing (38 species in third week from September). **Mansour *et al*. (2020)** recorded 49 sp. in autumn and lowest appearing (6 species in both first week from March and third week from February at late winter season) throughout the year, however, **Zakaria (2006)** was the highest season in spring season, while **Mansour *et al*. (2020)** recorded the lowest seasons was recorded in spring. None of the recorded species was found to be persistent all the year round, but a few species extended their existence for 24-43 weeks, namely *Centropyxise cornis, Epiplocylis blanda, Epiplocylis blanda, Favella helgolandica, Schmidingerella serrata, Oxytricha fallax, Oithona nana, Acartia clausi* and *Euterpina acutifrons.* The dominant species in Eastern Harbor was represented by 15 species, the species mentioned in the previous paragraph in addition to *Coxliella ampla, Protorhabdonella simplex, Rhabdonella spiralis, Acartia latisetosa, Oncaea venusta* and *Oithona plumifera.* Moreover, Nauplius larva under copepod group was dominant in all year round. In Table (2), the number of species was divided into four divisions, the first one was called low occurrence, under which 10 species appeared in weeks ($w_{7,}$ w_{11} January, w_{13} March in winter season), second division was called middle occurrence comprised 10- 20 species, appearing in winter and spring seasons, third division was named good occurrence, representing 21- 30 species and appearing in summer, and the fourth division was called very good occurrence, containing 31- 38 species and appearing in months of autumn season. Rotifer occurrence was in this period and reprehensive by 6 species. **Mansour *et al*. (2020)** recorded 4 species from Rotifera, and assumed that the E.H. is semi-closed basin and receives daily about 15,000 m^3 of domestic sewage.

3.5. Comparative between number and occurrence zooplankton species from 1976 to 2020

The data in Table (1) showed that the total species of zooplankton in five studies in the period from 1976 to 2020. The highest number of species was recorded in the study of **Mansour *et al*. (2020)**. In the period from 2017 -2018, 87 species were registered. While, **Zakaria (2006)** monitored 85 species. In comparison, the current study recorded 65 species, while the lowest was recorded in the study of **Dowidar *et al*. (1983)** in the period from 1967-1977, but in the period from 1999-2003, 19 species were identified **(El-Gindy *et al*., 2007)**. The present study mediates studies that recorded 86 species.

3.6. Biostatistics for weekly Zooplankton population

The data in the Table (2), reported that the diversity indices were widely ranged among investigated weeks all year around. Whereas, the species richness was at its highest value (3.284) in week 39 during September in third week of month in autumn season, followed by 2.94 week 4 from December during winter. On the other hand, it was at its lowest value (0.606) in week 13 during March, followed by (0.642) in week 11 during February. Concerning the evenness values, the highest value (0.989) occurred in week 13 during March and (0.980) in week 36 during August, while the lowest (0.477) occurred in w44 during

October. On other hand, for the Shannon index, the highest value (3.265) was recorded in week 36 during August and (3.225) in week 40 during September, while the lowest value (1.622) was in week 44 during October, (1.760, 1.771) week 11 during February and week 13 during March, respectively. These data are similar to the diversity indices of **Mansour *et al.* (2020)**.

Table 1. Number of species and larvae or occurrences recorded in Eastern Harbor from 1967 to 2018

Group	**Dowidar *et al*. (1983)**	**AboulEzz, (1990)**	**El-Gindy *et al.* (2007)**	**Zakaria (2006)**	**Mansour *et al.* (2020)**	**The current study**
	1967-1977	**1986 - 1987**	**1999-2003**	**2006**	**2017-2018**	
Total species			19	85	87	65
Protozoa	+	+	+	53	24	33
Copepoda	+	+	+	13	39	17
Decapoda	-	+	-	-	1	2
Ostracoda	-	+	-	1	3	1
Cladocera	-	+	-	3	3	1
Cirripede Larvae	+	+	+	1	1	1
Mollusca	+	+	-	1	1	3
Nematode larvae	-	+	-	1	1	1
Fish larvae	-	-	-	1	1	1
Annelida	+	+	+	1	3	4
Rotifera	+	+	+	7	5	6
Cnidaria	-	+	-	1	2	3
Echinodermata	-	+	-	1	1	1
Medusa	-	+	-	-	-	1
Amphipod larvae	-	+	-	1	1	1

(+) found species (-) no found species

Table 2. Biostatics for weekly zooplankton at Eastern Harbor in 2012-2013

Time	Weak	No. Sp.	No. indi./ m^3	Richness(d)	Evenness (j)	Diversity(H)
Dec. 1	w1	11	14800	1.041	0.858	2.057
Dec. 2	w2	28	89400	2.368	0.755	2.517
Dec. 3	w3	24	146200	1.934	0.697	2.214
Dec. 4	w4	35	105200	2.940	0.724	2.575
January1	w5	16	12690	1.588	0.896	2.483
January2	w6	14	15600	1.346	0.879	2.320
January3	w7	7	4200	0.719	0.974	1.895
January4	w8	11	10050	1.085	0.960	2.302
Feb. 1	w9	14	18800	1.321	0.968	2.556
Feb. 2	w10	13	17220	1.230	0.854	2.191
Feb. 3	w11	6	2400	0.642	0.982	1.760
Feb. 4	w12	14	10000	1.411	0.941	2.484
March1	w13	6	3825	0.606	0.989	1.771
March2	w14	12	7280	1.237	0.974	2.421
March3	w15	10	8400	0.996	0.952	2.192
March4	w16	26	12700	2.646	0.974	3.173
April1	w17	15	11100	1.503	0.944	2.557
April2	w18	11	7100	1.128	0.961	2.305
April3	w19	24	24200	2.279	0.892	2.836
April4	w20	18	18800	1.727	0.905	2.615
May1	w21	22	47400	1.951	0.866	2.676
May2	w22	29	61400	2.540	0.907	3.053
May3	w23	25	43500	2.247	0.947	3.047
May4	w24	19	20600	1.812	0.934	2.751
June1	w25	25	44000	2.245	0.941	3.031
June2	w26	18	19700	1.719	0.914	2.642
June3	w27	27	31400	2.511	0.978	3.225
June4	w28	18	13900	1.782	0.962	2.782
Julay1	w29	25	58500	2.186	0.883	2.843
Julay2	w30	30	129750	2.463	0.921	3.134
Julay3	w31	18	18200	1.733	0.951	2.750
Julay4	w32	27	33550	2.495	0.875	2.884
August1	w33	16	65600	1.352	0.797	2.211
August2	w34	22	59800	1.909	0.794	2.454
August3	w35	16	30000	1.455	0.875	2.425
August 4	w36	28	26200	2.654	0.980	3.265
sep.1	w37	30	85360	2.554	0.687	2.337

sep.2	w38	31	163650	2.499	0.683	2.346
sep.3	w39	38	78000	3.285	0.834	3.035
sep.4	w40	27	24000	2.578	0.978	3.225
Oct.1	w41	34	207650	2.695	0.862	3.039
Oct.2	w42	22	28050	2.050	0.948	2.931
Oct.3	w43	31	47000	2.789	0.934	3.208
Oct.4	w44	30	306000	2.296	0.477	1.622
nov.1	w45	23	34750	2.104	0.944	2.960
nov.2	w46	20	32000	1.832	0.895	2.681
nov.3	w47	21	34350	1.915	0.955	2.907
nov.4	w48	24	108400	1.984	0.943	2.997

3.7. Similarity between weeks

The dendrogram showed similarity among the 48 weeks in 12 months. The data indicated the presence of many clusters as presented in Fig. (11). The highest similarity in this period was between the fourth week of January and the first week of February, while the lowest similarity was detected between the third week of February and the first week of March; this similarity is described as weeks.

Table 3. Comparison of historical changes of the annual average concentrations of physicochemical parameters in the Eastern Harbor during the latest decades.

Sampling Time (average)	pH	DO (mg L^{-1})	NH_4 (µM)	NO_3 (µM)	NO_2 (µM)	PO_4 (µM)	Si (µM)	Ref.
1979	----	----		12.35	----	0.82	----	**(El-Nady, 1981)**
1985-86	----	----	3.76	7.12	----	0.56	----	**(Aboul-Kassim, 1987)**
1989	----	----	1.5	4.12	----	1.08	11.2	**(Ibrahim, 1999)**
1999-2000	----	----	3.2	2.71	----	0.66	4.3	**(Tawfik, 2001)**
2002-2003	----	----	5.33	10.48	----	0.6	3.36	**(Madkour *et al.*, 2007)**
2004-2005	7.53 - 8.70	----	----	----	0.37	1.03	3.45	**(Faragallah *et al.*, 2009b)**
2007-2008	7.95 - 8.38	5.84- 15.01 (8.44)	9.23	12.96	0.67	0.58	5.18	**(Nessim *et al.*, 2014)**
Summer 2012		5. 3	4.31	3.15	1.33	6.95	45.58	**(Abdelsalam, 2015)**

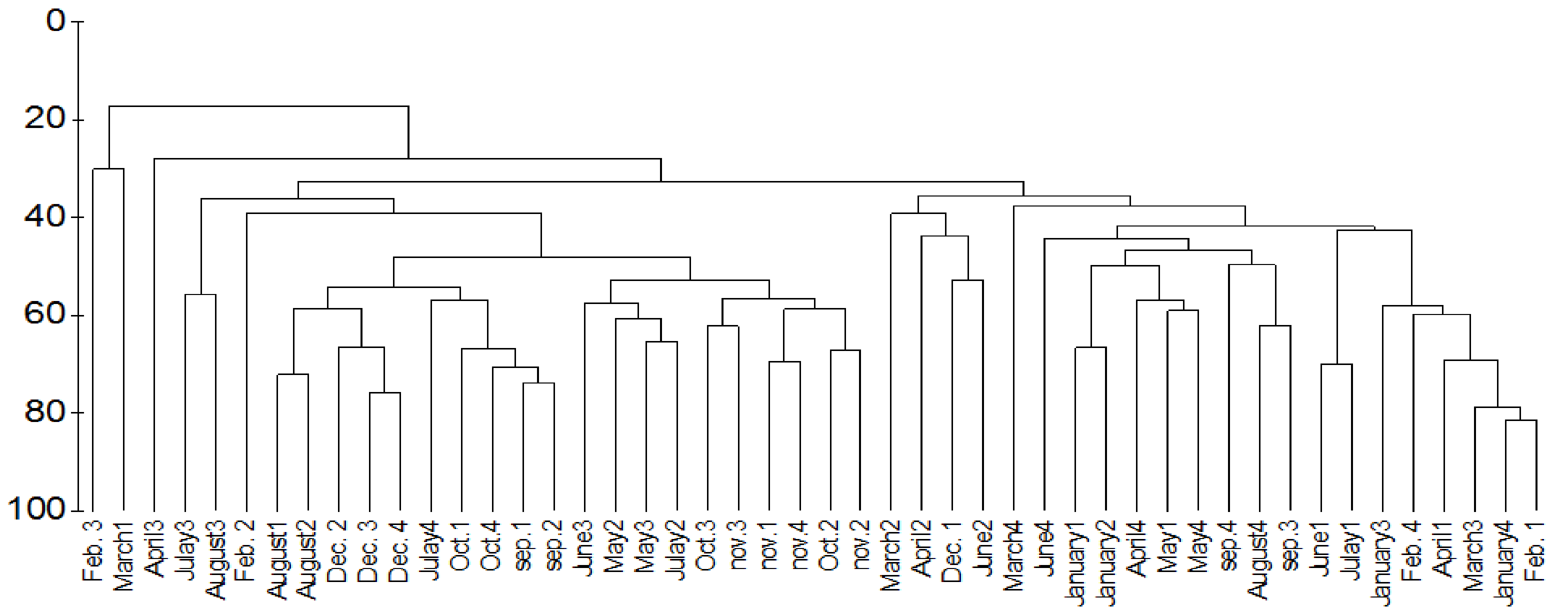


Fig. 11. Dendrogram representing the similarity among Eastern Harbor surveyed weeks during 2012

3.8. Correlation analysis

The statistical relationships were performed between different environmental variables and zooplankton abundance as shown in Table (4). It was noticed that, phosphorus concentration as environmental variable has positive correlation with the Copepoda and Ostracoda (r=0.45 and r=0.43, respectively) i.e., Copepoda and Ostracoda prefer phosphorus- rich environment to survive.

The dominant group Cladocera performed significant positive relationship with ammonia (r = 0.682) since cladocerans, which are deep red in color are often indicators of low dissolved oxygen conditions, accomplished with NH_3 increase. Furthermore, positive correlations were observed between mollusca and pH (r=0.521). While Cirripedia and medusa performed significant positive relationship with NO_2 (r=0.664 and 0.672) **(McCauley & Kaff (1981; Heneash *et al*., 2015)**. On the other hand, Ostracoda has negative correlation with NO_2 (r=-0.578) and pH (r=-0.663) as showed in Table (4). This data revealed that Cladocera is able to survive in low oxygen environment. Additionally, Mollusca prefer alkaline environment, while Ostracoda prefer acidic environment to survive. Notably, nitrite rich environment enforces the presence of Cirripedia and medusa rather than Ostracoda.

Protozoa, copepod, Nematoda, Decapoda, Annelida and cnidaria did not show any clear relationship with environmental variables. Salinity has not been proven as an influencing parameter for zooplankton population and their dominant groups that water quality in the harbor is in recovery state.

CONCLUSION

Interestingly, the data and insights obtained during this study would aid in initiating developing policies and regulatory frameworks for the long-term management of Eastern Harbor. Physical and chemical parameters, such as pH, temperature, salinity, dissolved oxygen, nitrate, nitrite, ammonium, silicate, and total phosphorus were investigated. The results showed that the lowest pH, DO, and NO_2 concentrations were observed in June 2012, while the greatest SiO_4^{2-} and DO concentrations were found in March. Likewise, the maximum salinity and pH measurements were obtained in October. On the other hand, quantitative and qualitative investigations of the zooplankton community in Eastern Harbor were performed. The maximum count (average $87.1x10^3$ ind/m^3) of zooplankton standing stock in Eastern Harbor was reported in spring, while the lowest (average $44.2x10^3$ ind/m^3) was recorded in summer. During the study period, the average zooplankton count was 60.5 $x10^3$ ind/m^3. Protozoa, Copepoda, and meroplanktonic Mollusca dominated the zooplankton assemblages in Eastern Harbor, accounting for 51.19 %, 27.90 %, and 12.10 % of the total zooplankton count, respectively. Also, the current study revealed significant changes in both the water fertility and the dynamics of the zooplankton community in the Eastern Harbor as compared to previous records. The statistical relationships revealed the correlation between environmental variables and zooplankton abundance. Ostracoda has positive correlation with phosphorus concentration while has negative correlation with NO_2 and pH. On the other hand, a positive correlation was observed between Mollusca and pH. Correlation analysis revealed that Cladocera can survive in low oxygen environment, indicated by positive correlation with ammonia. It can be concluded that the primary source of nutrients released to the Eastern Harbor is municipal wastewater and surface runoff from the surrounding area. Urgent measures are needed to reduce the amount of municipal wastewater entering Eastern Harbor to prevent further degradation of the ecosystem.

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