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Full Length Article

Spatio-temporal evaluation of the surface water quality in the middle Nile Delta using Palmer's algal pollution index

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ABSTRACT

This work aims to evaluate the spatio-temporal change in the surface water pollution in the middle Nile Delta using algal pollution index (Palmer Index). Water was sampled during winter and summer seasons from 18 stations distributed along the water pathways from south to north for two main irrigation canals (Qudaba and Mit-yazed canals) and two drains (El-Gharbia main drain and Janag drain). An algal analysis was carried out based on the species and genera that mentioned in Palmer Index (PI). High Palmer Index scores were noticed in most of the stations especially during summer, which might be related to various pollution supplies. Limited number of stations showed low palmer index scores indicating relatively clean water. In winter, the two irrigation canals showed similar spatial distribution patterns where PI values increased reaching its maximum at the middle of water pathways and then decreased. In summer, PI had no definite trend in Qudaba canal and decreasing trend in Mit-yazed canals along the water pathway to the northern direction. PI of El-Gharbia main drain showed increasing and decreasing trends in winter and summer, respectively. Janag drain had opposite patterns compared to that of El-Gharbia main.

One of the major differences between irrigation canals and drainage water was the algal community structure where the drainage water was characterized by the abundance of Euglenophyta and *Chlamydomonas* spp. and rare occurrences of Bacillariophyta except the last station of El-Gharbia main drain, which was of estuary nature.

1. Introduction

River Nile is the main water resource for Egypt. It supports the country with water needs for food, urban, industrial and environmental uses [1]. The main body of the River bifurcates near Cairo into Damietta and Rosetta branches. A network of Irrigation canals and drains covers all Delta regions (Fig. 1A). The irrigation canals network helps to deliver the water to most of the cultivated lands and urban areas, while the drains help to discharge the waste water.

River Nile provides Egypt with about 55.5 Billion cubic meters of fresh water every year [2]; however there is an increased shortage of water. So, suitable management of water resources should be considered, including the control of water loss and the amount of pollutants that deteriorate the water quality in the river and the irrigation canal network due to the irresponsible discharging of variety of wastes in the water pathways.

Organic pollution in the river Nile considers an essential active field of research [3,4]. It became a significant environmental problem. Almost all freshwater bodies are widely affected by the human population explosion and urbanization. Water pathways are polluted by organic material such as sewage, food waste and farm effluent [5,6]. So, detecting the organic pollution and trying to manage this environmental crisis are considered important tasks to do.

Algae are considered an important component of any aquatic ecosystem and are responsible for the primary productivity of those systems [7]. Due to their relatively short life spans, their community composition alters quickly in a response to the changes of the water physico-chemical parameters [8]. That is why algal communities are used as indicators of aquatic pollution [9].

The first attempt to identify and prepare a list of the most tolerant algal species and genera to pollution had been done by palmer [10]. Palmer index is considered a rapid, reliable and relatively inexpensive way to record water pollution probability across number of sites [11]. It is used beside other indices for inorganic pollution and eutrophication level [9]. Palmer index has been used before in Egypt by El-Kassas and Gharib [12]. In the present

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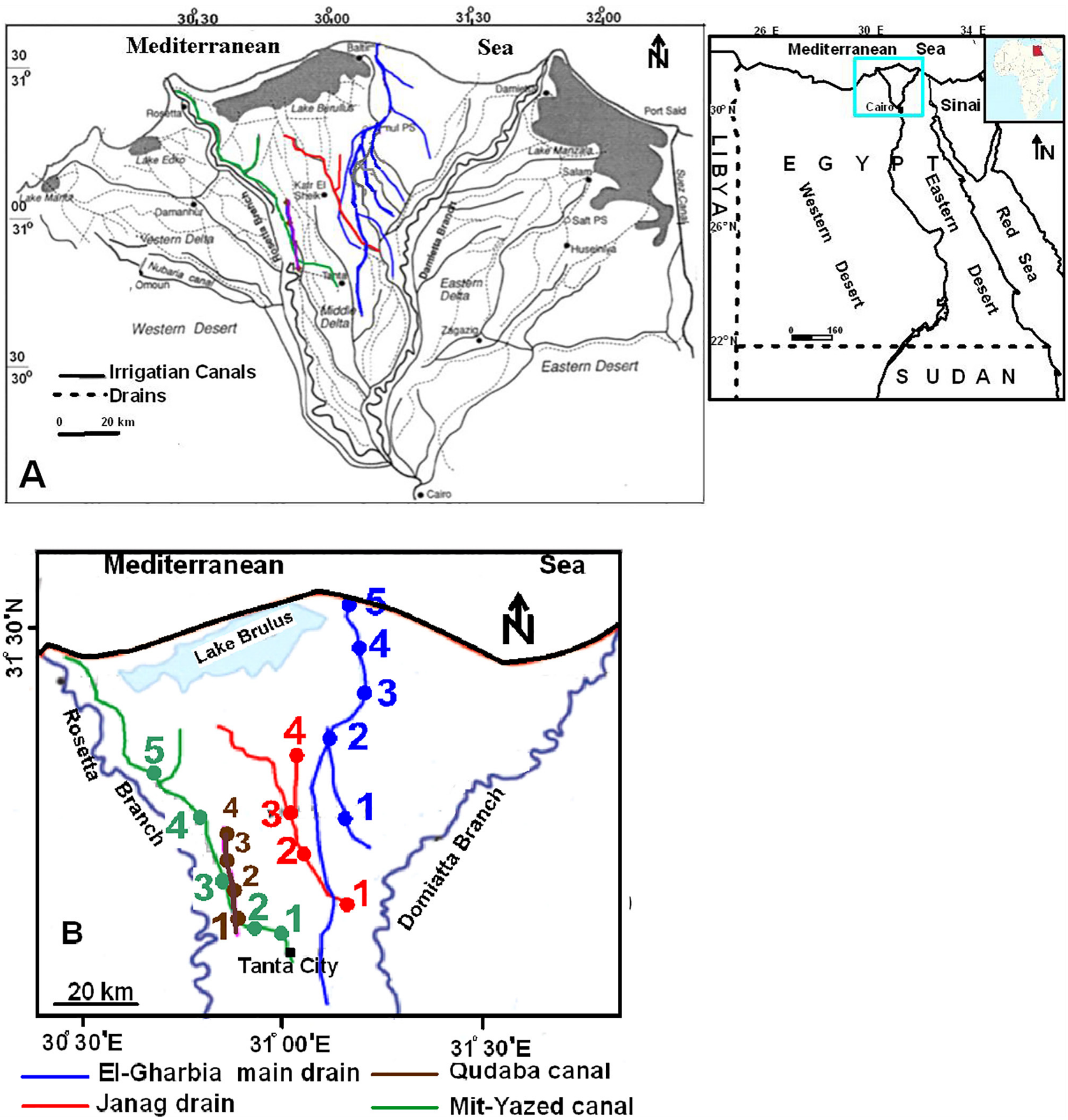

Fig. 1. Maps of the Nile Delta show the distribution of irrigation canals and drains (A) and sampling stations (B).

study Palmer index (PI) was used to obtain information about the water pollution probability along the path of two main irrigation canals and two main drains in the Middle part of the Nile delta.

2. Material and methods

Water was sampled from 18 sites (Fig. 1B) twice from every location in 2015, once in winter and the other in summer. Sampling sites were distributed along the path ways from south to north of two main irrigation canals (Mit-Yazed, 4 sites and Qudaba canal, 5 sites) and two main drains (El-Gharbia main drain, 5 sites and Janag drain, 4 sites). Mit-yazed canal is recharged from Shubin rivulet at 30°52′ N and 31°08′ E. Qudaba canal receives water from Rosetta branch near El-Qanater El-khiria at 30°11′ N and 31°07′ E and goes parallel to the Rosetta branch until discharging in it at Rosetta city. El-Gharbia main drain starts in the middle part of the Nile Delta and collecting the agricultural, domestic and industrial waste water by number of smaller drains along its path and discharges in the Mediterranean Sea near Burullus Lake. Janag drain is a relatively short drain located in the middle Nile Delta region to the west and starts at Kafr El-Ziat City (Industrial city) and runs to the northern direction (Fig. 1B). Fig. 2 includes some photos showing the water bodies in some of the sampling stations.

2.1. Sampling and microalgae analysis

Samples were collected in clean opaque one liter-sized plastic bottles. About 7–10 ml of Lugol's solution (iodine in potassium

Fig. 2. Photographs of some sampling stations, (A) is The second station of Mit-yazed canal; (B) is the first station of Janag drain; (C) is the last station of Janag drain; (D) is the third station of El-Gharbia main drain.

iodide) was added to each sample at field for sample preservation. Preparation of samples for counting and identification of phytoplankton was started immediately after returning to the laboratory. The algal cells were let to sediment in a cylinder for 2 days. Most of the supernatant was carefully siphoned using a siphon droplet system (0.1 mm in diameter) with a tight piece of phytoplankton net (with meshes <10 mm) at its end. The sediment algal cells were then swirled to make a homogenous suspension. The final concentrated sample was about 100 ml. This technique is based on Utermöhl technique [13]. Sedgwick-rafter cell was used for cell counting. One milliliter of algal suspension liquid was transferred to the chamber for counting and the chamber was covered by its cover slip to be devoid from any air bubbles. Phytoplankton genera and species were identified according the following references [14–18].

2.2. Palmer index calculation

The species and genera which proposed by palmer [10] as pollution indicators were investigated in the studied samples. Only seventeen genera and seventeen species (Table 1) were appeared in the studied stations out of twenty genera and twenty species included in palmer index [10]. The taxa are considered significant if its concentration was at least (<50) cells per liter. The final palmer index value is the summation of the scores of all the present taxa in the station. Palmer index numerical values were calculated for both species and genera then compared with the reference values that proposed by palmer as following: 0–10 indicate no evidence of organic pollution, 10–15 indicate moderate pollution, 15–20 indicate probable high organic pollution and 20 or more indicate high organic pollution.

3. Results and discussion

Large numbers of genera and species were found in the studied irrigation canals and drains. Our most interest was the genera and species that were mentioned in Table 1. The occurrence and distribution of palmer algal genera and species, at the four water bodies during both winter and summer, was illustrated in Tables 2 and 3, respectively. Algal taxa, which were indicated probable high pollution and not included in the palmer index scoring, were also mentioned. Plate 1 shows some of the high organic pollution tolerant taxa. The living genera that were found in the drainage water confirmed high organic pollution levels in most of the sampling stations including *Chlamydomonas* spp., *Euglena* spp., *Phacus* spp. and *Lepocinclis* spp. especially in the summer season. Euglenophyceae generally is characterizing the eutrophication [10].

3.1. Qudaba canal

Winter data (Fig. 3A) showed no evidence of pollution at the first and last stations as both genera and species have palmer index scores below 10. The evidence for high pollution was increased along the water pathway from south (sample 2) to north (sample 4). Station 4 high Palmer index value could be related to the presence of high organic pollution tolerant algal taxa; *Cyclotella meneghiniana*, *Melosiera varians*, *Nitzschia palea*, *Nitzschia acicularis*, *Synedra ulna*, *Oscillatoria limosa* and *Chlorella vulgaris*. The presence

Table 1
Genera and species that are included in the palmer index and detected in the studied water bodies.

Taxa number	Genera index	Index value	Species index	Index value
1	*Ankistrodesmus*	2	*Ankistrodesmus falcatus*	3
2	*Chlamydomonas*	4	*Chlorella vulgaris*	2
3	*Chlorella*	3	*Cyclotella meneghiniana*	2
4	*Closterium*	1	*Euglena gracilis*	1
5	*Cyclotella*	1	*Euglena viridis*	6
6	*Euglena*	5	*Gomphonema parvulum*	1
7	*Gomphonema*	1	*Melosiera varians*	2
8	*Lepocinclis*	1	*Navicula cryptocephala*	1
9	*Melosira*	1	*Nitzschia acicularis*	1
10	*Navicula*	3	*Nitzschia palea*	5
11	*Nitzschia*	3	*Oscillatoria limosa*	4
12	*Oscillatoria*	5	*Oscillatoria princeps*	1
13	*Pandorina*	1	*Oscillatoria putrida*	1
14	*Phacus*	2	*Oscillatoria tenuis*	4
15	*Phormidium*	1	*Pandorina morum*	3
16	*Scenedesmus*	4	*Scenedesmus quadricauda*	4
17	*Synedra*	2	*Synedra ulna*	3
	Total	40	Total	44

Table 2
Palmer genera occurrence and distribution at different stations in the studied water bodies. Summer and winter data are presented by white and gray colors, respectively.

	Qudaba canal										Mit-yazed canal								El-Gharbia main drain										Janag drain							
	Stations																																			
Palmer genus list	1		2		3		4		5		1		2		3		4		1		2		3		4		5		1		2		3		4	
Ankistrodesmus		+	+		+		+	+					+	+	+					+								+								
Chlamydomonas																			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Chlorella			+	+			+	+				+						+						+												
Closterium			+		+															+							+									
Cyclotella	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+	+	+		+	+	+	+			+		+	+	+
Euglena												+		+	+	+		+	+	+		+	+	+	+	+	+	+			+			+		+
Gomphonema		+				+									+																					
Lepocinelis												+											+													
Melosira	+	+		+	+	+	+	+				+	+	+	+	+		+		+		+				+			+	+		+				
Navicula		+	+	+	+		+	+		+		+	+	+	+					+				+			+		+					+		
Nitzschia	+	+	+	+	+	+	+	+		+		+		+	+					+		+	+		+		+					+		+		+
Oscillatoria					+		+					+	+	+	+				+	+		+	+	+	+	+			+	+		+	+	+		+
Pandorina		+		+				+										+																		
Phacus												+			+	+				+	+	+												+		
Phormidium																+																				
Scenedesmus		+	+	+	+	+	+	+	+	+	+	+	+	+	+			+		+				+		+	+	+						+		+
Synedra		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+			+		+		+		+			+			+				+

Table 3
Palmer Species occurrence and distribution at different stations in the studied water bodies. Summer and winter data are presented by white and gray colors, respectively.

	Qudaba canal										Mit-yazed canal								El-Gharbia main drain										Janag drain							
	Stations																																			
Palmer species list	1		2		3		4		5		1		2		3		4		1		2		3		4		5		1		2		3		4	
Ankistrodesmus falcatus								+			+									+																
Chlorella vulgaris				+		+	+	+		+		+		+				+						+								+				
Cyclotella meneghiniana	+		+	+		+	+	+	+	+	+	+	+	+		+				+		+		+		+	+	+	+		+	+		+	+	+
Euglena gracilis												+										+					+									+
Euglena viridis												+				+		+				+	+		+		+	+								
Gomphonema parvulum		+				+																					+									
Melosiera varians							+								+												+									
Navicula cryptocephala		+				+		+				+		+						+																
Nitzschia acicularis					+	+	+	+				+		+						+					+		+									
Nitzschia palea		+	+		+	+	+			+		+			+							+	+				+		+							+
Oscillatoria limosa					+		+		+						+						+															
Oscillatoria princeps														+						+				+								+		+		+
Oscillatoria putrida																				+																
Oscillatoria tenuis												+	+							+		+		+		+						+		+		+
Pandorina morum				+																																
Scenedesmus quadricauda				+	+	+				+					+												+							+		
Synedra ulna	+	+		+	+	+	+		+	+	+	+	+	+	+		+												+							

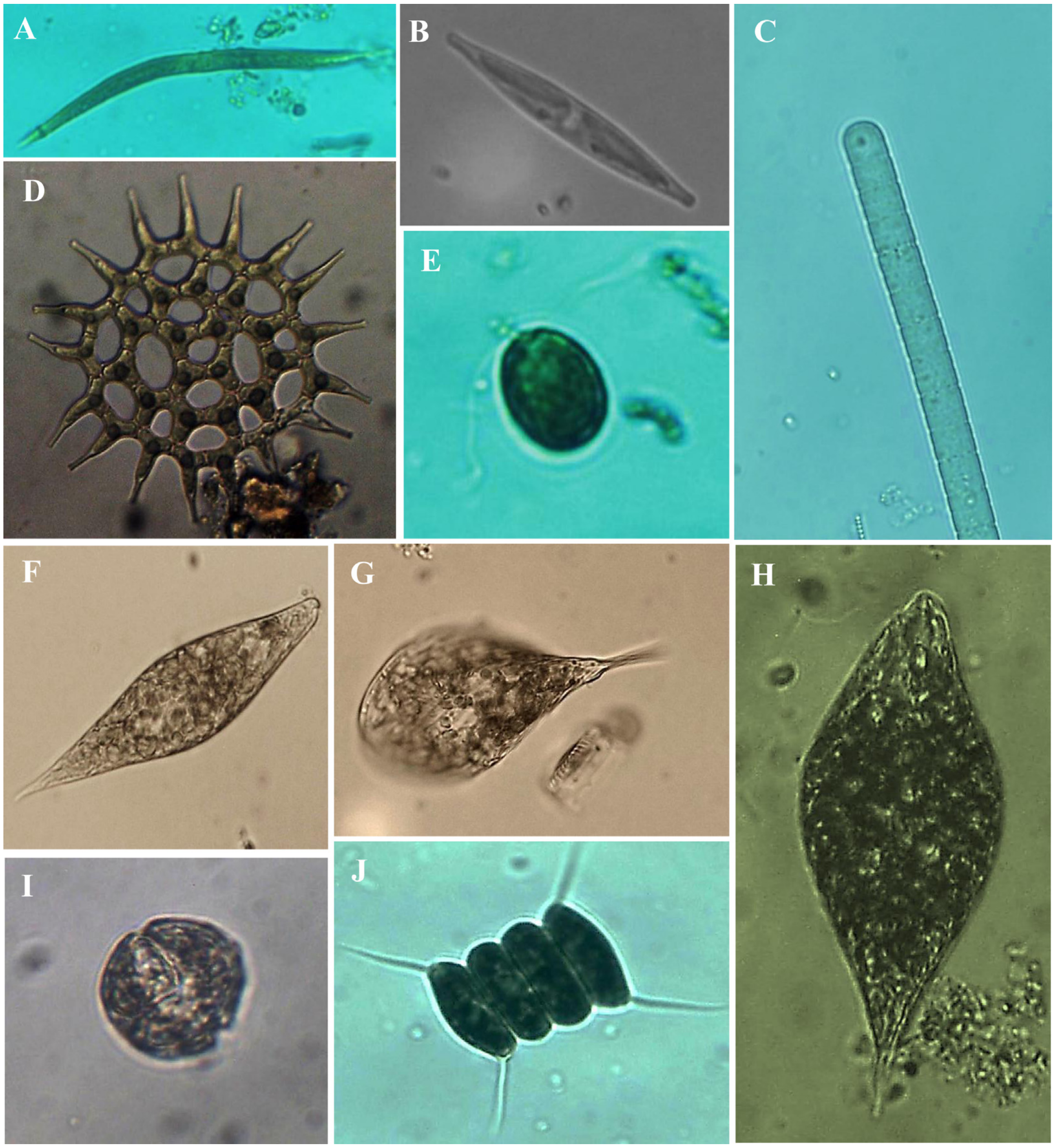

Plate 1. Some optical micrographs of high organic tolerant microalgae that present in the studied stations (Magnification power = 600X). (A) *Ankistrodesmus* falcatus; (B) *Nitzschia palea*; (C) *Oscillatoria* sp.; (D) *Pediastrum simplex*; (E) *Chlamydomonas* sp.; (F, H) *Euglena* sp.; (G) *Phacus tortus*; (I) *Peridinium* sp.; (J) *Scenedesmus quadricauda*.

of *Cryptomonas ovata* and *Rhodomonas lacustris*, which belongs to Cryptophyta, indicated relatively clean water [19].

During summer, the water depth was higher than that of winter season in both irrigation canals and drains which might impact the organic pollution load. Summer data of Qudaba canal (Fig. 3B) showed an increase of Palmer index of the five stations from moderated to high values indicating higher pollution load in summer compared to winter. The stations from 1 to 4 had similar PI values indicating high organic pollution level in general. Station five showed a higher palmer value compared to winter but still lower than the other stations.

In contrast to winter season, in summer Cryptophyta that indicates relatively clean water disappeared [9] and Chlorophyta exhibited flourishing of Chlorophycean taxa with large numbers of *Pediastrum* spp. and *Scendesmus* spp. were detected. Chlorophycean taxa give unwanted odour to the drinking waters and also indicate eutrophication [20,21]. Moreover, presence of Dinophycean taxa especially *Peridinium* spp. suggests advanced trophic level [22].

3.2. Mit-yazed canal

Winter data (Fig. 4A) showed no evidence of algal related organic pollution at the first and the last stations while an increase in PI values was detected along the path way from station 1 to 3 similar to the results of Qudaba canal. A higher palmer index score was noticed in the second station reaching the maximum score at station 3. This trend was confirmed by the presence of high organic pollution tolerant algal species; *Melosiera varians*, *Nitzschia palea*, *Oscillatoria limosa*, *Scenedesmus quadricauda* and *Synedra ulna*.

In contrast to winter season, during summer (Fig. 4B) data show a general decreasing trend in PI values along the water pathway with noticeable increase in stations 1, 2 and 4 and decrease in station 3. Such major spatial and seasonal differences could be related to higher waste water discharge to the irrigation canals in summer. Large numbers of *Pediastrum* spp. and *Scendesmus* spp. are detected in all the stations which give unwanted odor to the drinking waters and also indicate eutrophication [20,21].

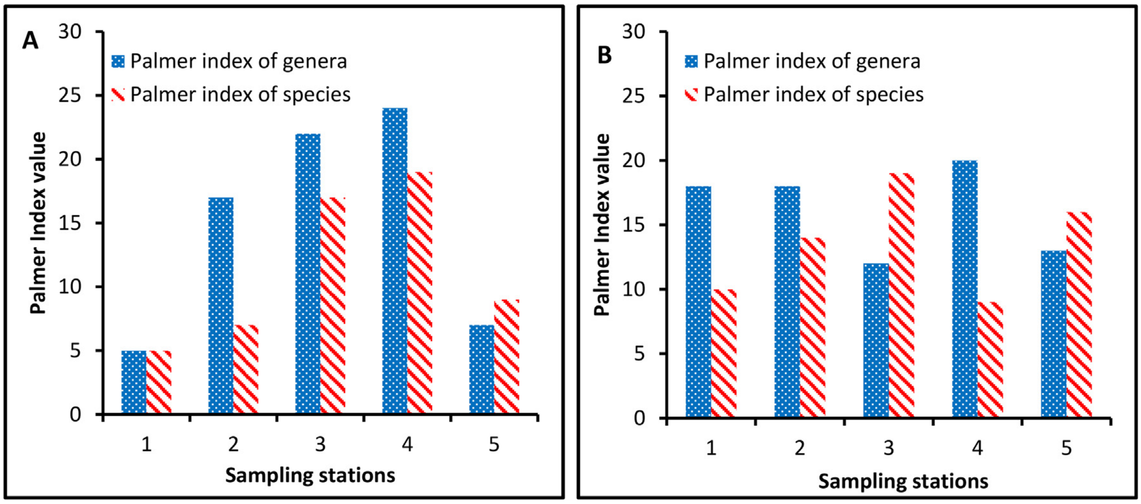

Fig. 3. Pollution index scores of algal genera (blue) and species (red) at the selected sampling stations of Qudaba irrigation canal. (A) is the Palmer index during winter and (B) is the Palmer index during summer.

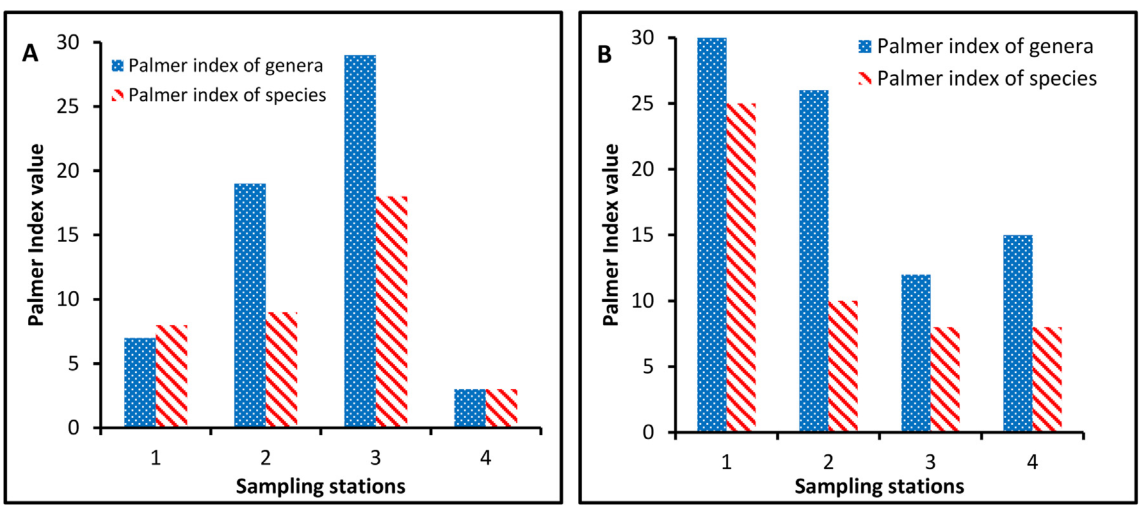

Fig. 4. Pollution index scores of algal genera (blue) and species (red) at the selected sampling stations of Mit-yazed irrigation canal. (A) is the Palmer index during winter and (B) is the Palmer index during summer.

Moreover, the presence of Dinophycean taxa especially *Peridinium* spp. and Euglenophyceae in the summer at all stations indicated advanced trophic level there, which could be related to leakage from Semtay drain where its water is transferred under the canal using pipe lines at the second station.

3.3. El-Gharbia main drain

In winter (Fig. 5A), Palmer index scores are low (station 2), moderate (stations 1), probable high (station 3, 4) and high load (station 5). Therefore the last there stations have high organic pollution load. This drain is wide, long and receives water from many other small drains along its path (Fig. 1A and B) therefore; no definite trend of Palmer index was noticed in winter data.

Summer data (Fig. 5B) showed a general decreasing trend of Palmer index from south to north (from station 1 to 5). The first four stations 1, 2, 3 and 4 showed high organic pollution evidence with the maximum value at station 1. This high pollution load was confirmed by the presence of organic pollution tolerant algal species; *Ankistrodesmus falcatus*, *Cyclotella meneghiniana*, *Navicula cryptocephala*, *Nitzschia acicularis*, *Oscillatoria princeps*, *Oscillatoria putrida* and *Oscillatoria tenuis*. Palmer index value of station 5 is lower than the other stations and located in the probable high organic pollution range. Compared to winter data, summer water of this drain showed higher pollution load.

3.4. Janag drain

Genera Palmer index values during winter showed the highest value with probable high organic pollution at the first station and no evidence for organic pollution at station 2, 3 and 4 (Fig. 6A). During summer season this drain receives more water compared to winter, therefore, Palmer index values of summer are higher than that of winter (Fig. 6A and B). Fig. 6B shows an increasing trend from station 1 (low value) to station 3 (high value) and then decreased a little in station 4. In general, organic pollution was confirmed by the presence of high organic pollution tolerant algal taxa; *Cyclotella meneghiniana*, *Oscillatoria princeps*, *Oscillatoria tenuis* and *Scenedesmus quadricauda*.

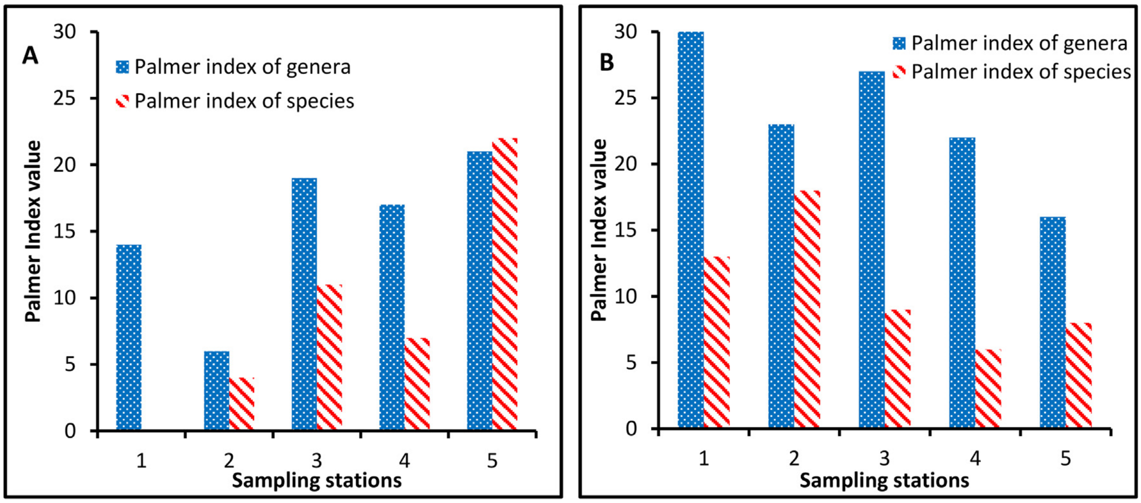

Fig. 5. Pollution index scores of algal genera (blue) and species (red) at the selected sampling stations of El-Gharbia main drain. (A) is the Palmer index during winter and (B) is the Palmer index during summer.

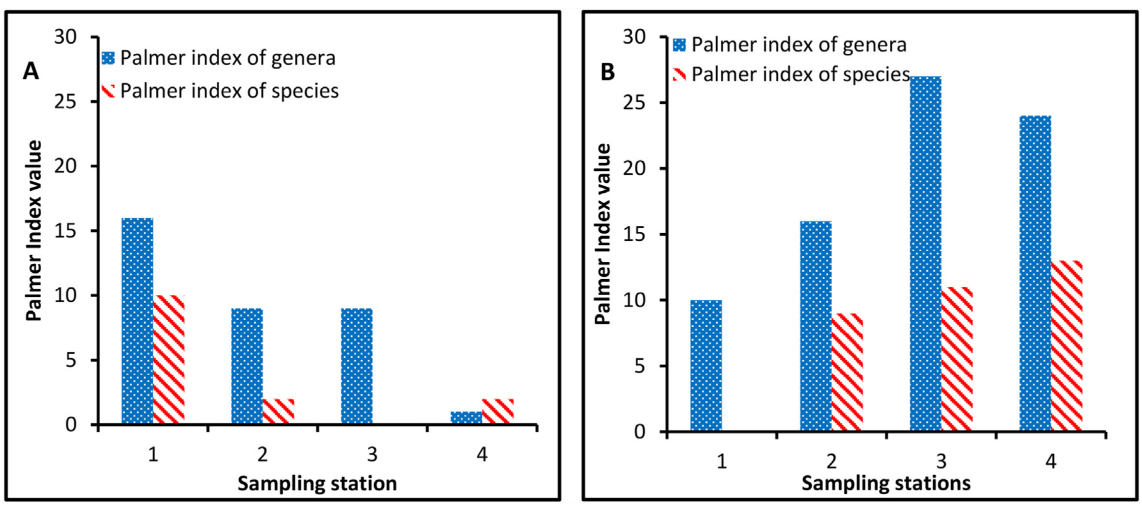

Fig. 6. Pollution index scores of algal genera (blue) and species (red) at the selected sampling stations of Janag drain. (A) is the Palmer index during winter and (B) is the Palmer index during summer.

4. Conclusions

Palmer index was a significant tool to show the pollution probability in the surface water of the Nile Delta either irrigation canals or drains. The Palmer index of genera was more helpful than that of the species in case of drainage water. Pollution load in form of Palmer index changes spatially along the water pathways or temporally from winter to the summer for the same sampling station. In general, the surface water of the Nile Delta suffers from organic pollution in most of the sampled stations. In winter where the water depth is shallow and either canals or drains received a little water, the organic pollution was lower than that of the summer and generally, increased along the water pathways from south to north. In summer where the water depth was higher than winter, organic pollution load was noticed at all the stations. Mit-yazed maximum organic pollution was higher than that of Qudaba canal, due to the higher urbanization along Mit-yazed canal pathway compared to Qudaba canal. El-Gharbia main drain as a big drain had higher palmer index scores than Janag drain. As the canal water is used for drinking and drain water is used sometimes for fish and cultivation farms, therefore, caution and treatment should be done to avoid the hazardous effects of the detected pollution.

Conflicts of interest

The authors declare no conflict of interest.

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