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Research Article
Biological Characterization of Water in Damietta Branch of the Nile River, Egypt

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Abstract

Background and Objective: Damietta branch is one of the two main branches of the Nile River (Egypt), that often inhabited by many aquatic organisms, which affect and reflect its water characteristics. This study examine the relation between submerged macrophytes, their epiphytic microalgae and bacterial communities as well as the variations in their distribution and species composition with respect to season and location. **Materials and Methods:** Macrophytes, epiphytes and water samples were collected from 5 sites distributed along Damietta branch. Macrophytes, epiphytes and bacterial indicators of pollution were identified using standard methods. **Results:** Three submerged macrophytes (*Myriophyllum spicatum*, *Ceratophyllum demersum* L. and *Potamogeton crispus*) and 191 epiphytic algal taxa dominated by 87 Bacillariophyta and 62 Chlorophyta were recorded with significance seasonal and spatial variations. *Myriophyllum spicatum* was the most frequent macrophyte (p = 100%) and represent about 100, 100, 97.4 and 64.9% kg DW m^{-2} of the total collected macrophytes biomass during autumn, winter, spring and summer respectively. The relation between some epiphytic algal species and specific macrophytes was evident and the high organic pollution tolerant algal species like, *Melosira granulata*, *Nitzschia palea*, *Synedra ulna*, *Oscillatoria limosa*, *Microcystis aeruginosa* were recorded. Results of bacteriological analysis revealed a significance difference in total viable bacterial counts developed on either 22 or 37°C, total coliform, fecal coliform, fecal streptococci and *Escherichia coli* attributed to the seasons and sites. **Conclusion:** The results indicated different relations between macrophytes, epiphytes and bacteria, which is a useful biological tool for characterization of water quality in Damietta branch for different purposes.

Key words: Biological characterization, macrophytes, epiphytes, bacteria, indicators of pollution

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Damietta branch is one of the two main branches of the Nile River, passes through 5 governorates with an average width of 200 m, length of about 242 km and depth varying[1] from12-20 m. It has considered as the major source of water needed for municipal, agricultural, industrial and feeding fish farms which dispersed between El-Serw and Faraskour region[2].

This water body is often inhabited by different aquatic macrophytes life forms (submerged, floating and emergent). Submerged macrophytes are considered as important component of the aquatic ecosystem as they play key ecological roles in river, primarily as a source of food, shelter and as habitat for abundant and diverse of many aquatic organisms[3-7]. In addition to their role in improving water quality by removing toxic compounds and inhibiting algal blooms through the reduction of nutrients, shading and allelopathy[8-10].

Epiphytic microalgae are common constituents to determine the trophic status of aquatic ecosystems[11,12]. They also, act as a food source for higher trophic levels[13,14] and play a significant role in the functioning of shallow ecosystems, contributing to material circulation, water quality and food web interactions in aquatic ecosystems[15,16]. Although the presence of epiphytic algae was dependent on aquatic macrophytes as a host[17] and the relationship between epiphytic algae and macrophytes plays an important role in maintaining the function and stability of the shallow ecosystems[18,19]. The relation between host plants and attached algae in the natural environment is still incompletely understood[20,21] and their community structure is recorded to be influenced by a number of biotic and abiotic factors[22-24].

Bacteriological water qualities are important issues in any water resources management especially water used in drinking purposes. Currently, total coliforms, fecal coliforms and enterococcus spp. are used as microbial indicators for predicting water pollution[25]. Fecal coliform bacteria are a harmful microbial contaminant, may cause diseases such as gastroenteritis, hepatitis A, typhoid fever, dysentery and cholera so, the drinking water standard requires that the Fecal coliform bacteria be totally absent from potable water[26]. Presence of *E. coli* is an indicative of fecal contamination of water source[27]. Very little studies dealing with the distribution of macrophytes and epiphytes had been carried out on the Nile River and its branches[28-31,21]. There are also some studies of El-Fadaly *et al.*[32], Sabae *et al.*[33] and Sabae and Rabeh[34] dealing with the microbial quality of the Nile River waters. Nothing was found in literature dealing the relation between submerged macrophytes, their epiphytic microalgae and bacterial indicator of pollution at Damietta branch of the Nile River.

The present study accounted briefly on the floristic status of the submerged macrophytic plant vegetation, their epiphytic algae and bacterial indicator of pollution throughout the Damietta Branch of Nile River, Egypt. Another aim was to put the light on the role of these aquatic organisms as biological indicator of water quality of this water body.

MATERIALS AND METHODS

Sampling sites: Five sampling sites distributed along the Damietta branch of the Nile River were selected (Fig. 1, Table 1).

Macrophytes and epiphytes collection and identification: The sampling program was carried out over four season period extended from autumn (2017) to summer (2018) at the previously mentioned sites (Table 1). At each site a quadrates (50×50 cm) were used and the submerged macrophytes were handily collected from each quadrate and stored in river water before taking to the laboratory. In the laboratory the plants of each quadrate were separated into different taxa, identified based on Tackholm[35].

For epiphytes collection, each collected macrophytes sample was placed separately in plastic bottles filled with deionized water. The periphyton on the macrophytes sections was scrapped off many times and the plant sections were washed with deionized water several times to completely detached all the attached algae. Epiphytes were separated from the plants by vigorous shaking for 3 min, the process was repeated at least three times and then the epiphyte suspension was poured into 1 L glass cylinder. The periphyton algal suspension was passed via a 300 µm mesh to avoid contamination by small macrophyte fragments[36] poured into 1 L glass cylinder and the volume of 1 L. was completed. Lugol's iodine solution was added until the colour changed to faint tea colour. Attached algal cells were allowed to settle for 5 days then completed as mentioned above. Species identification and counting were performed in an inverted light microscope (Zeiss, Axiovert 25C) at 10· eyepiece and 400· objectives. The species were identified using the methods from previous studies[37-42].

Table 1: Sampling sites at Damietta branch

Sample No.	Stations	Symbols	Latitude	Longitude
1	Banha	1D	31 10 34.61	30 27 28.07
2	Meit-Ghamr	2D	31 15 4.58	30 42 53.07
3	El-Mansoura	3D	31 24 5.49	31 3 45.91
4	El-Serw	4D	31 38 50.41	31 14 30.31
5	Faraskour	5D	31 46 57.97	31 24 22.52

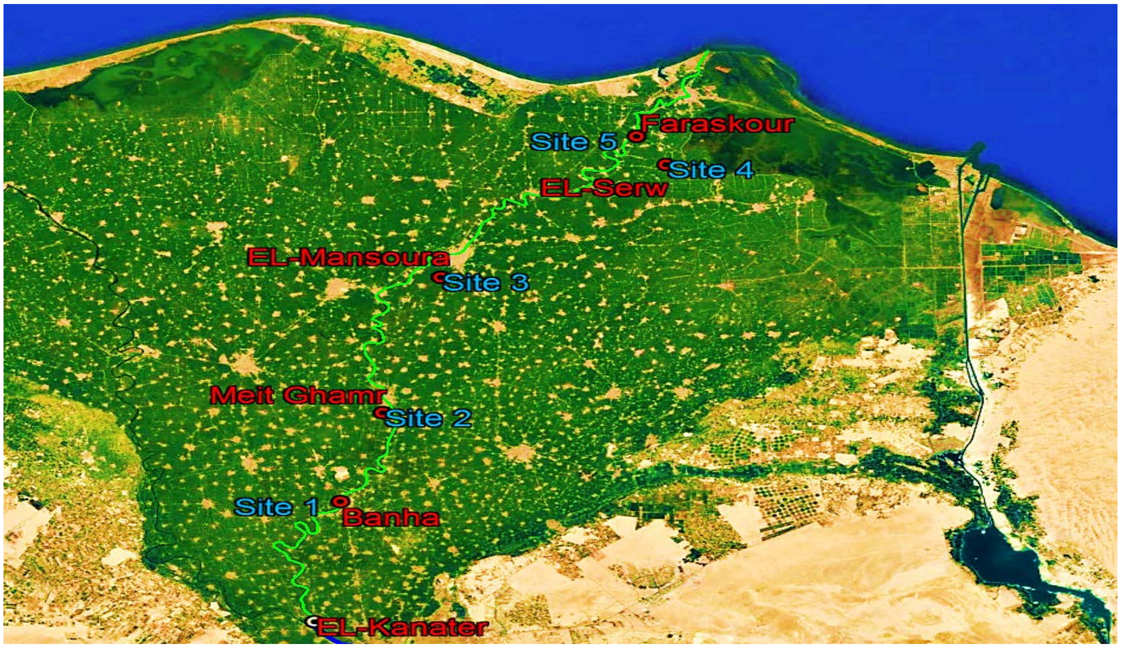

Fig. 1: Map of Damietta branch with the selected sampling sites (Google Earth)

Quantitative study of vegetation cover: After removing the epiphytic algae, samples of each macrophyte species were weighted for estimation of their biomass production and the results were expressed[43] as kilo gram wet weight m^{-2} (kg wet wt m^{-2}). This is followed by drying in shade and drying at 100°C for biomass estimation as kilo gram dry weight m^{-2} (kg dry wt m^{-2}). Frequency (percent presence) of plants was calculated from the number of quadrats of occurrence for a species and the total number of quadrats sampled.

Bacteriological analysis

Sampling: Twenty water samples were collected seasonally from Damietta branch at autumn 2017 to summer 2018 at the 5 selected sites. The samples were collected using sterilized glass bottles. The collected samples were brought in an iced insulated container during transport and delivered to the analytical laboratory for microbial analyses.

Methods of analysis: All bacteriological analysis of samples was carried out according to APHA[44], Samples were analyzed for TVBC at 22 and 37°C by poured plate techniques. The TC, FC and FS using MPN techniques and *E. coli* enumerations take placed by membrane filtration technique.

Poured plates technique: Total bacterial load growing on nutrient agar medium after decimal dilution of samples, the inoculated plates were incubated[44] for 24-48 h at 37°C and 48-72 h at 22°C.

Most probable number (MPN) techniques: The decimal dilution of samples were used to inoculate 5 tubes, each tube containing 5 and 10 mL of suitable medium at single strength and double strength respectively, the tube were s incubated at 37°C for 2 days. The positive presumptive tubes were used to inoculate the confirmed test as following[44]:

- **Total coliform bacteria (TC):** the media used at presumptive test were Lauryl tryptose broth media, tubes showed gas and acid were positive test and for confirmation test inoculate using brilliant green lactose bile broth medium. Production of gas and acid considered a positive confirmed test
- **Fecal coliform bacteria (FC):** From positive brilliant green lactose bile broth medium tubes inoculation in the EC broth tubes were occurred, incubated at 44.5°C for 1 day, gas production indicated positive result, for confirmation the bacteria streaked on Eosin Methylene blue agar medium (EMB), incubated at 37°C for 1 day. Metallic sheen colonies considered as a positive result
- **Fecal streptococci bacteria (FS):** The media used for presumptive test of FS detection are Azide dextrose broth media turbid tubes were positive, for confirmation, inoculum into ethyl violet azide broth medium, (EVA) were used, incubation at 37°C for 2 days and turbid tube were considered positive results

Enumeration of *Escherichia coli*: Samples were filtrate using bacterial filter paper (0.45 µm pore size), the filter transferred into EMB agar plates, incubated at 44.5°C for 1 day. Then filters were examined for typical colonies (2-3 mm in diameter, smooth with entire edge and green metallic sheen). Colonies were counted. Colonies purified by streaking on nutrient agar plate and subject to microscopic examination and biochemical tests for confirmation[44].

Statistical analysis: The data recorded in this study were subjected to Pearson's correlation analysis and principal component analysis (PCA) in order to evaluate the relationships between the 3 recorded aquatic macrophytes, their epiphytic microalgae (dominant species), bacteria and different water characteristics of the study area using XL Stat (2016) program.

RESULTS AND DISCUSSION

Vegetation analysis: Damietta branch of Nile River in Egypt is obviously populated by different communities of aquatic macrophytes that spread very rapidly and fill up the whole water body in some ecological sites. Three submerged macrophytes species *Myriophyllum spicatum* L., *Ceratophyllum demersum* L. and *Potamogeton crispus* were recorded throughout the study period (Table 2). This is coming in agreement with the study of El-Amier *et al.*[30], they recorded similar number of species in Damietta branch (3 species), but higher than that found at El-Rayah Al-Behery (2 species) by Haroon and Hussian[31]. Lower than that mentioned by Zahran[28] who recorded the presence of 21 of submerged macrophyte species, dominated by 8 species in the Nile River as a whole and also lower than that detected by Hussian and Haroon[21] they recorded the existence of 5 submerged macrophyte species related to 3 genera in the Nile River. This variation in species numbers compared with the previously mentioned results could be related to different abiotic and biotic factors such as sampling sites, environmental conditions, as well as the effect of human impact on water bodies.

Throughout the study period the distribution and abundance of recorded macrophytes species was being affected by both season and sampling site (Table 2). Autumn and winter showed the poorest seasons in species number, where *Myriophyllum spicatum* L. was the only recorded species found in all sites and represent p =100% of the total collected macrophytes sample. While spring and summer recorded the highest species number seasons (3 species). In this study *Myriophyllum spicatum* L. was recorded as the most abundant species during spring present in 80% of the macrophytes sampling sites. However both *Potamogeton crispus* and *Ceratophyllum demersum* L. were the least frequent species present in 20% of the macrophytes sampling sites. Like the other three seasons *Myriophyllum spicatum* L. was found as the most abundant species registered in all sites (p = 100%). However, *Potamogeton crispus* was found in 2 sites (site 1 and 3, p = 40%) and *Ceratophyllum demersum L.* was recorded at one site (site 4, p =20%).

Vegetation standing crop: Biomass estimation is an important tool in aquatic plant research for studies such as species distribution and abundance, succession and assessment of weed management operations[45]. As shown in results (Fig. 2a, b) during autumn, winter and at sites 3 and 4 *M. spicatum* shows it is highest standing crop value (9.49 and 23.22 kg wet wt m^{-2}, respectively). However,

Table 2: Floristic composition of the different ecological sites in Damietta branch of the Nile River, Egypt

				Ecological sites						
Species	Seasons	Life span	Life form	Site 1	Site 2	Site 3	Site 4	Site 5	NS	P (%)
Myriophyllum spicatum L.	Autumn	Per.	Hy	+	+	+	+	+	5	100
Ceratophyllum demersum L.		Per.	Hy	-	-	-	-	-	0	0
Potamogeton crispus		Per.	Hy	-	-	-	-	-	0	0
Myriophyllum spicatum L.	Winter	Per.	Hy	+	+	+	+	+	5	100
Ceratophyllum demersum L.		Per.	Hy	-	-	-	-	-	0	0
Potamogeton crispus		Per.	Hy	-	-	-	-	-	0	0
Myriophyllum spicatum L.	Spring	Per.	Hy	+	+	+	-	+	4	80
Ceratophyllum demersum L.		Per.	Hy	-	-	-	+	-	1	20
Potamogeton crispus		Per.	Hy	-	-	-	-	+	1	20
Myriophyllum spicatum L.	Summer	Per.	Hy	+	+	+	+	+	5	100
Ceratophyllum demersum L.		Per.	Hy	-	-	-	+	-	1	20
Potamogeton crispus		Per.	Hy	+	-	+	-	-	2	40
Species number				2	1	2	2	2		

NS: Number of sites in which the plants is recorded, P (%): Presence percentage, life span: Per.: Perennials, Life form: Hy: Hydrophytes, +: Presence and -: Absence

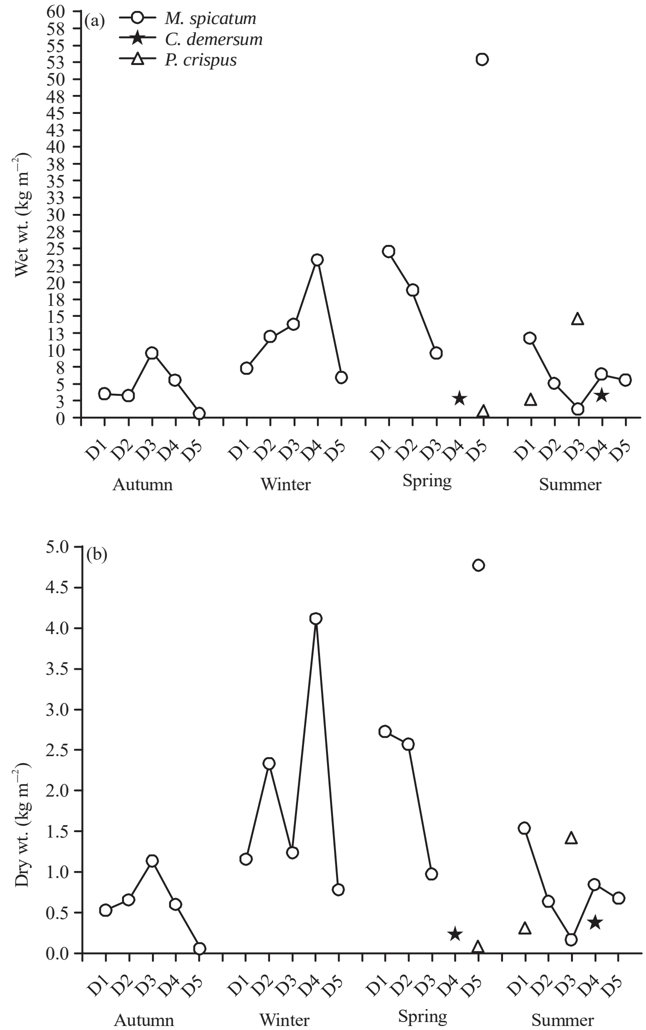

Fig. 2(a-b): Seasonal vegetation cover percentage for the recorded submerged *Macrophytes* species

during spring the maximum growth production value (52.78 kg wet wt. m^{-2}) was detected for the same species from site 5. In summer the submerged macrophyte species *P. crispus* recorded the highest standing growth values (14.30 and kg dry wt. m^{-2}) compared with the other 2 species. During the whole study period *M. spicatum* showed the highest biomass production value and constituent 100, 100, 96.89 and 59.0% wet wt of the total collected macrophytes biomass (Fig. 3).

Biomass production of submerged aquatic macrophytes is regulated by climatic and environmental factors like: Temperature, solar irradiance, day length, humidity, wind and water physicochemical characteristics[46-49]. In the present investigation, the maximum biomass production value for *M. spicatum* (52.78 and 4.76 kg dry wt. m^{-2}) was found during spring at site 5, however, *C. demersum* (3.35 kg wt. m^{-2}) and *P. crispus* (14.30 kg wet wt. m^{-2}) attended their highest production values during summer at sites 4 and 3, respectively (Fig. 2a). According to scientists[46,48], the summer highest production values of these species may be due to the plant avoids the competition for light, nutrient and space with the aquatic plants which have their peak of growth in summer. These data were relatively lower than that reported by Hussin and Haroon[21] during cold season for *M. spicatum* (66.00 kg wet wt. m^{-2}) and *C. demersum* 18.85 kg wet wt. m^{-2} from Nile River Egypt, but higher than the value of 3.35 kg wet wt. m^{-2} that was reported for *P. crispus*. On the other hand, lower values were recorded by El-Sheekh *et al.*[29] and Shaltout *et al.*[49] for *Ceratophyllum demersum* (0.036-1.094 kg wet wt. m^{-2}) and *P. crispus* (0.400 kg dry wt. m^{-2}) from different sites of the Nile Delta, respectively.

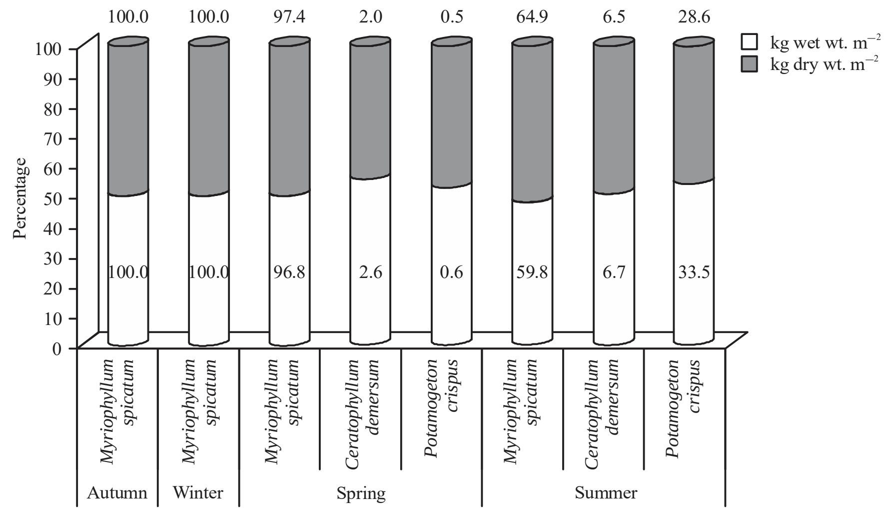

Fig. 3: Mean percent of each macrophyte species biomass in relation to the total collected macrophytes biomass during study period

Epiphytic algae on the three aquatic plants in Damietta branch: Changes in the submerged aquatic macrophyte community can be considered as one of the most important factors that affecting changes in the epiphytic algal community structure[50]. During the study period a total of 191 algal taxa were identified on the three collected macrophyte species (Table 3, 4, Fig. 4). Which being higher than that recorded by Deyab *et al.*[51] and Ahmed[52] they recorded 141 epiphytic algal species on *Phragmites australis* and 105 attached algal species in the Nile River and irrigation canals at Sohag district. At the same time the present results were relatively lower than that detected by Hussian and Haroon[21] they recorded 200 epiphytic species on submerged aquatic macrophytes of the Nile River (Egypt), in which Bacillariophyceae were detected as the dominant algal group (92.3%) on all aquatic macrophytes, with 119 taxa related to 31 genera. In this investigation Bacillariophyceae was recorded as the dominant algal group 87 algal species followed by Chlorophyta 62, Cyanophyceae 29, Dinophyceae 5, Euglenophyceae 2, Cryptophyceae 5 and Xanthophyceae 1 species. This variation may be due to the variation in nutrients concentration, released substances from macrophyte and water pollution[53,54]. As shown in Table 3 and 4 the percentage of epiphyte algae varied according to the host plant species, stations and seasons. Diatoms were the dominant group with the highest presence percentage during winter and summer seasons (91.94 at site 4 and 96.23% at site 5, respectively), however Chlorophyceae attended their highest presence during spring (40.16% at site 5) and Cyanophyceae increased in spring (11.74% at site 3). At the same time xanthophyceae was recorded only during summer.

The dominancy of diatoms among other attached algal classes was observed in different Damietta sites (Table 3). This is in accordance with Dere *et al.*[55], Albay and Aykulu[56] and Deyab *et al.*[51]. That dominancy may be due to their ability to resist different environmental stresses such as deficiency of light and their ability to grow on different aquatic substrate due to their possessing of silicate cell wall[57,58]. Chlorophyceae followed diatoms in importance and Cyanophyceae increased in spring and summer. As shown in Fig. 4 the percentage of the most common epiphytic algal species recorded was varied seasonally. In addition some algal species appeared during all seasons of study period such as *Cyclotella ocellata* Pant and *Syndra ulna* (Nitzsch) Her., while *Scenedesmus quadricauda* (Turpin) Brébisson, *Lyngbya limnetica* Lemmermann and *Microcystis aeruginosa* Kützing species appeared during most seasons of study period as shown in results (Table 4) which may be due to their wide range in temperature tolerance as pointed out by Hickman and Klarer[59].

Organic carbon released by macrophytes is a major substrate for epiphytic bacteria[60,61]. While, little phosphorus is released by living aquatic plants[62] and epiphytic algae obtain less than 10% of their phosphorus from the host macrophyte[63]. On the other hand, epiphyte algae may rapidly assimilate phosphorus released from decomposing macrophytes[64] and provide food for grazers. According to the abundance and seasonal occurrence of the three hydrophytes namely *Myriophyllum spicatum*, *Ceratophyllum demersum* and *Potamogeton crispus* along the study area, their epiphytic microalgae were analyzed. Seasonal and spatial data about the occurrence of different epiphytic microalgae on the three macrophytes are given in Table 4. These data indicated

Table 3: Abundance (%) of the different recorded classes of epiphytic algae attached to macrophytes in Damietta branch during study period

Stations	Autumn	Winter	Spring	Summer	Mean	Maximum	Minimum
Bacillariophyceae							
1D	67.8	81.0	90.1	51.6	72.6	90.1	51.6
2D	68.0	83.6	53.8	95.0	75.1	95.0	53.8
3D	81.4	82.5	67.8	94.7	81.6	94.7	67.8
4D	87.1	91.7	70.7	95.5	86.3	95.5	70.7
5D	87.5	81.8	80.1	96.2	86.4	96.2	80.1
Mean	78.4	84.1	72.5	86.6			
Maximum	87.5	91.7	90.1	96.2			
Minimum	67.8	81.0	53.8	51.6			
Chlorophyceae							
1D	31.3	18.8	8.1	33.4	22.9	33.4	8.1
2D	26.8	15.9	40.2	1.5	21.1	40.2	1.5
3D	15.8	8.4	20.1	2.0	11.6	20.1	2.0
4D	9.7	7.1	23.4	1.8	10.5	23.4	1.8
5D	12.1	16.7	17.9	1.6	12.1	17.9	1.6
Mean	19.1	13.4	21.9	8.1			
Maximum	31.3	18.8	40.2	33.4			
Minimum	9.7	7.1	8.1	1.5			
Cyanophyceae							
1D	0.9	0.1	1.6	9.5	3.0	9.5	0.1
2D	3.1	0.5	5.5	3.5	3.1	5.5	0.5
3D	2.8	7.8	11.7	2.0	6.1	11.7	2.0
4D	2.4	0.8	4.7	2.6	2.6	4.7	0.8
5D	0.4	1.5	1.9	2.1	1.5	2.1	0.4
Mean	1.9	2.2	5.1	3.9			
Maximum	3.1	7.8	11.7	9.5			
Minimum	0.4	0.1	1.6	2.0			
Dinophyceae							
1D	0.0	0.0	0.2	0.0	0.1	0.2	0.0
2D	1.0	0.0	0.3	0.0	0.3	1.0	0.0
3D	0.0	1.2	0.4	0.0	0.4	1.2	0.0
4D	0.8	0.4	1.2	0.0	0.6	1.2	0.0
5D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.4	0.3	0.4	0.0			
Maximum	1.0	1.2	1.2	0.0			
Minimum	0.0	0.0	0.0	0.0			
Euglenophyceae							
1D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2D	0.5	0.0	0.2	0.0	0.2	0.5	0.0
3D	0.0	0.0	0.0	0.3	0.1	0.3	0.0
4D	0.0	0.0	0.0	0.1	0.0	0.1	0.0
5D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.1	0.0	0.0	0.1			
Maximum	0.5	0.0	0.2	0.3			
Minimum	0.0	0.0	0.0	0.0			
Cryptophyceae							
1D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2D	0.5	0.0	0.0	0.0	0.1	0.5	0.0
3D	0.0	0.0	0.0	0.1	0.0	0.1	0.0
4D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5D	0.0	0.0	0.1	0.0	0.0		
Mean	0.1	0.0	0.0	0.0			
Maximum	0.5	0.0	0.1	0.1			
Minimum	0.0	0.0	0.0	0.0			
Xanthophyceae							
1D	0.0	0.0	0.0	5.4	1.4	1.4	0.0
2D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3D	0.0	0.0	0.0	0.8	0.2	0.2	0.0
4D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5D	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.0	0.0	0.0	1.3			
Maximum	0.0	0.0	0.0	5.4			
Minimum	0.0	0.0	0.0	0.0			

Table 4: Seasonal and spatial occurrence of different epiphytic microalgae of the selected hydrophytes along the study area

Epiphytes	Autumn					Winter					Spring					Summer				
	S1 *M. s.*	S2 *M. s.*	S3 *M. s.*	S4 *M. s.*	S5 *M. s.*	S1 *M. s.*	S2 *M. s.*	S3 *M. s.*	S4 *C. d.*	S5 *M. s.*	S1 *M. s.*	S2 *M. s.*	S3 *M. s.*	S4 *C. d.*	S5 *M. s., P. c.*	S1 *M. s., P. c.*	S2 *M. s.*	S3 *M. s., P. c.*	S4 *M. s.*	S5 *M. s.*
Bacillariophyceae																				
Amphora ovalis kutz.	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bacillaria paradoxa J.F.Gmelin in Linnaeus	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Caloneis permagna (Bailey) Cleve	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-
Cocconeis diminuta Pantocsek	-	-	-	-	-	+	+	+	+	+		+	+	+	-	-	-	-	-	-
Cocconies placentula Ehr.	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	-	-	-	-	-	-	-	+	+	-	-	-	+	+	-	-	-	-	-	-
Cocconeis placentula var. skvortzowii (Skv.) Ska.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cocconeis scutellum Ehrenberg	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Coscinodiscus lacustris Grunow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Cyclotella glomerata Bachmann	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Cyclotella ocellata Pant	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
Cyclotella operculata (Ag.) kutz.	+	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-	+	-	-	-
Cyclotella meneghiniana kutz.	-	+	+	+	+	-	+	-	+	-	+	-	-	-	+	+	-	-	-	+
Cymbella affinis Kützing	-	-	-	-	+	-	-	-	-	+	-	-	-	+	+	-	+	-	+	-
Cymbella cistula (*Hemprich*) *Grun*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-
Cymbella delicatula Kützing	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Cymbella laevis Nägeli	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Cymbella microcephala Grunow in Van Heurck	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-
Cymbella prostrata (Berkeley) Cleve	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Diatoma elongata (Lyngbye) C. Agardh	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diploneis smithii (Brébisson) Cleve	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eunotia veneris (Kützing) De Toni	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Eunotia sp.	-	-	-	-	+	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-
Epithemia argus (Ehrenberg) Kützing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragilaria construns (Ehr.) Grun	-	-	-	-	-	-	-	-	+	-	+	+	+	+	-	-	+	+	+	+
Fragilaria construns var. *veneter* (Ehr.) Grun	-	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Fragilaria crotonensis Kitton	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Fragilaria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Fragilaria virescens Ralfs	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema augur Ehrenberg	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema olivaceum (Langb.) Kutz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Gomphonema lanceolatum Kützing	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema montanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
Gomphonema truncatum var. *capitatum* (Ehrenberg)	-	-	-	-	-	-	-	-	+	+	-	-	–		+	-	-	+	+	+
Gomphonema sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Gomphonema ventricosum W. Gregory	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Gyrosigma acuminatum (Kützing) Rabenhorst	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Mastogloia elliptica var. dseri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Mastogloia smithii Thwaites ex W. Smith	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Melosira granulata (Her.) Ralfs	+	+	+	+	+	+	+	+	+	-	+	-	+	+	-	+	+	+	+	+
Melosira granulata var. angustissima Muller	-	-	-	-	-	-	-	-	+	-	+	+	+	+	+	-	-	-	-	-
Melosira varians C. A. Agradh	+	-	-	+	+	+	-	-	+	+	-	+	+	+	+	-	-	-	-	-
Meridion circulare (Greville) C. Agardh	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula atomus (Kützing) Grunow	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-

Table 4: Continue

Epiphytes	Autumn					Winter					Spring					Summer				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
	M. s.	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s., P. c.*	*M. s., P. c.*	*M. s.*	*M. s., P. c.*	*M. s.*	*M. s.*
Navicula confervacea (Kützing) Grunow	-	+	-	+	-	-	-	-	-	+	-	+	+	+	+	+	-	-	-	-
Navicula cryptocephala Kutz	-	+	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Navicula cryptocephala var. veneter (Kutz.) Grun	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula cryptocephala var. intermedia Gran.	-	-	-	-	-	–		+	-	-	+	+	-	-	-	-	-	-	-	-
Navicula cuspidata (Kutzing) Kutzing	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula festiva Krasske	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Navicula helvetica (Brun)	-	+	-	+	-	-	+	+	+	-	-	-	-	-	-	-	+	-	-	-
Navicula lanceolata Ehrenberg	-	-	-	-	+	-	+	-	-	+		+	+	+	+	+	+	+	+	+
Navicula punctulata W. Smith	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Navicula pupula Kutz.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Navicula rhyncocephala Kützing	-	-	-	-	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
Navicula salinarum Grunow	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Navicula salinarum var. intermedia (Grunow) Cleve	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Navicula tuscula Ehrenberg	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-
Navicula viridula (Kützing) Ehrenberg	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia acicularis W. Smith	-	+	+	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-
Nitzschia acula (Kützing) Hantzsch	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Nitzschia filiformis (W. Smith) Van Heurck	-	-	-	-	+	-	-	-	-	+	-	+	-	-	+	-	+	+	+	+
Nitzschia fonticola Grun.	-	+	+	-	-	-	-	-	+	+	+	-	-	+	+	-	-	-	-	-
Nitzschia frustulum (Kützing) Grunow	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia dissipata (Kutz.) Grum	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+
N. gracilis Hantz	+	+	-	-	+	+	-	-	+	+	+	+	-	+	+	-	-	-	-	-
Nitzschia hantzschiana Rabenhorst	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. holastica Hust.	-	+	+	+	-	+	-	-	+	-	-	-	+	+	-	-	-	+	+	+
N. linearis W. Smith	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Nitzschia obtusa var. scalpelliformis	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
N. palea (Kutz.) W. Smith	-	+	+	+	+	-	-	-	+	+	-	-	-	-	-	+	+	+	+	+
N. paleacae Grum	-	+	+	+	+	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-
Nitzschia sigmoidea (Nitzsch) W. Smith	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia sublinearis Hustedt	-	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pleurosigma elongatum W. Smith	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Stauroneis anceps Ehrenberg	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stauroneis schroederi Hustedt	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Suriirella obtusa var. splandida	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Synedra actinastroides Lemmermann	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Syndra acus Kutz	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Synedra acus var. angustissima (Grunow) Van Heurck	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Synedra affinis Kützing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synedra delicatissima W. Smith	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synedra nana F.Meister	+	+	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-
Syndra ulna (Nitzsch) Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Synedra ulna var. *biceps* (Kützing) Schönfeldt	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Synedra ulna var. *ramesi* (Herib.) Hust.	+	-	+	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-
Number of taxa/ site	16	25	14	23	25	12	16	10	30	17	16	19	21	20	20	9	18	12	16	15

Table 4: Continue

Epiphytes	Autumn S1 *M. s.*	Autumn S2 *M. s.*	Autumn S3 *M. s.*	Autumn S4 *M. s.*	Autumn S5 *M. s.*	Winter S1 *M. s.*	Winter S2 *M. s.*	Winter S3 *M. s.*	Winter S4 *C. d.*	Winter S5 *M. s.*	Spring S1 *M. s.*	Spring S2 *M. s.*	Spring S3 *M. s.*	Spring S4 *C. d.*	Spring S5 *M. s., P. c.*	Summer S1 *M. s., P. c.*	Summer S2 *M. s.*	Summer S3 *M. s., P. c.*	Summer S4 *M. s.*	Summer S5 *M. s.*
Chlorophyceae																				
Actinastrum hantzschii Lagerheim	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus falcatus (Corda) Ralfs	-	+	-	+	-	+	+	-	+	-	-	-	-	-	-	-	+	-	-	-
Ankistrodesmus fusiformis Corda	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-	+
Ankistrodesmus convulatus Corda	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Basicladia vivipara Normandin and Taft	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorella vulgaris Beyerinck	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Choricystis coccoides (Rodhe and Skuja) Fott	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Closterium accrosum (Schr.) Ehr.	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	+	+	+
Closterium acutum Bredisson	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coelastrum cambricum Archer	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cosmarium depressum (Nägeli) P. Lundell	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Cosmarium formosulum var. *nathorstii* (Boldt) West and G.S. West	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Cosmarium ochthodes Nordstedt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Cosmarium sp.	-	+	+	-	-	-	-	-	-	–		+	–		+	-	-	-	-	-
Crucigenia quadrata Morren	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dictosphaerium pulchellum Wood	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Docidium baculum Brébisson ex Ralfs	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Gloeotila sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Kirchneriella contorta (Schmidle) Bohlin	-	-	-	-	-	-	-	-	-	-	+		-	-	-	-	-	-	-	-
Koliella spiculiformis (Vischer) Hindák	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Legerheimia citriformis (Snow) G.M. Smith	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Monoraphidium dybowskii (Wol.) Hindák& Komárková-Legenerová	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Monoraphidium contortum Thuret	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Monoraphidium griffithii (Ber.) Komárková-Legnerová	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Mougeotia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Oedogonium sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Oocystis solitaria Wittrock	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
Oocystis borgei Snow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Pediastrum araneosum	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Pediastrum clathratum (Schröder) Lemmermann.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Pediastrum duplex Meyen	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum simplex Meyen	-	+		+	+	+	-	-	-	+	-	-	-	-	+	-	+	-	-	-
P. simplex var. ramci (Reinsch) wolle	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum tetras (Ehrenberg) Ralfs	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Planktonema lauterbornii Schmidle	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudosphaerocystis lacustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Quadrigula closterioides (Bohlin) Printz	-	-	-	-	-	-	-	-	-	-	+	-	-	-	–		-	-	-	-
Scenedesmus acutiformis Schröder	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Scenedesmus acuminatus (Lagerh.) Chodat	-	+	-	-	-	+	+	-	-	+	-	+	+	-	-	+	-	+	-	-
Scenedesmus obliqus (Turpin) Küzing	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-

Table 4: Continue

Epiphytes	Autumn					Winter					Spring					Summer				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
	M. s.	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s., P. c.*	*M. s., P. c.*	*M. s.*	*M. s., P. c.*	*M. s.*	*M. s.*
Scenedesmus opoliensis P.G. Richter	-	-	-	-	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-
Scenedesmus dimorphus (Turpin) Küzing	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scenedesmus ecornis (Ehrenberg) Chodat	-	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	-	-	-	-
Scenedesmus bicudatus Dedusenko	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Scenedesmus intermedius Chodat	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Scenedesmus quadricauda (Turpin) Brébisson	-	-	-	-	-	+	+	-	+	+		+	+	+	+	+	-	+	-	-
Scenedesmus protuberans Fritsch	+	-	-	+	+	-	-	-	-	-	-	-	+	+			-	-	-	-
Scenedesmus subspicatus Chodat	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scenedesmus sempervirens Chodat	-	-	-	-	-	-	-	-	-	-	-	-	+	–			-	-	-	-
Scenedesmus spinosas Chodat	+	-	-	-	-	+	+	-	-	-	-	-	+	+	+	+	-	-	-	-
Scenedesmus bijugatus (Turp.) Kutzing	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Sphaerocystis schroeteri Chodat	-	-	-	-	-	-	-	-	-	+	–		+	+	-	-	-	-	-	-
spirogyra sp.	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-
Staurastrum manfeldtii Delponte	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Staurastrum paradoxum Meyen ex Ralfs	-	+	-	-	-	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-
Stichococcus bacillaris Nägeli	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Tetraedron triangulare Korshikov	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Tetraedron minimum (A. Braun) Hansgirg	-	-	-	-	-	+	-	-	-	-	+		+	+	-	-	-	-	-	-
Tetradesmus wisconsinensis G.M. Smith	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-
Ulothrix sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	–		+	-	-	-
Westella botryoides (West) De Wildeman	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Zygnema sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of taxa/site	16	25	14	23	25	12	16	10	30	17	16	19	21	20	20	9	18	12	16	15
Cyanophyceae																				
Chroococcus dispersus (Keissler) Lemmermann	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Chroococcus minutus (Kützing) Nägeli	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Chroococcus turgidus (Kützing) Nägeli	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cylindrospermopsis raciboroskii Woloszynska	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-
Gomphosphaeria fusca Skuja	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Leptolyngbya Limnetica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Leptolyngbya perelegans (Lem.) Anag. And Komá.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+			
Lyngbya limnetica Lemmermann	-	-	-	+	+		+	+	-	-	+	+	+	-	-	+	-	+	+	+
Lyngbya major Meneghini ex Gomont	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Lyngbya profundalis Lindstedt	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Merismopedia punctata Meyen	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-
Microcystis aeruginosa Kützing	+	+	+	+	-	-	-	-	-	-	-	+	+	+	-	–		+	+	+
Microcystis flosaquae (Wittrock) Kirchner	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria agardhii Gomont	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria chalybea Mertens ex Gomont	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria exospira Skuja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
Oscillatoria limnetica Lemmermann	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oscillatoria limosa C. Agardh ex Gomont	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Oscillatoria tenuis C. Agardh ex Gomont	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-

Table 4: Continue

	Autumn					Winter					Spring					Summer				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Epiphytes	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s.*	*M. s.*	*M. s.*	*M. s.*	*C. d.*	*M. s., P. c.*	*M. s., P. c.*	*M. s.*	*M. s., P. c.*	*M. s.*	*M. s.*
Phormidium dictyothallum Skuja	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
Phormidium interruptum Kutz	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phormidium laminosum Gomont ex Gomont	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phormidium molle Gomont	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Phormidium sp.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudanabaena galeata Böcher	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Rhabdoderma irregulare (Naumann) Geitler	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Rhabdoderma lineare Schmidle and Lauterborn	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Rhabdoderma lineare var. unicellulare Hollerbach	-	-	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+
Spirulina platensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Number of taxa/site	16	25	14	23	25	12	16	10	30	17	16	19	21	20	20	9	18	12	16	15
Dinophyceae																				
Ceratium hirundinella (O.F.Müller) Dujardin	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Exuviaella apora Schiller	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peridinium cinctum O.F.Muller	-	-	-	-	-	-	-	-	+	+	+	+	-	+	-	-	-	-	-	-
Peridinium penardiforme Lindemann	-	-	-	-	-	-	-	-	+	-	+	+	-	+	-	-	-	-	-	-
Phormidium. sp.	-	+	-	+	-	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-
Euglenophyceae																				
Euglena pisciformis Klebs	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Phacus caudatus Huoner	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-
Cryptophyceae																				
Chromonas acuta Utermohl	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cryptomonas erosa Ehrenberg	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Cryptomonas marssonii Skuja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Cryptomonas rostrata Triozkaja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Cryptomonas phaseolus Skuja	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Xanthophyceae																				
Tribonema minus (*Wille*) *Hazen*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
Number of taxa/site	29	45	21	35	32	27	28	15	39	33	30	39	40	36	33	23	25	24	22	24

M. s.: Myriophyllum spicatum, C. d.: Ceratophyllum demersum, P. c.: Potamogeton crispus, +: Presence, -: Absence, S: Site

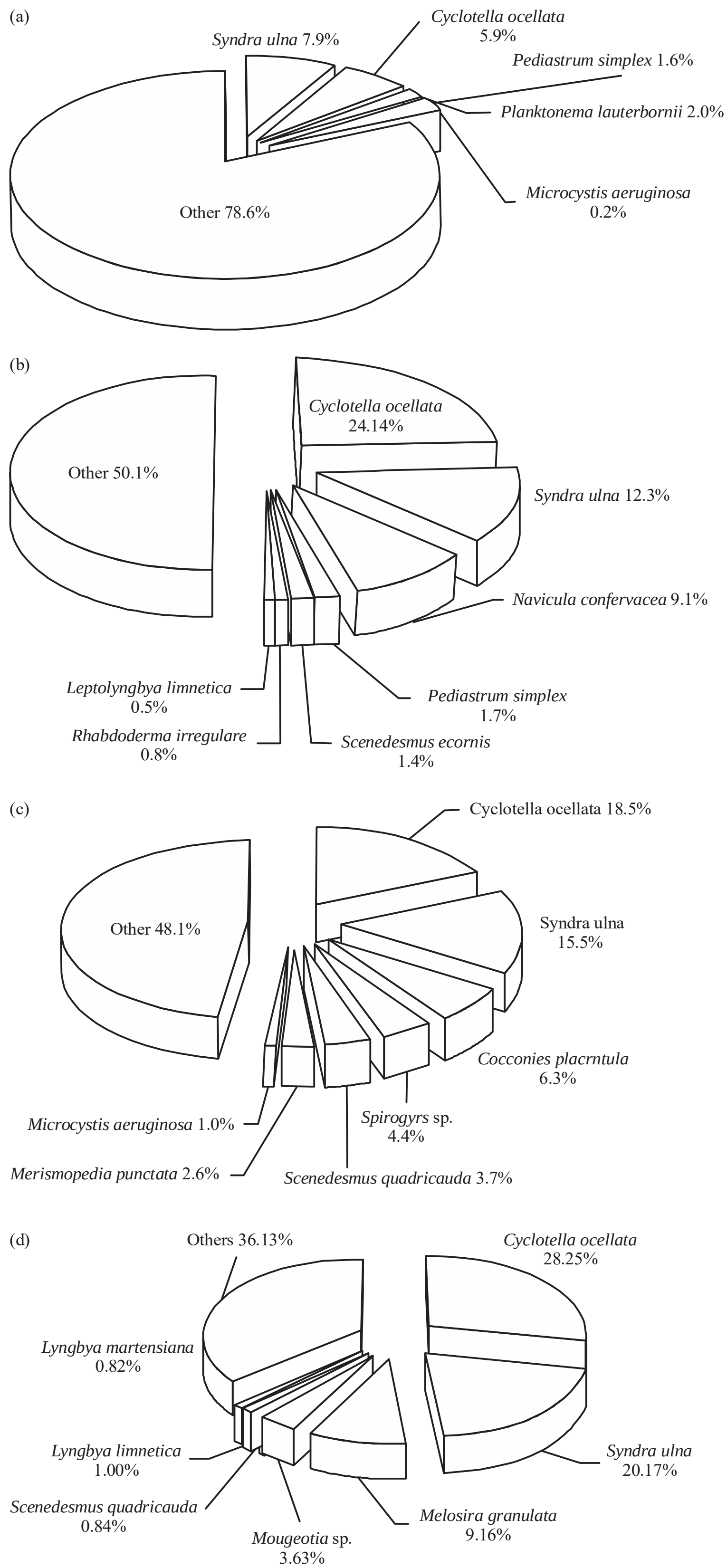

Fig. 4(a-d): Average of the percentage of the most common epiphytic algal species recorded in Damietta branch during study period, (a) Autumn 2017, (b) Winter 2018, (c) Spring 2018 and (d) Summer 2018 that epiphytes were largely dependent on season, plant species and sampling sites. During the study period there are some epiphytic algal species occurred with specific submerged macrophyte species (Table 4) like: *Amphora ovalis* kutz., *Diatoma elongata* (Lyngbye) C. Agardh., *Diploneis smithii* (Brébisson) Cleve), *Fragilaria construns* var. *veneter* (Ehr.) Grun, *Meridion circulare* (Greville) C. Agardh, *Navicula punctulata* W. Smith, *Nitzschia sigmoidea* (Nitzsch) W. Smith, *Synedra actinastroides* Lemmermann, *Syndra acus* Kutz, (Bacillariophyceae), *Dictosphaerium pulchellum* Wood, *Monoraphidium* spp., *Zygnema* sp., (Chlorophyceae) *Chroococcus turgidus* (Kützing) Nägeli and *Phormidium* spp. (Cyanophyceae) were occurred only in autumn and winter, which indicated the specificity of these spp. to *M. spicatum*. While Cryptophyceae and Xanthophyceae appeared only in spring and summer seasons with the occurrence of *C. demersum* and. *P. crispus.* The same result was observed by Albay and Aykulu[56] and Ahmed[52].

Bacteriological analysis

Total viable bacterial count: Bacteriological water qualities are important issues in any water resources management especially water used in drinking purposes. During the study period, the total viable bacterial counts developed on either 22 or 37°Cat Damietta branch water were varied significantly with season and sampling site (Table 5). They were particularly higher in spring and summer (up to 200×10^3 and 275×10^3 CFU mL^{-1}, respectively) compared to the other two seasons. In addition, water samples from sites 1 and 4 were found to have the minimum numbers of TVBC developed on either 22 or 37°C (0 and 0.1×10^3 CFU, respectively).

Bacterial indicators: Now-a-days, with increasing of human activities, the monitoring of fresh water pollution should be occurred for health and environmental protection. Therefore, the bacteriological characteristics for water quality of Damietta branch are studied.

Results of bacterial indicators for water samples during four seasons are illustrated in Table 5 and varied depending on the site and the season. Total coliform, Fecal coliform and Fecal streptococci at water samples of Damietta branch were in the range of (1.1×10^2 to 460×10^2), (0.4×10^2 to 28×10^2) and (4.3×10^2 to 2100×10^2) MPN/100 mL water, respectively and the numbers of *E. coli* were in the range of 0-6.8×10^2 (CFU/100 mL water). Bacterial indicators of pollution were monitored in the studied area with the highest numbers in warm seasons and the obtained results indicated of the suitability of the water for irrigation not for drinking.

Similar results were concluded for bacterial indicators of Nile River and two branches by many Authors[34,65,66]. Results of coliform group in the present study are not in a compliance with the Egyptian standards[67] for drinking water quality where recommended that the drinking water samples should be free from bacterial indicators and pathogens (e.g., TC, FC) in 100 mL water.

High numbers of bacterial indicators at Damietta branch might be explained by direct effects of domestic and agricultural wastes discharge from different sources at the urbanized surrounding area and these results agree with Sabae and Rabeh[34].

In conclusion, according to WHO[68] the results of bacteriological investigation indicate that, the quality of Damietta branch water is subjected to sewage pollution and not acceptable for drinking purposes.

Relation between macrophytes, epiphytes, bacterial indicator of pollution and water characteristics: In this study the principal correspondence analysis (PCA) and simple linear correlation coefficient and at $\alpha = 0.05$ show different relations between macrophytes, epiphytes, bacteria and different water parameters (Fig. 5, 6, Table 6). Relations between epiphytic microalgae and the host aquatic plant show the whole ecosystem character and the ecosystem responses to the altering environmental conditions[69]. There are some epiphytic algal classes were closely correlated with special macrophytes species (Fig 5a). Bacillariophyceae was associated with the three macrophytes species, however, Cryptophyceae and Euglenophyceae were significantly correlated with *P. crispus* (r = 0.350 and 0.557, respectively) and Dinophyceae was more associated with *C. demersum*.

The correlation statistical analysis in Damietta branch (Fig. 5a) show a significance positive relation between TVBC at 22°C and the submerged macrophytes species *M. spicatum* and *C. demersum* (r = 0.411 and 0.360, respectively). In addition it shows a very weak positive relation with Bacillariophyceae, Chlorophyceae, Cyanophyceae and a significance relation with the algal species *Cocconies placentula* Ehr (r = 0.208. 0.284, 0.231 and 0.446, respectively). TVB°C at 37°C showed a significant positive relation with *M. spicatum*, *C. demersum*, Bacillariophyceae, Cyanophyceae and Dinophyceae. Where, the total coliform bacteria attended their highest values during autumn and winter associated with the presence of *M. spicatum.* However, during summer the highest number was found in site 4 occupied by *M. spicatum* and *C. demersum*. Both Fecal Coliform and Fecal streptococci bacteria recorded their highest numbers during

Table 5: Bacteriological analysis of water samples at Damietta branch

Stations	Autumn	Winter	Spring	Summer	Mean	Maximum	Minimum
TVBC at 22°C×10³ (CFU mL⁻¹)							
1D	4.0	0.0	200.0	4.0	52.0	200.0	0.0
2D	1.0	10.0	177.0	3.0	47.8	177.0	1.0
3D	4.0	7.2	96.0	24.0	32.8	96.0	4.0
4D	1.0	9.9	110.0	115.0	58.9	115.0	1.0
5D	2.0	6.2	100.0	38.0	36.6	100.0	2.0
Mean	2.4	6.7	136.6	36.8			
Maximum	4.0	10.0	200.0	115.0			
Minimum	1.0	0.0	96.0	3.0			
TVBC at 37°C×10³ (CFU mL⁻¹)							
1D	2.0	17.0	17.0	3.0	9.8	17.0	2.0
2D	2.0	24.0	24.0	8.0	14.5	24.0	2.0
3D	3.0	124.0	124.0	14.0	66.3	124.0	3.0
4D	0.1	91.0	91.0	275.0	114.3	275.0	0.1
5D	9.0	25.0	25.0	11.0	17.5	25.0	9.0
Mean	3.2	56.2	56.2	62.2			
Maximum	9.0	124.0	124.0	275.0			
Minimum	0.1	17.0	17.0	3.0			
TC×10² (MPN /100 mL)							
1D	4.3	64.0	43.0	1.5	28.20	64.0	1.5
2D	15.0	4.0	9.0	1.1	7.275	15.0	1.1
3D	15.0	240.0	15.0	110.0	95.00	240.0	15.0
4D	21.0	4.0	7.0	460.0	123.00	460.0	4.0
5D	460.0	460.0	29.0	9.5	239.625	460.0	9.5
Mean	103.1	154.4	20.6	116.4			
Maximum	460.0	460.0	43.0	460.0			
Minimum	4.3	4.0	7.0	1.1			
FC×10² (MPN /100 mL)							
1D	0.9	ND	4.0	0.9	1.9	4.0	0.9
2D	0.7	4.0	ND	0.4	1.7	4.0	0.4
3D	2.1	7.0	21.0	2.1	8.1	21.0	2.1
4D	4.3	ND	4.0	9.3	5.9	9.3	4.0
5D	12.0	9.0	28.0	3.9	13.2	28.0	3.9
Mean	4.0	6.7	14.3	3.3			
Maximum	12.0	9.0	28.0	9.3			
Minimum	0.7	4.0	4.0	0.4			
FS×10² (MPN /100 mL)							
1D	4.3	11.0	460.0	93.0	142.1	460	4.3
2D	9.3	11.0	1100.0	7.5	282.0	1100	7.5
3D	4.3	9.0	2100.0	15.0	532.1	2100	4.3
4D	15.0	9.0	1500.0	110.0	408.5	1500	9.0
5D	110.0	150.0	1100.0	53.0	353.3	1100	53.0
Mean	28.6	38.0	1252.0	55.7			
Maximum	110.0	150.0	2100.0	110.0			
Minimum	4.3	9.0	460.0	7.5			
***E. coli* ×10² (CFU/100 mL)**							
1D	0.4	ND	2.0	0.5	1.0	2.0	0.4
2D	0.2	1.2	ND	0.3	0.6	1.2	0.2
3D	1.3	2.5	1.1	1.4	1.6	2.5	1.1
4D	2.2	ND	2.8	6.8	3.9	6.8	2.2
5D	4.5	5.3	1.4	2.4	3.4	5.3	1.4
Mean	1.7	3.0	1.8	2.3			
Maximum	4.5	5.3	2.8	6.8			
Minimum	0.2	1.2	1.1	0.3			

TVBC: Total viable bacterial count, TC: Total coliform, FC: Fecal coliform, FS: Fecal streptococci

spring at sites 5 and site 3 associated with the presence of *M. spicatum*, *P. cripus* and *M. spicatum*. However *E. coli* recorded their highest number at site 4 during summer associated with the presence of *M. spicatum* and *C. demersum*.

Several studies have shown reductions in the species richness of submerged and floating-leaved macrophyte communities with increasing nutrient levels[70,71]. The relation between macrophytes distribution and water physicochemical characteristics (Fig. 5b) shows that the existence of

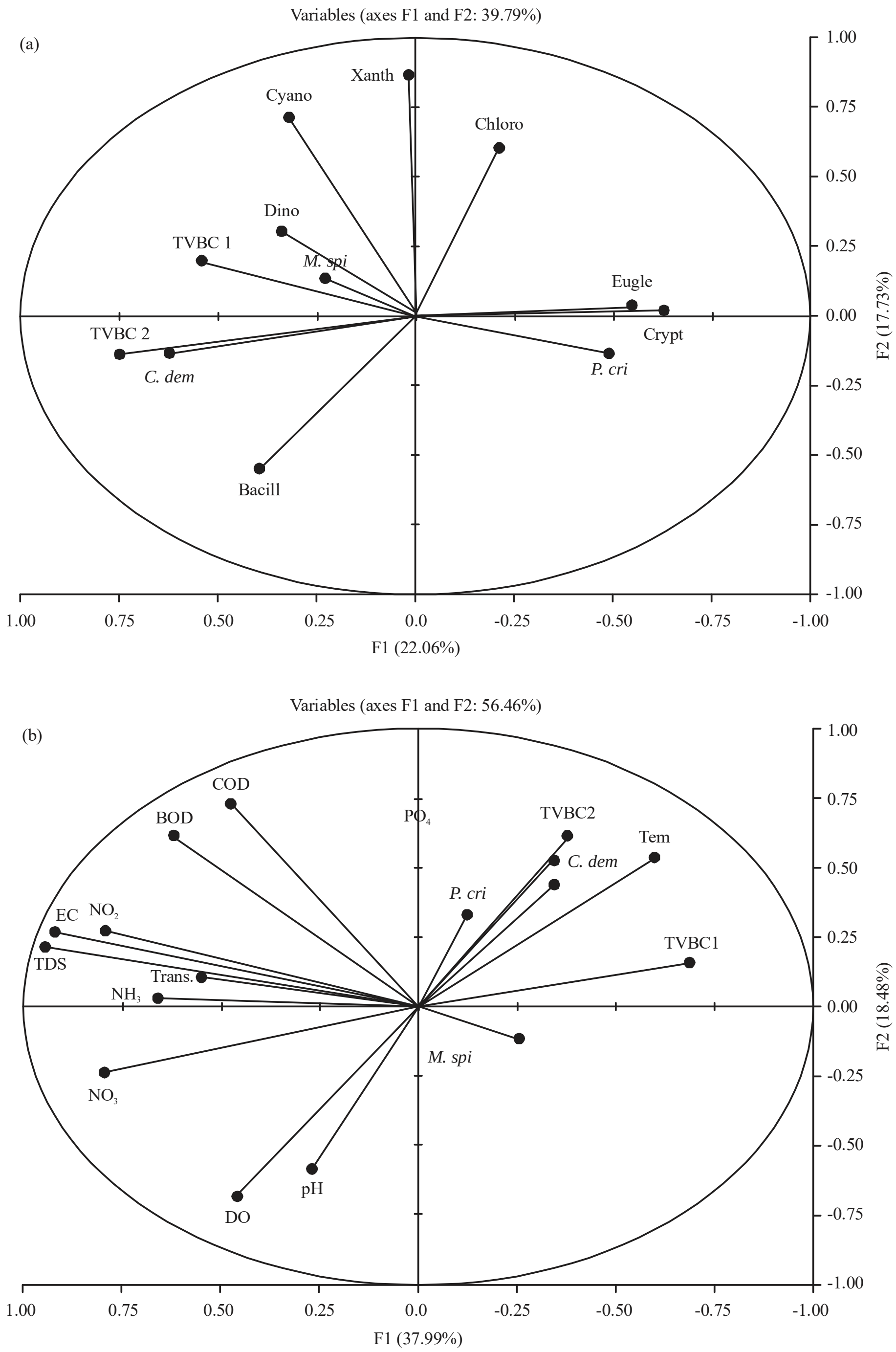

Fig. 5(a-b): (a-b) Principal component analysis (PCA) (Axis 1 and 2) performed on relation between submerged macrophytes, epiphytic algal classes, TVB°C at 22, 37°C and some water variables throughout the study period

M. spi: Myriophyllum spicatum, *P. cri: Potamogeton crispus*, *C. dem: Ceratophyllum demersum*, TVBC1:TVBC at 22°C, TVBC2: TVBC at 37°C, Bacill: Bacillariophyceae, Chloro: Chlorophyceae, Cyano: Cyanophyceae, Dino: Dinophyceae, Crypto: Cryptophyceae, Eugle: Euglenophyceae, Xanth: Xanthophyceae

submerged macrophytes species *M. spicatum* was associated with decreasing levels of EC, TDS, DO, BOD and nitrite (r = -0.314, -0.247, -0.230, -0.229 and -0.224, respectively) without any clear relation with water temperature which explain its appearance throughout the study period. The two other macrophytes species *C. demersum* and *P. crispus* were negatively correlated with some water variables like: Trans., pH, DO and NO_2, however,

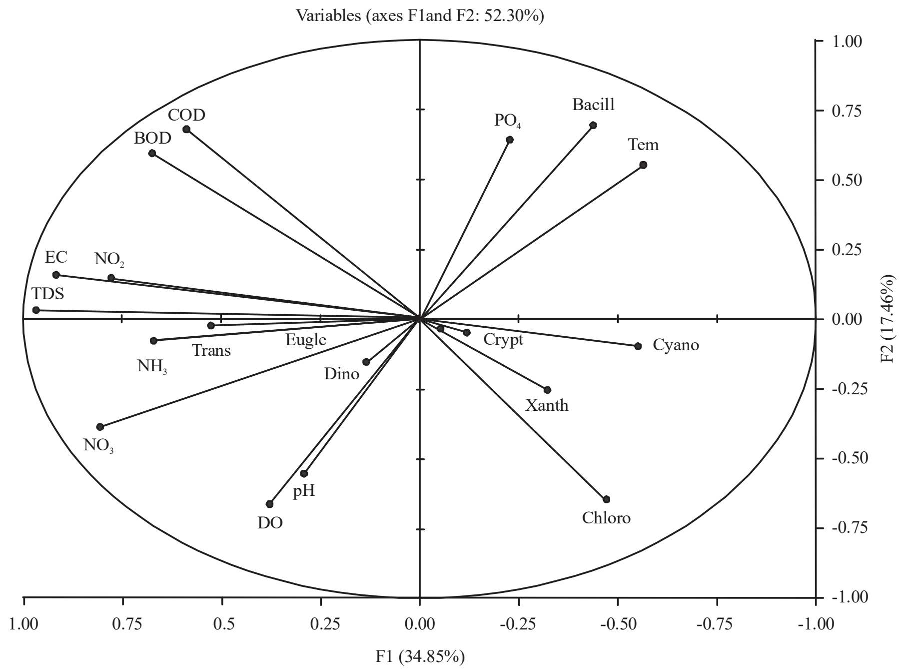

Fig. 6: Principal component analysis (PCA) (Axis 1 and 2) performed on different algal classes with different water variables
Bacill: Bacillariophycae, Chloro: Chlorophyceae, Cyano: Cyanophyceae, Dino: Dinophyceae, Crypto: Cryptophyceae, Eugle: Euglenophyceae, Xanth: Xanthophyceae

they were positively correlated with temperature which discussed the appearance of these 2 species during hot seasons only (spring and summer). Uedeme-Naa *et al.*[72] mentioned the presence of positive relation between aquatic macrophytes and water temperature, as the photosynthetic activity is increased by increasing of temperature.

Results in Fig. 2 and 5b show that, the lowest and the highest biomass production values of *P. crispus* were recorded in summer season at site 1 associated with the highest transparency, highest DO and low value of EC and low PO_4 and at site 3 associated with relatively low transparency and high values of NO_3, PO_4 and lowest DO respectively. This finding was supported by Li[73] he noted the ability of this species to tolerate wide ranges of water characteristics. Significance positive relation between the submerged recorded macrophytes species (*M. spicatum* and *C. demersum*) and water PO_4 was observed (Fig. 5b). This agrees with the results of other investigators, like Haroon and Hussian[31] they recorded a positive relation between *M. spicatum* and PO_4 and Frankouich *et al.*[74] they mentioned the correlation between macrophyte growth, distribution and nutrient rich environments especially nitrate and phosphate which have been noted to favour the growth of macrophytes. Moreover, the highest biomass production value of *C. demersum* at site 4 during summer associated with the relatively high values of TDS, NO_3, NH_3, PO_4 and low transparency indicate the ability of this species to survive in water of high nutrients. So and as recorded by Ali *et al.*[75] this plant could be regarded as nutrient tolerant hydrophyte.

Regarding the relation between water physicochemical characteristics and different algal classes (Fig. 6, Table 6). Bacillariophyceae and its dominant species were more affected by temperature and PO_4 ($r = 0.454$ and $r = 0.448$, respectively at $\alpha = 0.05$). At the same time it was negatively affected by TDS $r = -0.505$ and NO_3 $r = -0.689$. Chlorophyceae shows a significance negative relation with EC, TDS, BOD, COD and NO_2 (r = -0.573, -0.449, -0.640, -0.546 and -0.466, respectively). Cyanophyceae was negatively affected by water EC, TDS and NO3 (r =-0.503, -0.477 and -0.444, respectively) and Xanthophyceae was only affect by COD ($r = -0.471$). Different relations were observed between the dominant algal species, macrophytes and bacteria like: The significant positive relation between *M. spicatum* and *Pediastrum simplex* Meyen (0.456), *Cocconies placentula* Her and the submerged macrophytes species *C. demersum*, TVBC at 22, 37°C, Bacillariophyceae (0.628, 0.445, 0.750 and 0.693, respectively). In addition, the dominant algal species *Spirogyra* sp. and Microcystis aeruginosa Kützing were correlated with TVBC at 22°C and with cyanophyceae (Table 6).

Table 6: Simple linear correlation coefficient between the different macrophytes biomass, bacteria, different algal classes and dominant algal species

Variables	*M. spic*	*P. crispus*	*C. dem*	TVBC1	TVBC2	Bacill	Chloro	Cyano	Dino	Crypt	Eugle	Xanth	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
M. spic	1.00*																												
P. cri	-0.15	1.00*																											
C. dem	-0.21	-0.09	1.00*																										
TVBC1	0.41	-0.10	0.36	1.00*																									
TVBC2	0.00	-0.13	0.74*	0.32	1.00*																								
Bacill	0.21	0.22	0.20	0.21	0.38	1.00*																							
Chloro	0.19	-0.18	-0.06	0.28	-0.17	-0.44	1.00*																						
Cyano	0.02	0.00	0.05	0.23	0.31	-0.06	0.44	1.00*																					
Dino	-0.09	-0.18	0.27	0.15	0.29	-0.10	0.14	0.41	1.00*																				
Crypt	-0.08	0.36	-0.12	-0.13	-0.20	-0.22	-0.02	-0.12	0.12	1.00*																			
Eugle	-0.18	0.56*	-0.01	0.08	-0.06	-0.13	0.06	-0.05	0.06	0.85*	1.00*																		
Xanth	-0.02	0.26	-0.09	-0.17	-0.16	-0.18	0.40	0.46*	-0.17	-0.03	-0.01	1.00*																	
S1	-0.15	0.30	0.00	0.23	-0.12	0.36	0.02	-0.05	-0.33	-0.01	0.18	0.04	1.00*																
S2	-0.14	0.08	0.05	0.11	0.12	0.65*	-0.28	0.04	0.03	-0.18	-0.07	-0.21	0.69*	1.00*															
S3	0.10	0.15	0.63*	0.45*	0.75*	0.69*	-0.40	0.19	0.03	-0.11	0.00	-0.19	0.13	0.31	1.00*														
S4	0.11	0.10	0.26	0.12	0.18	0.06	-0.14	-0.22	-0.24	-0.09	0.01	-0.10	-0.35	-0.40	0.26	1.00*													
S5	-0.14	0.11	-0.03	-0.11	-0.09	0.10	0.14	0.08	-0.25	-0.08	-0.07	0.38	-0.20	-0.31	0.03	0.08	1.00*												
S6	0.26	0.08	0.04	0.03	0.00	0.28	0.05	-0.13	-0.24	-0.01	-0.05	-0.04	-0.32	-0.31	0.25	0.39	0.73	1.00*											
S7	0.34	-0.11	-0.16	-0.11	-0.22	-0.16	0.21	-0.31	-0.28	0.03	-0.15	-0.13	-0.15	-0.26	-0.16	0.05	0.11	0.43	1.00*										
S8	0.46*	-0.12	-0.19	-0.11	-0.25	-0.09	0.06	-0.33	-0.18	0.14	-0.10	-0.15	-0.44*	-0.39	-0.16	0.37	0.15	0.56*	0.59*	1.00*									
S9	0.18	-0.18	0.15	0.01	-0.10	-0.16	0.14	-0.21	0.13	0.00	-0.12	-0.19	-0.30	-0.28	-0.15	-0.08	0.06	0.23	0.09	0.17	1.00*								
S10	-0.18	-0.15	0.08	-0.11	-0.04	-0.33	0.39	0.30	0.23	0.27	0.06	0.16	0.13	-0.03	-0.20	-0.44	-0.14	-0.27	-0.12	-0.03	0.33	1.00*							
S11	-0.13	-0.07	-0.16	-0.32	-0.24	-0.20	0.31	-0.19	-0.31	-0.17	-0.22	0.22	0.40	0.14	-0.41	-0.38	-0.06	-0.22	0.50*	-0.05	-0.18	0.23	1.00*						
S12	0.13	-0.03	-0.10	0.43	-0.12	-0.29	0.67*	0.22	0.01	-0.04	0.32	0.10	0.14	-0.08	-0.27	0.05	-0.07	-0.09	-0.03	-0.18	-0.10	-0.18	0.03	1.00*					
S13	0.02	-0.12	0.26	0.52*	0.26	-0.12	0.52*	0.62*	0.44	-0.11	0.00	-0.12	0.05	-0.03	0.21	0.00	-0.17	-0.07	-0.14	-0.15	0.13	0.43	-0.21	0.34	1.00*				
S14	0.01	0.12	-0.08	-0.15	-0.14	-0.22	0.44	0.47*	-0.15	-0.08	-0.10	0.99*	-0.01	-0.23	-0.21	-0.11	0.37	-0.05	-0.11	-0.13	-0.16	0.19	0.24	0.10	-0.10	1.00*			
S15	-0.01	-0.05	-0.12	0.49*	0.10	-0.10	0.36	0.46*	0.01	0.02	0.26	-0.15	0.10	0.00	0.14	-0.04	0.03	0.03	-0.19	-0.22	-0.10	0.10	-0.28	0.58*	0.64*	-0.15	1.00*		
S16	-0.08	0.18	-0.13	-0.17	0.16	-0.10	0.22	0.79*	0.28	0.09	0.05	0.69*	-0.13	-0.03	0.03	-0.28	0.17	-0.17	-0.27	-0.26	-0.37	0.26	0.00	-0.05	0.11	0.68*	0.10	1.00*	
S17	0.18	0.01	-0.15	0.20	-0.23	-0.10	0.21	0.20	-0.19	-0.16	-0.20	0.65*	0.21	-0.04	-0.19	-0.33	0.27	-0.17	-0.22	-0.25	0.05	0.14	0.14	-0.01	-0.19	0.67*	-0.13	0.34	1.00*

*Values are different from 0 with a significance level " = 0.05, M. spi: Myriophyllum spicatum, P. cri: *Potamogeton crispus*, C. dem: *Ceratophyllum demersum*, TVBC1: TVBC at 22EC, TVBC2: TVBC2 at 37EC, Bacill: *Bacillariophycae*, Chloro: Chlorophyceae, Cyano: Cyanophyceae, Dino: Dinophyceae, Crypto: Cryptophycae, Eugle: Euglenophycae, Xanth: Xanthophycae, S1: *Syndra ulna* (Nitzsch) Ehr., S2: *Cyclotella ocellata* Pant, S3: *Cocconies placentula* Ehr., S4: *Melosira varians* C. A. Agradh, S5: *Melosira granulata* (Her.) Ralfs, S6: *Navicula lanceolata* Ehrenberg, S7: *Planktonema lauterbornii* Schmidle, S8: *Pediastrum simplex* Meyen, S9: *Dictosphaerium pulchellum* wood, S10: *Scenedesmus ecornis* (Ehrenberg) Chodat, S11: *Scenedesmus spinosas* Chodat, S12: *Scenedesmus quadricauda* (Turpin) Brébisson, S13: *Spirogyra* sp., S14: *Mougeotia* sp., S15: *Microcystis aeruginosa* Kützing, S16: *Lyngbya limnetica* Lemmermann, S17: *Cylindrospermopsis raciboroskii* Woloszynska

Physico-chemical analysis, macrophytes, epiphytic algal species and bacteria proved good integrated tools for reliable assessment of water quality of Damietta branch of Nile River (Fig. 5, 6, Table 6). As mentioned by Barbour *et al.*[76] epiphytic algae can be used as a good indicators of water quality and environmental changes due to their sensitivity to external sources of pollutions. Results of the present investigation show the presence of high organic pollution tolerant algal species; *Melosira granulate*, *Nitzschia palea*, *Synedra ulna Oscillatoria limosa*, *Microcystis aeruginosa* during summer season. Similar results were recorded by Ali and El Shehawy[77] they reported the presence of *Microcystis aeruginosa*, *Cyclotella* sp., *Melosira granulata* and *Nitzschia palea* along the study segment of the Nile River. In addition *Scendesmus* spp., which was known by its ability to grow in water polluted by heavy metals and can be used as an indicator of Eutrophication[78] was also observed in various sites of the studied area characterized by it is high levels of organic matter. Moreover the diatom species *Cocconeis placentula*, recorded by Toporowska *et al.*[79] as bio-indicator of slightly alkaline and meso-eutrophic water was recorded with high quantity at sites 3, 4 and 5.

The finding of this study suggested that the highest biomass production values of submerged macrophyte species *M. spicatium* and *C. demersum* during summer and spring at sites 4, 5 associated with the highest TVBC may indicate the presence of agricultural drainage sources of pollution at these areas. These findings are in accord with Ali and Soltan[80] they recorded that high dry weight standing crop values of *C. demersum* and *M. spicatum* may indicate the presence of agricultural drainage sources of pollution, while high value of *P. crispus* may indicate the presence of industrial source of pollution.

CONCLUSION

This study indicates that the distribution and species composition of submerged aquatic macrophytes, their epiphytic algae and bacterial indicators of pollution are affected by season, environmental characteristics of the study area as well as interaction between these aquatic organisms. In addition, Damietta Branch might be subjected to different sources of biological pollution specially in summer season and at El- Serw and Faraskour, that was confirmed by prevalence of some species of either submerged macrophytes (*M. spicatum*, *C. demersum* and *P. crispus*) pollution tolerant algal (*M. granulate*, *N. palea*, *S. ulna*, *O. limosa*, *M. aeruginosa*, *Scendesmus* spp. and *C. placentula*) and bacteria (total coliform and fecal coliform, streptococci and *Escherichia coli*) which were reported previously as biological indicators of pollution.

SIGNIFICANCE STATEMENT

This study discovered that, the distribution and species composition of submerged aquatic macrophytes, their epiphytic algae and different bacterial groups are affected by different environmental variables especially water quality. That can be beneficial for using these organisms as a good biological indicators of water pollution. In addition, the allelopathic interaction between these organisms, beside the ability of submerged macrophytes to absorb nutrients in large quantities may help the researchers to determine the most suitable ways that needed for utilizing these organisms in purposes of improving water quality.

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