International Journal of Ecology and Environmental Sciences 45 (1): 107-122, 2019
ISSN: 2320-5199 (Online)

Sensitivity of Submerged Aquatic Macrophytes and Their Epiphytic Microalgae to the Different Environmental Variables in River Nile, Egypt

Abd-Ellatif M. Hussian*[1] and Amany M. Haroon[2]

National Institute of Oceanography and Fisheries (NIOF), El Qanater Research Station, 101- El Kasr El Aini St., Cairo, Egypt

E-Mail: [1] abdellatif_elgoaabar@yahoo.com; [2] amanyharoon30@yahoo.com
*Corresponding author

ABSTRACT

This paper examines the difference in distribution, abundance and species composition of the submerged aquatic macrophytes and their epiphytic microalgae in relation to the environmental variables along the River Nile from Aswan High Dam to Al Kanater Al-El-Khayria during hot and cold seasons (summer and winter) 2017. A total of 200 epiphytic microalgal species related to 72 genera and 6 classes were identified on the recorded aquatic plants (*Myriophyllum spicatum* L., *Ceratophyllum demersum* L., *Potamogeton crispus, Potamogeton perfoliatus* L. and *Potamogeton pectinatus* L.). There were major differences in community structure between the two seasons, in addition to the highest diversity in hot season. Among the recorded macrophytes species *Myriophyllum spicatum* was the most frequent (observed in P =80% and 86.7% of the samples collected during the cold and hot seasons, respectively). It represented 62% of the total submerged macrophytes standing crop. The phytochemical screening revealed the presence of some biologically active substances in the macrophytes. Bacillariophyceae were the dominant algal group (92.3%) on all aquatic macrophytes, with 119 taxa related to 31 genera. The dominant epiphytic algal species of *Cocconies placentula*, *Cyclotela occellata, Synedra ulna*, *Scenedesmus ecornis, S. quadricauda*, *Lyngbya limnetica* and *Microcystis aeruginosa* were found on all types of the investigated aquatic plants in all habitats during the two seasons. PCA showed the selectivity between epiphytes and macrophytes, where Bacillariophyceae and Chlorophyceae were more associated with *Ceratophyllum demersum* and *Myriophyllum spicatum* (r=0.7 and 0.6, respectively) in hot season. However, Cyanophyceae was more abundant on *Myriophyllum spicatum* (r=0.7) in cold season. In addition, the interaction between epiphytes, macrophytes and environmental factors were observed.

Key Words: Epiphytic Microalgae; Aquatic Plants; Dominant Species; PCA; River Nile

INTRODUCTION

Aquatic macrophytes and epiphytic algae are a major constituent of aquatic ecosystems (Albay and Aykulu 2002). Epiphytic algae act as a source of food for invertebrates and fish in the coastal zone (Abe et al. 2007) and their presence was dependent on aquatic macrophytes as a host (Cattaneo et al. 1998). Macrophytes perform many ecosystem functions and contribute to the general fitness and diversity of a healthy aquatic ecosystem (Madsen et al. 2001), bioindicators of environmental conditions, provide suitable habitats for macroinvertebrates, insects, fish, and other aquatic or semiaquatic organisms. They also aid in the anchoring of soft bottom sediments, removing suspended particles and nutrients from the water column and affect the long-term ecological changes in water quality (Madsen et al. 1996, Madsen et al. 2001, Bernot et al. 2006 and Lacoul and Freedman 2006). Aquatic plants environment and specific architecture of plants may also effect on the growth of epiphytic algae (Vis et al. 2006), in addition to some abiotic factors, e.g. the quantity of nutrients in the environment (Frankovich et al. 2006), light regime (Muller 1995), water contamination (Olmsted and

Gomez 1995), the disturbance of water by rain and wind (Paul and Hopson 1997), and seasonal variations (Goldsborough and Hickman 1991). On the other hand, the epiphytic algae can reduce macrophytes production and their growth by taking of nutrients faster than macrophytes (Pelton et al. 1998) and by their shading effect (Takashi et al. 2004). The association between macrophytes as a host plants and attached algae in the natural environment are still incompletely understood (Buczko 2007). A lot of plant substrata are extremely active in their physical characteristics and their chemical association with attached flora (Wetzel 1983). During growth and decay, aquatic macrophytes release dissolved organic matter. An unknown fraction of this dissolved organic matter consists of biochemically active allelochemicals (Perez and Sommaruga 2006) which are chemically diverse secondary plant metabolites and exert multifunctional properties (Einhellig 1995). When these substances are released into the water, they can inhibit the growth of epiphytes (Kufel et al. 2007) and thereby provide a competitive advantage for the struggle of light, because they reduce the shading effect of phytoplankton up on the macrophytes. The allelopathic effect of some common submerged macrophytes e.g. *Ceratophyllum demersum*, *Elodea* sp., *Myriophyllum* sp., *Najas marina* and *Stratiotes aloides* had been confirmed by Mulderij et al. (2005), Haroon and Abdel all (2016) and El-Sheekh et al. (2018).

Therefore, the present paper describes briefly the floristic status of the submerged aquatic macrophytes and their epiphytic microalgae, local variations, distribution and abundance at different stations and seasons, as well as their allelopathic interaction and their relations to the environmental conditions in River Nile, Egypt.

MATERIALS AND METHODS

Study Area

River Nile is the longest river in the world (6,650 km) and the most important natural feature of Egypt. It is the main source of fresh water, fish production and fertility of agricultural lands (Fishar and Williams 2008). The topographical and hydrological characters of River Nile have been exhaustively presented by many authors (El-Gohary 1989 and Belal 2012). Our study covered the River Nile from Aswan High Dam northward to El-Kanater El-Khayria, Cairo, for a distance of about 920 km. Nile flows northward in a relatively narrow flat-bottomed groove until reaching Cairo. This region belongs to the arid region of North Africa which is generally characterized by hot summer and fresher cold winter with low rainfall (Ahmed and Fawzi 2009). The river extends from latitude 4°S to latitude 31°N (Abu-Zeid 1995). The river banks are sedimentary and muddy whilst the midstream is more erosional with a coarse sandy substrate. A rocky substrate occurs immediately downstream of the Aswan High Dam, followed by coarse sand and eventually a mud substrate immediately above the Al Kanater El-Khayria (Fishar et al. 2006).

Sampling Stations

A total of fifteen sites were selected along the River Nile (Figure 1). Sampling was designed to cover the whole of study area during cold and hot seasons (winter and summer 2017).

Table 1. Sampling locations and their positions at the River Nile from Aswan to Cairo

Site .	Location	Latitude, N	Longitude, E
N1	Kima	24º 09′ 09.5″	32º 52′ 57.6″
N2	Kom Umbu	24º 25′ 25.8″	32º 56′ 18″
N3	Al Kajui	24º 41′ 6.8″	32º 54′ 59.7″
N4	Edfu	24º 58′ 42.9″	32º 52′ 55.3″
N5	Esna	25º 13′ 34″	32º 38′ 57.2″
N6	Armant	25º 35′ 16.1″	32º 30′ 33.1″
N7	Luxorin	25º 50′ 29.2″	32º 46′ 19.6″
N8	Dishna	26º 09′ 00.9″	32º 42′ 6.3″
N9	Naja Hammady	26º 08′ 45.9″	32º 10′ 42.9″
N10	Al Balyana	26º 13′ 39.8″	32º 00′ 22.2″
N11	Sohag	26º 33′ 35.3″	31º 42′ 29.4″
N12	Assuit	27º 10′ 50.7″	31º 11′ 42.3″
N13	Al Qusiyyah	27º 23′ 28.1″	30º 55′ 19.2″
N14	Matay	28º 24′ 15.5″	30º 48′ 17.4″
N15	Al-Kanater El-Khayria	30º 10′ 25″	31º 08′ 20″

Sample Processing

Macrophytes and epiphytes collection and identification At each site, submerged macrophytes were harvested by carefully removing individuals from substrate using quadrats (50×50 cm) and placed in plastic bags in a dark cooler place. Processing of plant samples never exceeded 4 hr from collection time. In the laboratory plants of each

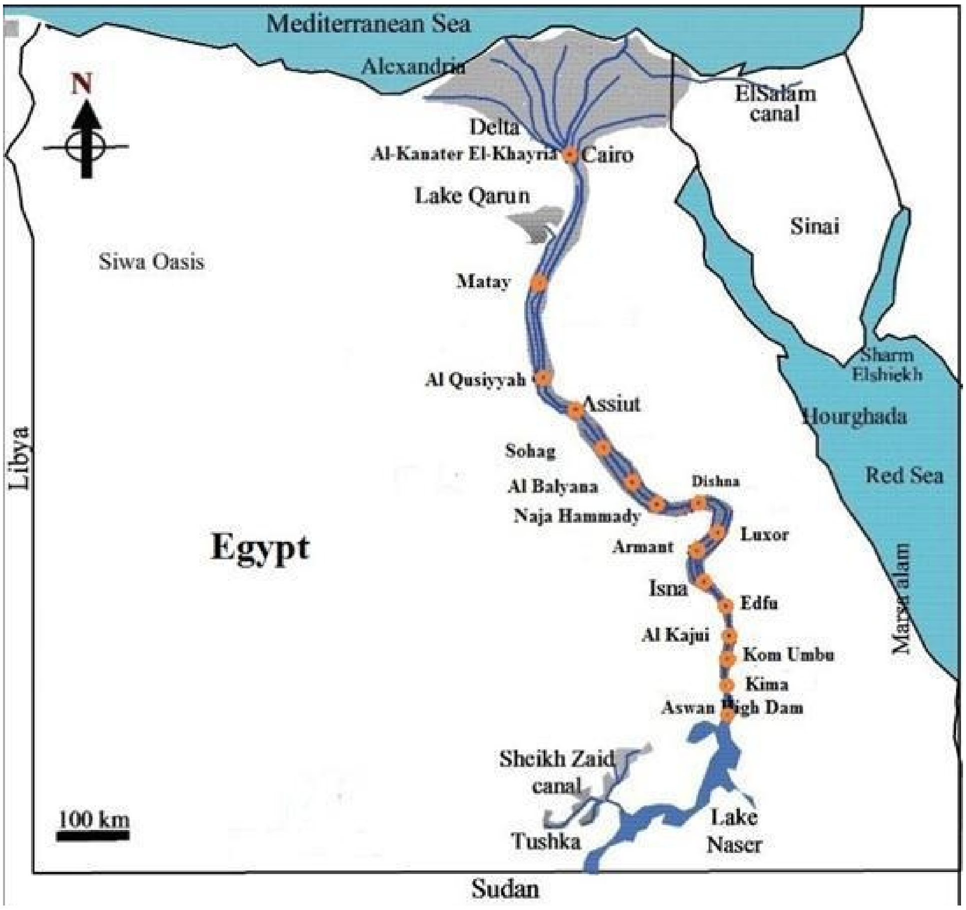

Figure 1. Map of river Nile and sampling locations

quadrat were weighed for estimation of their biomass production and identified based on Täckholm (1974) and Boulos (1999).

For epiphytes collection, a definite weight of submerged macrophytes of each quadrat was placed in plastic bottles. Deionized water (100 mL) was used to rinse each plant, and then the bottle was capped and manually shaken for 10 seconds. Host plant materials was removed from the epiphytic slurry and placed in second bottles. Deionized water (100 mL) was again added and the bottle shaken for an additional 10 seconds. Host plant was removed and the first and the second epiphyte slurry were collected. Lugol's iodine solution was added for preservation and then the volume (500 mL) was concentrated to 50 mL for taxonomic enumeration. Species identification and counting were performed in an inverted light microscope (Zeiss, Axiovert 25C) at 10X· eyepiece and 400X· objectives. Identification of the algal species was carried out according to Bourrelly (1968, 1970), Prescott (1978), Philipose (1967), Hindak et al. (1975) and Cox (1996).

Quantitative Study of Vegetation

The standing crop of the macrophytes was obtained following (Misra 1968) and the results were expressed as g wet weight m^{-2} (g ww m^{-2}). After removing the epiphytic algae, the fresh plants were divided into two parts: one of them was dried at 100 °C for estimation of biomass as g dry weight m^{-2} (g dw m^{-2}), while the other part was dried at 60°C to constant weight, ground to fine powder and preserved in well stoppered sample vessels for chemical analysis.

Frequency (percent presence) of plants was calculated from the number of quadrats of occurrence for a species and the total number of quadrats sampled.

Preliminary phytochemical screening for some biologically active substances was done following the methodology of Kokate (2001).

Statistical Analysis

Pearson's Correlation Analysis was performed to evaluate the relationships between environmental variables, submerged aquatic macrophytes and their epiphytic microalgae (dominant species). The data recorded in this study were subjected to principal component analysis (PCA) in order to relate submerged aquatic macrophytes with epiphytic microalgae and their dominant species to the abiotic variables under study, using XL Stat (2016) program.

RESULTS AND DISCUSSION

Vegetation Surveys

Zahran (2009) recorded a total of 21 submerged macrophyte species, dominated by 8 species, in the river Nile as a whole. However, El-Amier et al. (2015) recorded only three submerged macrophytes in Damietta Branch, River Nile, and Haroon and Hussian, (2017) recorded two submerged macrophytes in El-Rayah Al-Behery, River Nile. Data of the present investigation (Table, 2) revealed existence of only five submerged macrophyte species related to three genera. This variation in species numbers could be related to the variation in sampling sites, environmental conditions, as well as the effect of human impact on water bodies. In the cold season, *Myriophyllum spicatum* (northern water-milfoil), *Ceratophyllum demersum* (coontail) and *Potamogeton perfoliatus* were the only recorded species. *Myriophyllum spicatum* was the most frequent species observed in 80% of the samples collected, followed by *P. perfoliatus* and *C. demersum* (P =33.33 and 20% for the two species respectively. There were geographical differences in species distribution where, *M. spicatum* was found alone in seven sites, however it was found associated with *C. demersum* in two sites and with *P. perfoliatus* in three sites (Table 3). During the vegetation survey on hot season, five submerged macrophytes species were recorded (Table 3). Like in cold season, *M. spicatum* was the most dominant and well represented species followed by *P. perfoliatus* and *C. demersum* (P =86.7, 46.7 and 20% for the three species respectively. However *P. crispus* was recorded in only two sites (P =13.3%) and *P. pectinatus* was recorded in one site N7 (P = 6.7%). The standing crop data (Table 3) of the collected submerged macrophytes from different sites within the study area showed a considerable seasonal and spatial variation. During the whole study period *M. spicatum* showed a continuous dominance reaching a peak standing crop during the cold season (66.0 kg ww m^{-2}) at site N2. The annual mean standing crop value of *C. demersum* fluctuated from 30.37± 2.75 kg ww.m^{-2} in cold season to 22.56 ±9.85 kg ww.m^{-2} in hot season, for the three *Potamogeton* species the annual mean standing crop values ranged from 41.25± 6.04 kg ww.m^{-2} for *P. perfoliatus* to 3.59 ±2.20 and 2.2 ±0.00 kg ww.m^{-2} for *P. crispus* and *P. pectinatus*, respectively.

As shown in Figure 2, in River Nile there were a major differences in community structure between the two seasons. *M. spicatum* was the most abundant species making up 69% and 54% of the total standing submerged macrophytes crop in cold and hot season respectively, with the highest productivity during cold season. In contrast *P. perfoliatus* was more abundance in hot season rather than cold season (p =27 and 16% for the two season respectively. Throughout the study period about 62% of the total submerged macrophytes standing crop was made up of *M. spicatum;* however 38% was made up of the other species. In addition to some species like *P. crispus* and *P. pectinatus* were very rare andshowed affinity to one season than the other season.

The Phytochemical screening for the tested plants (Table 4) revealed the presence of some important and active substances (flavonoids, sterols, glycosides, carbohydrates, tannins, mucilage, saponins, terpenes and alkaloids) with a few exceptions , where saponins were absent from *C. demersum* and terpenes and flavonoids were absent from *P. pectinatus*. This is coming in agreement with some authors like Haroon (2006), Fareed et al. (2008), Haroon and Abd el all (2016) and El-Sheekh et al. (2017).

Table 2. Species of aquatic macrophytes recorded in the studied area.

Scientific name	Species Code	Life Span	Life Form	Family
Dicotyledons				
Myriophyllum spicatum L.	*M. spi*	Per.	Hy	Haloragaceae
Ceratophyllum demersum	*C. dem*	Per.	Hy	Ceratophyllaceae
Monocotyledons				
Potamogeton perfoliatus	*P. per*	Per.	Hy	Potamogetonaceae
Potamogeton crispus	*P. cri*	Per.	Hy	Potamogetonaceae
Potamogeton pectinatus	*P. pec*	Per.	Hy	Potamogetonaceae

Abbreviations: Per. = Perennial; Hy = Hydrophyte

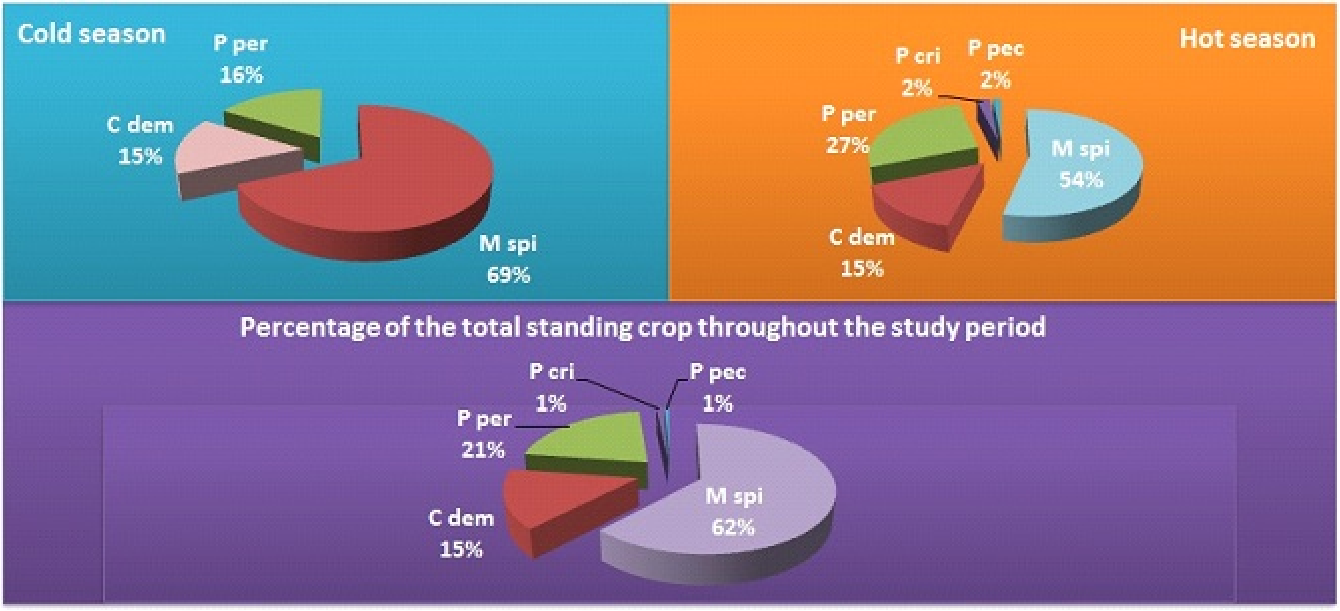

Figure 2. Percentage of each macrophyte species in the total macrophyte standing crop during the study period.

Table 3. Mean values of submerged macrophytic standing crop (g. m^{-2} ww and g .m^{-2} dw) in the River Nile sites.

Sites	Cold season						Hot season									
	M. spicatum		*C. demersum*		*P. perfoliatus*		*M. spicatum*		*C. demersum*		*P. perfoliatus*		*P. crispus*		*P. pectinatus.*	
	ww	dw	ww	dw	ww	dw	ww	dw	ww	dw	ww	dw	ww	dw	ww	dw
N1	12170	2010	-	-	-	-	2161.88	353.75	-	-	-	-	-	-	-	-
N2	66000	7219	5792	435.68	-	-	3891.875	700.13	-	-	2691.88	378.125	239.38	33.94	-	-
N3	14840	1478	-	-	-	-	2447.5	376.06	-	-	93.75	7.5	3348.75	390.13	-	-
N4	-	-	14247.5	872.5	-	-	4187.5	601.44	-	-	-	-	-	-	-	-
N5	8697.5	852.5	10328.25	1302.5	-	-	-	-	18846	2273.75	-	-	-	-	-	-
N6	5370	538	-	-	4600	585	20195	3620	-	-	-	-	-	-	-	-
N7	4040	478	-	-	-	-	790.13	114.88	-	-	1078.75	155.5			2201.25	301.25
N8	3704	470.56	-	-	6728	708.16	717.69	115	-	-	6337.69	715.63	-	-	-	-
N9	5070.4	509.6	-	-	-	-	6141.75	1032.5	-	-	10020	1266.25	-	-	-	-
N10	-	-	-	-	1165.2	201.8	-	-	-	-	17292.25	2387.5	-	-	-	-
N11	4517.5	623.75	-	-	4652.8	616	6687.5	755.25	-	-	-	-	-	-	-	-
N12	-	-	-	-	15920	2096.5	4112.5	563.25	1006.25	134.5	3736.25	438.94	-	-	-	-
N13	4037.5	561.25	-	-	-	-	4198	482.5	2708.125	329.63	-	-	-	-	-	-
N14	3595	526.5	-	-	-	-	12288	1650.24	-	-	-	-	-	-	-	-
N15	6075.5	754.25	-	-	-	-	13731.84	2080	-	-	-	-	-	-	-	-
MA	138.12±17.53	16.02±1.91	30.37±2.75	2.61±1.51	33.07±3.42	4.21±2.04	77.36±5.97	11.84±1.02	22.56±9.85	2.74±1.18	41.25±6.04	5.35±0.83	3.59±2.20	0.42±0.25	2.2±0.00	0.3±0.00
NS	12		3		5		13		3		7		2		1	
P%	80		20		33.33		86.7		20		46.7		13.3		6.7	

Abbreviations: M = *Myriophyllum*; C= *Ceratophyllum*; P= *Potamogeton*; MA= Mean annual values (expressed as Kg.m−2); NS = Number of sites in which the plants was recorded; P% = Presence percentage; ww= wet weight and dw= dry weight.

Table 4. A preliminary phytochemical screening of the collected macrophytes species.

Tested substances	*Myrio. spicatum*	*Cerato. demersum*	*Potam. perfoliatus*	*Potam. crispus*	*Potam. pectinatus*
Flavonoids	+++	++	+	+++	-
Sterols	+++	++	++	+	+
Glycosides	++	++	+	++	++
Carbohydrates	++	++	+	++	++
Tannins	++	+	+	+	+
Mucilage	++	+	+	++	+
Saponins	++	-	+	+	+
Terpenes	++	+	+	+++	-
Alkaloids	+++	++	++	++	+

Epiphytic Algae

Epiphytic microalgae on different aquatic plants included a total of 200 species related to 72 genera during the hot and cold seasons as shown in Table 5.

During study period, diatoms were the dominant group (92.3%) on all aquatic macrophytes, with 119 taxa related to 31 genera in the epiphytic community. Chlorophyta (6.5%) and Cyanophyta (0.9%) were the other main groups in the epiphytic flora, 47 species of 22 genera belonging to Chlorophyta. Whereas, 25 species of 14 genera belonging to Cyanophyta. These results agreed with Ahmed (2010), Salman et al. (2013) and Fawzy (2016. In addition to, diversity index values of epiphytic diatoms were mostly higher than green and blue-green algae coincided with Konsowa (2007).

Dinophyta, Euglenophyta and Cryptophyta were the smallest groups and represented only 0.3% of epiphytic algae. There were 4 species of two genera of Dinophyta, two species of one genus of Euglenophyta and 3 species of two genera belonging to Cryptophyta. This result in accordance with Dere et al. (2002) and Albay and Aykulu (2002).

Epiphytic Algal Standing Crop

The highest total algal counts expressed as cells were 4035×10^5 cell g^{-1} plant wet wt. recorded in cold season at site N13, while the lowest count was 101×10^5 cell g^{-1} plant wet wt. recorded in hot season at site N11 (Figure 3). The variation in the total number of epiphytic microalgal species during study period may be due to several factors such as plant growth period, chemical and physical factors (Dere et al. 2002). In general, the density and distribution of epiphytic microalgae in Nile River were dependent on the variation of pH, nutrient, transparency of water and temperature (Aboellil and Aboellil 2012), and variation in the host plants, sites and seasons (Adam et al. 2017).

Temporal and Spatial Distribution of the Dominant Epiphytic Algae

Through the entire period of study, it was observed that the attached species of diatoms (mainly *Cocconies placentula*, *Cyclotela occellata* and *Synedra ulna*) were widespread on all types of the investigated aquatic plants in all habitats. This result is in accordance with the observations of Ahmed (2010). Among Chlorophyceae and Cyanophyceae *Scenedesmus ecornis, S. quadricauda* and *Lyngbya limnetica* and *Microcystis aeruginosa*, respectively, were found on all types of the submerged aquatic plants during hot and cold seasons. During the hot season, the most dominant epiphytic algal group was Bacillariophyceae (Figure 4) represented by *Cocconies placentula* (21%), *Syndra ulna* (17%), *Gomphonema truncatum var. capitatum* (7%) and *Gomphonema olivaceum* (6%), while Cholorophyceae were dominated with *Oedogonium sp.* (29%), *Scenedesmus opoliensis* (15%) and *Dictosphaerium pulchellum* (10%). Cyanophyceae were dominated with *Lyngbya limnetica* (29%), *Microcystis aeruginosa* (15%) and *Lyngbya martensiana* (7%). Also, during the cold season, diatoms were the most dominant group (Figure 4) signified by *Cyclotella ocellata* (41%), *Syndra ulna* (23%) while Cholorophyceae were dominated with *Scenedesmus quadricauda* (24%), *S. ecornis* (23%), *Oedogonium* sp. (19%) and *S. spinosas* (10%). This result also agrees with Ahmed (2010). *Lyngbya limnetica* (18%), *Plankatolyngbya limnetica* (12%), *Microcystis aeruginosa* (9%), *Phormidium sp.* (9%) and *Oscillatoria chalybea* (8%) were dominant species of Cyanophyceae group. The highest diversity of algal species was observed in cold season. Many factors may affect the diversity and abundance of epiphytic algae such as the environmental conditions (Frankovich et al. 2006), biological factors such as grazing (Hillebrand et al. 2000), and physiological responses (Ruesink 1998), which may explain the succession of other groups on each host plant during the study period.

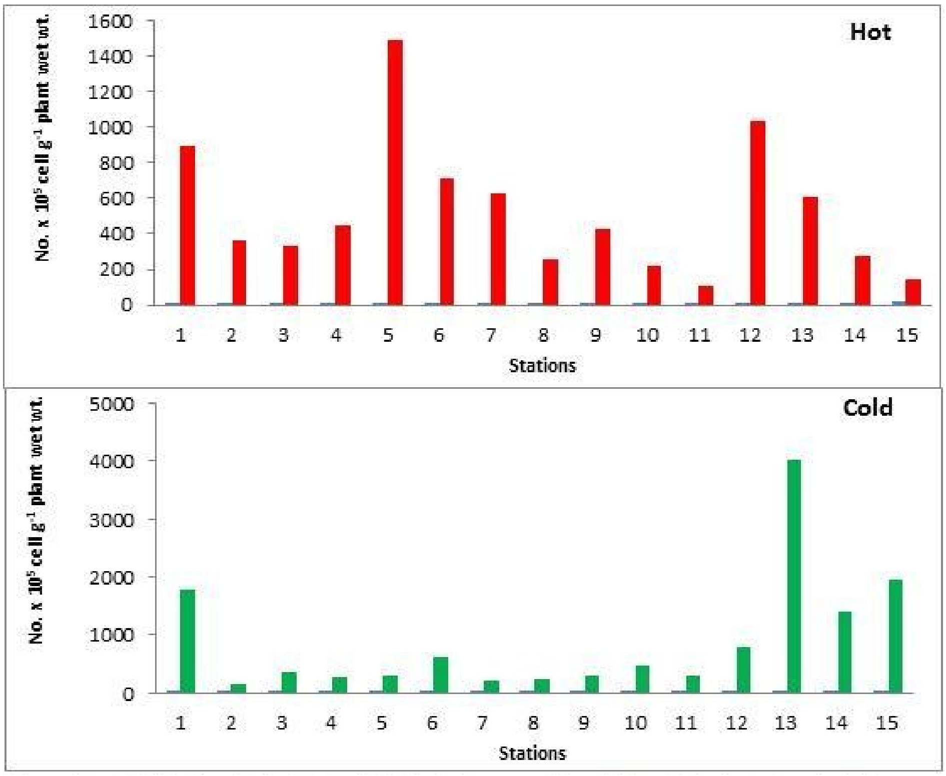

Figure 3. Distribution of the total epiphytic algal crop at the different sites in hot and cold seasons

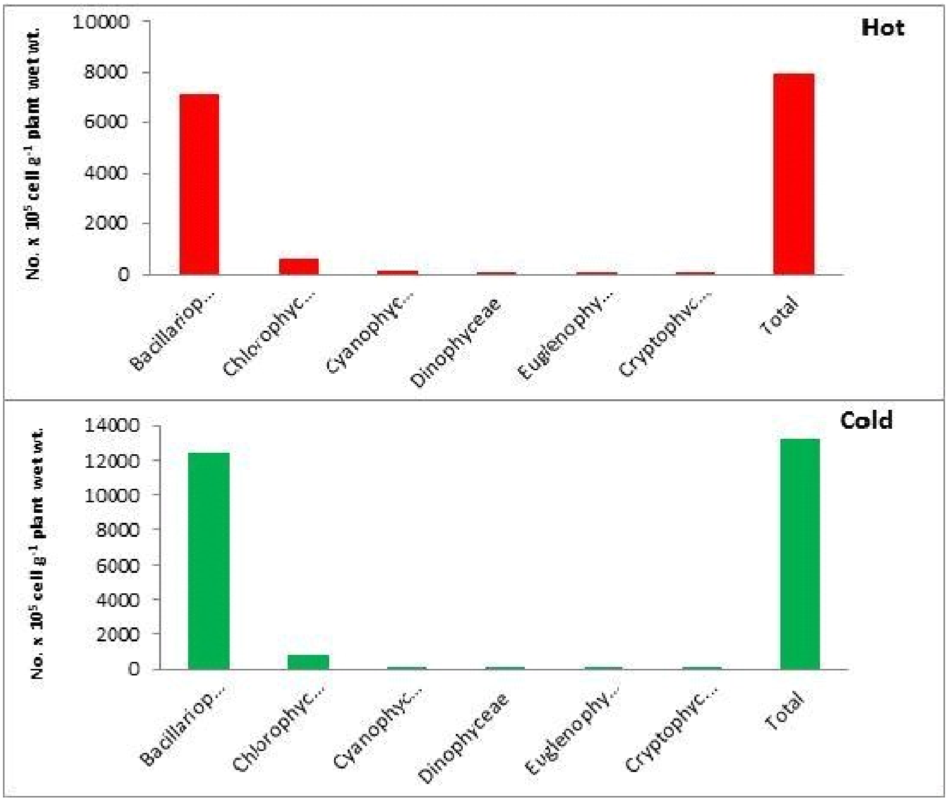

Figure 4: Total Epiphytic algal crop with classes' composition values in Hot and Cold seasons

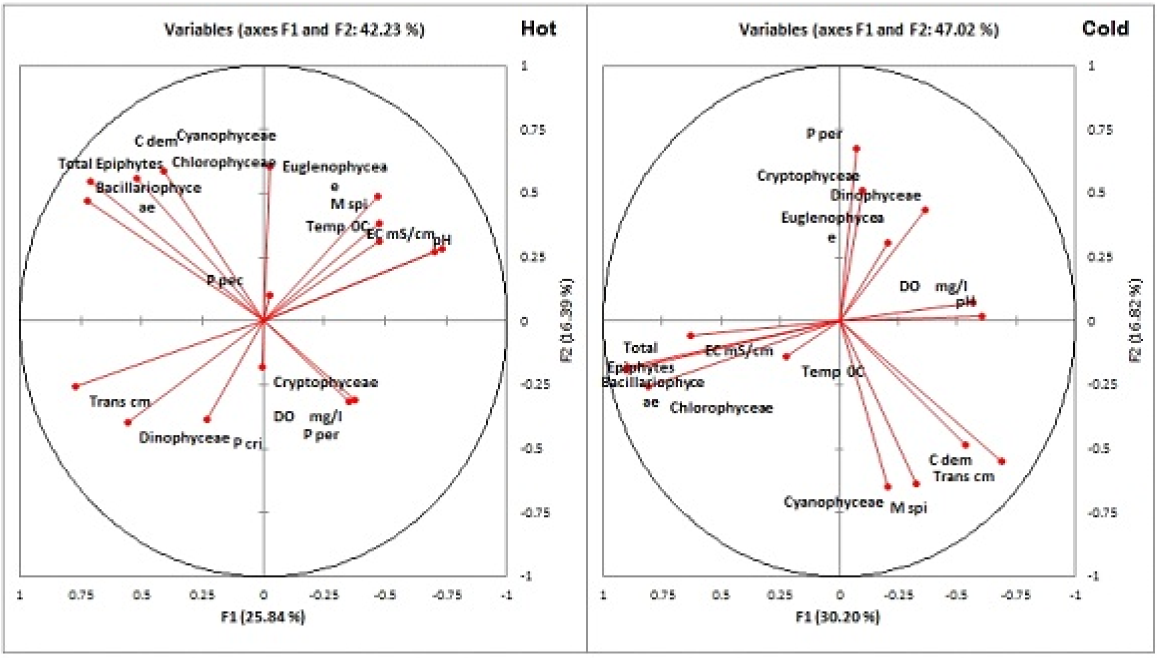

Figure 5. Principal component analysis (PCA) (Axis I and II) performed on epiphytic algae, submerged macrophytes and some environmental variables in hot and cold seasons.

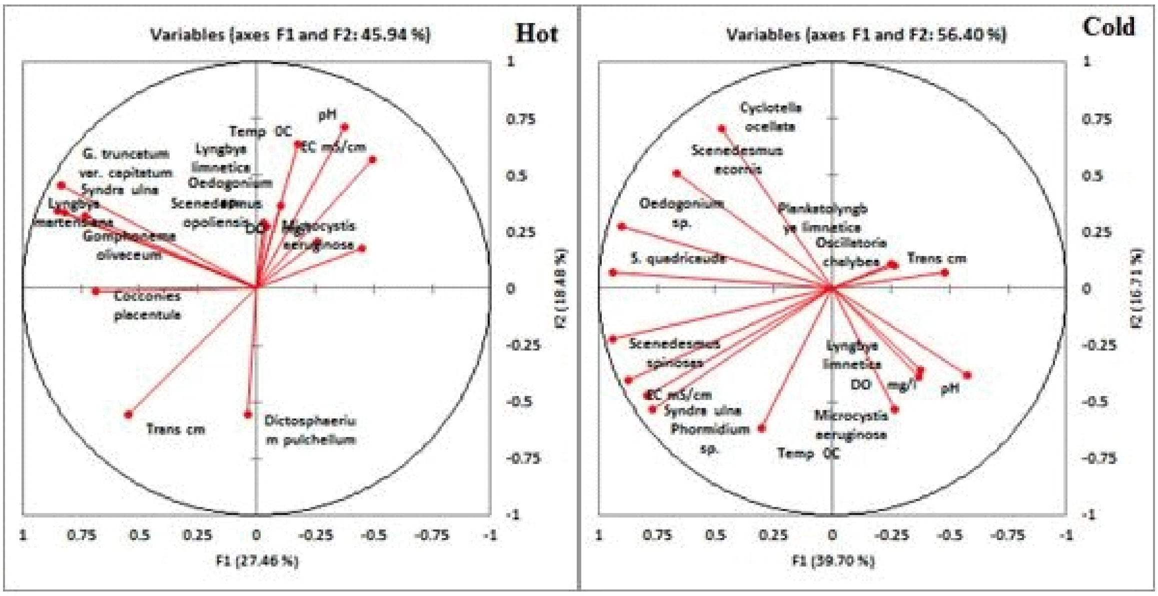

Figure 6. Principal component analysis (PCA) (Axis I and II) performed on dominant epiphytic algal species with some environmental variablesin hot and cold seasons.

Dominant Species on the Submerged Macrophytes

It was observed that, the high amount of diatom species (primarily *Cocconies placentula*, *Cyclotela occellata* and *Synedra ulna*) were found on M*yriophyllum spicatum*. While *Cocconies placentula* and *Synedra ulna* were more abundant on *Potamogeton perfoliatus.* Cyanophyta represented by *Lyngbya limnetica* and *Pseudanabaena galeata* were found on *Ceratophyllum demersum*. These are in accordance with Ahmed (2010). Really, there is no special role for epiphytes and there is a high controversy about the reason for selection of a definite host. Several authors stated different results. Patrick et al. (1968) found differences in the species composition as a function of host that represent the existence of selectivity between the host and the epiphytic microalgae species, but Sullivan (1984) found a similarity in the communities of epiphytic algae, signifying non-selectivity between the host and epiphytic algae. The current study recorded the highest number of epiphytic species (53 sp.) on M*yriophyllum spicatum* at site 1. This is similar to the report by Adam et al. (2017). The lowest number of species was 24. recorded on *Potamogeton perfoliatus* at site 10 (Table 2).This is may be attributed to temperature and photoperiod (Adam et al, 2017), as well as other factors such as water quality, type of host plant, and variation of nutrients (Kupferberg 2003).

Relationship Between Environmental Parameters, Macrophytes and Dominant Epiphytic Algae

The abundance and distribution of aquatic plants are influenced by many factors, like nutrients, water and sediment physicochemichal characteristics, water velocity, grazing animal, water depth and allelopathic interaction between macrophytes, phytoplankton and epiphytes (Van Donk and Otte 1996, Middelboe and Markager 1997 and Armengol et al. 2003). In our study the principal correspondence analysis (PCA) of the epiphytic algae, submerged macrophytes and water physicochemical parameters proposed that, the existence of *Myriophyllum spicatum*, *Potamogeton perfoliatus* and *Potamogeton pectinatus* during hot season were associated with increasing levels of of NO_2, pH and DO (r =0.5, 0.5 and 0.4 for the three species respectively). However, during cold season *Ceratophyllum demersum* was more associated with transparency (r =0.7). Relations between epiphytic microalgae and the host aquatic plant show the whole ecosystem character and the ecosystem responses to the altering environmental conditions (Liboriussen and Jeppesen 2003. There are some epiphytic algal classes closely correlated with some submerged macrophytes species (Figure 4). Bacillariophyceae and Chlorophyceae were more associated with *Ceratophyllum demersum* and M*yriophyllum spicatum* (r=0.7 and 0.6, respectively) in hot season. Cyanophyceae was more abundant on M*yriophyllum spicatum* (r=0.7) in cold season (Figure 5). Moreover, the selectivity between macrophytes and epiphytic microalgal species was observed (Figure 6). In hot season *Oedogonium sp*. and *Microcystis aeruginos*a were positively correlated with *M. spicatum* and *Gomphonema olivaceum*, *G. truncatum* and *Synedra ulna* with *C. demersum*. In cold season, *Oscillatoria chalybea* was associated with *C. demersum*.

Numerous studies have shown that macrophytes can successfully suppress or enhance the algal growth in nature and under experimental systems through releasing allelochemical substances (Gross et al. 2007, Haroon and Abdel-all 2016). So, the different interaction between macrophytic species and different epiphytic classes could be related to the effect of allelochemical substances secreted by these plants under different environmental conditions, in addition to the variation in morphological feature of the host plant as well as, the diverse effect of macrophytes in water physicochemical characteristics (Haroon and Daboor 2009).

The correlation analysis (Figure5) demonstrated significant relationships among Bacillariophyceae and total epiphytic algae (r=0.9) in hot and cold seasons. Bacillariophyceae was dominated with *Cocconies placentula* and *Cyclotella ocellata* in hot and cold seasons, respectively. Regarding the effect of water physicochemical characteristics (Figures 5 and 6), this group and its dominant species were more affected with transparency in hot season and temperature and EC in cold season. Chlorophyceae and its dominant species of *Oedogonium sp.* were positively associated with temperature and pH in hot season, while *Scenedesmus quadricauda* was completely associated with temperature (r=0.3) and EC (r=0.5) in cold season. Cyanophyceae was dominated with *Lyngbya limnetica* in hot and cold seasons. This result coincided with Albay and Akçaalan (2003) who reported that Cyanophyta have a wide range of tolerance to physical disturbance. Cyanophyceae and its dominant species were positively correlated with transparency, as well as effect of temperature on them in hot season and EC in cold season, as shown in Figure 6.

CONCLUSION

Investigation of submerged macrophytes and their epiphytic microalgae showed the variations in the distribution, abundance and diversity of the both macrophytes and their epiphytic microalgal communities with seasons and sampling sites. The allelopathic interaction between epiphytes and macrophytes, the morphological feature of the hosted macrophyte species and the environmental conditions at the study area, may be the main factors affecting these variations.

Table 5. Occurrence of algal taxa associated to the different aquatic plants in the studied sites during hot and cold seasons 2017.

Algal species	St. 1 M. spi	St. 2 M. spi C. dem P. per. P. cri	St. 3 M. spi P. per. P. cri	St. 4 M. spi C. dem	St. 5 M. spi C. dem	St. 6 M. spi P. per.	St. 7 M. spi P. pec. P. per.	St. 8 M. spi P. per.	St. 9 M. spi P. per.	St..10 P. per.	St.11 M. spi P. per.	St. 12 M. spi C. dem P. perf.	St. 13 M. spi C. dem	St. 14 M. spi	St. 15 M. spi
Bacillariophyceae															
Achnanthes brevipes C.Agardh					H										
Achnanthes lanceolata Breb.		H				H	C		H	H			H		H
Achnanthes minutissima Kützing	H		H	H&C	H&C		H&C	H	H	H	H&C	H	C	H&C	H
Aanthocerus zachariasii (Brun)Simonsen							H					C			
Amphora coffeiformis (C.Agardh) Kützing	H														
Amphora ovalis Kutz.	H				H										
Amphora laevis W.Gregory	H														
Bacillaria paradoxa J.F.Gmelin in Linnaeus					C		C		C						
Biddulphia laevis Ehrenberg					H					H					
Caloneis permagna (Bailey) Cleve				C											H
Cocconeis diminuta Pantocsek	H	H&C	C	C	C	C						H			
Cocconies placentula Ehr.	H&C	H&C	H	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C
Cocconeis placentula var. skvortzowii (Skv.)	H		H			C						H			
Cocconeis scutellum Ehrenberg		H			H			H					H		
Cyclotella bodanica Eulenstein ex Grunow	H														
Cyclotella glomerata Bachmann	H&C	C	H			C			H			C			
Cyclotella ocellata Pant	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H	H&C	H&C	H&C	H&C	H&C
Cyclotella operculata (Ag.) Kutz.			C				H							H	
Cyclotella meneghiniana Kutz.	H		C	C	C						H	H		H	
Cyclotella stelligera (Cleve & Grunow)					H							H			
Cymatopleura solea (Brébisson) W.Smith				C					H		H				
Cymbella affinis Kützing	H	H&C				H	C		H&C				H		
Cymbella amphicephala Näegeli				H	H										
Cymbella cistula (Hemprich) Grun		H&C	H	C	H&C	H	H&C	H&C	H&C	H	H&C	H	H&C	H&C	H
Cymbella microcephala Grunow	H													C	
Cymbella minuta Hilse in Rabenhorst			H				C	H	C			H		C	
Cymbella turgida W.Gregory	H	H	H	H							H		C	C	
Cymbella sp.		H													
Cymbella ventricosa (C.Agardh)				H											
Diploneis antiqua A.Cleve	H				H			H	H	H			H		H
Diploneis ovalis (Hilse) Cleve			H		H										
Eunotia sp.		H													
Epithemia argus (Ehrenberg) Kützing				H					H&C						
Epithemia proboscidea W.Smith				H											
Fragilaria construns (Ehr.) Grun	H	C	C	H&C	H&C	H	H&C	H&C	H&C	H&C	H&C	H	H&C	H&C	H&C
Fragilaria construns var. veneter (Ehr.)		C	H			H&C							H		
Fragilaria crotonensis Kitton		H					H								
Gomphonema olivaceum (Langb.)Kutz	H	H	H	H	H&C	H&C	H&C	H	H&C	H	H&C	C	H	H&C	H&C
Gomphonema bohemicum Reichelt et															
Gomphonema gracile Ehrenberg	H														
Gomphonema montanum (J.Schumann)	H				H								C	C	
Gomphonema parvulum var. lagenulum	H&C											H			
Gomphonema truncatum var. capitatum	H&C	H	H&C		H&C	H&C	H&C	H&C	H&C	H	H&C	H	H	H	H
Gomphonema ventricosum W.Gregory	H	H	H&C	H	H	H	H	H	H	H	H		H	H	H
Gyrosigma acuminatum (Kützing) Rabenhorst	C														
Lithodesmium sp.		H													
Mastogloia elliptica (C.Agardh) Cleve			H												
Mastogloia elliptica var. danseii (Thwaites)												H			
Mastogloia pumilla				C											H

Table 5. (Continued)

Algal species	St. 1 M. spi	St. 2 M. spi C. dem P. per. P. cri	St. 3 M. spi P. per. P. cri	St. 4 M. spi C. dem	St. 5 M. spi C. dem	St. 6 M. spi P. per.	St. 7 M. spi P. pec. P. per.	St. 8 M. spi P. per.	St. 9 M. spi P. per.	St..10 P. per.	St.11 M. spi P. per.	St. 12 M. spi C. dem P. perf.	St. 13 M. spi C. dem	St. 14 M. spi	St. 15 M. spi
Mastogloia smithii Thwaites ex W.Smith				C	C	C	C		C						
Mastogloia smithii var. lacustris Grunow														C	
Melosira granulata (Her.) Ralfs			C		H	H	H	H	H	H&C	H	C	H&C	C	
Melosira granulata var. angustissma Muller														H	
Melosira varians C. A. Agradh	H&C		H	C	C		H	C	C				C	C	
Melosira sp.															
Meridion circulare (Greville) C.Agardh			H						C						
Navicula angalica Ralfs		C										C			
Navicula cincta (Ehrenberg) Ralfs			H		H										
Navicula confervacea (Kützing) Grunow	H&C		H	C	H&C	C	H	C					C	C	C
Navicula cryptocephala Kutz	H	C	H	H	H		H	H	H		H	H	H	H&C	H
Navicula cryptocephala var. veneter (Kutz.)															
Navicula cryptocephala var. intermedia					H		H								
Navicula exigua (Gregory) O. Muller					H										
Navicula festiva Krasske		C	C	C				H					C	C	
Navicula helvetica (Brun)			H									H			
Navicula lanceolata Ehrenberg	H&C		C	C	H&C	C	C	C	C		C	H	C	H&C	C
Navicula luzonensis Hustedt	H			C		H						C	H		
Navicula pumilla					H										
Navicula pupula Grun		C			H		H						C	C	
Navicula rhyncocephala Kützing	H&C		H	C	H&C		H&C	H&C	H&C	H	H&C		H&C	H&C	
Navicula salinarum var.intermedia (Grunow)	H				H										
Navicula specula														H	
Navicula tuscula Ehrenberg															
Navicula vulpina Kützing	H				H		H								
Nitzschia acicularis W. Smith						C			H				C	C	
Nitzschia acula (Kützing) Hantzsch	C		H		H		H								
Nitzschia amphibian				C	C						C	H			
Nitzschia apiculata (W.Gregory) Grunow				H						C					
Nitzschia communis Rabenhorst						H							H		
Nitzschia filiformis (W.Smith) Van Heurck		C						C	H						
Nitzschia fonticola Grun.	H	C	H	H&C	H&C	H	H&C	H	H&C	H	H&C	H	H&C	H&C	H&C
Nitzschia frustulum (Kützing) Grunow					H										
Nitzschia dissipata (Kutz.) Grum					H		H								
N. gracilis Hantz				H									C	C	C
Nitzschia hantzschiana Rabenhorst															
N. holastica Hust.	H&C			H	H	H	H	H&C	H&C	H	H		H		
N. kutzingiana Hilse	C														
N. linearis W. Smith	C	C		H		H						H	C	C	
Nitzschia obtusa var. scalpelliformis				H	H			H							
N. palea (Kutz.) W. Smith	H&C		C	C	C	C	C					H	C	C	
N. paleacae Grum				C	C		H					C			
Nitzschia recta Hantzsch ex Rabenhorst									H		C				
Nitzschia sigmoidea (Nitzsch) W.Smith	H											C		H	
Nitzschia sublinearis Hustedt	H&C		H	H		H	H&C	H&C	H&C	H	H&C	H	H	H	H
Nitzschia subtilis (Kützing) Grunow															
Nitzschia thermalis (Ehrenberg) Auerswald					H		H								
Opephora martyi var. polymorpha Jouravleva	C														
Pleurosigma elongatum				C	H		H			C			C	C	
Rhoicosphenia curvata (Kützing) Grunow					H		H								
Rhopalodia musculus (Kützing) Otto Müller			H												
Stauroneis anceps Ehrenberg							H						H		

Table 5. (Continued)

Algal species	St. 1 M. spi	St. 2 M. spi C. dem P. per. P. cri	St. 3 M. spi P. per. P. cri	St. 4 M. spi C. dem	St. 5 M. spi C. dem	St. 6 M. spi P. per.	St. 7 M. spi P. pec. P. per.	St. 8 M. spi P. per.	St. 9 M. spi P. per.	St..10 P. per.	St.11 M. spi P. per.	St. 12 M. spi C. dem P. perf.	St. 13 M. spi C. dem	St. 14 M. spi	St. 15 M. spi
Stauroneis schroederi Hustedt								C			H				
Stephanodiscus astraea (Kützing) Grunow							H								
Suriirella obtusa var. splandida															
Suriirella ovalis				C	C										
Synedra actinastroides Lemmermann						H							C		
Syndra acus Kutz	C														
Synedra acus var. angustissima (Grunow)	C							H							
Synedra affinis Kützing															C
Synedra affinis var. fasciculata (Lyngbye)			H						C						
Synedra delicatissima W.Smith														H	
Synedra nana F.Meister															C
Synedra pulchella (Ralfs ex Kützing) Kützing		H							C			H			C
Synedra tabulata var. acuminata (Grunow)	C	H					C								
Syndra ulna (Nitzsch) Ehr.	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C	H&C
Synedra ulna var. biceps (Kützing)	C				H										C
Synedra ulna var. oxyrhynchus (Kützing)	H&C			C											C
Synedra ulna var. ramesi (Herib.) Hust.	H				H										
Triceratium sp.			H												
Chlorophyceae															
Ankistrodesmus falcatus (Corda) Ralfs				C	C		C								
Ankistrodesmus spiralis (Turner) Lemm.										H		C			
Ankistrodesmus nitzschioides G.S. West					H										
Closterium acutum Bredisson									H						
Closterium acutum var. variabile (Lem.)					C						C				
Closterium ceratium Perty						H									
Coelastrum reticulatum (P.A.Dangeard) Senn														H	
Cosmarium laeve var. distentum G.S.West			C												
Cosmarium punctulatum Brébisson														H	
Cosmarium sp.		C	C		H&C										
Dictyosphaerium planctonicum Tiffany								C			C				
Dictosphaerium pulchellum Wood				H					H		H				
Golekinia radiata Chodat			H												
Keratococcus suecicus Hindák												H	C		
Kirchneriella contorta (Schmidle) Bohlin				C										C	
Monoraphidium contortum Thuret					C	H					C	H	H		
Mougeotia sp.															
Nephrocytium limneticum															
Oedogonium sp.						H	H						H&C	C	C
Oocystis solitaria Wittrock		C							H						
Oocystis marssonii Lemmermann								C							
Oocystis parva W.&G.S. West											H				
Oocystis borgei Snow			H	H										H	H
Oocystis elliptica W. West							H								
Oocystis crassa Wittrocle		H						H		C		H	H		
Pediastrum tetras (Ehrenberg) Ralfs					C										
Planktonema lauterbornii Schmidle				H									C	C	
Quadrigula chodatii		C													
Scenedesmus opoliensis P.G.Richter			H			H		H				H	H		
Scenedesmus dimorphus (Turpin) Küzing															
Scenedesmus acuminatus (Lagerh.) Chodat					H	C				C					
Scenedesmus ecornis (Ehrenberg) Chodat					C		C	H&C	C		C		H&C	C	C

Table 5. (Continued)

Algal species	St. 1 M. spi	St. 2 M. spi C. dem P. per. P. cri	St. 3 M. spi P. per. P. cri	St. 4 M. spi C. dem	St. 5 M. spi C. dem	St. 6 M. spi P. per.	St. 7 M. spi P. pec. P. per.	St. 8 M. spi P. per.	St. 9 M. spi P. per.	St..10 P. per.	St.11 M. spi P. per.	St. 12 M. spi C. dem P. perf.	St. 13 M. spi C. dem	St. 14 M. spi	St. 15 M. spi
Scenedesmus bicudatus Dedusenko											H				
S. intermedius Chodat															
S. quadricauda (Turpin) Brébisson									H	C			C	H&C	H&C
S. protuberans Fritsch															
S. subspicatus Chodat															
Scenedesmus sempervirens Chodat								C							
Scenedesmus spinosas Chodat													C	C	C
Scenedesmus bijugatus (Turp.) Kutzing					H										
Schroederia setigera (Schröder) Lemmer.			C										C		
Staurastrum natator West				H		H	H						H		
Staurastrum paradoxum Meyen ex Ralfs				H	H		H	H					C	C	
Tetrachlorella alternes						H							H		
Tetraedron triangulare Korshikov						H							H		
Tetraedron minimum (A. Braun) Hansgirg													C	C	
Zygnema sp.							H								
Cyanophyceae															
Chroococcus dispersus (Keissler) Lemmer.		H&C		H											
Chroococcus minutus (Kützing) Nägeli					C								H		
Cyanothece sp.		C									H			C	
Cylindrospermopsis raciboroskii Woloszynska		C	H			H	H		H				H		
Gomphosphaeria aponina Kützing		H													
Gomphosphaeria compacta (Lammer.)		H											H		
Gloeocapsa montana Kützing		H	H		C				H						
Leptolyngbya perelegans (Lem.)		H				H							H		
Lyngbya limnetica Lemmermann		H	H&C	H	H&C	H	H&C	H&C	H&C		H&C		H		H
Lyngbya major Meneghini	C								H						
Lyngbya martensiana Meneghini ex Gomont					H										
Lyngbya profundalis Lindstedt			H	H			H								
Merismopedia elegans	H								H						
Microcystis aeruginosa Kützing	H			H		H&C	H&C	H	H&C		H&C		H	H	H
Microcystis reinboldii (Richter) Forti	H	H		H			H		H						
Oscillatoria chalybea Mertens ex Gomont				C							C				
Oscillatoria exospira Skuja	H														
Oscillatoria limnetica Lemmermann					H			H						C	
Oscillatoria peronata Skuja						H		C					H		H&C
Phormidium molle Gomont															
Phormidium sp.						C		H							C
Plankatolyngbya limnetica (Lemmermann)		C	H						C	H					
Pseudanabaena galeata Böcher				H	H		H								
Pseudanabaena papillaterminata (Kissler)															
Romeria victoriae Komarek &Cronberg				C	H										C
Dinophyceae															
Ceratium hirundinella (O. F. Müller) Dujardin	H														
Peridinium cinctum O.F.Muller	H			H					H						
Peridinium penardiforme Lindemann					C			C			C				
Peridinium sp.		H													
Euglenophyceae															
Phacus caudatus Huoner						H		H	H&C		H&C		H	H	H
Phacus pleuronectes (O.F.Müller)							H							H	

Table 5. (Continued)

Algal species	St. 1 M. spi	St. 2 M. spi C. dem P. per. P. cri	St. 3 M. spi P. per. P. cri	St. 4 M. spi C. dem	St. 5 M. spi C. dem	St. 6 M. spi P. per.	St. 7 M. spi P. pec. P. per.	St. 8 M. spi P. per.	St. 9 M. spi P. per.	St..10 P. per.	St.11 M. spi P. per.	St. 12 M. spi C. dem P. perf.	St. 13 M. spi C. dem	St. 14 M. spi	St. 15 M. spi
Cryptophyceae															
Chromonas acuta Utermohl								C							
Cryptomonas erosa Ehrenberg															H
Cryptomonas reflexa (M.Marsson) Skuja				H				H							
Number of taxa A25/ site	53	42	48	56	68	42	53	42	47	24	35	36	59	51	36

Abbreviations: H= Hot, C= Cold, macrophyte species codes listed in Table 2

ACKNOWLEDGEMENTS

We express our sincere thanks to Prof. Dr. Mohamed E. Goher, Head of Chemistry Lab and Dr. Seliem M. El-Sayed for providing laboratory assistance.

Author Contributions: The first author made the data collection, tabulation, interpretation of the data by statistical analysis and prepared the manuscript with the second author who participates in the laboratory work and writing of this research work.

REFERENCES

Abe, S.; Uchida, K.; Nagumo, T. and Tanaka, J. 2007. Alterations in the biomass-specific productivity of periphyton assemblages mediated by fish grazing, Freshwater Biology 8: 1486-493.

Aboellil, A. and Aboellil, A.H. 2012. Colonization abilities of microflora to attach aquatic plants. Global Journal of Science Frontier Research, Biological Sciences 12: 21-27.

Abu-Zeid, M.1995.The River Nile: Main Water Transfer Projects in Egypt and Impacts on Egyptian Agriculture. Water Research Centre Publication, Ministry of Irrigation, Cairo. 256 pages.

Adam, M.S.; Hifney, A.F.; Mustafa, A.; Fawzy, M.A.; Al-Badaani, A.A. 2017. Seasonal biodiversity and ecological studies on the epiphytic microalgae communities in polluted and unpolluted aquatic ecosystem at Assiut, Egypt, European Journal of Ecology 2: 92-106.

Ahmed, A. and Fawzi, A. 2009. Meandering and bank erosion of the River Nile and its environmental impact on the area between Sohag and El-Minia, Egypt. Arabian Journal of Geosciences 4: 1-11.

Ahmed, Z.A. 2010. Preliminary study on epiphytic microalgae on aquatic plants at Sohag District. Egyptian Journal of Phycology 11: 103-119.

Albay, M. and Akcaalan, R. 2003.Comparative study of periphyton colonization on common reed (*Phragmites australis*) and artificial substrate in a shallow lake, Manyas, Turkey. Hydrobiologia 1: 531-540.

Albay, M. and Aykulu, G. 2002. Invertebrate grazer-epiphytic algae interaction on submerged macrophytes in a mesotrophyic Turkish lake. E.U. Journal of Fisheries and Aquatic Sciences 19: 247-258.

Armengol, J.; Caputo, L.; Comerma, M.; Feijoo, C.; Garcia, J.C.; Marce, R.; Navarro, E. and Ordonez, J. 2003. Sau reservoir's light climate: relationships between Secchi depth and light extinction coefficient. Limnetica22: 195-210.

Belal, D. 2012.epipelic Diatoms As A Tool for Monitoring Pollution in River Nile From Aswan to Cairo. M. Sc. Thesis. Faculty of Science Cairo University, Egypt. 109 pages.

Bernot, M. J.; Tank, J. L. and Royer, T. V. 2006. Nutrient uptake in streams draining agricultural catchments of the Midwestern United States. Freshwater Biology 51: 499 -509.

Boulos, L. 1999. Flora of Egypt. Al-Hadara Publishing, Cairo, Egypt. 419 pages.

Bourrelly, P. 1968. Les algues d'eau douce initiation a la systematique. Tome 11. Les Algues jaunes et brunes, Chrysophycées, Xanthophycées et Diatomées Ed. N. Boubee and Cie, Paris, France. 438 pages.

Bourrelly, P. 1970. Les algues d'eau douce initiation a la systematique. Tome111. Les Algues bleus et rouges. Ed. N. Boubee and Cie, Paris, France. 512 pages.

Buczko, K. 2007. The occurrence of the epiphytic diatom *Lemnicola hungarica* on different European Lemnaceae species. Fottea Olomouc 1: 77-84.

Cattaneo, A.; Galanti, G.; Gentinetta, S. and Romo, S. 1998. Epiphytic algae and macroinvertebrates on submerged and floating-leaved macrophytes in an Italian lake. Freshwater Biology 4: 725-40.

Cox, E.J. 1996. Identification of Freshwater Diatoms From Live Material. Chapman and Hall, London. 156 pages

Dere, S.; Karacaoglu, D. and Dalkiran, N. 2002.A study on the Epiphytic algae on the Nilufer stream (Bursa), Turkish Journal of Botany 26: 219-233.

Einhellig, F.A. 1995. Mechanism of action of allelochemicals in allelopathy. ACS Symposium Series 582: 96-116.

El-Amier, Y. A.; Zahran, M. A. and Al- Mamoori, S. O. 2015. Plant diversity of the Damietta Branch, River Nile, Egypt: An ecological insight. Mesopotamian Environment Journal 1: 109-129.

El-Gohary, F. 1989. Egypt and the River Nile: Protection of the environment of the River Nile Basin. Proceedings of Regional Symposium: 56-74. The Scientific Association of Arab Women in Egypt, Cairo, Egypt.

El-Sheekh, M.M.; Haroon, A.M. and Sabaa, S. 2017. Activity of some Nile River aquatic macrophyte extracts against the cyanobacterium *Microcystis aeruginosa*. African Journal of Aquatic Science 3: 271-277.

El-Sheekh, M.M.; Haroon, A.M. and Sabaa, S. 2018. Seasonal and spatial variation of aquatic macrophytes and phytoplankton community at El-Quanater El-Khayria River Nile, Egypt. Beni-Suef University Journal of Basic and Applied Sciences 344-354.

Fareed, M.F.; Haroon, A.M. and Rabh, S.A. 2008.Antimicrobial activity of some macrophytes from Lake Manzalah Egypt. Pakistan Journal of Biological Sciences 21: 2454-2463.

Fawzy, M.A. 2016.Spatial distribution of epiphytic algae growing on the aquatic macrophytes *Phragmites australis* and *Echinochloa stagnina* at Assuit-Egypt. Minia Science Bulletin 2: 1-26.

Fishar, M. R.; Thorne, R.and Williams, W. P. 2006.Physico-chemical conditions and macroinvertebrate fauna in the River Nile from Aswan to Cairo. African Journal of Aquatic Science 2: 247-259.

Fishar M.R. and Williams, W. P. 2008. The development of a Biotic Pollution Index for the River Nile in Egypt, Hydrobiologia 598: 17-34.

Frankovich, T. A.; Gaiser, E. E.; Zieman, J. C. and Wachnicka, A. H. 2006. Spatial and temporal distributions of epiphytic diatoms growing on *Thalassia testudinum* Banks ex Konig: relationships to water quality. Hydrobiologia 1: 259 - 271.

Goldsborough, L. G. and Hickman, M. 1991. A comparison of periphytic algal biomass and community structure on *Scirpus validus* and on a morphologically similar artificial substratum. Journal of Phycology 27: 916 - 928.

Gross, E.M.; Hilt, S.; Lombardo, P. and Mulderij, G. 2007. Searching for allelopathic effects of submerged macrophytes on phytoplankton-state of the art and open questions. Hydrobiologia 584: 77-88.

Haroon, A.M.2006. Effect of some macrophytes extracts on growth of *Aspergillus parasiticus*. Egyptian Journal of Aquatic Research 32: 301-313.

Haroon, A.M. and Abd el all, E.I.2016. Chemical composition and in vitro anti-algal activity of *Potamogeton crispus* and *Myriophyllum spicatum* extracts. Egyptian Journal of Aquatic Research 42: 393-404.

Haroon, A.M. and Daboor, S.M. 2009. The role of different macrophytes groups in water quality, sediment chemistry and microbial flora of both irrigation and drainage canals. World Applied Science Journal 9: 1221-1230.

Haroon, A.M. and Hussian, A.M. 2017. Ecological assessment of the macrophytes and phytoplankton in El-Rayah Al-Behery, River Nile, Egypt. Egyptian Journal of Aquatic Research 43: 195-203.

Hillebrand, H.; Worm, B. and Lotze, H.K. 2000.Marine microbenthic community structure regulated by nitrogen loading and grazing pressure. Marine Ecology Progress Series 204: 27-38.

Hindak, F.; Kamarek, J.; Marvan, P. and Ruzicka, J. 1975. Kluc Na Urcovanic Vytrousnych Rastlin, I. Diol. Riasy..

Kokate, C.K. 2001. Pharmacognosy. 16th Edition., Nirali Prakasham, Mumbai, India. 880 pages.

Konsowa, A. 2007. Spatial and temporal variation of phytoplankton abundance and composition in the hypersaline Bardawil Lagoon, North Sinai, Egypt. Journal of Applied Sciences Research 3: 1240-1250.

Kufel, L.; Pasztaleniec, A.; Czapla, G. and Strzałek, M. 2007. Constitutive allelochemicals from *Stratiotes aloides* L. affect both biomass and community structure of phytoplankton. Polish Journal of Ecology 2: 387-393.

Kupferberg, S. 2003. Facilitation of periphyton production by tadpole grazing: functional differences between species. Freshwater Biology 37: 427-439.

Lacoul, P. and Freedman, B. 2006. Environmental influences on aquatic plants in freshwater ecosystems. Environmental Reviews 14: 89-136.

Liboriussen, L. and Jeppesen, E. 2003. Temporal dynamics in epipelic, pelagic and epiphytic algal production in a clear and a turbid shallow lake. Freshwater Biology 48: 418-431.

Madsen, J.D.; Bloomfield, J.A.; Sutherland, J.W.; Eichler, L.W. and Boylen, C.W. 1996. The aquatic macrophyte community of Onondaga Lake: Field survey and plant growth bioassays of lake sediments. Lake and Reservoir Management 12: 73-79.

Madsen, J.D.; Chambers, P.A.; James, W.F.; Koch, E.W. and Westlake D.F. 2001. The interactions between water movement, sediment dynamics and submersed macrophytes. Hydrobiologia 444: 71-84.

Middelboe, A.L. and Markager, S. 1997. Depth limits and minimum light requirements of freshwater macrophytes. Freshwater Biology 35: 553-568.

Misra, R. 1968. Ecology Work Book. Oxford and IBH Publishing, Calcutta. 244 pages.

Mulderij, G.; Mooij, W.M.; Smolders, A.J.P. and Van donk, E. 2005. Allelopathic inhibition of phytoplankton by exudates from *Stratiotes aloides*. Aquatic Botany 82: 284-296.

Müller, U. 1995. Vertical zonation and production rates of epiphytic algae on *Phragmites australis*. Freshwater Biology 34: 69 - 80.

Olmsted, I. and Gomez, M. 1995. Distribution and conservation of epiphytes on the Yucatan Peninsula. Selbyana 17: 58-70.

Patrick, R.; Cairns, J. and Scheier, A. 1968.The relative sensitivity of diatoms, snails and fish to twenty common constituents of industrial wastes. Progressive Fish-Culturist 30: 137-140.

Paul, V. Z. and Hopson, M. S. 1997. Quantification of epiphyte removal efficiency from submersed aquatic plants. Aquatic Botany 58: 173 - 179.

Pelton, D.K.; Levine, S.N. and Braner, M. 1998. Measurements of phosphorus uptake by macrophytes and epiphytes from the La Platte river (VT) using P-32 in stream microcosms. Freshwater Biology 39: 285-99.

Perez, M.T. and Sommaruga, R. 2006. Differential effect of algal- and soil-derived dissolved organic matter on alpine lake bacterial community composition and activity. Limnology Oceanography 6: 2527-2537.

Philipose, M. T. 1967. Chlorococcales. Indian Council of Agricultural Research, New Delhi. 365pages.

Prescott, A. C. W. 1978. How to Known the Fresh Water Algae. Third edition. W.C. Brown & Co., Dubuque, IA. 293 pages.

Ruesink, J.L. 1998. Diatom epiphytes on *Odonthalia floccosa*: The importance of extent and timing Journal of Phycology 34: 29-38.

Salman, J.M.; Hadi, S.H. and Mutaer, A.A. 2013. Spatial and temporal distribution of phytoplankton and some related physical and chemical properties in Al-Abasia river (Euphrates), Iraq. International Journal of Geology, Earth & Environmental Sciences 3: 155-169.

Sullivan, M.J. 1984. Community Structure of Epiphytic Diatoms from the Gulf Coast of Florida, USA. Pages 373-384, In: Mann, D.G. (Editor) Proceedings of the Seventh International Diatom Symposium. Otto Koeltz-Science Publishers, Philadelphia.

Täckholm, V. 1974.Students Flora of Egypt. 2nd edition. Cairo University Press, Cairo. 888 pages.

Takashi, A.; Munira, S.; Jagath, M. and Takeshi, F.2004. The effect of epiphytic algae on the growth and production of *Potamogeton perfoliatus* L. in two light conditions. Environmental and Experimental. Botany 3: 225-238.

Van Donk, E. and Otte, A. 1996. Effects of grazing by fish and waterfowl on the biomass and species composition of submerged macrophytes. Hydrobiologia 340: 285-290.

Vis, C.; Hudon, C. and Carignan, R. 2006. Influence of the vertical structure of macrophyte stands on epiphyte community metabolism. Fisheries and Aquatic Science 5: 1014- 1026.

Wetzel, R .G. 1983. Periphyton in Ecosystems. Dr. W. Junk, Boston, 346 pages.

Zahran, M.A. 2009. Hydrophytes of the Nile in Egypt. Pages 463-478, In: Dumont, H.J. (Editor) The Nile: Origin, Environments, Limnology and Human Use. Springer Science Business Media, Dordrecht.

Received 22November 2018
Accepted 29 January 2019