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A Contribution to the Epipelic Algal Ecology in Lotic Ecosystem of Iraq

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Abstract

The study was conducted on epipleic diatoms in a lotic ecosystem. The Al-Shamiyah River was selected which is a distance from industrial activities. Four sites along the river were selected for sampling during the period from March 2013 to February 2014. A total of 173 species of epipelic diatoms were identified. The pennate diatoms predominated and represented about 92.49% of the total diatoms, while centric diatoms formed only 7.51%. The total number of diatoms ranged between 185.1 - 422.34 cell × 10^4/cm^2. Some of the pennate diatom species were *Achnanthes affinis* Grunow, *Achnanthes mintussima* Küetzing, *Cocconeis placentula* var. euglypta (Ehr.) Cleve, *Cymbella affinis* Küetzing, *Diatoma vulgare* Bory, *Fragilaria capucina* Desmazieres, *Gomphonema angustatum* var. productu Grun., *Navicula lanceolata* (Ag.) Kuetzing, *Navicula radiosa* Küetzing, *Navicula viridula* Küetzing, *Nitzschia palea* (Kutz.) W. Smith, *Nitzschia romana* Grunow. The physicochemical and epipelic algae species indicated that the water quality of the river was clean to moderate water quality.

Keywords

Diatom, Epipelic Algae, Lotic System, Euphrates River

1. Introduction

The importance of benthic algae in Iraqi aquatic ecosystems was subjected to investigations recently [1]-[4]. Many authors have previously recognized benthic algae as bioindicators in different aquatic ecosystems of Iraq [5]-[7].

Benthic algae play a role as energy source for many benthic fauna. Moreover, their roles in recycling nutrients

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(through the water column and sediment) and transformation of inorganic material into organic via photosynthesis in sediment were also known. Also, it was considered as oxygen sources for the water and sediment [7]-[9]. The benthic algae were considered as resistant to alterations of the environment and pollution due to their ability to attach to benthic substrates [10].

The abundance of diatomic algae was also observed in different studies. The abundance of some diatomic species may reflect the status of the aquatic ecosystem such as the trophic status [11] or extent of organic pollution [1] [5] and to water quality [3]. Many authors have pointed out the abundance of diatoms and explained that the diatomic algae had the ability to alter the conditions of their environment, but their community structure responded to altered physicochemical and biological variables in the ecosystem [12]-[14].

Al-Lami *et al*. [15] observed high diversity of epipelic algae in four aquatic systems having a gradient of salinity in central of Iraq. Essa [16] used diatoms as bioindicators in some aquatic systems in Basra region, Iraq, where the author stated that the status of these sites ranged between oligo-mesotrophic and mesotrophic except only one site which was trophic.

This investigation is the first attempt to fill the gap of information about epipelic algal ecology in Al-Shamiyah River and the possibility to use epipelic algae as bioindicators.

2. Material and Methods

Four sites were selected along a branch of the Euphrates River, the Al-Shamiyah River (a Lotic System). The branch originates after passing Kifil city in the middle region of Iraq, and passes through the Shamiyah town which is just 284 km from Baghdad city (the capital of Iraq) and only 40 km from Al-Diwanyiah Province. The river converges with the Kufa River (a second branch of Euphrates River) at Shinafya town. The selected sites (**Figure 1**) were characterized by vast agricultural activity and the presence of macrophytes (sites 1, 2 and 3), while site 4 was located within a paddy field having dense growth of macrophytes.

All physicochemical parameters were measured according to the methods of APHA [17], Parsons *et al*. [18] and Gaudette *et al*. [19] (for Total Organic Carbon (TOC%). Biological diversity indices (Species richness and Shannon-Weaver) were calculated according to Magurran [20]. Canonical Corresponded Analysis (CCA) Ver. 4.5 was applied for the statistical analysis.

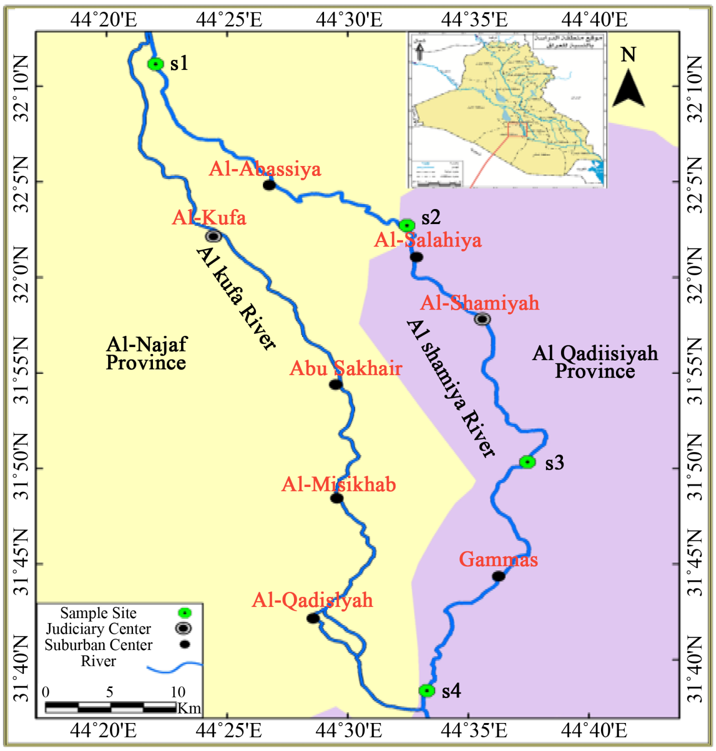

Figure 1. Map of the studied area.

Epipelic algae samples were taken according to Eaton and Moss [21]. Microtransect method was used for estimation of the total number of epipelic algae after preparing permanent slides [21]. Identification of epipelic algae relied on description given in the following references: [22]-[26].

3. Results

The physicochemical parameters of the Al-Shamiyah River were already discussed in terms of seasonal and spatial variation [27]. In winter (December and February 2014) and summer 2013 (August 2013), respectively, air and water minimum temperature (AT and WT) were not less than 11˚C, while maximum did not exceed 39˚C (**Table 1**). Water flow rates ranged between 20 meter/min^{-1} at site 3 in April 2013 and 49.99 meter/min^{-1} at site 1 in January 2014. Records of turbidity (Tur) were Low in April 2013 (8.25 NTU) while higher value (22.11 NTU) was recorded in January 2014 at sites 3 and 1, respectively. Electric conductivity (EC) and salinity (S‰) ranged 1108 - 1560 µ/cm and 0.71‰ - 0.99‰, respectively. Total suspended solids (TSS) value was higher at site 1 (39.02 mg/l) and low (16.50 mg/l) at site 3 in January 2014 and April 2013, respectively. Light penetration (LP) ranged between 24.40 and 65.00 cm at sites 1 and 3 in January 2014 and April 2013, respectively. All pH values were higher than 7.00 and reached 8.23 during most of the study period. Total alkalinity (TA) values ranged between 97 and 162 mg/l at sites 1 and 4 in September and June 2013, respectively.

No anoxia was recorded in this study and dissolved oxygen (DO) concentrations ranged between 6.30 and 10.5 mg/l (**Table 1**). The lowest recorded concentration was in July 2013 while the highest was in February 2014. Maximum value of biochemical oxygen demands (BOD_5) (2.50 mg/l) in August 2013 at site 4 and the lowest value was 0.99 mg/l at site 1. Total hardness (TH), calcium (Ca), and magnesium (Mg) concentrations ranged between 259.63 and 572.00 mg $CaCO_3$/l, 74.41 and 150.55 mg/l, 12.57 and 63.10 mg/l during the study period, respectively for sites 1 to 4.

Table 1. Range of physicochemical parameters in Al-Shamiyah River during the study period.

Parameter	Range
Air temp. (˚C)	13.33 - 39.00
Water temp. (˚C)	11.00 - 36.00
Water flow (m/min)	20.00 - 49.99
Turbidity (NTU)	8.25 - 22.11
Light penetration (cm)	24.40 - 65.00
Electric C conductivity (µs/cm)	1108 - 1560
Salinity ‰	0.71 - 0.99
Total dissolved solids (mg/l)	709 - 998
Total suspended solids (mg/l)	16.50 - 39.02
pH	7.46 - 8.23
Dissolved oxygen mg/l	6.30 - 10.50
Biochemical oxygen demand mg/l	0.99 - 2.5
Alkalinity mg $CaCO_3$/l	97 - 162
Hardness mg $CaCO_3$/l	259.63 - 572
Calcium mg/l	74.41 - 150.55
Magnesium mg/l	12.57 - 63.10
Nitrite µg/l	0.16 - 2.20
Nitrate µg/l	40.38 - 117.46
Phosphate µg/l	0.012 - 0.22
Silicate µg/l	93.13 - 160.8
Total organic carbon mg/l	0.24 - 1.85

Nutrient concentration records showed resemblance among river's sites. Mean concentration of nitrite (NO_3), nitrate (NO_2), phosphate (PO_4) and silicate (SiO_3) ranged between 1.22 and 154, 57.00 and 73.00, 0.01 and 0.12, 120.25 and 140.73 µg/l, respectively for sites 1 to 4.

A total of 173 taxa of epipelic algae were identified in this study. At site four 108 species were recorded while at sites 1 to 3: 89, 96 and 98 species were recorded, respectively. There were different numbers of genera and species recorded among the study sites (**Table 2** and **Table 3**). It is evident that pennate diatoms were dominant and represented 92.49% of the total identified diatoms. The pennate diatoms however represented: 91.01%, 91.67%, 91.84% and 92.59% at sites 1, 2, 3 and 4, respectively. The centric diatoms represented between 7.42% and 8.99% where the lowest percentage was at site 4 and the highest at site 1.

Some of the species recorded in this study were present in high numbers contrasting those of other epipelic algae. Four species recorded for each of the genera: Cyclottela, Achnanthes, and Cocconeis at site 1. While Cymbella, Gomphonema, Gyrosigma, Navicula and Nitzschia recorded 6, 5, 5, 10 and 20 at the same site, respectively. These genera also were recorded in other sites with different numbers of species. While the higher number of species, (26 species for Nitzschia) was recorded at site 4. While the genera Cymbell and Gomphonema were represented by ten species at sites 3 and 4. Number of Navicula species ranged between 10 and 16 at site 1 and 3, respectively.

Some species were present for the most period and sites of the study (**Table 4**). At site 1, the following species were found: *A. ambigua*, *C. ocellata*, *C. menenghiana*, *C. placentula* var. euglypta, *C. affinis*, *G. angustatum* var. *productum*, *N. radiosa*, *N. viridula*, *N. romana*, *S. ulna*. While at site 2 species present were as follows: *C. menenghiana*, *A. affinis*, *C. lacustris*, *C. affinis*, *D. vulgare*, *G. angustatum* var. productum. However, at site 3 species present were *A. ambigua*, *C. lacustris*, *C. placentula* var. euglypta, *N. viridula*, *N. romana*, and *N. palea*, while at site 4 species present were *A. ambigua*, *C. lacustris*, *C. menenghiana*, *C. ocellata*, *N. viridula*, *S. ulna* and *Gyrosigma acuminatum*, *G. angustatum* var. *productum*.

Total number of epipelic algae ranged 185.154 × 10^4/cm - 422.345 × 10^4/cm at sites 2 and 4, respectively. Seasonal variation of the total number of epipelic algal species was observed in this study. For centric diatoms, *Aulacoseira ambigua* (0.51 - 2.31 cells × $10^4/cm^2$ at sites 2 and 4), *C. menenghiana* (1.17 - 7.86 cells × $10^4/cm^2$ at sites 1 and 3), *C. ocellata* (0.66 - 6.45 cells × $10^4/cm^2$ at sites 2 and 4). Most of high total number for pennate diatoms was recorded at site 4. Total number of some pennate diatoms were as follows: 4.92 - 35.79 cells × $10^4/cm^2$ for *G. angustatum* var. *productum* at sites 3 and 4, 1.3 - 20.94 cells × $10^4/cm^2$ for *N. palea* at sites 2 and 3, 1.2 - 19.11 cells × $10^4/cm^2$ for *C. affinis* at sites 1 and 4, 11.28 - 17.46 cells × $10^4/cm^2$ for *A. affinis* at sites 3 and 2, respectively.

Table 2. Range (Mean ± SD) biological parameters in Al-Shamiyah River during the study period.

Parameters	Site 1	Site 2	Site 3	Site 4
Total diatoms algae cell × $10^4/cm^2$	6.75 - 44.49 (20.78 ± 12.97)	3.75 - 42.51 (15.42 ± 13.12)	2.28 - 59.13 (26.96 ± 18.09)	3.87 - 115.8 (35.19 ± 31.02)
Chlorophyll a µg/cm^2	0.36 - 1.66 (1.08 ± 0.48)	0.07 - 1.45 (0.67 ± 0.54)	0.07 - 6.72 (1.72 ± 2.25)	0.07 - 2.24 (0.7 ± 0.64)
Pheophytin a µg/cm^2	0.08 - 1.16 (0.36 ± 0.32)	0.012 - 0.61 (0.19 ± 0.23)	0.04 - 2.64 (0.63 ± 0.71)	0.03 - 0.98 (0.25 ± 0.27)

Table 3. Total number of genera and species of centrals (C) and pennales (P) of epipelic algae in the studied sites (S) during the study period in Al-Shamiyah River.

	S1		S2		S3		S4	
	C	P	C	P	C	P	C	P
Genera	3	22	3	24	4	25	4	20
Species	8	81	8	88	8	90	8	100
Percent (%)	8.99	91.01	8.33	91.67	8.16	91.84	7.42	92.59
Total genera	22		25		29		24	
Total species	89		96		98		108	

Table 4. List of some dominant epipelic taxa and its total number (cell × 10^4/cm^2) during the study period in Al-Shamiyah River.

Aulacoseira ambigua O. Muller	0.66	0.51	1.95	2.31
A. Dicikiei (Thwaites) *Kutzing*	0.21	-	-	-
A. distanse (Ehr.) Kutz	-	0.09	-	-
A. granulate (Ehr.) Ralfs	0.3	0.69	0.21	0.72
Cycllotella comta (Ehr.) Kuetzing	0.57	0.12	7.95	0.3
C. glomerata Bachmann	-	-	-	0.12
C. kuetzingiana Thwaites	-	1.95	-	-
C. menenghiana Kuetzing	1.17	1.98	7.86	3.18
C. ocellata Pantocsek	6.42	0.66	1.47	6.45
C. stelligera Cleve et Grunow Van Heurck	-	-	0.54	-
Achnanthes affinis Grunow	14.01	17.46	11.28	15.33
A. hungarica Grunow	13.02	-	0.33	-
A. lanceolata Grunow	-	-	-	0.06
A. linearis W. Smith Grunow	-	-	6.81	-
A. microcephala (Ktz.) Grunow	0.33	4.68	0.12	12.69
A. mintussima Küetzing	0.75	15.48	0.06	17.79
A. saxonic Krasske	0.12	-	-	-
Cocconeis pediculus Ehrenberg	2.01	0.51	-	1.62
C. placentula Ehrenberg	5.43	11.4	4.38	1.95
C. placentula var. euglypta (Ehr.) Cleve	10.41	9.39	7.08	16.11
Cymbella affinis Küetzing	1.2	7.5	2.13	19.11
Cymbella aspera H. paragallo	-	0.33	-	0.24
C. caespitosa (Kutz.) Brun	-	-	-	6.45
C. cistula (Ehr.) Kirchn	0.36	0.24	-	-
C. gracilis (Rabh.) Cleve	-	-	-	6.99
C. helvetica Kuetzing	0.18	0.51	-	0.06
C. lanceolata	-	0.3	-	-
C. obtusiuscula (Kutz.) Grun	-	-	-	0.06
C. parva (W. Smith) Kitchn	-	-	0.18	-
C. tumida (Bréb.) V. Heurck	0.51	1.17	1.83	4.83
C. tumidula Grun	-	-	-	0.24
C. turgida (Greg.) Cleve	5.52	0.21	-	0.12
Gomphonema acuminatum Ehr.	-	0.09	15.45	-
G. acuminatum var. turris Cleve	-	-	-	0.06
Gomphonema angustatum (Ktz.) Rabenhorst	5.67	0.9	1.32	
G. angustatum var. product Grun	11.28	11.73	4.92	-
G. augur Ehrenberg	-	-	0.66	35.79
G. constrictum Eher	-	-	-	-
G. constrictum var. capitat (Ehr.) Cleve	-	-	0.36	0.06

Continued

G. gracile Ehrenberg	-	1.05	6.96	0.12
G. intricatum Küetzing	0.18	0.24	0.09	8.04
G. intricatum var. lunata nov	8.82	10.95	0.18	0.6
G. lanceolatum Ehrenberg	0.15	0.18	1.17	10.5
G. parvulum (Kuetz) Grun	-	-	-	6.57
Gyrosigma acuminatum (Ktz.) Rabenhorst	0.36	0.21	4.29	0.06
G. attenuatum (Ktz.) Rabenhorst	1.02	0.06	0.09	0.96
G. scalproides (Raben) Cleve	0.12		-	-
G. macrum (W. Smith) Griff et. Henfr	-	0.24	-	-
G. spenceri (Quek) Griff et Henfr	0.15	-	-	-
G. tenuirostrum (Grun.) Cleve	0.18	-	-	-
Fragilaria brevistriata Grunow	-	-	1.35	-
F. capucina Desmazieres	0.48	1.02	15.21	-
F. construens Grunow	-	-	-	14.43
F. construens var. subsalina Hust.	-	0.03	-	0.06
F. crotonensis Kitton	1.11	0.42	3.69	-
F. intermedia Grunow	0.21	1.53	1.44	7.14
Navicula angilica Ralfs	-	0.15	0.09	1.14
N. angilica var. subsulsa	-	-	1.56	-
N. bacillum Ehrenberg	-	-	0.09	-
N. cincta (Ehr.) Kuetzing	9.57	5.07	6.81	3.57
N. creptocephala Kuetzing	9.75	0.15	4.26	0.18
N. decussis Oestrup	-	0.06	-	-
N. dicephala W. Smith	-	-	0.18	4.2
N. fusca Greg	-	0.12	-	-
N. gibbula Cleve	-	-	-	0.03
N. gracilis	0.39	1.08	2.01	5.34
N. graciloides A. Mayer	-	-	7.44	-
N. gregaria Donkin	-	-	-	0.06
N. grimmei Krasske	-	0.78	0.66	1.35
N. halophila (Grun.) Cleve	14.97	0.9	0.54	1.89
N. lanceolata (Ag.) Kuetzing	13.5	5.85	7.14	8.97
N. mutica Kuetzing	0.24	0.45	-	-
N. parva (Menegh) Cleve	0.15	-	-	-
N. phyllepta Kuetzing	5.43	-	1.35	6.87
N. radiosa Küetzing	22.41	17.58	40.35	14.67
N. rhynchocephala Kuetzing	-	-	0.24	-
N. schroeteri Meister	-	-	7.56	-
N. spicula (Hickie) Cleve	-	0.45	-	-
N. viridula Ktz.	10.08	0.36	16.59	9.36
Nitisha acicularis (Ktz.) W. Smith	0.42	0.93	0.99	0.18
N. acuta Hantzsch	0.06	-	-	0.24
N. amphibia Grunow	-	0.09	-	-

Continued

N. apiculata (Greg.) Grunow	0.18	0.9	-	0.12
N. circumsuta	0.3	-	-	-
N. clausii Hantzsch	-	6.6	0.3	5.25
N. commutata Grun	0.03	-	-	-
N. dissipata (Ktz.) Grunow	8.1	0.09	0.3	11.73
N. dubia W. Smith	-	0.54	-	-
N. fasciculate Grunow	-	-	-	0.15
N. filiforms (W. Smith) Hustedt	0.12	-	0.12	1.29
N. fonticola Grunow	-	0.09	-	-
N. gracilis Hantzsch	1.92	0.18	0.6	9.24
N. hantzschiana Rabh	0.12	-	0.63	0.24
N. hungarica Grunow	0.48	0.63	0.6	0.63
N. ignorata Krasske	-	-	-	0.12
N. inconspicua Grun	-	--	-	10.02
N. intermedia Hantzsch ex Cleve & Grunow	0.12	2.19	0.24	6.66
N. linearis W. Smith	2.85	0.18	1.8	0.12
N. lottoralis Grunow	0.15	-	-	-
N. longissima Ralfs	0.15	0.12	0.69	0.27
N. microcephala Grun	-	0.21	0.15	6.21
N. obtusa W. Smith	-	-	-	0.12
N. palea (*Kutz.*) W. Smith	4.29	1.32	20.94	7.14
N. puctata (W. Smith) Grunow	0.15	-	-	-
N. pusilla (Kutz.) Grunow	0.15	-	1.77	0.39
N. recta Hantzsch	-	-	12.27	6.57
N. romana Grunow	7.35	10.23	24.66	24.51
N. rostellata Hustede	-	-	0.42	-
N. sigma W. Smith	-	-	-	0.06
N. sigmoidea (Ehr.) W. Smith	0.24	0.99	-	1.41
N. stagnorum Rabh	-	0.15	-	-
N. sublinearis Hustedt	-	0.18	-	-
N. tryblionella Hantsch	5.7	-	0.69	0.15
N. tryblionella var. debilis A. Mayer	-	-	0.12	
N. tryblionella var. levidensis Grunow	-	0.87	10.29	0.24
N. umbonate (Ehrenberg) Lange 0 Bertalot	-	-	0.12	-
Synedra acus Kuetzing	0.18	0.54	0.21	1.29
S capitata Ehrenberg	-	0.06	1.05	0.09
S. pulchella (Ralfs) Kuetzing	-	0.09	-	0.09
S. rumpens Kg	-	-	-	0.12
S. tabulata var. fasciculate Agardh	0.09	0.06	0.09	0.21
S. ulna (Nitz.) Ehrenberg	8.91	3.6	0.54	7.86
S. vaucheriae Kuetzing	0.36	0.6	0.9	0.06

Minimum value of Chlorophyll-a concentration ranged between 0.07 and 6.72 μg/cm^2 at sites 2, 3 and 4 (**Table 2**), while the maximum values were recorded at site 3 in late winter 2014 and autumn 2013, respectively.

Phaeophytin-a concentration ranged between 0.012 and 2.64 µg/cm^2 in late winter 2014 and spring 2013, respectively. For both chlorophyll-a and phaeophytin-a significant variation ($P < 0.05$) among concentrations, sites and seasons were noticed.

Index of species richness ranged between 7.46 at site 4 in spring 2013 and 27.91 at site 3 in autumn 2013. While Shannon Species Diversity index showed high values (>1) at all studied sites, and ranged between 1.35 - 3.23 at sites 2 for both valuesin summer and autumn 2013, respectively. For both estimations of biodiversitya significant difference ($P < 0.05$) was recorded among sites and seasons. **Figure 2** illustrated the spatial and temporal variation of the studied biological diversity. **Figure 3** illustrated CCA analysis ofspecies-environment correlations.

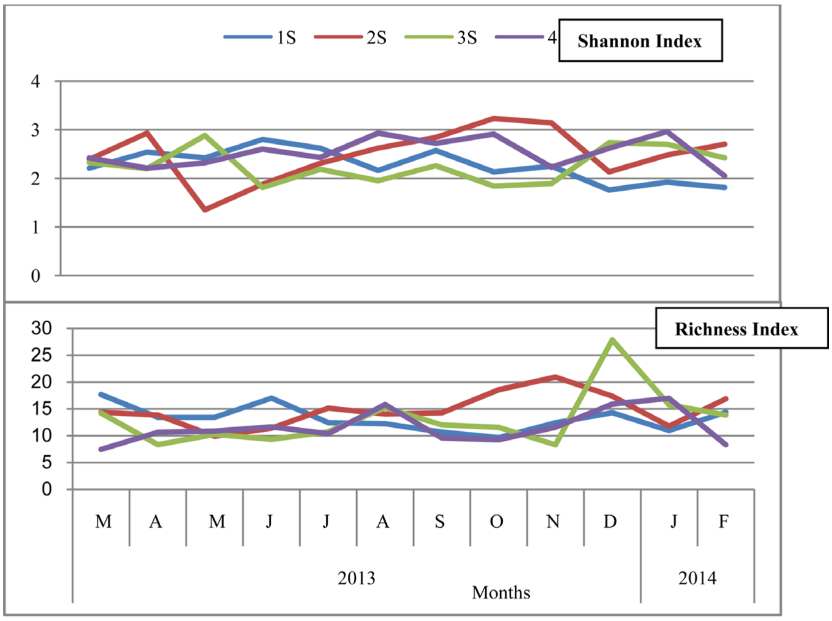

Figure 2. Spatial and temporal variations of the studied biological indices in Al-Shamaiyah.

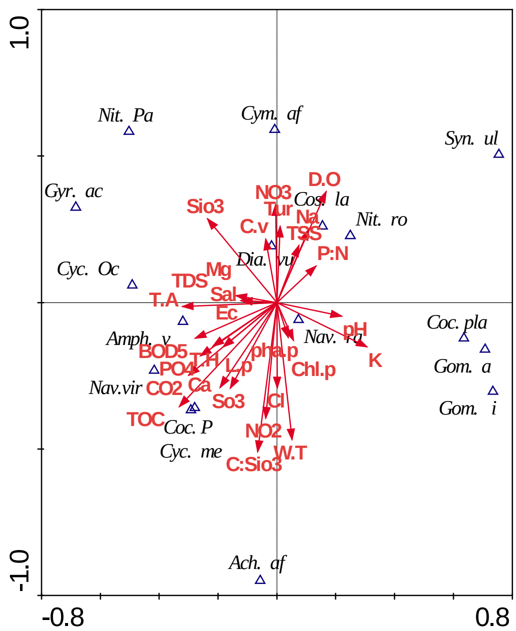

Figure 3. CCA analysis of species—environment correlations.

4. Discussion

Both the air and water temperatures varied with season where lowest values were recorded in winter and the highest in summer. These findings were similar to observations made in previous studies in Iraqi aquatic ecosystems [28]-[31]. These results may be explained in view of Iraq's climate being continental and subtropical [32]. Water flow rate variation mostly affected mainly by operation of river regulation and channel morphology [33] [34]. Also, light penetration influenced by means of physical and chemical properties of the river. These factors include turbidity, water drainage, the density of microorganism (including phytoplankton) and macrophytes cover [35]. EC, salinity, and TDS values recorded exceeded levels recorded in previous studies in Euphrates River [2]-[28]. According to APHA [17] and SWRCB [36] as mentioned by Manivanan [37], the river is considered within freshwater, in which the conductivity range between 100 and 2000 µS/cm, and brackish water in the range of 0.5‰ to 29‰. The Iraqi natural water ecosystems are known to be of buffer capacity of alkaline to hard water [38] [39]. Well-oxygenated water in the river was noticed during the study period, and the highest values recorded in spring may be due to the increasing photosynthesis activity during this season and low temperature during the summer. BOD5 results reflected that Al-Shamiyah River was clean to moderately polluted river [40]. These results did not indicate a limitation role for nutrients in algae.

Spatial and temporal variations of epipelic algae in the studied river were obvious. The variation might be due to the different environmental characteristics among sites and seasons in addition to the texture of sediment. The dominance of diatoms in benthos ecosystems was well known. This dominance may be due to their ability to adapt in an altering environment with less available light intensity [41]-[43]. This dominance is also referred to in other studies of aquatic ecosystems in Iraq [1]-[3].

It is very known that in freshwater ecosystems the pinnate diatoms are predominate, while in marine ecosystems the centric diatoms are predominate [44]. Results of the present investigation confirmed the latter authors' findings. The density of epipelic algae was related to many factors. These factors may be that some algae have the ability to reproduce in unsuitable conditions. In addition to that, their ability to secrete mucilage sheath that helps their daily rhythms [7]. Moreover, algal adhesion affected by nutrient concentrations, grazing process and other factors [2] [45]. Temporal variation may be due to the climate characteristics of the study area that lies within the hot desert climate. Iraq is characterized by great temperature diurnal and seasonal variations. Most of the high number of total epipelic algae in spring and autumn during this study. These results also were noticed by other researchers in Iraqi aquatic ecosystems [1] [2]. Chlorophyll-a concentration did not exceed 2.24 to 2 µg/l, and may be attributed to the oligotrophic status of the river [46] [47]. Nutrient concentrations and other physicochemical factors affect chlorophyll-a concentration and epipelic algae growth [48]. CCA analysis revealed positive correlation among some epipelic algae (*C. lacustris*, *C. affinis*, *N. romana* and *S. ulna*) and DO, Na, N:P, NO_3, TSS, and Turbidity. While a negative correlation observed among these species and EC, BOD5, PO_4, NO_2, Ca, SO_4, TOC and C:SiO_3.

C. menenghiana, *C. placentula* var. euglypta, *N. viridula*, *A. affinis*, and *A. veneta* showed positive correlation with the following factors (EC, BOD5, TH, light pentertion (LP), CA, SO_4, CO_2, PO_4, NO_2, TOC and C:SiO_3). While negative correlation with other factors (DO, Na, N:P, NO_3, TSS and Turbidity).

The studied physicochemical parameters confirmed that the dominant species of epipelic algae in this investigation can be used as bioindicator for water quality. These factors reflected the clean to moderate water quality of the study sites [44] [49] [50].

5. Conclusion

The diatom community in Al-Shamiyah River reflected the level of water quality in terms of dominant species. The studied physicochemical parameters in this investigation also confirmed the water quality status (clean to moderate) of the river.

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