Asian Journal of Water, Environment and Pollution, Vol. 20, No. 3 (2023), pp. 67-76.
DOI 10.3233/AJW230039

Diversity and Ecology of Non-diatomic Algae in the Middle Hilla River, Iraq

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Received May 4, 2022; revised and accepted June 23, 2022

Abstract: The present study aimed to investigate the non-diatomic algae community and some biodiversity indices in the Hilla River during the study period from October 2018 to July 2019 for three sites along the Hilla River. Physicochemical parameters of water quality assessment and the phytoplankton population is measured using a sedimentation technique identified mainly using some diagnostic sources. Where a total of (48) genera and (100) species were diagnosed, belonging to 5 classes as follows: Chlorophyceae (23 genera, 59 species), Cyanophyceae (16 genera, 30 species), Dinophyceae (4 genera and 4 species), Chrysophyceae (3 genera, 5 species) and Euglenophyceae (2 genera and 2 species). The highest and low values recorded for biodiversity were (1.9 and 2.9) at site 3 and 1, respectively, while the richness index ranged between 43 and 48, and the highest value for numerical Evenness Index was (0.77) at site 3 and the lowest values (0.51) at site 1 and 2, Simpson dominance index has recorded the highest value (0,272) at site 1 and 2 and the lowest values was (0.122) at site 3. Canonical Correspondence Analysis (CCA) was used to estimate the relationship between environmental factors and algae, water temperature (water temp.) salinity, pH, chloride, and alkalinity were important factors influencing the distribution of phytoplankton community.

Key words: Freshwater algae, biodiversity, water quality, Hilla, Iraq.

Introduction

The phytoplankton is an important biological indicator of freshwater quality (Yusuf, 2020). Phytoplankton studies are useful to control the physico-chemical and biological conditions of the water quality (Gharib et al., 2011). At the same time, algae diversity rapidly responds to changes in the aquatic environment (Chellappa et al., 2008) and can be used as indicators of the status of ecological systems and has a relationship with productivity in ecology. So, several algal species served as bio-indicator (Hoch et al., 2008) and can be considered as a useful tool for understanding water pollution studies (Ahmad, 1996). Phytoplankton, including non-diatomaceous algae, has a temporal and spatial distribution, and this is due to the variations in the biological properties of the water in addition to the physical and chemical properties and nutritional status of the water surface. Therefore, algae in general are highly sensitive to environmental changes, and any environmental change may cause changes in their dominance and diversity (Ghorbani et al., 2016). Also, the diversity of phytoplankton not only affects the stability, productivity, and resource use efficiency that is measured as the amount of phytoplankton biomass produced per unit of phosphorus (Filstrup, 2014) but, also affects zooplankton through predator-prey interaction (Striebel, 2012). On the other side, algae is important to understand the species diversity preservation (Stomp et al., 2011). Algal species richness can be considered a simple measure to express and quantify the complexity of an area (Nabout et al., 2007).

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Also, diversity indicators are applied in many studies to assess and study the effects of pollution on the diversity and composition of species (Archibald, 1972). Where species diversity responds to changes, especially to pressures and specific factors, and thus reflects many interactions that may characterise societies. It is a study of the diversity of non-diatomaceous algae recorded on different sites of the Hilla River with the identification of their species to use as indicators to measure the pollution status in Hilla river.

Materials and Methods

Study Area Description

Three sites were identified from the Hilla River. The first site is an agricultural area located about 10.3 km north of the Hilla center. The second site is located in the city center where large amounts of sewage are discharged into the riverbed. While the third site is located in an agricultural area outside the south of the city center about 11.9 km away, where fish cages are abundant (Figure 1).

Sample Collection

Samples were collected monthly from October 2018 to June 2019 using polyethylene containers with three replicates for each sample. Water temperature was measured directly using a graduated thermometer (0°C-100°C). Multi-parameters (Oakton) was used for pH and salinity. Azide modification was used for the Winkler method to measure dissolved Oxygen and Biological Oxygen demand (APHA, 2003). Phytoplankton was collected from the sampling stations with Phytoplankton nets with holes diameter of 20 µm for the qualitative study where the filter samples were placed in polyethylene bottles and preserved by adding Lugol's solution (Vollenweider, 1974). While for a quantitative study, the phytoplankton population is measured using a sedimentation technique, the haemocytometer methods were used for counting algae. It was identified mainly using some diagnostic sources (Desikachary, 1959; Prescott, 1973).

Biodiversity Indices

Species Richness - The number of different species found in a particular environment.

$$S = \sum_{i=1}^{S} P_i^0$$

Evenness (E) - A measure of how similar the abundances of different species are in the community.

Figure 1: Three sites (red color) of phytoplankton communities from Hilla river.

$$E = H/\ln S$$

Shannon-Weiner index (H) - This diversity measure came from information theory and measures the order (or disorder) observed within a particular system. In ecological studies, this order is characterised by the number of individuals observed for each species in the sample plot.

$$H = \sum_{i=1}^{s} p_i \ln P_i$$

Simpson's index (D): The probability that two randomly selected individuals in the community belong to the same category (e.g., species).

$$D = \sum_{i=1}^{s} N(N-1)/n(n-1)$$

Simpson's index of diversity (1-D): The probability that two randomly selected individuals in a community belong to different categories (e.g., species).

$$D = 1 - (\Sigma n(n-1)/N(N-1))$$

Simpson's reciprocal index (1/D): The number of equally common categories (e.g., species) that will produce the observed Simpson's index.

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

Results and Discussion

Table 1 and Figure 2 show the total number of diagnosed species of non-diatomic algae during the study period. Where a total of 48 genera and 100 species were diagnosed, the majority of which belonged to Chlorophyceae as it formed 23 genera, 59 species followed by Cyanophyceae which formed 16 genera, 30 species, then 4 genera and Species for Dinophyceae, 3 genera and 5 species for Chrysophyceae and 2 for each of the genera and Species for Euglenophyceae.

Table 1: Identified algae in the present study

Identified algae	*Total number*		
Cyanophyceae	*St1*	*St2*	*St3*
Aphanocaps abiformis A.B	-	0-82.8	-
Aphanotheca microscopia Naegeli	0-82.8	0-20.7	-
Chlorogloea fritschii Mitra	-	0-20.7	-
Chroococcus montanus forma Rao, C.B		0-62.1	-
Chroococcussp	0-62.1	-	-
Doctylococcopsissp	0-165.6	-	-
Gloeocapsasp	-	0-20.7	-
Gleothecasamoensis	0-20.7	-	-
Lyngbyalimnetica Lemm	-	0-20.7	-
Merismopedia glauca	-	0-20.7	-
Merismopedia punctate Meyen	0-20.7	-	-
Merismopedia tenuissima Lemm (Orig)	-	-	0-20.7
Microcystis aeruginosa kuetzemend Elenkin	-	0-20.7	-
Microcystis aeruginosa V.major (wuiv) Smith	-	-	-
Microcystissp	-	0-807.3	-
Oscillatoria acuta Bruhl Biswas	-	0-20.7	0-20.7
Oscillatoria chalybea var *insularis* Gaidner	0-20.7	-	
Oscillatoria hamelii Fremy	0-20.7	-	
Oscillatoria formosa Bory	-	-	0-20.7
Oscillatoria limnetica Lemmermann	- 4140	0-62.1	0-103.5
Oscillatoria perarnata Skuja	0-20.7	-	-
Oscillatoria spp.	0-82.8	-	-
Phormidium fragile (Menegh) Gom	0-20.7	-	-
Phormidium retzii (Ag.) Gomont	-	0-20.7	-
Phormidium tenue (Menegh) Gomont	0-20.7	-	-
Spirolina laxissima west G.S	-	-	0-20.7
Synechocystis pevalekii Ercegaic	-	0-20.7	-
Chlorophyceae			-
Actinastrum hantzchii Lagerhein	0-20.7	0-41.4	0-41.4
Aegagropila profunda (Brand) Nordst	0-20.7	-	-
Ankistrodesmus convolutes corda	-	0-20.7	0-20.7
Ankistrodesmus falcatus var *mirabilis* (west and west)	-	-	-
Ankistrodesmussp	-	-	0-20.7
Botryococcussp	-	0-20.7	-
Chlamydomonas dinobryoni G.M Smith	0-41.4	-	-
Chlamydomonas epiphytica G.M Smith	-	-	0-41.4
Chlamydomonas globosa snow	-	-	0-20.7
Chlamydomonas rienhartii	-78660	0-538.2	0-289.8
Chlorella sp.	0-82.8	-	0-310.5
Closteridium lunula Reinsch	-	-	0-41.4
Closteriopsis longissima Lemm	-	-	0-20.7
Coelastrum microporum Naegeli	0-103.5	0-331.2	-
Cosmarium contractum var *incrassatumscott*	-	-	0-20.7
Echinosphaerella limnetica G.M. Smith	0-20.7	-	-
Eudorina elegans	0-62.1	-	0-41.4
Golenkinia paucispina west and west	-	0-41.4	-

(*Contd.*)

Table 1: (*Contd.*)

Identified algae	*Total number*		
Cyanophyceae	*St1*	*St2*	*St3*
Golenkinia radiate	-	0-20.7	-
Gonium sp	-	-	0-20.7
Kirchneriellacontrota (schmidle) Bohlin	-	0-62.1	0-20.7
Micractiniumpusllium	-	0-20.7	-
Mougeotiasp	-	0-20.7	-
Oocystisnatans	0-765.9	-	-
Oocystisparva west and west	-	-	0-20.7
Oocystispusilla Hansgirg	-	0-20.7	-
Oocystissubmarina (Orig)	-	-	0-82.8
Pediastrum boryanum (Turp) *meneghini*	0-20.7	0-41.4	-
Pediastrum boryanum var *forcipitatum*	-	0-41.4	0-20.7
Pediastrum duplex var duplex	20.70	-	-
Pediastrum simplex (n.chodat)	-20.7،	-	-
Pediastrum simplex (meyen) Lemm	0-82.8	0-124.2	0-41.4
Pediastrum simplex var. *duodenarium* (Bailey) Rabenh	-	-	0-20.7
Pediastrum simplex var simplex	20.7	-	-
Pediastrum sp.	-	-	0-20.7
Scendesmus abandons var. *brevicauda*	0- 41.4	0-20.7	0-41.4
Scendesmus acuminatus (lag.) Chodat	-	-	0-20.7
Scendesmus aculeolatus Lemm	0-41.4	-	-
Scendesmus arcuatus var. *platydiscus* G.M Smith	0-103.5	-	0-124.2
Scendesmus bernardii G.M Smith	0-41.4	0-41.4	0-20.7
Scendesmus bijuga (Turp) Loderheim	-	-	0-41.4
Scendesmus carinatus varcarinatus	-	0-227.7	0-41.4
Scendesmus denticulatusn.uherko	0-20.7	0-20.7	-
Scendesmus ecorins (Orig)	0-621	0-41.4	0-41.4
Scendesmus obliguus (Turp)	-	-	0-20.7
Scendesmus obtusus Meyen	-	0-165.6	-
Scendesmus opoliensis (Orig)	0-103.5	0-20.7	0-20.7
Scendesmus opoliensis var *contactaprescott*	0-310.5	0-62.1	0-20.7
Scendesmus quadricauda (Turp) de Brebisson	0-1097.1	0-20.7	-
Scendesmus quadricauda var. *longispina* (Chodat) G.M Smith	0- 3829.5	0-62.1	0-62.1
Scendesmus quadricauda var. *westii* G.M Smith	0-124.2	0-20.7	0-20.7
Scendesms spp.	0-227.7	0-289.8	0-144.9
Tetradron minimum (A. Braun) Hansgirg	0-20.7	-	-
Tetradron regular var *incus* (n.Teiling)	0-20.7	-	-
Treubaria setigerum (Archer) G.M Smith	0-20.7	-	-
Westellasp	-	-	0-41.4
Euglenophyceae			
Euglena oxyuris var *minor* De Flandra	-	-	0-20.7
Euglena sp.	-	-	0-20.7
Phacus sp.	0-20.7	0-165.6	-
Chrysophyceae			
Dinobryon divergens imhof	0-20.7	-	-
Mallomonas sp.	0-20.7	0-20.7	-
Mallomonas acaroidsperty	-	-	0-20.7
Mallomonas alpinapascher and Ruttner	0-62.1	0-62.1	0-62.1
Dinophyceae			-
Glenodinium folioccum	0-62.1	0-20.7	-
Cryptophyceae			-
Campylomonas cryptomonasreflexa	0-41.4	-	0-62.1
Rhodomonas sp.	0-20.7	-	-

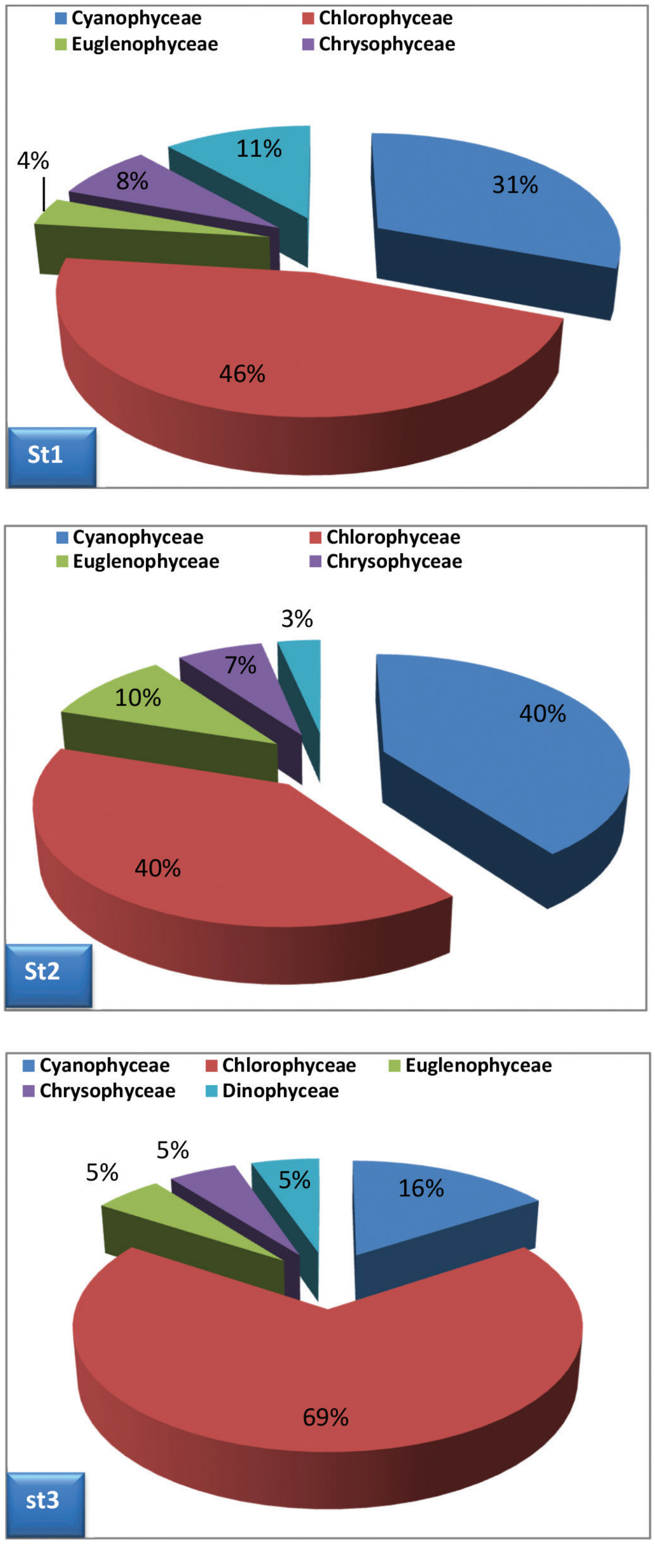

Figure 2: Phytoplankton compositions in Hilla river.

As for the sites, the third site shows a decrease in the numbers of genera and species that belong to bluish green algae compared to the first and second sites, and perhaps this is a good indication of the

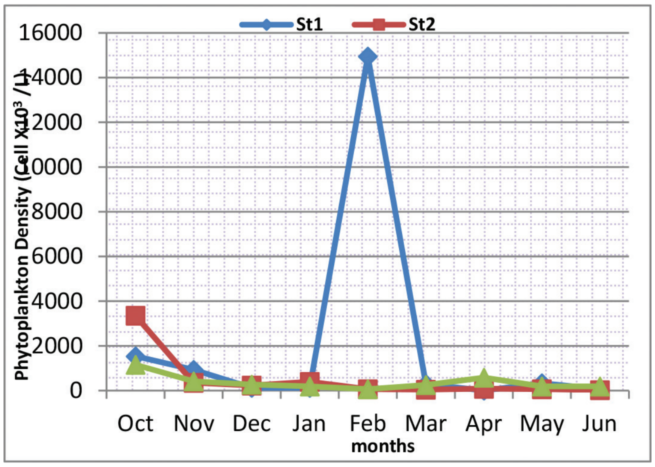

Figure 3: Phytoplankton density in Hilla river.

cleanliness of the water in this site (Saikia et al., 2010). The presence of blue-green algae indicates that the water is rich in organic matter (Onyema and Nwank, 2009).

Quantitative counts of phytoplankton cells were 0 -14945.4, 20.7-3353.4 and 62.1-972.9 Cell $\times 10^3$ /L at stations 1, 2, 3 respectively (Figure 3). In this study, the cell numbers recorded seasonal variation with maxima during early spring at the first station and this may be related to the fact that the phytoplankton composition in the river is usually affected by light availability,the discharge, morphometry, hydrology and trophic status (Kolayli and Sahin, 2009). Where the first station recorded its highest density in February month, and this rise was associated with an increase in the numbers of some algal species such as *Chlamydomonas rienhartii*, *Scendes musquadricauda* var. *longispina* (Chodat) G.M Smith, *Scendesmus quadricauda* (Turp) de Brebisson and *Oocystisnatans*. While, the second and third stations recorded their highest density in October, as the increase in these stations were linked to an increase in the types of some algae such as *Microcystissp*, *Chlamydomonas rienhartii*, *Coelastrum microporum* Naegeli, *Scendes musspp., Scendes muscarinatus varcarinatus, Scendesmus obtusus* Meyen, *Phacus* sp. *and Pediastrum simplex* (meyen) Lemm*)* for station 2, and *Scendesmus opoliensis* (Orig), *Scendesmsspp* and *Chlamydomonas rienhartii* for station 3 (Figure 2).

The results in Table 2 show the values of some physical and chemical factors recorded in the current study, where the temperature ranged between 8.8°C and 28.5°C). The lowest and highest values of pH (6.9 and 8.7) were recorded in October at site 1 and Feb at site 2, respectively. The lowest concentration of salinity 0.52 ‰ was recorded in Jun at site 2, while the highest concentration 0.80‰ was observed in Mar at site 2, respectively. The BOD_5 concentration ranged between 0.7 mg/L was recorded during Dec at site 2 and 3.73 mg/L in April at site 2 respectively, the lower concentrations of BOD_5 may be due to the self-purification of the river (Piirsoo et al., 2010), while the high concentrations of it may be related to organic matter loads discharge into river from the area near agricultural land and sewage effluent (Hassan et al., 2005). The total alkalinity ranged between (87 mg/L and 200 mg/L) recorded in Nov at site 3 and in Jan at site 2 respectively. The increase in alkalinity values during the cold months may be attributed to the effect of rain which leads to the dissolution of alkaline constituents from adjacent soils and dredged them into the river (Al-lami et al., 2001).

Table 2: Environmental parameters (range of mean) of surface water from Hilla river

Parameters	*Range*
Water temp. °C	8.8-28.5
Water pH	6.9-8.7
Salinity ‰	0.52-0.80
BOD5 mg oxygen/L	0.7-3.73
Total alkalinity mg/L	87-200

The statistical information of CCA analysis (Figure 4) shows the relationship between some environmental factors and phytoplankton types in the three studied sites. Results showed that phytoplankton species were affected by environmental factors. A total of (23%, 20.3% and 18.4%) of cumulative percentage variance of (St1, St2 and St3) species data respectively was explained by the four CCA axes with over 90% of the correlation between environmental factors and phytoplankton species, while the Monte Carlo test confirmed that the no significant ($p > 0.05$) of first canonical axis for three sites (Table 3). In CCA ordination (Figure 5) the length of the arrow was proportionally related to the importance of variables and its correlation with other environmental factors and phytoplankton species.

The phytoplankton species *Aphanotheca microscopia* Naegeli, *Chroococcussp, Doctylococcopsissp, Oscillatoria chalybea* var *insularis* Gaidner, *Actinastrum hantzchii Lagerhein, Aegagropila profunda* (Brand) Nordst, *Coelastrum microporum* Naegeli, *Eudorina elegans, Pediastrum duplex* var *duplex, Pediastrum simplex* (n.chodat), *Pediastrum simplex* (meyen) Lemm, *Pediastrum simplex* var *simplex, Scendesmus abandons* var. *brevicauda, Scendesmus aculeolatus* Lemm, *Scendesms* spp., *Glenodinium folioccum* were negatively correlated with pH. This negative correlation with pH may be due to the fact that algae thrive and grow in a specific range of pH (Reid, 1961). Their ability to photosynthesis decreases in alkaline waters. Because the carbon dioxide available for photosynthesis decreases with increasing alkalinity, as the ability of algae to photosynthesise is weak with increasing pH, the abundance of algae will decrease in water with high alkalinity.

The result of phytoplankton species in Figure 5 show some of the biodiversity indices. Diversity indices are often used to assess pollution in the aquatic environment and the state of the phytoplankton community. The Shannon-Weaver index value is considered one of the good indices which can be used for phytoplankton communities to indicate the state of pollution in water (Khuantrairong and Traichaiyaporn, 2008). Where values greater than 3 are interpreted as clean water, while values less than 1 are considered polluted severely (Whitton, 1975). The values of biodiversity in the three stations were 1.9, 2 and 2.9, respectively. It is noted that the first and second stations were close in diversity values, while they increased in the third station, which may be due to the availability of suitable conditions for biodiversity, where Jonge (1995) mentioned that in natural conditions, the water quality is appropriate to increase the diversity because of the wide range of suitable growth conditions for the increase of the species, and the opposite occurs under difficult conditions.

As for the richness index, it recorded the highest value (48) on the second site, and the lowest value (43) on the third site. Low values of the richness index reflect the predominance of certain types of algae, which in turn reduces the index values for the rest of the species. This may be due to the variability in environmental conditions such as plant nutrients, temperature and light transmittance that makes a number of species resistant or adapted to these conditions (Jenkerson and Hickman, 1983).

As for the evenness index, the third station recorded the highest value of (0.772), while each of the first and second sites recorded a value of (0.51). We note that the equivalence index is linked with the diversity values, as the third station recorded high values for the two indices, while it decreased for the first and second sites. Several research studies show that the correlation between the Shannon–Wiener index (H0) and evenness (J) is strong and positive. Also, the diversity may change

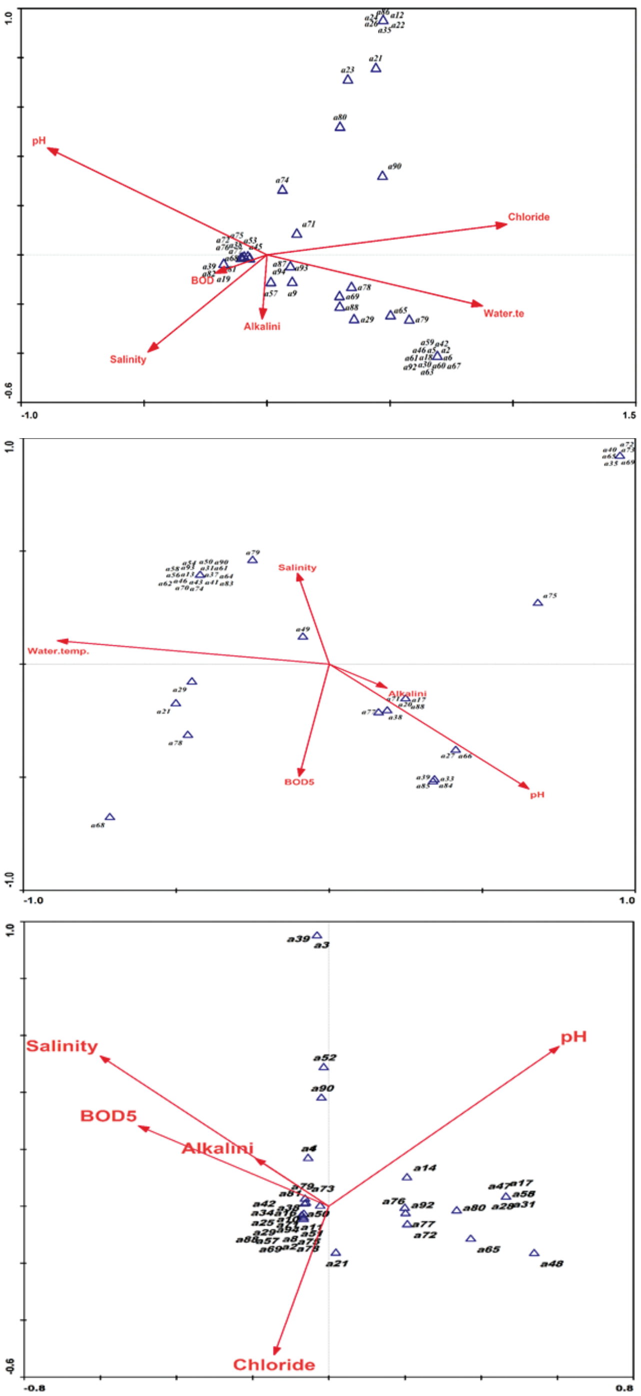

Figure 4: Spatial ordination resulting from CCA of most abundant algae species with respect to physical-chemical parameters for St1, St2 and St3 .name codes: ***Aphanocapsa biformis*** **A.B (a1);** ***Aphanotheca microscopia*** **Naegeli (a2);** ***Chlorogloea fritschii*** **Mitra (a3);** ***Chroococcus montanus forma*** **Rao, C.B (a4);** ***Chroococcus*** **sp. (a5);** ***Doctylococcopsis*** **sp. (a6);** ***Gloeocapsa rupestris*** **Kuetzing (a7);** ***Gloeocapsa*** **sp. (a8);** ***Gleothecasa moensis*** **(a9);** ***Lyngbya limnetica*** **Lemm (a10);** ***Merismopedia glauca*** **(a11);** ***Merismopedia punctate*** **Meyen (a12);** ***Merismopedia tenuissima*** **Lemm (Orig) (a13);** ***Microcystis aeruginosa kuetzemend.*** **Elenkin (a14);** ***Microcystis aeruginosa*** **v.major (wuiv) smith (a15);** ***Microcystis*** **sp. (a16);** ***Oscillatoria acuta*** **Bruhl Biswas (a17);** ***Oscillatoria chalybea*** **var** ***insularis*** **Gaidner (a18);** ***Oscillatoria hamelii*** **Fremy (a19);** ***Oscillatoria formosa*** **Bory (a20);** ***Oscillatoria limnetica*** **Lemmermann (a21);** ***Oscillatoria perarnata*** **Skuja (a22);** ***Oscillatoria*** **spp. (a23);** ***Phormidium fragile*** **(Menegh) Gom (a24);** ***Phormidium retzii*** **(Ag.) Gomont (a25);** ***Phormidium tenue*** **(Menegh) Gomont (a26);** ***Spirolina laxissima*** **west G.S (a27);** ***Synechocystis pevalekii*** **Ercegaic (a28);** ***Actinastrum hantzchii*** **Lagerhein (a29);** ***Aegagropila profunda*** **(Brand) Nordst (a30);** ***Ankistrodesmus convolutes corda*** **(a31);** ***Ankistrodes musfalcatus*** **var** ***mirabiliss*** **(west and wet) (a32);** ***Ankistrodesmus*** **sp. (a33);** ***Botryococcus*** **sp. (a34);** ***Chlamydomonas dinobryoni*** **G.M Smith (a35);** ***Chlamydomonas epiphytica*** **G.M Smith (a36);** ***Chlamydomonas globosa snow*** **(a37);** ***Chlamydomonas rienhartii*** **(a38);** ***Chlorella*** **sp. (a40);** ***Closteridium lunula*** **Reinsch (a41);** ***Closteriopsis longissima*** **Lemm (a42);** ***Coelastrum microporum*** **Naegeli (a43);** ***Cosmarium contractum*** **var** ***incrassatum*** **Scott (a44);** ***Crucigenia rectangularis*** **(a45);** ***Echino-sphaerella limnetica*** **G.M. Smith (a46);** ***Eudorina elegans Golenkinia paucispina*** **west and west (a48);** ***Golenkinia radiata Gonium*** **sp. (a49);** ***Kirchneriella controta*** **(schmidle) Bohlin (a50);** ***Micractinium puslLium*** **(a51);** ***Mougeotia*** **sp. (a52);** ***Oocystis natans*** **(a53);** ***Oocystis parva*** **west and west (a54);** ***Oocystis pusilla*** **Hansgirg (a55);** ***Oocystis submarina*** **(Orig) (a56);** ***Pediastrum boryanum*** **(Turp)** ***meneghini*** **(a57);** ***Pediastrum boryanum*** **var.** ***forcipitatum*** **(a58);** ***Pediastrum duplex*** **var** ***duplex*** **(a59);** ***Pediastrum simplex*** **(n. Chodat) (a60);** ***Pediastrum simplex*** **(meyen) Lemm) (a61);** ***Pediastrum simplex*** **var.** ***duodenarium*** **(Bailey) Rabenh (a62);** ***Pediastrum simplex*** **var** ***simplex*** **(a63);** ***Pediastrum*** **sp. (a64);** ***Scendesmus abandons*** **var.** ***brevicauda*** **(a65);** ***Scendes musacuminatus*** **(lag.) Chodat (a66);** ***Scendesmus aculeolatus*** **Lemm (a67);** ***Scendesmus arcuatus*** **var.** ***platydiscus*** **G.M Smith (a68);** ***Scendesmus bernardii*** **G.M Smith (a69);** ***Scendes musbijuga*** **(Turp) Loderheim (a70);** ***Scendesmus denticulatusn.uherko.*** **(a71);** ***Scendesmus ecorins*** **(Orig) (a72);** ***Scendesmus obliguus*** **(Turp) (a73);** ***Scendesmus opoliensis*** **(Orig) (a74);** ***Scendesmus opoliensis*** **var** ***contacta prescott*** **(a75); Scendes musquadricauda (Turp) de Brebisson(a76);** ***Scendesmus quadricauda*** **var.** ***longispina*** **(Chodat) G.M Smith (a77);** ***Scendes musquadricauda*** **var. westii G. Msmith (a78);** ***Scendesms*** **spp. (a79);** ***Tetradron minimum*** **(A. Braun) Hansgirg (a80);** ***Tetradron regular*** **var** ***incus*** **(n. Teiling) (a81);** ***Treubaria setigerum*** **(Archer) G.M Smith (a82);** ***Westella*** **sp. (a83);** ***Euglena oxyuris*** **var** ***minor*** **DeFlandra (a84);** ***Euglena*** **sp. (a85);** ***Phacus*** **sp. (a86);** ***Dinobryon divergens imhof*** **(a87);** ***Mallomonas*** **sp. (a88);** ***Mallomonasa caroids perty*** **(a89);** ***Mallomonas alpina pascher*** **and Ruttner (a90);** ***Urgolenopsis americana*** **(calkins) Lemm (a91);** ***Glenodinium folioccum*** **(a92);** ***Campylomonas*** **(*****cryptomonas reflexa*****) (a93);** ***Rhodomonas*** **sp. (a94).**

Table 3: Results for three sites of canonical correspondence analysis (CCA) for non-diatomic algae species–environment variables relationship with summary of Monte Carlo test

Axes	*1*	*2*	*3*	*4*	*Total inertia*
Site 1					
Eigenvalues	0.721	0.594	0.435	0.376	3.132
Species-environment correlations:	0.995	1.000	1.000	0.976	
Cumulative percentage variance					
of species data	23.0	42.0	55.9	67.9	
of species-environment relation:	27.6	50.3	66.9	81.3	
Sum of all eigenvalues					3.132
Sum of all canonical eigenvalues					2.617
Test of significance of first canonical axis: eigenvalue	0.721				
F-ratio	0.299				
P-value	0.2140				
Site 2					
Eigenvalues	0.661	0.528	0.439	0.249	3.251
Species-environment correlations:	0.985	0.966	0.980	0.996	
Cumulative percentage variance					
of species data	20.3	36.6	50.1	57.8	
of species-environment relation:	33.2	59.7	81.7	94.2	
Sum of all eigenvalues					3.251
Sum of all canonical eigenvalues					1.993
Test of significance of first canonical axis: eigenvalue	0.661				
F-ratio	0.766				
P-value	0.2520				
Site 3					
Eigenvalues	0.796	0.759	0.619	0.513	4.335
Species-environment correlations:	0.994	0.988	0.939	0.979	
Cumulative percentage variance					
of species data	18.4	35.9	50.2	62.0	
of species-environment relation:	28.0	54.8	76.6	94.6	
Sum of all eigenvalues					4.335
Sum of all canonical eigenvalues					2.839
Test of significance of first canonical axis: eigenvalue	0.796				
F-ratio	0.675				
P-value	0.4640				

with main ecological processes such as succession, competition and predation each of which can alter Shannon–Wiener index through changes in evenness without any change in species richness (Stirling and Wilsey, 2001). The low evenness values observed in this study represent a situation in which all the species are not equally abundant.

Simpson dominance index recorded the highest value (0,272) at sites 1 and 2 and the lowest value was 0.122 at site 3. Lower Simpson dominance index leads to higher diversity indices observed in all stations, lower index means higher diversity and vice versa (Ogbeibu, 2005). According to Shah and Pandit (2013), sites with low species always have higher Simpson value, and when the dominance is shared by a large number of species, As such, in this study, anthropogenic activities could be impacting some of the phytoplankton community, In most cases, an increase in Simpson index makes evenness to go in the opposite direction. Simpson's index of diversity also interprets the same results that site S3 was most species diverse, as its value was 0.878 for S3, 0.729 for S2 and 0.728 for S1. The Simpson's Reciprocal Index is often used to quantify the biodiversity of habitats. It takes into account the number of species present as

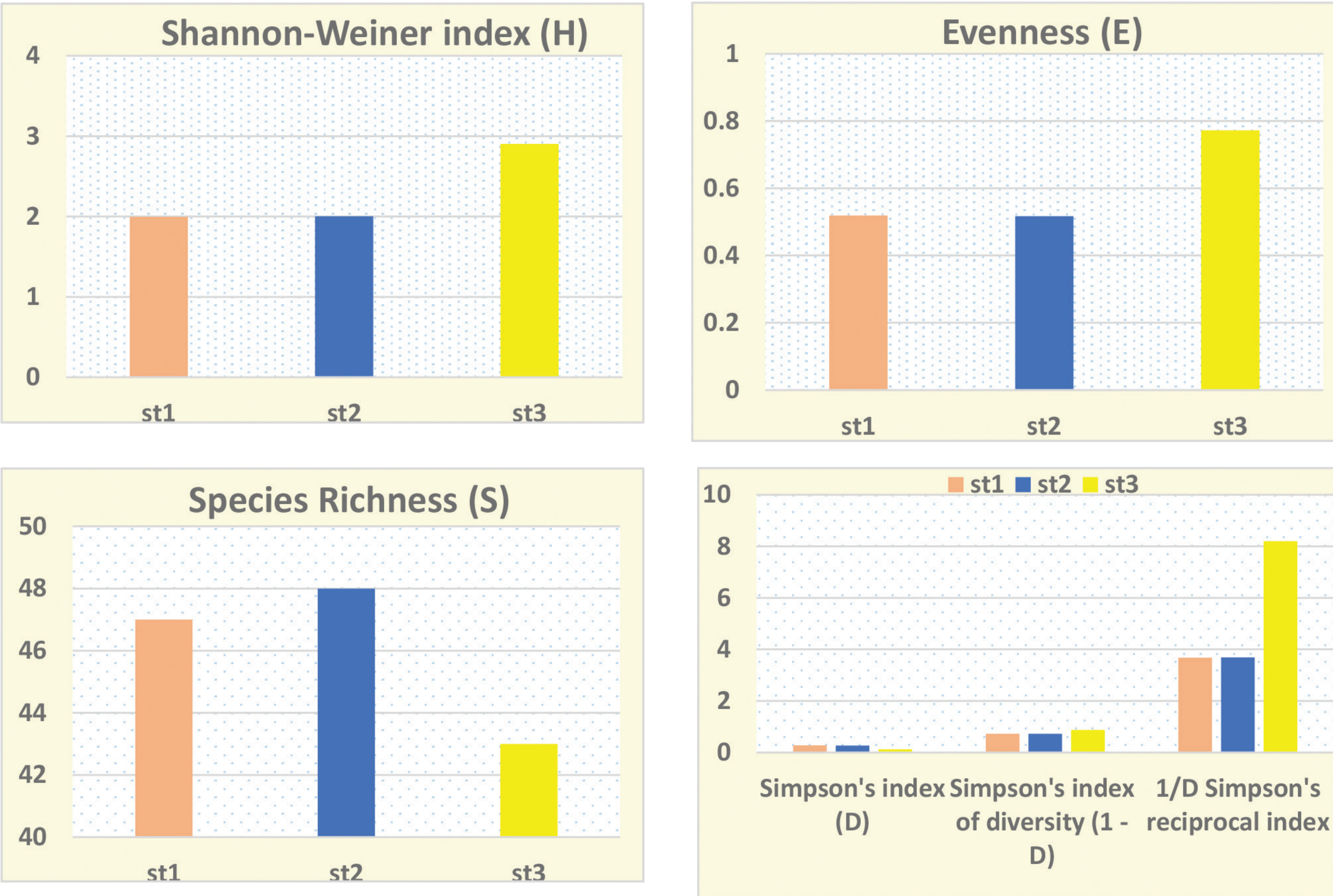

Figure 5: Biodiversity Index (Shannon–Wiener, Species Richness, Evenness and Simpson's Index) for Phytoplankton in Hilla river stations.

well as the abundance of species. The annual averages of Simpson's Reciprocal Index were 3.677, 3.69 and 8.197 at sites 1, 2 and 3 respectively. The higher the value, the greater the diversity. It was observed from this index that, the studied sites follow the following order: site 1 < 2 < 3.

Conclusion

Algae composition and abundance varied at the studied sites. No single factor is responsible for this variability. However, temperature, dissolved oxygen, water pH, salinity BOD_5, seasonal variations, and nutrient enrichment may be responsible for the variable changes in the Algae distribution, composition and abundance but pH was the most negatively correlated factor with phytoplankton density. The present study demonstrated that the phytoplankton diversity index (H-) at the studied sites was low and this is an indication of moderate pollution. Also, the diversity to some extent increase with increase nutrients.

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