Algal Research 5 (2014) 37–41

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Relationship between phytoplankton composition and environmental variables in an artificial pond

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ARTICLE INFO

Article history:
Received 8 December 2012
Received in revised form 18 March 2014
Accepted 9 May 2014
Available online 27 May 2014

Keywords:
Phytoplankton
CCA
Physico-chemical factors
Tolerance

ABSTRACT

Relation between phytoplankton composition and environmental variables was explored in a shallow artificial pond in Gaziantep, Turkey from June to December 2011, using canonical correspondence analyses (CCA) and weighted average (WA) regressions. The number of phytoplankton species increased during the fall season. The most dominant group was Chlorophyta (21 taxa), followed by Cyanobacteria (5 taxa), and Charophyta (5 taxa). *Pediastrum boryanum, Scenedesmus communis, Golenkinia paucispina, Pediastrum duplex, Kirchneriella contorta,* and *Cosmarium leaves* were the frequently found taxa which were closer to the center of CCA ordination. The first two axes of CCA explained 91.2% of the correlation between species and environmental variables and 17.9% of cumulative variance of species data. Explanatory factors (dissolved oxygen, temperature, PH, and redox potential) played a significant role in the distribution of species. According to the results of WA, phytoplankton species had different ecological preferences at different environmental conditions. Commonly recorded phytoplankton taxa with cosmopolitan characteristics had a relatively high tolerance and broad optimum ranges.
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1. Introduction

Phytoplankton plays an important role in aquatic ecosystems as they produce oxygen and food, which sustain all other forms of life, ensuring ecological balance [1,2]. Phytoplankton species can be useful as a biological tool for understanding water quality [3–6]. Phytoplankton species are affected by environmental factors and have different cell organizations in water bodies such as lakes, streams, pond, etc. [7–9].

Limno-ecological studies show that different species have specific ecological preferences and tolerances to environmental conditions [1,10,11]. Furthermore, information on ecological preferences of species based on long-term data provides useful information about the changes in aquatic habitats [12,13]. Temporal and/or spatial changes of environmental variables affect phytoplankton community in an ecosystem; how to recognize composition and dynamics of phytoplankton is a serious problem. Multivariate analysis can explain how phytoplankton composition and dynamics are related to habitat variables. Canonical Correspondence Analysis (CCA) has been widely used to reduce numbers of data and determine main environmental variables responsible for the fluctuations in the abundance and dynamics of phytoplankton community [8,14].

Phytoplankton species are present in a huge amount in natural and man-made aquatic ecosystems. Studies concerning algae for monitoring water quality show that changes in phytoplankton composition reflect not only variation in water quality, but also changes in physical and chemical variables and biotic interactions. This implies the importance of bio-monitoring studies in a variety of aquatic ecosystems. Ecological studies include seasonality of phytoplankton and variation of physico-chemical factors in water bodies and evaluate the relationship between algal taxa and environmental factors [14–16]. Phytoplankton species have developed morphological and physiological adaptive strategies for surviving in different environments [2,11]. Defined functional groups of phytoplankton from morphological and physiological traits may potentially dominate or co-dominate in a given environment.

Sommer et al. [17] developed a Plankton Ecology Group (PEG) model related to seasonal succession of plankton in community assembly. The PEG model attributed to describe factors driving the seasonal changes in phytoplankton succession in ecosystems. This model [17,18] handled physical and biological (competition for nutrients and grazing) constraints set at the start and end of the growing season.

Information about environmental conditions related to phytoplankton community in pond system is little [19]. Thus, in the present study, phytoplankton succession had been examined periodically from June to December 2011 in the artificial pond. The aim of the study was to evaluate the relationships between phytoplankton composition and

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http://dx.doi.org/10.1016/j.algal.2014.05.002
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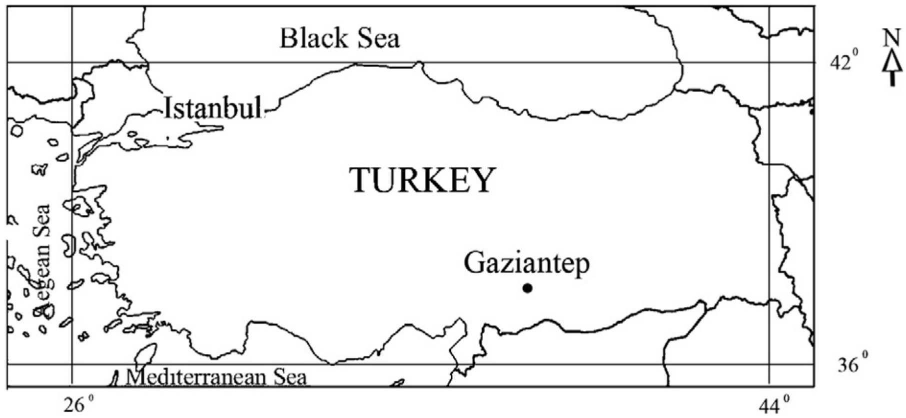

Fig. 1. Map of the study area.

environmental factors by the use of multivariate analyses, and to increase our knowledge about phytoplankton succession patterns in the pond.

2. Materials and methods

The artificial pond, located nearby the Department of Biology, University of Gaziantep (Fig. 1), had a maximum depth of about 1.7 m, length of 13 m and width of 7 m. It contains fauna and is surrounded by flora.

Water samples were collected weekly from just beneath the surface of the pond between June and December 2011. The samples were concentrated by use of sartorius filtration technique with a 0.45 μm mesh size of acetate filter for identification of phytoplankton. Taxonomic keys were used for identification [7,20–29]. Seven environmental variables were measured *in situ*: temperature, dissolved oxygen concentration, conductivity, total dissolved solid (TDS), salinity, pH, and oxidation reduction potential (ORP) by using YSI 556 model oxygen-temperature meter.

Measured physico-chemical variables were compared with analysis of variance (ANOVA) [30]. Tukey's honestly significant difference (HSD) multiple range tests were also carried out for comparing environmental changes. Spearman's rank correlation analysis was used to evaluate relationships among the environmental variables. Detrended correspondence analysis (DCA) was used to determine the gradient length of phytoplankton composition, which was a unimodal response before performing CCA [31]. Canonical correspondence analysis (CCA), a direct gradient analysis technique, was used to elucidate the relationship between predictor variables (environmental factors) and response variables (phytoplankton species) in the pond. Environmental variables were transformed (ln (x + 1), except the pH) to reduce skewness [32]. Obtained data were analyzed with forward selection of Monte Carlo permutation test (499 unrestricted permutations). Net-phytoplankton composition with binary data was used in this analysis. The program CANOCO was performed for the ordination analyses [31,32]. Weighted averaging (WA) regression of the CALIBRATE program [33] was carried out to estimate species optima (u_k) and tolerance (t_k) levels for environmental variables.

Species diversity was calculated by the use of Shannon Wiener and Simpson's indices with randomization test [34,35]. Species Diversity and Richness Version 4 (SDR4) program was performed for the species diversity analyses [36].

3. Results and discussion

3.1. Environmental variables

Physico-chemical variables are given in Table 1. Values of environmental variables fluctuated in the artificial pond during the present study. Tukey's HSD test showed that there were significant differences ($p < 0.05$) among the environmental variables during study period. Water temperature one of environmental variable changed from 4 to 32 °C for N3 (3rd week of November) and A4 (4th week of August), respectively. There was not significant change in water temperature among the summer months. However, significant differences were determined among fall's months. Dissolved oxygen (DO) values showed a significant variation ($p < 0.05$) in the pond and increased at the weeks of fall. Significant differences ($p < 0.05$) in conductivity and total dissolved solid (TDS) values were found in the pond. Both mentioned variables decreased at A1 (the first week of August), A3 (3rd week of August) and S3 (3rd week of September). This could be due to addition of tap water and precipitation. Salinity and pH values changed from 0.18 to 0.45 ppt and from 6.74 to 9.51, respectively. Alkalinity of water in the pond had changed to basic. A similar result was also found in a freshwater pond in Japan [37].

Spearman's rank analyses indicated significant correlations among environmental variables and their results are given in Table 2. Spearman's rank correlation test showed that DO was inversely correlated with water temperature ($p < 0.01, r = 0.940$). Positive correlation was found between conductivity and TDS ($p < 0.01, r = 0.852$). Besides, according to this correlation analysis, salinity was positively correlated with conductivity ($p < 0.01$, $r = 0.726$) and TDS ($p < 0.01$, $r = 0.906$), while pH was inversely correlated with ORP ($p < 0.01$, $r = 0.907$) (Table 2). Adverse correlation between pH and ORP was also reported by O'Neil [38].

3.2. Net-phytoplankton composition

Total 39 net-phytoplankton taxa (Table 3) belonging to 24 genera were identified in this study. Chlorophyta (21 of 39) was the dominant group, followed by Cyanobacteria (5 of 39). *Scenedesmus* had the most abundant species in the artificial pond. Some species such as *Pediastrum boryanum*, *Scenedesmus communis*, *Golenkinia paucispina*, *Pediastrum duplex*, *Kirchneriella contorta* and *Cosmarium leave* were frequently

Table 1
The minimum, maximum, and mean ± SD (standard deviation) values of environmental and biological variables combined from sampling stations in the artificial pond.

	Unit	Minimum	Maximum	Mean ± SD
Temperature	°C	4.00	32.02	23.19 ± 9.68
Conductivity	μS cm^{-1}	399.0	1002.0	638.7 ± 127.8
TDS	g L^{-1}	0.26	0.60	0.40 ± 0.07
Salinity	ppt	0.20	0.50	0.31 ± 0.07
DO	mg L^{-1}	11.30	16.90	13.09 ± 1.82
pH		6.70	9.50	8.41 ± 0.77
ORP	mV	66.03	170.50	118.78 ± 29.46

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