Turkish Journal of Botany

Volume 35 | Number 1 Article 9

1-1-2011

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Turk J Bot
35 (2011) 77-84
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doi:10.3906/bot-1001-284

Research Article

Seasonal changes in phytoplankton community structure in relation to physico-chemical factors in Bukan dam reservoir (northwest Iran)

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Received: 13.01.2010
Accepted: 11.08.2010

Abstract: This study examines the relationship between phytoplankton population and some important physicochemical variables in the Bukan Dam Reservoir. The sampling was performed monthly from 8 sampling sites from April 2008 to February 2009. Phytoplankton counts were made by inverted microscope. Totally, 55 phytoplankton taxa were identified and included Chlorophyta, Bacillariophyta, Dinophyta, Cyanobacteria, Euglenophyta, Chrysophyta and Cryptophyta. Correlations between some important physicochemical factors and total phytoplankton number were calculated. Results indicated that phytoplankton total number positively correlated with NH_3 (R^2 = 0.845) and negatively correlated with Secchi disc depth (R^2 = -0.613).

Key words: Iran, Bukan, reservoir, phytoplankton, physicochemical factors

Introduction

One of the most important living organisms in the aquatic ecosystem is phytoplankton. Phytoplankton, the primary producer, plays an important role in the material circulation and energy flow in the aquatic ecosystem. Its presence often controls the growth, reproduction capacity, and population characteristics of other aquatic organisms (Ariyadej et al., 2008). Changes in the phytoplankton of freshwater lakes have long been recognised as providing a good indicator of the trophic status and environmental quality of the system (Reynolds, 1996). Increased growth of certain groups of phytoplankton especially blue green algae can cause deoxygenation of the water leading to fish deaths (Whitton & Patts, 2000). In surface waters, an increase in phytoplankton biomass is often associated with nutrient enrichment (Smith, 2003).

A reservoir can be viewed as a very dynamic lake in which a significant portion of its volume possesses characteristics of and functions biologically as a river (Wetzel, 2001). The constructing a dam can lead to serious ecological variation (Baykal et al., 2009). Phytoplankton is affected by different environmental factors such as pH, light, and temperature (Graham & Wilcox, 2000; Buzzi, 2002; Çelekli et al.; 2007). The phytoplankton composition can reflect the ecological status of reservoirs and respond both qualitatively and

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quantitatively to changes therein (El-otify, 2002). The dynamics and species diversity of phytoplankton are greatly influenced by the water's physico-chemical and biological factors (Harris, 1986; Reynolds, 1986; Sommer, 1989).

Zarrineh Rood River is one of the largest rivers in north-west Iran and the biggest in Urmia lake basin. Bukan Dam Reservoir is located on this river, 36 km east of Bukan city (Figure 1). Bukan Dam (max. volume 650×10^6 m^3, useful volume 486×10^6 m^3, total length 27.5 m, and total area of reservoir 4.5×10^7 m^2) was constructed in 1969. The reservoir provides irrigation and domestic water supply for about 250,000 people, which along with its crucial role as an important fisheries source in the region, makes Bukan Dam Reservoir's significance 2-fold. Despite these values, few studies have been performed on the Bukan Dam Reservoir's water quality, such those by Masoudi et al. (2004) and Sarang et al. (2001). Yet, there are no studies on the reservoir phytoplankton. Therefore, the aim of the present study was to investigate the phytoplankton composition, their seasonal occurrence, and the relationships between phytoplankton composition and physicochemical parameters in the Bukan reservoir.

Materials and methods

The samples were collected monthly by a Ruttner type sampler at 8 sampling sites from April 2008 to February 2009 (Figure 1). In each site 3 samples were taken: 1 for phytoplankton enumeration and the other 2 for chemical analysis and chlorophyll *a* determination. Phytoplankton samples were immediately fixed by 4% formaldehyde and preserved in cold, dark conditions for laboratory analysis. Phytoplankton counting and identification were made using 5-mL settling chambers with a Nikon TS100 inverted microscope at 400× magnification by Utermöhl's (1958) method. At least 50 fields or 100 individuals of the most abundant species were counted in each sample (Venrick, 1978).

Water temperature, dissolved oxygen, electron conductivity (EC), total dissolved solids (TDS), and pH were measured in situ at every sampling site in the superficial water layer (50 cm depth) with a WTW 320 Oxymeter, a WTW LF 320 ECmeter, and a Testo 320 pH meter respectively. Water samples of 1 L were collected at the same depth for analysis of other chemical parameters. Dissolved nutrients (ammonia, nitrites, nitrates, and phosphates) were analysed as described in Greenberg et al. (1992).

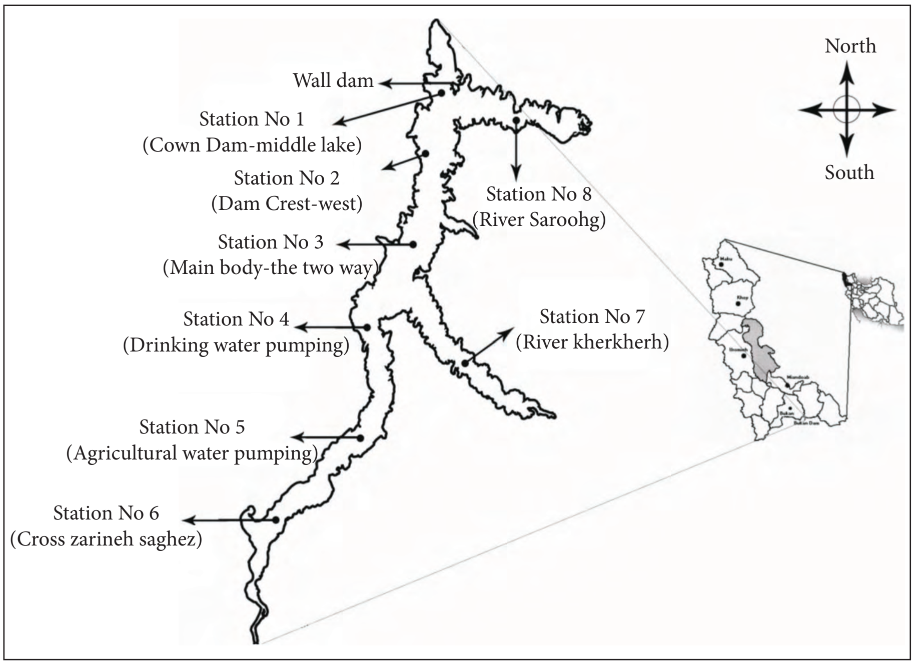

Figure 1. The map of sampling sites on Bukan Dam Reservoir.

The phytoplankton community in each site was analysed in terms of taxonomic composition, species, and orders density. Samples for chlorophyll *a* determination were filtered through a glass fibre filter (GF/C) buffered with magnesium carbonate. Chlorophyll *a* concentrations were estimated according to the method of Parsons and Strickland (1965) after 24 h extraction in 90% acetone. The phytoplankton taxa were identified according to the following references: Smith (1950), Prescott (1962), Tiffany and Britton (1971), and Bellinger (1992). Correlations and regression equations were obtained using Excel.

Results and discussion

In total, 55 phytoplankton taxa were observed in the samples (Table 1). Chlorophyta was the richest algal group, with 28 taxa, followed by Diatoms, with 10 taxa. Other algal groups were Dinophyta (6 taxa), Cyanobacteria (5 taxa), Euglenophyta (3 taxa), Chrysophyta (2 taxa), and Cryptophyta (1 taxon) (Figure 2).

It seems that there is a seasonal as well as a spatial pattern of phytoplankton population changes in Bukan Dam Reservoir. In fact, Chlorophyta, with 7.557×10^6 ind. L^{-1} (82%), had the highest density in the spring. Green algae such as *Oocystis* spp. and

Table 1. Phytoplankton species composition and abundance in Bukan Dam Reservoir in 2008-2009.

Species	Season	Spring	Summer	Autumn	Winter
Chlorophyta		22	20	21	19
1	*Chlamydomonas* sp.	++	++	+	++
2	*Tetraëdron minimum* (A.Braun.) Hansg.	++	-	+++	+++
3	*Pediastrum simplex v.duodenarum* (Baily) Rabenhorst.	++	++	+	++
4	*Laegerhemia quadriseta* (Lemm.) Smith.	+	+	+++	++
5	*Laegerhemia ciliata* (Lag.) Chodat.	-	-	-	-
6	*Oocystis borgei* Snow.	++	++	++	+
7	*O. solitaria* Wittr.	-	+	++	-
8	*O. crassa* Wittr.	++	+	+++	+
9	*O. parva* West & West.	+	++	-	++
10	*Ankistrodesmus convolutes* Corda.	++	++	+	+
11	*A. falcatus v.acicularis* (A.Braun) West.	+	-	++	+++
12	*Coelastrum* sp.	++	+	+++	-
13	*Dictyosepharium ehrenbergianum* Nag.	++	++	-	+
14	*Franceia droescheri* (Lemm.) Smith.	-	-	-	-
15	*Crucigenia apiculata* (Lemm.) Schmidle	++	++	+	+
16	*Scenedesmus acuminatus* (Lag.) Chodat	+	++	+++	-
17	*S. bijuga* (Turp.) Lagerh.	+	-	+	+++
18	*S. acutiformis* Schrod.	++	++	+	+
19	*S. quadricauda v.quadriauda* (Turp.)Breb.	++	++	++	++
20	*Scenedesmus* sp.	-	-	-	-
21	*Closterium Linula* (Mueller) Nitzech.	+++	-	++	++
22	*C. gracile* Brebisson	-	++	++	-
23	*C. setaceum* Ehrenberg	-	-	-	-
24	*Staurastrum asperum* Breb.	++	+	+++	+++
25	*Asterococcus* sp.	++	++	++	+
26	*Chodatella subsalsa* Lemmermann	+	+	+	++
27	*Chlorella vulgaris* Beyerinck	++	++	++	-
28	*Mesotaenium* sp.	++	++	-	++

Species Season		Spring	Summer	Autumn	Winter
Bacillariophyta		9	5	9	8
29	*Melosiera* sp.	+++	+	++	++
30	*Cyclotella* sp.	++	++	+	+++
31	*Diatoma elongatum* Ag.	-	-	++	+++
32	*Nitzschia* sp.	+++	-	+	++
33	*Synedra acus* Kutz.	++	-	-	-
34	*S. ulna* Grun.	+	++	+	++
35	*Navicula salinarum* Grunow	+	+	+	-
36	*N. gracilis* Ehrenberg	++++	-	+	++
37	*Cymbella prostrate* (Berkley) Cleve.	+++	+	++	++
38	*C. lanceolata* (Ehr.) V. H.	++	-	+	+++
Cyanobacteria		5	4	3	3
39	*Microcystis aeruginosa* Kutz.	+	+++	+	-
40	*Merismopedia elegans* A.Br.	+	++	++	+
41	*Aphanizomenon flos-aquae* (L.)Ralfs	+	+	-	++
42	*Oscillatoria* sp.	+	+++	+	-
43	*Spirulina major* Kutz.	+	-	-	+
Euglenophyta		3	2	2	2
44	*Euglena acus* Ehrenberg	+	+	+	++
45	*E. proxima* Dangeard	+	-	-	+
46	*Trachelomonas* sp.	+	+	+	-
Dinophyta		1	2	2	2
47	*Gymnodinium fuscum* (Ehrenberg) Stein	-	-	-	-
48	*Glenodinium quadridens* (Stein) Schiller	-	++	+	-
49	*Glenodinium* sp.	+	+	-	+
50	*Peridinium* sp.	-	-	-	-
51	*Ceratium hirudinella* (Muller)	-	-	-	-
52	*Dinoflagelate cyst*	-	-	+	+
Crysophyta		1	1	—	1
53	*Dinobryon sociale* Ehrenberg	-	-	-	-
54	*Mallomonas* sp.	+	+	-	+
Cryptophyta		1	—	1	—
55	*Cryptomonas* sp.	+	-	+	-
Total		42	34	38	35

+ Observed in 25% of samples, ++ Observed in 50% of samples;
+++ Observed in 75% of samples; ++++ Observed in 100% of samples

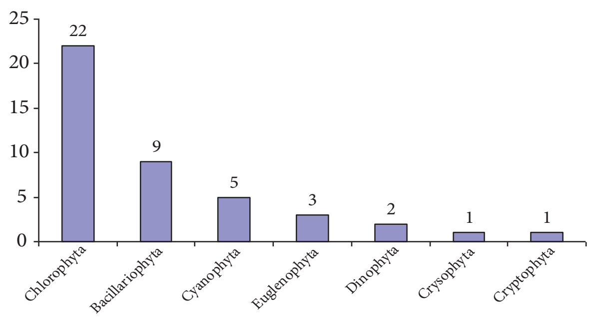

Figure 2. Species number of phytoplankton groups in Bukan Reservoir in 2008-2009.

Tetraedran minimum and Cyanobacteria like *Aphanizomenon flos-aqua* and *Oscillatoria* were abundant during early and late summer respectively. In this season, Cyanobacteria showed the highest abundance (2.23×10^6 ind. L^{-1}), comprising 56% of total phytoplankton density (Figure 3). Again, in autumn green algae like *Closterium setaceum* was observed abundantly (83% of total phytoplankton density). Diatoms, particularly *Cyclotella*, were dominant in the winter and early spring. Chlorophyta with 3.805×10^6 ind. L^{-1} and Diatoms with 3.135×10^6 ind. L^{-1} showed higher densities respectively.

On the other hand, the density of *Aphanizomenon flos-aqua* decreased gradually downstream of the reservoir main body, so that it had the highest density in Site 6 and the lowest in Site 1. This spatial distribution may reflect nutrients densities, which were highest in Sites 5 and 6 where Sagez city sewage water entered the reservoir and then indicated a gradual decreasing scheme. The presence of Cyanobacteria in Bukan Dam Reservoir as a factor to give unpleasant taste and odour to the water was first

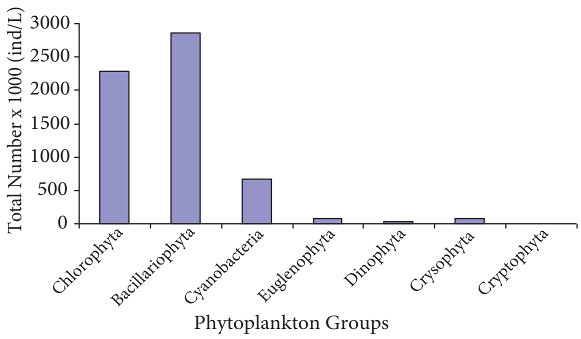

Figure 3. Total number of phytoplankton groups in Bukan Reservoir in 2008-2009.

reported by Masoudi et al. (2004). They introduced the Cyanobacteria genus *Microcystis* as the principle agent which produces an organic compound named Geosmin. *Microcystis aeruginosa* was first reported from Bukan Reservoir in the present study associated with some other Cyanobacteria which reached high densities during the dry period, indicating an early eutrophy in some stations of the reservoir. Therefore, our conclusion about the trophy state of Bukan Dam Reservoir was confirmed by Sarang et al. (2001) in a study which they performed on the physicochemical parameters of Bukan reservoir water. They attributed the initiation of eutrophic condition in the water to the untreated sewage water that entered the reservoir from Sagez River. Cyanobacteria blooms resulted in fish death have been reported in several studies (e.g. Azevedo, 1996; Jochimson et al., 1998; Chellappa et al., 2000; Chellappa and Costa, 2003). It should be noted that algal bloom in Bukan Reservoir is in an initial stage at few stations, and so it has not imposed any reverse effects on the lake fish. However, considering the crucial role of the Bukan Dam Reservoir in terms of fisheries and domestic water supply in the region, suitable methods should be regarded to limit excess nutrients flow into this valuable aquatic source.

Determination of water quality by phytoplankton species composition has been a well documented method in the world. In the present study, we observed a few phytoplankton species such as *Ceratium hirundinella, Peridinium* sp., and *Glenodinium quadridense*, which are known as indicators of meso-eutrophic waters (APHA, 1988; Wetzel & Likens, 1991).

The concentration of chlorophyll *a* is used to determine the water quality, trophic level, and phytoplankton distribution (Akbulut, 2003). In Bukan Dam Reservoir chlorophyll *a* was between 0.21 and 25.19 μg/L. Maximum and minimum chlorophyll *a* concentrations were recorded in March 2008 as 25.19 μg/L and in October 2008 as 0.21 μg/L. Chlorophyll *a* average concentration changes are indicated in Figure 4. According to Wetzel (1983) the level of chlorophyll *a* in oligotrophic lakes is 0.33-3 μg/L, in mesotrophic lakes 2-15 μg/L, and in eutrophic lakes 10-500 μg/L. Comparing the data with previous studies suggests that the concentration of chlorophyll *a* and total cell

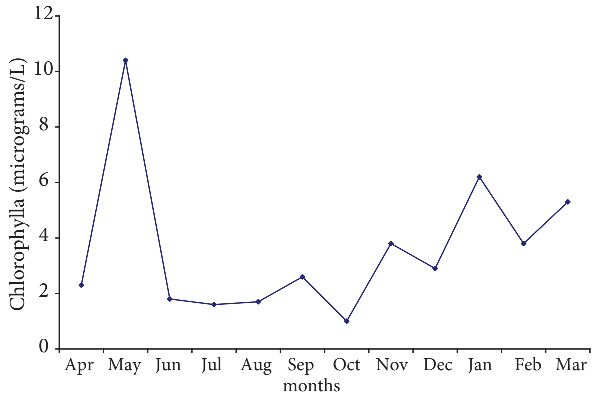

Figure 4. Chlorophyll a changes in Bukan Dam Reservoir in 2008-2009.

numbers of Bukan Reservoir are well within the range of mesotrophic lakes. On the other hand, the Secchi disc depth in our study was between 0.84 and 2.04 m, which also confirmed the mesotrophic state of the Bukan Reservoir (Smaili Sari, 2000).

The correlations between the total phytoplankton numbers of sampling sites in different months were determined and regression coefficient (R^2) was calculated. The results indicated that there was no variation between surface and deep samples in respect of phytoplankton number; in addition, there was a good correlation between surface and deep samples in Sites 1 (R^2 = 0.887) and 3 (R^2 = 0.879). This indicated that phytoplankton total number did not highly fluctuated in surface and deep layers of water column in different months, which was related to light penetration through water in the reservoir. In addition, a decreasing pattern of correlation was observed among the density of various algal groups in sampling sites with increased distance between them along the main body of the Bukan Reservoir (Sites 1-6). This pattern may illustrate a continuous change in phytoplankton population and ecological parameters along the main water body of this reservoir.

The most important physicochemical parameters in the Bukan Dam Reservoir are shown in Table 2. We determined correlations and calculated regression coefficient (R^2) between the total phytoplankton number and some physicochemical parameters for 4 sampling sites (1, 3, 4, 5) located along the main body of the reservoir. The results indicated that total phytoplankton number negatively correlated with Secchi disc depth (R^2 = -0.613), (Figure 5), which corresponded with studies conducted by Nasrollahzade Saravi and Hoseini, (2004), and Sivakumar and Karuppasamy (2008). On the other hand, there was a positive correlation between the total phytoplankton number and the concentration of NH_3 (R^2 = 0.845), (Figure 6), a negative correlation between the total number of phytoplankton and the concentration of PO_4 (Figure 7), TDS, and water temperature with R^2 values that were -0.669, -0.836 and -0.32, respectively, and no correlations between the total phytoplankton number and the concentration of NO_3 (R^2 = 0.031). According to research conducted on freshwater ecosystems (e.g. Parham et al., 2007) dissolved oxygen (DO) usually decreased as water temperature increased. A similar pattern was observed in our study. In other words,

Table 2. Some important physicochemical parameters of Bukan Dam Reservoir in sampling sites.

Station Parameter	1	2	3	4	5	6	7	8
Water temperature (°C)	16.0	16.3	16.0	15.5	14.8	15.8	16.0	15.9
pH	7.87	8.14	7.91	7.77	8.04	8.08	7.85	7.95
DO (mg/L)	8.45	10.47	9.25	10.21	11.36	11.80	8.76	9.03
SD (cm)	204	177	162	137	108	84	122	124
TDS (mg/L)	95.5	94.2	94.2	92.8	92.7	91.4	95.3	96.8
EC (µmohs/cm)	172	147	149	139	120	113	89	121
PO_4 (mg/L)	0.52	0.71	0.56	0.35	0.48	1.11	0.15	0.24
P-PO_4 (mg/L)	0.29	0.23	0.18	0.11	0.16	0.39	0.05	0.11
TN (mg/L)	1.34	1.68	1.43	1.17	1.32	1.52	1.03	1.59
NH_3 (mg/L)	0.096	0.198	0.285	0.168	0.237	0.276	0.076	0.053
NO_3(mg/L)	5.55	6.72	5.7	5.54	6.36	6.00	5.25	6.75

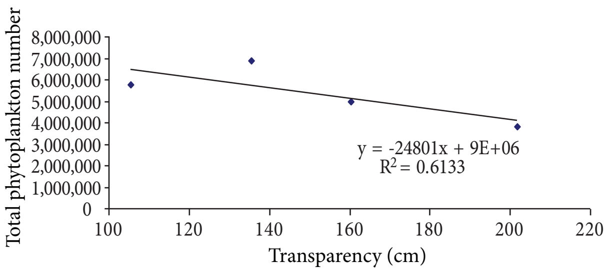

Figure 5. Correlation between total phytoplankton number and transparency in Bukan Reservoir.

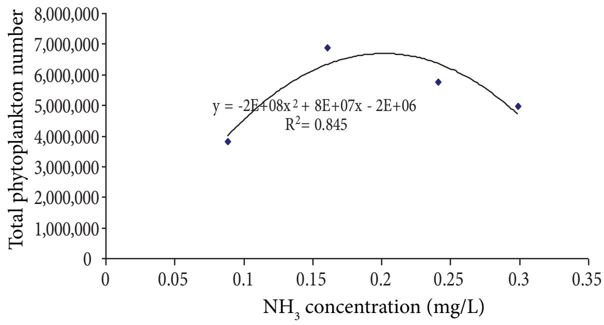

Figure 6. Correlation between total phytoplankton number and NH3 in Bukan Reservoir.

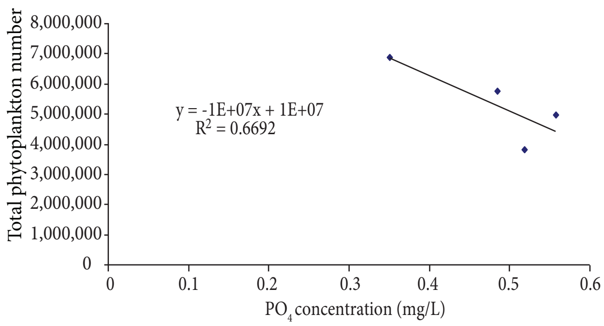

Figure 7. Correlation between total phytoplankton number and PO4 in Bukan Reservoir.

DO was negatively correlated to water temperature during the study period (R^2 = -0.77).

Finally, with regard to the physical, chemical, and biological variables studied, it can be concluded that the water of the Bukan Reservoir is mesotrophic.

Acknowledgements

We would like to express our heart-felt gratitude and appreciation to the Iranian Fisheries Research Organization (IFRO), which supported this work financially, and to the Iranian Artemia Research Centre, which provided us with equipment, laboratory analysis, and facilities.

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