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Impacts of cage culture of the common carp, *Cyprinus carpio* Linnaeus 1758, on water quality and phytoplankton communities in Golestan reservoir, north of Iran

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ABSTRACT

Regarding to fish cage culture development in freshwater reservoirs, it is essential to evaluate its environmental impacts. The present study was aimed to evaluate the environmental impacts of common carp, *Cyprinus carpio* cage culture on water quality and phytoplankton communities of Golestan reservoir, north of Iran. Sampling was monthly conducted from six stations (5, 100, 200, 400, 1000 and 2000 m distance from cages) along this reservoir during April to September, 2016. The water quality parameters and phytoplankton population alterations were sampled at all stations. No significant differences were observed in the environmental variables (except for BOD) among the sampling stations. However, all these variables showed significant differences between the sampling periods. The highest abundances of identified phytoplankton were belonged to Cyanophyta, Bacillariophyta and Chlorophyta respectively in both seasons. Canonical correspondence analysis (CCA) diagrams presented differences in the temporal distribution of sampling units and phytoplankton abundances in both seasons. However, no significant spatial differences were observed. Based on results, we found no consistent environmental alteration caused by cage culture, hence it can be allowed in Golestan reservoir, Iran byclose monitoring its impacts.

Keywords: Cage culture, Environmental impact, Phytoplankton, Freshwater reservoir.
Article type: Research Article.

INTRODUCTION

Inland freshwater bodies including dams, lakes and reservoirs can be used for freshwater fish cage culture due to some advantages including perfect food chain, simple management, low cost of harvesting, and efficient monitoring of fish growth (Degefu *et al.* 2011). However, cage culture is known to have some environmental impacts (Guo *et al*. 2009). Nutrient-rich waste such as uneaten feed and fish excrement released from cage can affect the environment (Walker *et al*. 2003; Rebeca *et al*. 2010). The severity of cage-related environmental impacts usually depends on the intensity of fish production within a lake or reservoir. Since the exchange time of freshwater systems is shorter than that in marine environments, the environmental effects of wastes produced by freshwater cage fish culture are much stronger than those in marine environments (Beveridge *et al.* 1997). In recent years, special attentions are paid to fish cage culture in inland freshwater reservoir of Iran. Common carp, *Cyprinus carpio* and rainbow trout, *Oncorhynchus mykiss* are the major fish species for cage culture in freshwater systems. Golestan reservoir is a freshwater dam located in the northeast of Golestan Province, Iran, built on the Gorganrud River. The increasing development of the cage-culture industry has caused environmental and

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ecological concerns. Cage culture alters the physio-chemical characteristics of the water (Dias *et al*. 2011) and also the physiology, behaviour and finally the structure of communities. Thus, the evaluation of the environmental factors may be a good indicator to analyse the variation and structure of biotic communities in freshwater environments (Neiff 1996). In Iran, most of the studies have been focused on impact assessment of marine and open sea fish cages (Bagheri *et al*. 2016; Afraei Bandpei *et al*. 2016; Karimian *et al*. 2017; Jahani *et al*. 2018) and no study has been carried out on risk assessment of freshwater cage culture. Bagheri *et al.* (2016) reported the impact of the fish cage culture on the zooplankton population due to striking increase of *A. tonsa*, *B. improvisus, P. polyphemoides*, and bivalve-larvae abundance at the fish cage site. Moreover, Afraei Bandpei *et al.* (2016) reported that the density and biomass of phytoplankton and zooplankton in spring and winter were higher than in the other seasons which may be due to the activity of rainbow trout culture in the cages. The present study presents basic information regarding the environmental impacts of a cage culture system in freshwater by evaluating water quality and phytoplankton population structures. The aim of this study was to examine the relationship between the distance from the cage and any observed impacts.

MATERIALS AND METHODS

Study area

The study was conducted in Golestan reservoir at (coordinates: 55˚ 16' E and 37˚ 19' N), Golestan Province, Iran. The reservoir surface area and its volume were 152 km^2 and 5.7 km^3 respectively.

Field sampling

In this experiment,8 cages (each 120 m^3 in volume and8 tons in production capacity) were used in the Golestan dam between April and September, 2016. Water and phytoplankton were sampled from six stations. Furthermore, twice-a-day manually-feeding was done at 3-5% of fish body weight.

Collection of water samples

Water samples were collected monthly in the morning during six months from April to September, 2016. Samples were collected with the Ruttner sampler (with the depth ranging from 70 cm to 100 cm) along the stations transects (fluctuated 6.5-9 m, depending on the season), starting at 5, 100, 200, 400, 1000 and 2000 mnamedas distances I, II, III, IV, V and VI respectively away from the cage during six-month sampling (i.e., April, May, Jun, July, August, September). So, we used the data from different months as replicates of the sites.

Water quality monitoring

The water quality parameters including temperature, dissolved oxygen (DO), pH, salinity and electrical conductivity (EC) were monthly monitored. Other parameters including nitrate (No_3), ammonium (NH_4^+), phosphorus (P), biochemical oxygen demand (BOD), total dissolved solids (TDS), water hardness (H) were determined using water test kit and spectrophotometric methods (APHA 1975; Boyd & Tucker 1998).

Phytoplankton identification

Surface and bottom water (each 3 samples) were collected in 500-mL bottles at each station, processed by standard method of fixation with 4% formalin and further sedimentation, and then placed in the dark cool box before analysis. Phytoplankton was identified using the available keys (John *et al.* 2002; Bellinger & Sigee 2010) and under an inverted microscope at 400× magnification in the laboratory.

Statistical analysis

The significance of differences in phytoplankton abundance and physicochemical characteristics were evaluated using one way analysis of variance (ANOVA), followed by a Duncan̕s test to identify significant differences ($p < 0.05$) among the means. The analyses were carried out using SPSS 19 software. The relationships between the environmental variables and phytoplankton abundance were analysed through canonical correspondence analysis (CCA) using CANOCO software version 4.5. Phytoplankton abundance data were transformed by log (x + 1).

RESULTS

Environmental parameters

Table 1 shows water quality parameters in six sampling stations and also sampling periods. The experiment began during the spring, when all environmental variables (except dissolved oxygen) were in lowest amount. At the end of the experiment, all the variables significantly increased at summer. No significant differences were observed in the environmental variables (except BOD) between the sampling stations ($p > 0.05$). However, significant differences were found in all environmental variables between the sampling periods ($p < 0.05$). The results showed that the effect of nutrient discharge on DO was not significant ($p > 0.05$). Water temperatures showed seasonal trends, but the variation between stations was not statistically significant ($p > 0.05$). The nitrite levels were not significant ($p > 0.05$) between the stations.

Table 1. Spatial and temporal variation in physicochemical parameters registered in the Golestan reservoir, north of Iran. T: temperature; DO: dissolved oxygen; Sal: salinity; EC: electrical conductivity; TDS: total dissolved solids; H: hardness; Alk: alkalinity; NO_3: nitrate; NH_4^+: Ammonium; P: phosphorus; BOD: biochemical oxygen demand. Letters represent pairwise significant differences between treatments by Duncan test, with a 0.05 level of significance.

Variables	**Sampling stations**					
	5 m	**100 m**	**200 m**	**400 m**	**1000 m**	**2000 m**
Temperature (°C)	27.9 ± 1.6^a	27.9 ± 1.6^a	27.9 ± 1.6^a	27.9 ± 1.6^a	27.8 ± 1.5^a	27.8 ± 1.5^a
DO (mg L^{-1})	7.6 ± 0.6^a	7.6 ± 0.7^a	7.9 ± 0.8^a	7.9 ± 0.8^a	8.1 ± 0.8^a	8.1 ± 0.7^a
Salinity (ppm)	0.8 ± 0.2^a	0.2 ± 0.8^a	0.8 ± 0.2^a	0.8 ± 0.2^a	0.8 ± 0.2^a	0.8 ± 0.2^a
pH	8.1 ± 0.4^a	8.1 ± 0.4^a	8.0 ± 0.4^a	8.0 ± 0.3^a	8.0 ± 0.3^a	8.0 ± 0.2^a
EC (mscm^{-1})	1066.6 ± 170.6^a	1048.3 ± 161.9^a	950.8 ± 101.6^a	986.6 ± 121.1^a	976.6 ± 100.5^a	942.5 ± 102.5^a
TDS (gL^{-1})	987.1 ± 308.8^a	983.0 ± 293.4^a	949.1 ± 263.8^a	923.2 ± 244.5^a	911.7 ± 225.1^a	903.6 ± 235.3^a
Hardness	1070.1 ± 159.8^a	1061.0 ± 167.2^a	$165.7^a \pm 1045.9$	1020.6 ± 167.5^a	999.4 ± 161.3^a	975.2 ± 144.1^a
Alkalinity	111.6 ± 30.6^a	111.6 ± 30.6^a	107.2 ± 25.7^a	104.2 ± 27.3^a	101.5 ± 26.9^a	101.5 ± 26.9^a
Nitrate	1.0 ± 0.6^a	0.9 ± 0.6^a	0.9 ± 0.6^a	0.7 ± 0.5^a	0.7 ± 0.5^a	0.6 ± 0.4^a
NH_3	1.1 ± 0.8^a	1.1 ± 0.8^a	1.0 ± 0.8^a	0.8 ± 0.7^a	0.7 ± 0.6^a	0.7 ± 0.6^a
Phosphate	0.7 ± 0.4^a	0.7 ± 0.4^a	0.7 ± 0.4^a	0.6 ± 0.4^a	0.6 ± 0.3^a	0.6 ± 0.3^a
BOD	3.6 ± 1.2^a	3.3 ± 1.2^{ab}	2.6 ± 1.2^{abc}	2.1 ± 0.9^{bc}	1.6 ± 0.8^c	1.6 ± 0.8^c
Variables	**Sampling periods**					
	April	May	Jun	July	August	September
Temperature (°C)	25.5 ± 0.0^f	26.8 ± 0.0^e	27.6 ± 0.0^d	28.6 ± 0.5^c	30.0 ± 0.0^a	29.0 ± 0.0^b
DO (mg L^{-1})	8.8 ± 0.4^a	8.7 ± 0.2^a	7.9 ± 0.1^b	7.2 ± 0.2^c	7.2 ± 0.1^c	7.3 ± 0.3^c
Salinity (ppm)	0.6 ± 0.0^d	0.6 ± 0.0^c	0.6 ± 0.0^c	0.9 ± 0.0^b	1.1 ± 0.1^a	0.9 ± 0.1^b
pH	7.5 ± 0.1^c	7.6 ± 0.1^c	7.8 ± 0.1^b	7.9 ± 0.1^b	8.4 ± 0.1^a	8.2 ± 0.1^a
EC (mscm^{-1})	841.3 ± 30.6^d	855.1 ± 12.2^{cd}	955.0 ± 29.3^c	1083.3 ± 98.3^b	1166.2 ± 68.6^a	1040.3 ± 92.6^b
TDS (gL^{-1})	545.3 ± 15.6^e	723.0 ± 0.0^d	975.0 ± 0.0^c	1090.1 ± 113.0^b	1241.2 ± 49.9^a	1083.4 ± 68.8^b
Hardness	831.0 ± 21.1^e	883.2 ± 40.3^d	950.4 ± 44.6^c	1149.3 ± 56.9^b	1216.7 ± 40.6^a	1140.5 ± 32.6^b
Alkalinity	69.7 ± 3.6^f	86.7 ± 2.9^e	95.2 ± 5.6^d	114.0 ± 4.1^c	141.6 ± 6.3^a	131.7 ± 6.8^b
Nitrate	0.2 ± 0.1^e	0.4 ± 0.1^d	0.6 ± 0.1^c	0.9 ± 0.2^b	1.4 ± 0.2^a	1.5 ± 0.2^a
NH_3	0.1 ± 0.0^d	0.1 ± 0.0^d	1.1 ± 0.3^c	1.7 ± 0.1^a	1.4 ± 0.3^{ab}	1.3 ± 0.3^{bc}
Phosphate	0.2 ± 0.1^e	0.3 ± 0.0^d	0.4 ± 0.1^c	0.9 ± 0.1^b	1.1 ± 0.1^a	1.1 ± 0.1^a
BOD	1.3 ± 0.5^c	1.6 ± 0.8^c	2.0 ± 0.9^{bc}	3.0 ± 0.9^{ab}	3.3 ± 1.2^a	3.8 ± 0.9^a

Identified phytoplankton

During the study in Golestan reservoir, 30 taxa from 5 divisions have been identified: Cyanophyta, Chlorophyta, Bacillariophyta, Chrysophyta, Pyrrophyta and Euglenophyta. The identified genus categorized according to major groups includes: Cyanophyta (*Anabaena, Anabaenopsis, Chroococcus, Cylindrospermopsis, Lyngbya, Oscillatoria, Cylindrospermum, Gloeocapsa, Merismopedia, Aphanizomenon, Nostoc, Raphidiopsis*), Chlorophyta (*Ankistrodesmus, Chlamydomonas, Oocystis, Scenedesmus, Tetraederon, Chlorogonium*), Bacillariophyta (*Chaetoceros, Cyclotella, Navicula, Nitzschia, Skeletonema, Surirella, Synedra*), Chrysophyta (*Dinobryon*), Pyrrophyta (*Gymnodiniu* and *Peridinium*) and Euglenophyta (*Trachelomonas* and *Euglena*). The highest abundances in spring were related to Cyanophyta (59.4%), Bacillariophyta (19.4%) and Chlorophyta (19.7%) respectively. The main species in summer were Cyanophyta (50.9%), Bacillariophyta (23.3%) and Chlorophyta (18.8%). The results indicated significant differences in phytoplankton abundance at different sampling stations ($p < 0.05$) except for *Synedra* and *Peridinium*. Phytoplankton abundances significantly increased from March to September ($p < 0.05$). Also, phytoplankton abundances were different ($p < 0.05$) among the sampling stations and periods (Table 3).

Table 2. Identified composition of phytoplankton during cage culture.

Phylum	Class	Order	Family	Genus
Cyanobacteria	Cyanophyceae	Nostocales	Nostocaceae	*Anabaena*
				Anabaenopsis
				Cylindrospermopsis
				Cylindrospermum
				Aphanizomenon
				Nostoc
			Oscillatoriaceae	*Lyngbya*
				Oscillatoria
			Rivulariaceae	*Raphidiopsis*
		Chroococcales	Chroococcaceae	*Chroococcus*
				Gloeocapsa
				Merismopedia
Chlorophyta	Chlorophyceae	Sphaeropleales	Selenastraceae	*Ankistrodesmus*
			Scenedesmaceae	*Scenedesmus*
			Hydrodictyaceae	*Tetraederon*
	Trebouxiophyceae	Chlamydomonadales	Chlamydomonadaceae	*Chlamydomonas*
			Chlamydomonadaceae	*Chlorogonium*
		Chlorellales	Oocystaceae	*Oocystis*
Bacillariophyta	Bacillariophyceae	Chaetocerotales	Chaetocerotaceae	*Chaetoceros*
		Thalassiosirales	Stephanodiscaceae	*Cyclotella*
		Naviculales	Naviculaceae	*Navicula*
		Bacillariales	Bacillariaceae	*Nitzschia*
		Thalassiosirales	Skeletonemataceae	*Skeletonema*
		Surirellales	Surirellaceae	*Surirella*
		Fragilariales	Fragilariaceae	*Synedra*
Chrysophyta	Chrysophyceae	Ochromonadales	Dinobryaceae	*Dinobryon*
Pyrrophycophyta	Dinophyceae	Gymnodiniales	Gymnodiniaceae	*Gymnodinium*
		Peridiniales	Peridiniaceae	*Peridinium*
Euglenophycota	Euglenophyceae	Euglenales	Euglenaceae	*Trachelomonas*
				Euglena

Table 3. Spatial and temporal variation in phytoplankton abundance (10^2 ind. mL^{-1}) registered in the Golestan reservoir, north of the Iran. Letters represent pairwise significant differences between treatments by Duncan test, with a 0.05 level of significance.

Species		*Anabaena*	*Anabeanaposis*	*Chroccoccus*	*Cylindrospermopsis*	*Lyngbya*	*Oscillatoria*
Sampling stations	5 m	± 366.76 ^{a} 1762.33	3835.66 ± 448.72 ^{c}	2902.66 ± 316.69 ^{b}	3317.33 ± 339.44 ^{b}	10159.33 ± 803.61 ^{a}	± 879.05 ^{a} 10677.66
	100 m	± 468.50 ^{ab} 1451.33	9122.66 ± 728.52 ^{a}	2073.33 ± 276.70 ^{c}	2902.66 ± 316.69 ^{c}	4976.00 ± 440.78 ^{c}	7982.23 ± 695.32 ^{b}
	200m	± 487.11 ^{a} 2280.66	7671.33 ± 739.10 ^{b}	363.51 ^{a} ± 3732.00	4250.33 ± 469.85 ^{a}	6634.66 ± 552.22 ^{b}	497.00 ± 440.78 ^{c}
	400 m	± 1373.31 ^{a} 1866.00	2073.33 ± 276.70 ^{d}	1658.66 ± 260.25 ^{d}	2177.00 ± 200.44 ^{d}	3732.00 ± 739.28 ^{d}	497.00 ± 1199.40 ^{c}
	1000 m	± 468.50 ^{ab} 1451.33	2384.33 ± 386.40 ^{d}	1036.66 ± 78.65 ^{c}	1969.66 ± 187.97 ^{d}	3524.66 ± 528.14 ^{d}	4146.66 ± 388.32 ^{c}
	2000 m	829.33 ± 236.18 ^{b}	2591.66 ± 227.19 ^{d}	1451.33 ± 468.50 ^{d}	2177.00 ± 379.44 ^{d}	6427.33 ± 1033.03 ^{b}	4665.00 ± 871.87 ^{c}
Sampling periods	April	± 454.75 ^{b} 1037.83	± 2809.42 ^{a} 4086.50	1945.83 ± 843.79 ^{a}	2562.16 ± 678.70 ^{a}	5740.83 ± 2130.91 ^{a}	± 2321.30 ^{a} 6130.00
	May	± 467.61 ^{b} 1066.66	± 2887.21 ^{a} 4200.00	2000.00 ± 867.17 ^{a}	2633.33 ± 697.61 ^{a}	5900.66 ± 2189.97 ^{a}	± 2385.79 ^{a} 6300.00
	Jun	± 531.91 ^{b} 1212.83	± 3282.59 ^{a} 4775.50	2274.16 ± 985.95 ^{a}	2994.16 ± 793.26 ^{a}	6708.16 ± 2489.93 ^{a}	± 2712.71 ^{a} 7163.00
	July	± 678.86 ^{a} 1978.33	± 2875.00 ^{a} 4573.16	± 108456 ^{a} 2075.66	2691.83 ± 995.43 ^{a}	5351.50 ± 2545.48 ^{a}	± 2577.92 ^{a} 5578.33
	August	± 697.61 ^{a} 2033/33	± 2954.99 ^{a} 4700.00	± 1114.74 ^{a} 2133/33	± 1023.06 ^{a} 2766.67	5500.00 ± 2616.10 ^{a}	± 2649.27 ^{a} 5733.33
	September	± 793.10 ^{a} 2312.00	± 3360.03 ^{a} 5343.83	± 1267.56 ^{a} 2425/66	± 1163.24 ^{a} 3145.83	6253.50 ± 2974.49 ^{a}	± 3012.05 ^{a} 6519.00

Oocystis	*Chlamydomonas*	*Ankistrodesmus*	*Raphidiopsis*	*No/stoc*	*Aphanizomenon*	*Merismopedia*	*Glococapsa*	*Cylindrospermum*
829.83 ± 231.39^{c}	1141.00 ± 571.70^{c}	726.16 ± 343.20^{c}	3732.00 ± 739.28^{a}	1244.00 ± 456.01^{b}	2488.00 ± 295.58^{b}	4561.33 ± 414.02^{b}	1036.66 ± 426.08^{a}	± 339.44^{a} 3317.33
± 572.84^{a} 1348.66	2697.00 ± 475.14^{b}	± 144.66$^{b c}$ 1736.50	1036.66 ± 462.08^{c}	366.76 ± 1762.33	3317.33 ± 339.44^{a}	6531.00 ± 601.70^{a}	829.33 ± 236.18^{bc}	± 276.70^{c} 2073.33
± 464.63^{a} 1867.16	3941.83 ± 931.63^{a}	3008.33 ± 588.79^{a}	2177.00 ± 379.44^{b}	207.33 ± 93.17^{c}	1762.33 ± 175.67^{c}	3317.33 ± 339.44^{c}	829.33 ± 236.18^{bc}	± 339.44^{a} 3317.33
± 255.17^{a} 2281.16	2904.50 ± 270.92^{b}	1971.00 ± 151.22^{b}	2073.33 ± 276.70^{b}	829.33 ± 236.18^{c}	1658.66 ± 260.25^{c}	2073.33 ± 276.70^{d}	1347.66 ± 356.44^{a}	± 260.25^{d} 1658.66
518.66 ± 116.67^{a}	1384.50 ± 132.76^{c}	1384.50 ± 347.99^{b}	622.00 ± 232.56^{c}	725.66 ± 345.91$^{c d}$	1244.00 ± 246.49^{d}	4354.00 ± 968.74^{b}	518.33 ± 120.42^{cd}	± 172.69^{c} 2280.66
± 250.44^{a} 2047.66	2800.83 ± 369.50^{b}	± 138.30^{cd} 1556.00	725.66 ± 345.91^{c}	414.66 ± 229.80^{de}	1555.00 ± 163.93^{c}	2073.33 ± 276.70^{d}	414.66 ± 229.80^{d}	± 499.08^{b} 2695.33
± 774.92^{a} 1410.00	2047.50 ± 886.32^{a}	1443.50 ± 690.88^{a}	1459.50 ± 982.72^{a}	551.33 ± 483.09^{a}	1861.16 ± 831.72^{a}	± 1747.89^{a} 3762.33	551.50 ± 258.58^{c}	± 693.55^{a} 2335.16
± 769.41^{a} 1400.00	2033.33 ± 880.15^{a}	1433.33 ± 686.05^{a}	± 1009.95^{a} 1500.00	566.66 ± 496.65^{a}	1866.66 ± 854.79^{a}	± 1796.29^{a} 3866.66	566.66 ± 265.83^{c}	± 657.26^{a} 2400.00
154.00 ± 850.20^{a}	2246.83 ± 972.56^{a}	1583.83 ± 758.08^{a}	± 1148.27^{a} 1705.50	644.33 ± 564.84^{a}	2122.50 ± 971.88^{a}	± 2042.28^{a} 4396.33	644.16 ± 302.32^{bc}	± 747.27^{a} 2728.83
± 749.79^{a} 1476.83	± 1219.61^{a} 2752.33	1913.33 ± 813.21^{a}	± 1322.47^{a} 1783.66	1070.33 ± 587.08^{a}	1946.00 ± 627.61^{a}	± 1526.14^{a} 3405.50	± 397.16$^{a bc}$ 1005.50	± 714.06^{a} 2465.00
± 744.75^{a} 1466.66	± 1211.06^{a} 2733.33	1900.00 ± 807.46^{a}	± 1358.92^{a} 1833.33	1100.00 ± 603.32^{a}	2000.00 ± 644.98^{a}	± 1568.43^{a} 3500.00	1033.33 ± 408.24^{ab}	± 733.93^{a} 2533.33
± 822.95^{a} 1620.66	± 1338.22^{a} 3020.33	2099.50 ± 892.24^{a}	± 1544.85^{a} 2084.66	1250.66 ± 658.93^{a}	2274.00 ± 733.29^{a}	± 1783.26^{a} 3979.50	1174.83 ± 464.24^{a}	± 834.05^{a} 2880.33

Sceletonema	*Nytzschia*	*Navicula*	*Dinobryon*	*Cyclotella*	*Chaetoceros*	*Chlorogonium*	*Tetraederon*	*Scendesmus*
1229.83 ± 632.94 ^{c}	2392.83 ± 966.45 ^{b}	± 244.00 ^{ab} 543.83	217.50 ± 97.58 ^{b}	2066.50 ± 610.56 ^{c}	1087.66 ± 482.12 ^{b}	829.83 ± 456.85 ^{c}	726.16 ± 343.20 ^{c}	829.83 ± 231.39 ^{b}
1045.50 ± 440.31 ^{c}	486.91 ± 1522.83 ^{c}	341.58 ^{b} ± 761.33	326.33 ± 146.41 ^{ab}	3263.00 ± 519.16 ^{ab}	2284.16 ± 385.40 ^{c}	1659.83 ± 242.53 ^{b}	2282.16 ± 469.34 ^{b}	1141.16 ± 346.07 ^{b}
± 338.53 ^{ab} 1640.33	734.36 ^{b} ± 2610.50	± 585.59 ^{a} 1305.16	652.50 ± 299.75 ^{a}	3480.66 ± 748.56 ^{ab}	± 1106.54 ^{ab} 4242.00	3526.83 ± 927.36 ^{a}	± 1144.50 ^{ab} 2489.66	2593.33 ± 806.89 ^{a}
2410.50 ± 769.63 ^{a}	3698.16 ± 530.67 ^{a}	0.00 ± 0.00 ^{b}	0.00 ± 0.00 ^{b}	± 1204.55 ^{ab} 2610.33	3480.66 ± 784.56 ^{b}	3215.66 ± 951.62 ^{a}	3112.00 ± 157.52 ^{a}	2489.50 ± 260.14 ^{a}
± 494.04 ^{ab} 2049.16	3480.66 ± 748.56 ^{a}	0.00 ± 0.00 ^{b}	0.00 ± 0.00 ^{b}	4133.00 ± 542.85 ^{a}	4677.00 ± 462.52 ^{a}	3527.00 ± 488.83 ^{a}	1141.00 ± 127.53 ^{c}	726.16 ± 343.20 ^{b}
± 313.24 ^{ab} 2108.66	3589.33 ± 422.73 ^{a}	0.00 ± 0.00 ^{b}	0.00 ± 0.00 ^{b}	3480.50 ± 323.12 ^{ab}	4568.33 ± 556.44 ^{a}	3215.16 ± 591.62 ^{a}	1244.83 ± 236.10 ^{c}	2074.66 ± 690.49 ^{a}
± 639.37 ^{ab} 1478.16	2425.66 ± 971.80 ^{b}	0.00 ^{a} ± 0.00	0.00 ^{a} ± 0.00	± 1150.59 ^{a} 2956.33	± 1551.89 ^{a} 3221.66	± 1171.88 ^{a} 2282.50	1443.50 ± 904.41 ^{a}	1376.33 ± 809.76 ^{a}
1300.00 ± 562.13 ^{b}	2133.33 ± 854.79 ^{b}	0.00 ^{a} ± 0.00	0.00 ^{a} ± 0.00	± 1011.92 ^{a} 2600.00	± 1364.79 ^{a} 2833.33	± 1163.90 ^{a} 2266.66	1433.33 ± 898.14 ^{a}	1366.66 ± 804.15 ^{a}
± 632.86 ^{ab} 1464.00	2402.16 ± 962.59 ^{b}	0.00_{a} ± 0.00	0.00 ^{a} ± 0.00	± 1139.60 ^{a} 2927.50	± 1536.65 ^{a} 3190.50	± 1286.11 ^{a} 2504.66	1583.83 ± 992.45 ^{a}	1510.16 ± 888.59 ^{a}
2198.16 ± 699.71 ^{a}	3600.66 ± 867.86 ^{a}	909.66 ± 458.61 ^{a}	416.83 ± 222.87 ^{a}	3676.33 ± 739.09 ^{a}	± 1646.04 ^{a} 3865.83	± 1206.15 ^{a} 2886.66	± 1032.92 ^{a} 2114.66	± 1010.76 ^{a} 1812.050
± 602.21 ^{ab} 1866.66	± 763.32 ^{ab} 3166.66	± 403.319 ^{a} 800.00	366.66 ± 196.07 ^{a}	3233.33 ± 650.12 ^{b}	± 1447.75 ^{a} 3400.00	± 1197.77 ^{a} 2866.66	± 1025.67 ^{a} 2100.00	1800.00 ± 1003.99 ^{a}
2177.00 ± 692.86 ^{a}	3565.83 ± 859.54 ^{a}	900.66 ± 454.06 ^{a}	412.83 ± 220.76 ^{a}	3640.50 ± 731.94 ^{a}	± 1630.46 ^{a} 3828.50	± 1323.54 ^{a} 3167.66	± 1133.36 ^{a} 2320.50	1989.00 ± 1109.41 ^{a}

Euglena	*Trachelomonas*	*Peridinium*	*Gymnodinium*	*Synedra*	*Surirella*
$433.49^{a} \pm 986.66$	$394.39^{a} \pm 1407.66$	$364.26^{a} \pm 808.33$	$234.42^{a} \pm 523.33$	$238.54^{a} \pm 277.16$	$738.69^{b} \pm 1325.33$
$327.51^{a} \pm 909.33$	$322.07^{a} \pm 2006.66$	$289.86^{a} \pm 623.33$	$281.31^{a} \pm 628.00$	$166.66^{a} \pm 166.66$	$555.95^{b} \pm 1154.33$
$179.12^{b} \pm 382.66$	$413.81^{b} \pm 1464.00$	$203.38^{a} \pm 452.00$	$328.19^{a} \pm 732.66$	$0.00^{a} \pm 0.00$	$283.08^{b} \pm 1003.50$
$435.69^{ab} \pm 742.66$	$299.29^{b} \pm 1374.66$	$157.19^{a} \pm 347.33$	$234.42^{a} \pm 523.33$	$0.00^{a} \pm 0.00$	$1404.63^{a} \pm 2729.66$
$437.38^{ab} \pm 593.33$	$242.89^{ab} \pm 1652.00$	$299.83^{a} \pm 599.33$	$140.65^{a} \pm 314.00$	$0.00^{a} \pm 0.00$	$767.87^{a} \pm 2593.00$
$222.50^{ab} \pm 809.33$	$248.00^{ab} \pm 1685.33$	$229.81^{a} \pm 447.33$	$234.42^{a} \pm 523.33$	$0.00^{a} \pm 0.00$	$605.61^{a} \pm 2652.50$
$262.31^{b} \pm 414.67$	$275.86^{ab} \pm 1417.33$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{a} \pm 0.00$	$818.89^{a} \pm 1553.83$
$252.98^{b} \pm 400.00$	$265.83^{b} \pm 1366.66$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{a} \pm 0.00$	$720.18^{a} \pm 1366.66$
$284.13^{b} \pm 449.93$	$298.33^{ab} \pm 1524.66$	$0.00^{b} \pm 0.00$	$0.00^{b} \pm 0.00$	$0.00^{a} \pm 0.00$	$810.73^{a} \pm 1539.00$
$293.30^{a} \pm 1027.00$	$407.78^{ab} \pm 1728.33$	$435.06^{a} \pm 1037.00$	$275.73^{a} \pm 1071.50$	$189.50^{a} \pm 189.50$	$1318.23^{a} \pm 2501.50$
$282.84^{a} \pm 1000.00$	$395.49^{ab} \pm 1671.66$	$396.92^{a} \pm 1137.66$	$265.83^{a} \pm 1033.33$	$166.66^{a} \pm 166.66$	$1092.15^{a} \pm 2020.00$
$317.63^{a} \pm 1123.00$	$441.69^{a} \pm 1871.66$	$462.71^{a} \pm 1103.00$	$293.14^{a} \pm 1139.83$	$187.66^{a} \pm 187.66$	$1305.39^{a} \pm 2477.33$

CCA ordination of phytoplankton species with environmental variables 2

The canonical correspondence analysis (CCA), performed with 30 phytoplankton genus of the sampling and 12 environmental variables for spring and summer seasons separately (Figs. 1A and 1B). In spring, CCA diagram presented significant scores for the first two axes ($p < 0.05$), Eigen value for axis 1 (ʅ1 = 0.434) and axis (2 = 0.1777) according to the Monte Carlo test, indicating significant correlations (97%) between environmental variables and phytoplankton ($p < 0.05$). These two axes explained together 65% of the total data variability. In summer, CCA diagram explained 83% of the data joint variability in the first two components, presenting statistically significant ($p < 0.05$) eigen value for axis 1 (ʅ1 = 0.508) and axis 2 (ʅ2 = 0.151) according to Monte Carlo test. The species– environment correlation was high (95%) and significant for both axes of the CCA ($p <0.05$). CCA diagram presented differences in the temporal distribution of sampling units and phytoplankton abundances in Golestan reservoir in both seasons. However, significant spatial differences were not observed.NO_3, NH_4^+, DO, BOD, H, EC, and pH were the main variables associated with the phytoplankton community distribution (Figs. 1A and 1B). As indicated by CCA diagram (Figs. 1 A and 1B) three main taxonomic groups could be distinguished in spring and summer. The group 1 advantaged mostly from increasing DO and decreasing all of other variables in both seasons. The group2 were related positively to TDS, P, pH, Alk, NO_3, NH_4^+, and H and negatively to DO in spring. In other hand, the group 2 were related positively to P, pH, H, NO_3, and NH_4^+ and negatively to DO in summer. The group3 which were advantaged mostly from increasing T, Sal, EC, and BOD and decreasing DO in spring, while the group3 in summer were advantaged mostly from increasing Alk, TDS, and EC.

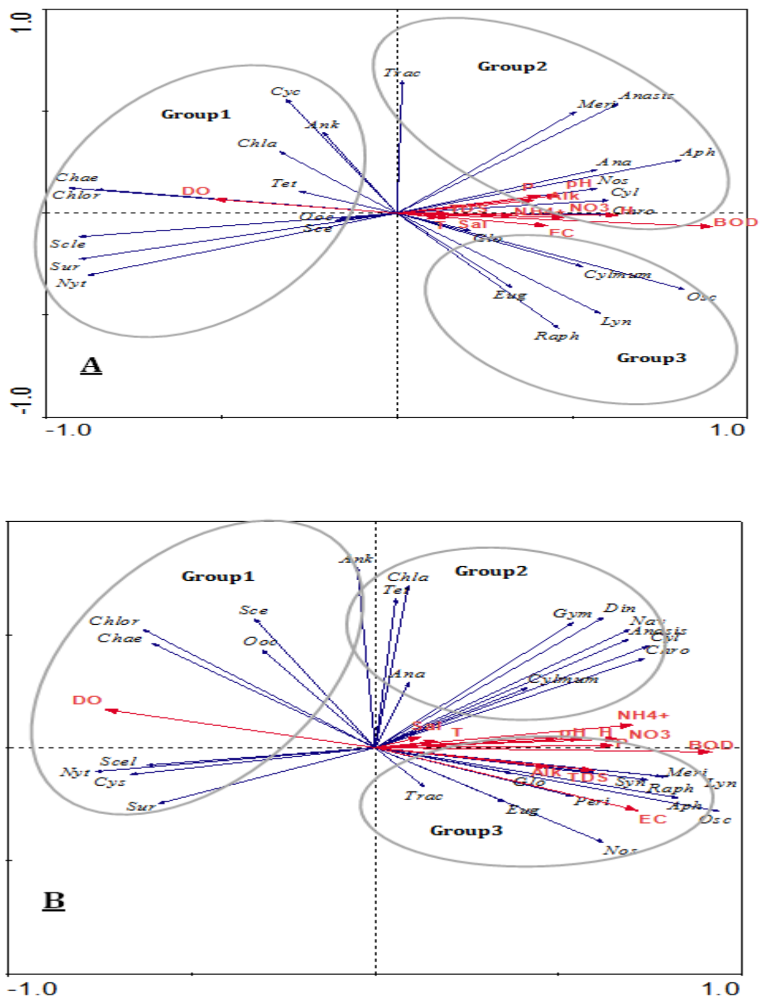

Fig. 1. Score dispersion of environmental variables and phytoplankton abundance for sampling periods; spring (A), and summer (B) along the first two Canonical Correspondence Analysis (CCA) axes. *Ana: Anabaena; Anasis: Anabeanaposis; Chro: Chroccoccus; Cyl: Cylindrospermopsis; Lyn: Lyngbya; Osc: Oscillatoria; Cylmum: Cylindrospermum; Glo: Glococapsa; Meri: Merismopedia; Aph: Aphanizomenon; Nos: Nostoc; Raph: Raphidiopsis; Ank: Ankistrodesmus; Chla: Chlamydomonas; Ooc: Oocystis; Sce: Scendesmus; Tet: Tetraederon; Chlor: Chlorogonium; Chae: Chaetoceros; Cyc: Cyclotella; Din: Dinobryon; Nav: Navicula; Nyt: Nytzschia; Scel: Sceletonema; Sur: Surirella; Syn: Synedra; Gym: Gymnodinium; Peri: Peridinium; Trac: Trachelomonas; Eug: Euglena*. Environmental variables codes are available in table1.

DISCUSSION

For cage systems of fish production, the data on BOD were significant among the sampling stations. BOD is directly linked with decomposition of dead organic matter and it can be correlated with pollution status. Yee *et al.* (2012) reported the lower pH value corresponded with low dissolved oxygen and high BOD values due to the oxygen consumption during the breakdown of organic matter from excess feed and fish excrement. Similar conclusions indicated that fish culture in cages does not appear to involve any risk of exceeding the levels admissible for water courses (Kubu 1987). Several authors demonstrated that nutrient levels might be increased by fish cage culture depending on the site and size of cages, water exchange rates and other characteristics of the water body (Phillips *et al.* 1985; Stirling & Dey 1990; Pitta *et al*. 1999; Heidary *et al*. 2016). Similar results obtained by Stirling & Dey (1990), where nitrite concentration showed no differences between the cage and control stations in Scottish freshwater loach. However, nitrate, ammonium and phosphorus were different among stations and varied monthly. Several studies have used phytoplankton for risk assessment of cage cultures in aquatic environments (Stirling & Dey 1990; Diaz *et al*. 2001, Longgen & Zhongije 2003). The predominance of Cyanophytes at the Golestan reservoir may be due to high concentrations of nutrients (nitrate, ammonia and phosphorous). As a result of nutrient load, increased phytoplankton expansion, especially Cyanobacteria, has been reported, reflecting a growing problem in ecosystems such as reservoirs (Borges *et al*. 2010). Our results were in line with the study of Mwaura *et al*. (2002), who also documented the dominance of Cyanobacteria in eight Kenyan highland reservoirs. In the present study, the Chlorophyta abundance was also high, which may be due to the high N:P ratio along with intermediate pH and water temperatures (Zevenboom & Mur 1980). These results were in agreement with the results of Degefu *et al.* (2011), who introduced Chlorophyta as dominant species throughout the study period in Yemlo cage culture. Moreover, Nasrollahzadeh Saravi *et al.* (2014) once working inthe southern part of the Caspian Sea showed that Bacillariophyta and Pyrrophyta were the dominant phyla, respectively. Eutrophic condition of the lake water allowed some species to grow faster, while this condition may restrict the growth of other species (Moss 1998, Sharifinia *et al*. 2012). Moreover, domestic sewage and soil erosion are the diffuse sources of nutrients by agriculture and other activities that might be influencing the phytoplankton community structure. In the present study, the most of the dissimilarities observed among the stations were related to changes in phytoplankton abundance rather than phytoplankton diversity, indicating the relatively low disturbance caused by cage culture in the dam.

CONCLUSION

Since freshwater resources are extremely limited in Iran, utilization should be maximized with minimum impacts and pollutions. Aquaculture causes alterations in water chemistry and ecology in most of the studied reservoirs. In our study, results showed that there were localized short-term impacts of the common carp cage but the long-term effects of different cage capacities are still unknown and need to be monitored in the future. Neither abiotic variables nor phytoplankton showed significant differences between the variations. The variations recorded in phytoplankton structure appear to have been mainly influenced by seasonal changes, temperature and nutrient availability. It seems that only temporal changes were observed due to the low number of cages. Although the results of the present study confirm the safety of carp cage culture site selection. however, permanent monitoring of cages are recommended.

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