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Sophia S. Barinova *et al*, The *Experiment, April, 2013 .Vol. 9(4), 566-586*

EXPERIMENTAL APPROACH TO A LAKE ECOSYSTEM ASSESSMENT IN THE GREAT LOTA, TURKEY

ABSTRACT

Experimentally selected from the benthic communities the cells of diatoms at one station of the karstic Great Lota Lake were used for assessment of the lake ecosystem dynamic in 2000-2001. Each *in vitro* experiment was about 15 days after the monthly sampling. A total of 48 diatoms taxa were identified in 19 samples, and used for ecological analysis by statistic methods. Bio-indication groups of temperature, habitat preferences, oxygenation, organic pollution (according to Sládeček and Watanabe's saprobity system), N-uptake metabolism, and trophic states were evaluated. The saprobity indices and new integral aquatic ecosystem state index (WESI) were calculated. As a result, experimentally selected diatoms from the lake benthos reflects temperate, low-saline, and alkaline water. The saprobity is oligo- and betamesosaprobic when the trophic state is eutrophic according to Van Dam's system. Living diatom communities with prevailing of moving cells of *Mastogloia* species are formed two major groups – winter and summer, which depend on climatic or anthropogenic environmental conditions. *Mastogloia* species can be used as special indicator for sulfates in arid lakes monitoring. Experimental assessment was compared with the same assessment on the base of whole benthic diatoms, and show preference to the living cells communities assessment for following monitoring.

Keywords: Diatoms, *in vitro*experiment, bio-indication, seasonality, Great Lota Lake, Turkey

INTRODUCTION

Whereas water quality monitoring system based on algal communities is well developed in Europe countries[1], the biological monitoring system in the Middle East still in initial stage[2,3].

Soft-sediment habitats in aquatic ecosystems frequently support extensive populations of benthic microalgae (microphytobenthos). These algal assemblages are dominated by species of motile benthic diatoms and form biofilm substances that create a complex microhabitat and act to stabilize sediments[4]. Algae (especially diatoms) are useful instruments as indicators of water quality because of their rapid response to environmental change[5,6,7]. Turkey has ca. 900 natural lakes and ponds covering an area of over 10 000 km^2. Many of these lakes have a high level of endemism among animals and plants due to habitat and climate diversity and lack of major disturbances[8]. Because the use of diatom indices and bio-indication in water quality monitoring is relatively new for Turkey, the investigations of the diatoms are important in these habitats for both ecological and taxonomical approaches. Significant climatic influence on diatom communities of submerged plants in the Great Lota Lake was revealed using of statistical methods[9]. Benthic communities are not only stabilizing lake sediments but also reflect a long-term influence on the sustainable lake ecosystem because it is mostly a conservative part of ecosystem[2,10]. As a result, diatoms from sediments give a possibility to assess the shallow lake ecosystem using the holistic approach[11] that included bio-indication methods. On the other hand, the lake sediments accumulated diatom shells from plankton, periphyton and benthos over many years. To arrive to realistic assessment of the diatom community, only living cells have been counted.

The aims of this study are to reveal indicator species from living microphytobenthiccommunities during *in vitro* experiment and to assess the water quality dynamic in the Great Lota Lake in relation to environmental variables based on species abundance.

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Study site

The GreatLotaLake is located in the middle of Turkey (39°83'N, 37°43'E) and has a depth of approximately 3-4 m. It is formed by the karst erosion over the east-west orientated gypsum plateau. The geological substrates consist of conglomerates, limestone ($CaCO_3$), gypsums ($CaSO_4 + 2H_2O$), marl, and mudstones[12,13](Figure 1).

MATERIAL AND METHODS

Experimental procedure

Samples of sediments were taken during October 2000 and June 2001 monthly. Each sample was collected using a glass pipe 11 mm in diameter and 1 meter in length. The collected sediment samples were transferred into plastic bottles and taken to the laboratory for further examination. The samples were put into Petri dishes for sedimentation. The supernatant was removed from the Petri dishes by micropipette and cover glass slides were placed over the sediments. After 24 hours the cover glasses were carefully taken and washed into beakers. Thereafter, diatoms were prepared following standard techniques: carbonate dissolution by HCI followed by oxidation of organic matter using H_2O_2[14]. Samples were neutralized by rinsing with distilled water[14], and a volume of 0.1 ml was dried onto 22 mm square cover slips. Permanent slides were mounted using Naphraxmedia (refractive index 1.74). At least 400 diatom valves were counted on each slide along randomly chosen transects. Identification and enumeration was made using an Olympus Vanox compound microscope with bright-field optics at a magnification of 1600X. The number of total diatoms (per cm^2) was calculated using Round's methodology[15], then diatom counts were converted to relative abundances (i.e., proportions of species to the total for each sample). Taxonomic identifications of diatoms were made according to Krammer and Lange-Bertalot[16,17,18,19].

Environmental variables

Dissolved oxygen concentration (DO) and water temperature (YSI 55B Model), conductivity and pH (Cyber Scan 510) were measured in the field. Water for chemical analyses was stored under cold dark conditions in acid-washed I- liter Pyrex bottles, following filtration through GF/C filters for ammonium, nitrate, and soluble reactive phosphorus determinations. Unfiltered water was used for other variables. All analyses were completed within 18 h of sampling. Alkalinity was determined by titration with HCI using BDH 4.5 indicator. Soluble reactive phosphorus (SRP), total soluble phosphorus (TSP), total phosphorus (TP), silicate (SiO_3), chlorine (Cl^-), calcium (Ca^{2+}), sulphate (SO_4^{2-}), and ammonium (NH_4^+)were determined according to Mackereth et al.[20] to a precision of ± 4%. Nitrate was determined by reduction to nitrite on spongy cadmium and subsequent diazotization to a pink dye, determined spectrophotometrically, to a precision of ± 3%. For determination of Chlorophyll-*a*concentration, water volumes of 500 ml were filtered immediately through GF/C glass fiber filters after the addition of 0.2 ml saturated $MgCO_3$. Filters were extracted in cold 90% acetone for 18-24 h. Following absorption measurements, the equations of Tallingand Driver[21] were used to determine chl-*a* concentration corrected for phaeopigments.

Bio-indication

Autecology of the diatom species were compiled in our database[23]. Ecological analysis were based on the groups of indicator species for pH, salinity, temperature, habitat preferences, streaming and oxygenation, organic pollution, N-uptake metabolism, and the water body trophic states. Each group was separately assessed according to its significant bio-indication. This bio-indication approach is based on the ecological classification, which is widely used in European and Asian countries[1,2,22] where the classification of water quality is correlated with organic pollution level, salinity, and tropic state assessment of aquatic ecosystems.The Saprobity Index (S) was calculated and defines the self-purification zone corresponding to five classes of water quality[24].The calculated index of ecosystem status (Aquatic Ecosystem State Index, WESI) is based on the water- quality classes[2,23,25,26,27]reflecting the self-purification

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capacities for each of the sampling stations. If WESI is equal to or larger than 1, the photosynthetic level is positively correlated with the level of nitrate concentration. If the WESI is less than 1, the photosynthesis is suppressed presumably according to toxic disturbance[2,25,27].

Species diversity was calculated using Shannon's formula by Odum[28].The relationship of diversity data (species richness and saprobity index S) with environmental data on the sampling stations can be used for climate-human-environment interaction assessment. In this case, the Canonical Correspondence Analysis was applied. CCA was used to reveal species sensitive to environmental variables for each sample in CANOCO Program[29]. The statistical methods are used with the help of the GRAPHS program[30] for comparative floristic analysis.

RESULTS AND DISCULLION

In Table 1 is presented measured variables in the Great Lota Lake during study period. The carbonate and sulfate concentration is extremely high. They were mostly not below 250-500 $mg.L^{-1}$ respectively means in all samples. In controversy, the conductivity range is related to freshwater and fluctuated between 700-900 µS/cm.
All freshwater variables are affected by the carbonate and sulfate bedrock, the expected value of sulfate[31] is between 3-30 $mgL^{-1}$and of calcium 6-78 mgL^{-1}, the measured values of these ions in Great Lota Lake can be considered extreme[9](Table 1). Chloride concentration is correlated with the lake level fluctuation and therefore it is decreased when level arise. Chlorophyll and carotenes fluctuated similar. They are increased in winter and decreased in summer with opposite of chlorides concentration. Therefore, environmental variables are correlated with precipitation-evaporation seasons.

A total of 48 diatom species were found during the study (Table2). *Mastogloiabraunii* was the most dominant species, and speciestaxa followed in decreasing magnitude of dominance (Table 3): *Mastogloiasmithii*Thwaites ex W.Smith, *Mastogloiagrevillei*W.Smith,*Halamphoracoffeaeformis* (Agardh) Levkov, *Amphora commutata*Grunow, *Cymbopleuraamphicephala* (Nägeli) Krammer in the lake's living sediments. As can be surmised from their autecology, these species can spread over the surface of substrates by active motion.

Bio-indication analysis of species preferences (Figure 2), on the basis of Table 2, shows that communities survived in temperate (Figure 2a), mostly standing (Figure 2b) moderate organic pollution (Figure 2c), low chloride (Figure 2d), alkaline (Figure 2e) water of Classes 2-3 of water quality (Figure 2f) and formed communities with the help of high photosynthetic activity (Figure 2g). The trophic state of the Great Lota Lake ecosystem fluctuated between oligotrophic and eutrophic with dominates the last within the period of investigation(Figure 2h).

Species richness in diatom communities is strongly correlated with cell abundance over all investigated periods and shows three peaks in December, May, and September (Figure 3). Species richness and cell abundance is lower in the winter season, whereas it increased in summer when temperature and sunlight intensity are high. Species richness shows fluctuation in community dominants from *Mastogloiabraunii*in December and May to *Mastogloiasmithii* in the autumn (Table 2, 3). It is significant that *Mastogloia*species prevail in glass slide communities all year round. The summer activity of diatoms can be dependent upon the incoming photosynthetic radiation as well as increases in the water temperature in the lake. Moreover, the periods of abundance fluctuation are correlates with fluctuations of the biomass. It can be assessed as the insolation productivity-dependent process with climatic impact.

Fluctuation of the Index Saprobity S, which reflects organic pollution influence on the algal community, is shown in Figure 4 and stays within the oligo- to slightly mesosaprobic range of self-purification, Class II-III of Water Quality.

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It was maximal at the end of summer 2001 (1.85), minimal at October 2000 (1.13), and increased over the study period. Its fluctuation can be divided into two periods in which Index S fluctuation are similar with species richness, cell abundance, and Shannon index dynamic between October 2000 and August 2001, whereas it has the opposite correlation with Shannon index from September to October 2001. Therefore, species diversity and productivity of diatom communities of the Great Lota Lake are slightly influenced by increases in organic pollution during the late summer-autumn period but are stimulated during the warmest summer periods across increasing photosynthetic activity. In any case, the structure of communities is rather complicated that confirm the Shannon index is high with fluctuation between 2.25 and 2.87.

Regarding CCA analysis of experimental communities (Figure 5), there are three major groups of variables that come from different sources. Group 1 comprises $N\text{-}NO_3$, Oxygen, and Dissolved Phosphorous (right upper quadrant) correlated with trophic base and dependent upon anthropogenic influence that suppress the development of sensitive species such as *Pinnulariasudetica* (Hilse) Hilse, *Entomoneisalata* (Ehrenberg) Ehrenberg, and*Naviculacari* Ehrenberg. Group 2 was the group of ammonia (NH_3), Conductivity, and Chlorides (upper left quadrant) correlated with increases of salinity. Sensitive halophilic species are *Entomoneisalata* and *Nitzschiaagnita*Hustedt. Group 3 was the group of Phosphorous, Calcium, and silicates (lower right quadrant) from the bottom carbonates and correlated with natural influences. Indicator species are *Navicularadiosa*Kützing and *Hantzschiaamphioxys* (Ehrenberg) Grunow, which were never abundant.

A triplot of relationships of diatom species in each community of the Great Lota Lake and environmental variables, which were measured on the same dates (Figure 6) shows that the studied assemblages are sensitive to a number of environmental variables that are thought to be as natural and anthropogenic. The diatom assemblages are mostly impacted by nitrates in April, ammonia in July, and salinity level in July-August.
Correlation of relationships between diatom species in each community of the Great Lota Lake and environmental variables on the base of *in vitro* experiment helps us to conclude that trophic elements come to the lake during the spring season, whereas epipelicliving community is impacted by increases in salinity and ammonia under high temperature in summer. On the other hand, the environmental heterogeneity is favorable for complex species-rich assemblages in summer that have better chances of survival under future climate warming due to their diverse ecologically differentiated species contents.

Remarkably, the most abundant species such as *Mastogloiabraunii, Halamphoracoffeaeformis* (Agardh) Levkov,*Cymbopleuraamphicephala*(Nägeli) Krammeror *Amphora commutata*Grunow, and many others have no specific correlations with environmental variables of the lake.
We calculated Index WESI for experimental diatom communities of the Great Lota Lake on the basis of Index Saprobity S and Nitrate concentration classification from the ecological point of view[2,23]. As a result, Figure 7 shows that the ecosystem of the lake fluctuated between periods when its state is rather healthy, with Index WESI more than 1 (December 2000, April-May and July 2001) or lower but not less than 0.5 during other periods. The periods when algal communities are periodically impacted were in autumn 2000 and March, May-June 2001, whereas constant influence we can see from the end of July till October 2001. Fluctuation of WESI index is correlated with periods of high species richness and abundance of diatoms as well as Index saprobity S, which means that the lake communities were impacted by nutrients during autumn 2000, late spring, and peak of summer-autumn of 2001.
We compared the diversity of diatoms to reveal similar communities on the basis of Table 3. Cluster analysis identified four groupings within the data (separated at the 50% similarity level), clustered into three broader divisions (Figure 8). Cluster 1 presents late autumn and winter communities with a high range of abundance and fluctuation of dominant *Mastogloia*cell numbers. Cluster 2 included summer-autumn communities with lower abundance about 1-2

thousand cells per cm^2, and lower domination of *Mastogloia* species. Cluster 3 combined diversity, presenting summer and autumn communities with an abundance of about 3,000 cells per cm^2.

We clarify the clustering results by the comparative floristic methods with the help of the GRAPHS program[30]. The dendrite of taxonomic composition overlap (Figure9) shows that the *in vitro* diatom communities of the Great Lota Lake formed three floristic cores. The maximal overlapping has communities that occupied substrates during October-March period. Similar to this also were summer communities in June-August period.

On the base of statistical methods we can conclude that a comparative floristic analysis reveals two types of communities (summer and winter), which can be revealed with the statistical approach only. Whereas climatic variables in the study area of Turkey can reflect four seasons, the Great Lota Lake communities shows only two as has been revealed in other aquatic objects in the Mediterranean region[2]. The Great Lota Lake communities are correlated not only with the climatic (summer high light intensity and temperature) but also the anthropogenic (winter organic pollution input) impact on the GreatLotaLake ecosystem.

Whereas the environments and epiphytic diatom communities on submerged *Potamogeton* and *Phragmites*spp. of the lake were previously investigated by[9], but diatom communities, which were extracted by *in vitro* experiment, were never studied in this lake. The results of the recent analysis showed that there was a strong correlation between diatom abundance in epiphytic communities and environmental variables such as temperature, Ca, TSP, and SO_4 in the lake.

The assessment results on the base of complite species list of benthic diatoms[32] show that full community preferred temperate, low saline and alkaline oligo- and betamesosaprobic water of eutrophic condition. Experimantal communities have decreased species richness, the same level of Index saprobity S and correlation of species richness with abundance during the summer period. But in winter period abundance and species richness were sharply decreased in experimental slides. It can be related with artificial enriched natural sediments by falling diatom shalls, which are absnt in experimental slides. *In vitro* experiment assessments show similarity with natural communities assessment in respect of major conditions of the lake but in addition revealed preference of high sulfate water.That is important for assessment of the arid region lakes of Kazakhstan and Eastern Mediterranean because are increased not only salinity but also sulfate concentration in the lake water[2,10,33] as a result of temperature and evaporation impact. Our experiment shows that *Mastogloia* species have high level of resistance for karstic sulfate lakes and can be used as bio-indicators.

Index WESI also looks like unrealistic in the natural samples. In contrary, experiment slides show more realistic picture of ecological assessment with normal or slighlty stressed lake ecosystem in summer. This result correlated with same assessments of Kazakhstan ared lakes[10] in which sulfates also play major role in the lakes chemistry.

Table.1 Seasonal fluctuation of environmental variables in the Great Lota Lake

.Variable	Code	30 Oct 2000	17 Nov 2000	6 Dec 2000	20 Dec 2000	31 Jan 2001	26 Mar 2001	19 Apr 2001	7 May 2001	21 May 2001	4 Jun 2001	19 Jun 2001	4 Jul 2001	18 Jul 2001	1 Aug 2001	14 Aug 2001	24 Aug 2001	12 Sep 2001	26 Sep 2001	12 Oct 2001
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Sulfate, mg/l	SO4	532.0	45.3	86.5	78.6	50.3	349.0	465.0	412.0	401.0	330.0	164.0	172.0	258.0	321.0	327.0	269.0	368.0	244.0	252.0
Soluble reactive Phosphate, mg/l	SRP	33.5	34.9	39.6	28.9	14.8	37.3	34.6	101.1	29.2	91.4	33.8	42.1	64.0	34.5	103.2	36.7	49.5	36.8	38.9
Total soluble Phosphorous, mg/l	TSP	43.6	12.6	1.0	18.6	10.0	43.9	52.0	9.2	33.4	114.6	56.6	50.6	41.6	48.9	129.0	50.9	50.7	55.2	47.5
TP total pho., mg/l	TP	71.0	32.6	13.9	29.6	12.2	51.5	50.6	8.5	35.9	234.6	58.6	38.1	52.4	47.0	106.0	49.2	42.3	46.7	42.7
Ammonia, µg/l	NH3	33.9	25.9	28.6	23.0	36.1	164.2	416.0	82.0	163.0	163.0	154.0	74.4	48.2	37.8	93.0	54.2	38.8	84.0	30.9
Nitrate, mg/l	NO3	0.2	0.3	0.6	0.7	0.3	0.4	0.5	0.5	0.3	0.2	0.2	0.6	0.2	0.1	0.2	0.1	0.2	0.2	0.1
Silicate, mg/l	SO2	3.8	2.1	2.8	2.5	2.5	2.9	0.8	2.3	1.9	2.6	2.1	3.2	3.0	0.8	2.0	2.5	2.3	3.1	2.5
Calcium, mg/l	Ca	536.0	368.0	345.0	286.0	334.0	178.0	286.5	176.0	164.0	224.4	194.3	571.1	591.1	569.0	611.2	641.2	637.2	617.0	615.2
Chloride, mg/l	Cl	0.9	1.6	1.9	1.6	1.0	1.2	0.7	0.6	1.1	1.1	1.0	1.1	1.3	1.1	1.0	1.1	1.0	0.7	1.0
Chlorophyll-a, mg/l	Chl-a	1.0	1.2	1.2	1.0	2.0	0.7	0.5	0.8	0.4	0.2	0.3	1.2	1.1	0.6	0.2	0.3	0.3	0.2	0.3
Carotene, mg/l	Carot	1.2	2.5	1.2	2.5	1.8	0.9	0.8	1.6	0.8	0.7	0.8	0.9	1.2	0.7	0.5	0.7	1.1	0.7	0.1
Temperature, C°	T	10.8	10.0	7.0	6.0	8.5	14.0	12.0	15.5	18.5	24.0	23.5	22.0	28.0	27.0	25.0	22.5	20.0	20.0	18.5
pH	pH	8.1	8.6	8.1	8.1	9.0	8.9	7.9	9.4	9.6	9.2	8.0	8.1	8.1	8.1	8.2	8.1	8.1	7.4	8.1
Dissolved Oxygen, mg/l	O2	83.0	80.0	83.0	88.0	7.0	60.0	63.0	58.0	62.0	72.0	60.0	60.0	48.0	54.0	66.0	66.0	58.0	60.0	79.0
Deep, m	Deep	2.0	2.3	2.0	2.3	2.2	2.0	2.1	2.0	1.8	1.9	2.0	2.3	1.9	1.9	2.0	2.3	2.3	1.8	1.9
Conductivity, µS/cm	Cond	789.0	711.0	728.0	711.0	894.0	822.0	2108.0	722.0	724.0	620.0	724.0	722.0	890.0	724.0	723.0	724.0	622.0	622.0	722.0

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Table2.The diatom indicators in the communities of the Great Lota Lake with species autecology[23].Ecological types (Hab): B, benthic; P–B, planktic-benthic; S, soil. Temperature (T): cool, cool-water; temp, temperate; warm, warm-water. Oxygenation (Reo): st, standing water; str, stream; st-str, standing-streaming. Saprobity[34] (D): es, eurysaprob; sx, saproxen; sp, saprophil. Halobity[35] (Sal): mh, mesohalobe; i, oligohalobious-indifferent; hl, oligohalobious-halophilous; hb, oligohalobious-halophobous. Acidity[36] (pH): ind, indifferent; neu, neutrophil; alf, alkaliphil; acf, acidophil; alb, alkalibiont.Saprobity[37] (Sap): o, oligosaprob; o-b, oligo-beta-mesosaprob; b, beta-mesosaprob; b-o, beta-oligomesosaprob; b-a, beta-alfa-mesosaprob; a, alfa-mesosaprob; a-b, alfa-beta-mesosaprob; x-o, xeno-oligosaprob; o-x, oligo-xenosaprob; o-a, oligo-alfa-mesosaprob. Nitrogen uptake metabolism[38] (Het): ats, nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen; ate, nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen; hne, facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen. Trophic state[38] (Tro): ot, oligotraphentic; o-m, oligo-mesotraphentic; m, mesotraphentic; m-e, meso-eutraphentic; e, eutraphentic; o-e, oligo- to eutraphentic (hypereutraphentic).

No	Species	Hab	T	Oxy	Sal	pH	D	Sap	Index s	Aut	Tro
1	*Amphora affinis*Kützing	B	temp	st	i	alf	es	-	-	-	-
2	*Amphora commutata*Grunow	B	-	-	hl	-	-	-	-	-	e
3	*Amphora minutissima*W.Smith	-	-	-	-	-	-	-	-	-	-
4	*Amphora ovalis* (Kützing) Kützing	B	temp	st-str	i	alf	sx	a-b	2.7	ate	e
5	*Amphora pediculus* (Kützing) Grunow ex A.Schmidt	B	temp	st	i	alf	sx	o-a	1.8	ate	e
6	*Caloneispermagna* (J.W.Bailey) Cleve	B	-	-	hl	alf	-	-	-	-	e
7	*Campylodiscus clypeus* (Ehrenberg) Ehrenberg ex Kützing	B	temp	-	mh	alb	-	b	-	-	e
8	*Cocconeisplacentula* Ehrenberg	P-B	temp	st-str	i	alf	es	o-b	1.4	ate	e
9	*Craticulacuspidata* (Kutzing) D.G.Mann	B	temp	st	i	alf	es	o	1.0	-	-
10	*Cyclotellameneghiniana*Kützing	P-B	temp	st	hl	alf	sp	o-a	1.8	hne	e
11	*Cyclotellaocellata*Pantocsek	P-B	-	st	i	ind	es	o	1.0	ats	me
12	*Cymatopleuraelliptica* (Brébisson) W.Smith	P-B	-	st-str	i	alf	-	b-o	1.7	ate	e
13	*Cymatopleurasolea* (Brébisson) W.Smith	P-B	-	st-str	i	alf	-	o	1.0	ate	e
14	*Cymatopleura solea* var. *gracilis*Grunow	B	-	-	i	alf	-	-	-	-	-
15	*Cymbellaamphicephala* var. *intermedia* Cleve-Euler	B	-	str	i	ind	sx	o-b	1.5	ats	o-m
16	*Cymbellacymbiformis*C.Agardh	B	temp	str	i	neu	sx	o	-	ats	o-m
17	*Cymbopleuraamphicephala*	B	-	str	i	ind	sx	o-b	1.5	ats	o-m

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	(Nägeli) Krammer										
18	*Cymbopleuranaviculiformis* (Auerswald ex Heiberg) K.Krammer	B	-	st-str	i	ind	es	o	2.0	ate	e
19	*Diatomatenue*C.Agardh	P-B	-	st	hl	ind	sx	b-a	2.5	ate	e
20	*Entomoneisalata* (Ehrenberg) Ehrenberg	P-B	-	st	mh	alf	-	-	-	-	-
21	*Epithemiaargus* (Ehrenberg) Kützing	P-B	-	st-str	i	ind	es	o	1.8	-	m
22	*Fragilariformavirescens* (Ralfs) D.M.Williams et Round	P-B	-	st	i	neu	es	o	1.3	ats	o-m
23	*Gyrosigmaacuminatum* (Kützing) Rabenhorst	B	cool	st-str	i	alf	-	o-x	2.2	ate	e
24	*Halamphoracoffeaeformis* (Agardh) Levkov	B	-	st-str	mh	alf	-	a	-	ate	e
25	*Hantzschiaamphioxys* (Ehrenberg) Grunow	B	temp	st-str	i	neu	es	b-o	1.7	ate	o-e
26	*Hippodontacapitata* (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	B	temp	st-str	hl	alf	es	o-b	1.4	ate	me
27	*Hippodontahungarica* (Grunow) Lange-Bertalot, Metzeltin et Witkowski	B	-	st-str	i	alf	es	b-o	2.4	-	-
28	*Mastogloiabraunii*Grunow	P-B	-	-	mh	alf	-	-	-	-	-
29	*Mastogloiagrevillei*W.Smith	B	-	-	i	alf	-	o	-	-	e
30	*Mastogloiasmithii*Thwaites ex W.Smith	B	-	-	mh	alf	sx	b	-	-	-
31	*Naviculacari* Ehrenberg	P-B	-	-	i	ind	es	b-a	-	-	o-e
32	*Naviculacincta* (Ehrenberg) Ralfs	B	warm	st-str	hl	alf	es	x-o	0.5	ate	e
33	*Naviculacryptocephala*Kützing	P-B	temp	st-str	i	alf	es	a	2.7	ate	o-e
34	*Navicularadiosa*Kützing	B	temp	st-str	i	ind	es	o	1.6	ate	me
35	*Nitzschiaagnita*Hustedt	-	-	-	hl	-	-	-	-	-	-
36	*Nitzschiaamphibia*Grunow	P-B,S	temp	st-str	i	alf	sp	o	1.3	hne	e
37	*Nitzschiabrevissima*Grunow	-	-	st-str	hl	neu	es	x-o	0.4	-	e
38	*Nitzschiaobtusa*W.Smith	B	-	-	mh	-	es	b	-	-	-
39	*Nitzschia* spp.	-	-	-	-	-	-	-	-	-	-
40	*Pinnulariasudetica* (Hilse) Hilse	B	-	-	hb	acf	-	o	-	-	o-m
41	*Reimeriasinuata* (Gregory) Kociolek et Stoermer	B	-	st	i	ind	sx	-	-	-	-
42	*Rhopalodiabrebissonii*Krammer	B	-	-	hl	alf	-	-	-	-	-
43	*Stauroneissmithii*Grunow	P-B	-	st-str	i	alf	-	x-o	0.5	ate	o-e
44	*Staurosiraconstruens* Ehrenberg	P-B	temp	st-str	i	alf	sx	o	2.0	-	-

45	*Staurosirellaleptostauron* (Ehrenberg) D.M.Williams et Round	B	-	st	hb	alf	es	a-b	2.7	-	-
46	*Staurosirellapinnata* (Ehrenberg) D.M.Williams et Round	B	temp	st-str	hl	alf	es	b-a	-	-	-
47	*Surirellaminuta*Brébisson	B	-	st-str	i	ind	es	o-a	1.85	-	ot
48	*Surirellavenusta*E.V.Østrup	B	-	-	-	-	-	-	-	-	-

Table3.The diatom species abundance (no of cells per cm^2) in communities of the GeratLota Lake with abbreviated names (code). In first row given no of sampled date 1-19 as in Table1.

No.	Species	Code/ Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	*Amphora affinis*	AmpAff	0	3	4	3	1	2	66	44	3	0	1	0	0	3	1	1	8	11	0
2	*Amphora commutata*	AmpCom	12	61	19	44	12	312	144	167	412	135	102	53	128	81	42	32	87	28	12
3	*Amphora minutissima*	AmpMin	2	0	59	42	0	2	0	0	0	3	2	3	0	3	3	2	0	2	0
4	*Amphora ovalis*	AmpOva	8	21	33	2	0	198	131	267	96	6	1	1	2	0	0	0	0	0	49
5	*Amphora pediculus*	AmphPe	0	2	0	0	5	2	0	0	0	0	5	6	2	0	2	2	0	0	3
6	*Caloneispermagna*	CaloPe	3	3	0	5	0	0	2	1	24	6	0	6	3	0	6	0	0	25	0
7	*Campylodiscus clypeus*	CampCl	1	6	9	1	4	37	11	21	12	2	0	6	6	9	0	0	0	0	0
8	*Cocconeisplacentula*	CocPla	6	22	0	20	2	43	15	17	6	3	6	0	6	0	9	2	2	13	35
9	*Craticulacuspidata*	CraCus	5	0	0	0	0	0	0	0	6	0	0	1	0	0	0	0	0	5	0
10	*Cyclotellameneghiniana*	CycMen	28	22	89	128	56	164	211	314	214	165	78	57	79	87	116	98	89	0	39
11	*Cyclotellaocellata*	CycOce	6	19	11	0	4	7	152	83	236	32	9	11	45	16	2	3	0	0	36
12	*Cymatopleurael liptica*	CymEll	2	1	8	0	0	0	22	0	6	0	0	9	6	9	0	0	3	0	0
13	*Cymatopleurasolea*var.*solea*	CymSol	16	4	11	53	12	86	43	49	126	119	142	101	69	23	46	96	132	69	15
14	*Cymatopleurasolea*var.*gracilis*	CySolG	6	0	6	14	2	0	0	11	0	6	2	6	5		0	0	4	0	0
15	*Cymbellaamphicephala*var.*inter*	CymAce	214	193	169	125	39	7	6	46	356	81	198	74	96	45	67	69	189	4	173

	media																				
16	*Cymbellacymbiformis*	CymCym	98	50	168	232	112	248	279	5	412	3	0	2	198	29	126	0	123	10	106
17	*Cymbopleuraamphicephala*	CymAmp	142	135	198	234	101	56	223	133	324	245	234	2	6	0	0	86	186	0	149
18	*Cymbopleuranaviculiformis*	CymNav	0	4	89	45	32	24	0	0	98	83	0	5	0	5	0	2	0	0	0
19	*Diatomatenue*	DiaTen	1	0	3	0	1	2	2	3	25	13	41	33	1	0	1	0	4	0	0
20	*Entomoneisalata*	EntAla	0	6	11	0	0	0	2	0	6	0	0	5	0	0	0	0	0	0	0
21	*Epithemiaargus*	EpiArg	16	18	49	23	11	75	42	58	158	129	143	159	109	65	76	135	164	76	23
22	*Fragilariformavirescens*	FraVir	0	11	209	101	42	145	54	298	68	32	19	55	15	12	0	11	32	44	19
23	*Gyrosigmaacuminatum*	GyrAcu	0	2	6	1	0	2	2	0	2	0	4	2	2	2	0	0	0	6	0
24	*Halamphoracoffeaeformis*	HalCof	32	3	2	45	6	345	456	241	345	185	86	45	165	91	49	71	45	16	45
25	*Hantzschiaamphioxys*	HanAmp	14	0	0	2	0	12	0	12	12	0	0	2	0	0	7	2	0	12	0
26	*Hippodontacapitata*	HipCap	0	0	4	3	0	0	6	13	6	13	6	10	13	0	2	6	0	0	0
27	*Hippodontahungarica*	HipHun	0	3	3	0	5	4	0	7	56	12	76	12	65	6	0	56	49	0	62
28	*Mastogloiabraunii*	MasBra	786	692	845	869	125	894	1021	987	1024	752	648	345	298	156	146	312	612	89	311
29	*Mastogloiagrevillei*	MasGre	289	245	369	412	88	268	456	685	745	595	412	289	173	98	121	296	421	45	263
30	*Mastogloiasmithii*	MasSmi	98	86	102	286	73	158	321	483	689	702	518	624	275	197	229	553	569	106	287
31	*Naviculacari*	NavCar	6	0	5	5	0	0	0	0	6	0	3	1	0	0	6	0	0	0	0

32	*Naviculacincta*	NavCin	0	3	3	0	0	45	1	65	43	0	12	10	0	0	0	0	12	0	0
33	*Naviculacryptocephala*	NavCry	0	12	45	28	12	35	9	0	26	33	35	41	68	18	21	36	45	24	0
34	*Navicularadiosa*	NavRad	15	0	8	2	2	0	0	0	0	3	0	2	3	0	0	0	0	4	0
35	*Nitzschiaagnita*	NitAgn	0	0	0	2	0	0	6	0	0	0	1	1	0	2	1	0	0	0	0
36	*Nitzschiaamphibia*	NitAmp	63	73	56	11	8	35	0	0	9	0	5	2	0	0	0	2	0	0	66
37	*Nitzschiabrevissima*	NitBre	15	3	9	3	1	16	51	3	60	5	0	19	12	12	24	0	2	16	2
38	*Nitzschiaobtusa*	NitObt	0	3	9	18	1	24	25	16	24	13	10	0	2	0	1	1	0	0	2
39	*Nitzschia*spp.	Nitzs	0	3	6	0	9	0	0	11	21	9	2	3	3	1	0	0	12	14	1
40	*Pinnulariasudetica*	PinSud	0	0	4	0	0	0	1	0	3	1	0	8	0	0	2	0	0	0	0
41	*Reimeriasinuata*	ReiSin	26	17	63	125	75	156	111	169	45	12	0	23	9	6	2	0	13	19	19
42	*Rhopalodiabrebissonii*	RhopBr	8	0	6	0	0	28	75	72	24	4	7	16	11	9	2	2	3	0	0
43	*Stauroneissmithii*	StaSmi	183	185	168	112	32	45	68	14	32	1	0	3	0	5	9	0	0	0	178
44	*Staurosiraconstruens*	StaCon	21	18	0	56	0	75	89	0	26	2	0	6	0	0	5	0	2	0	32
45	*Staurosirellalepstauron*	StrLep	0	35	102	3	23	85	2	0	63	0	75	12	103	12	106	23	134	0	32
46	*Staurosirellapinnata*	StaPin	6	19	56	87	47	145	241	114	214	153	96	56	0	0	0	97	68	49	21
47	*Surirellaminuta*	SurMin	0	0	4	0	0	0	2	0	3	0	6	3	0	3	0	0	1	0	0
48	*Surirellavenusta*	SurVen	0	2	1	0	2	0	2	3	12	6	9	0	2	3	0	2	0	0	0

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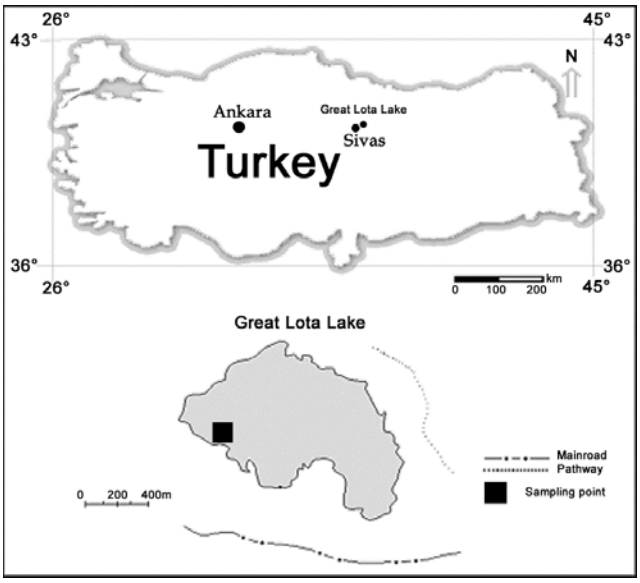
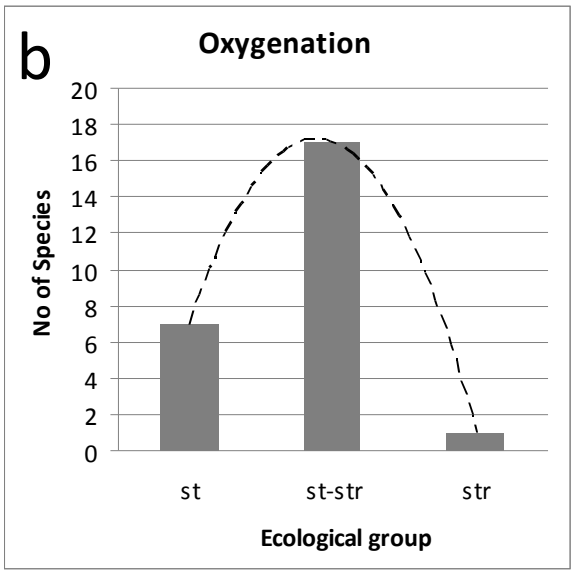
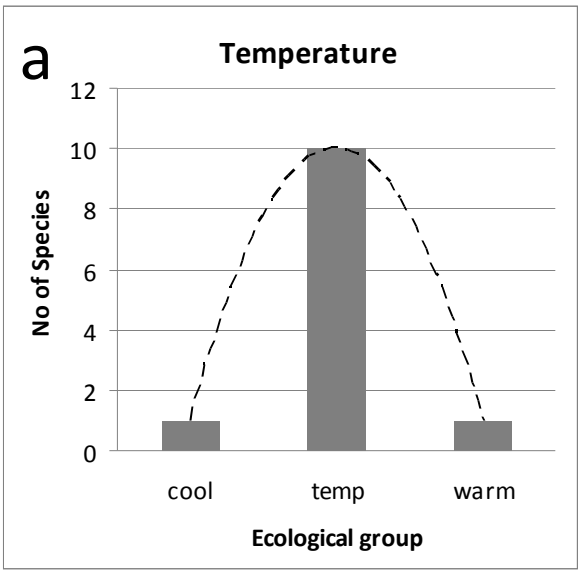


Figure 1. The location of the Great Lota Lake in Turkey





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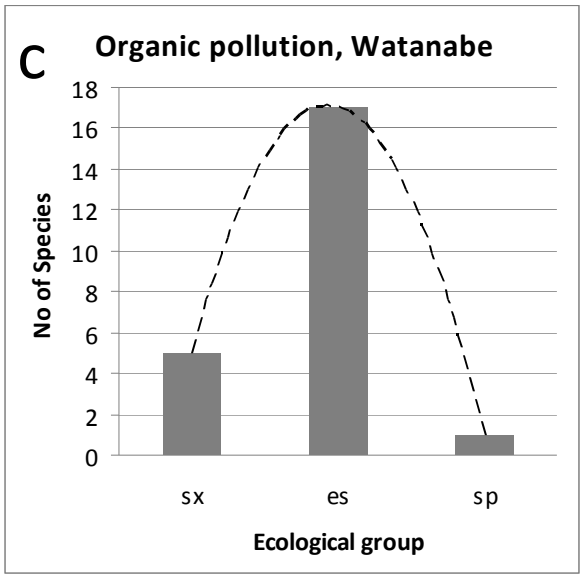

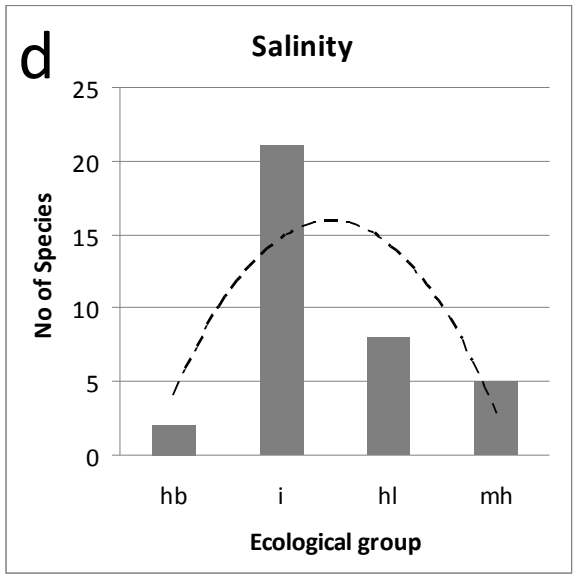

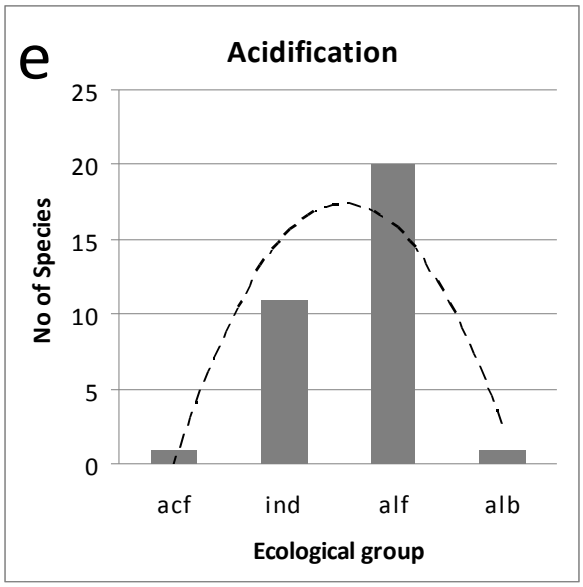

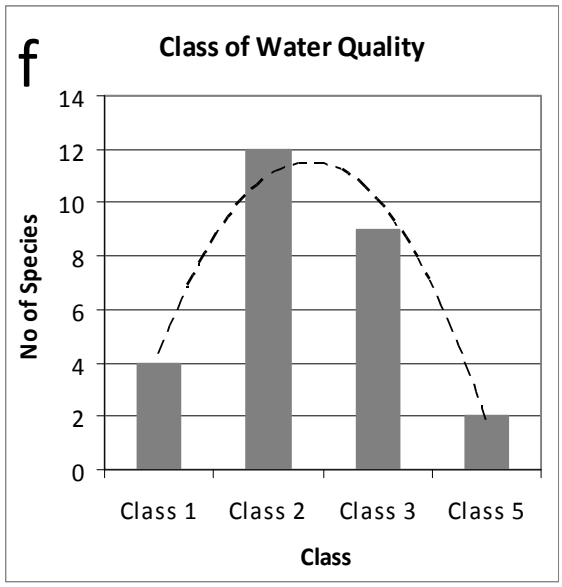

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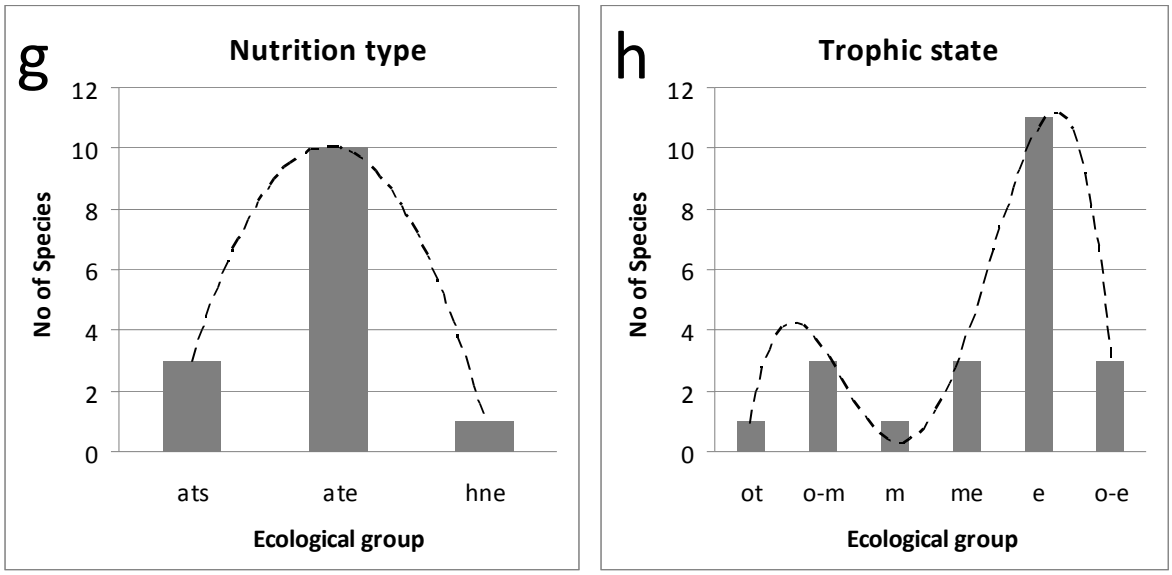

Figure 2. Bio-indication plot for the Great Lota Lake's microphytobenthic communities: a, temperature; b, oxygenation; c, organic pollution indicators (after Watanabe et al. 1986); d, salinity indicator group; e, acidification groups of indicator species; f, indicators of the Water Quality Class (after Sládeček 1973); g, photosynthetic activity as nitrogen uptake metabolism indicators (after Van Dam et al. 1994); h, trophic state indicator groups (after Van Dam et al. 1994). Symbols are the same as in Table2.

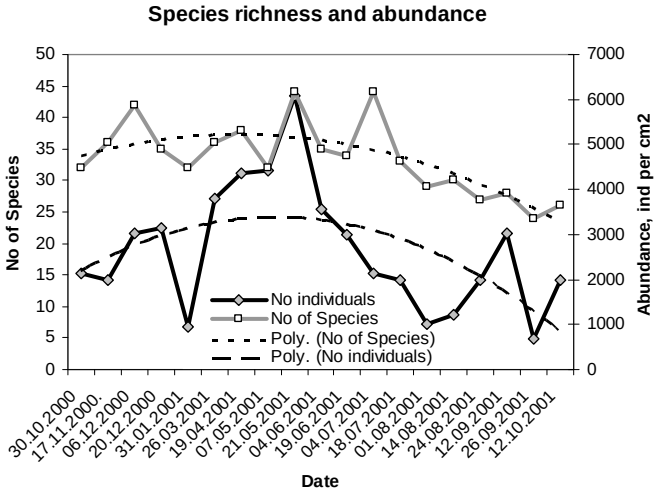

Figure 3.Dynamic of species richness and cell abundance in *in vitro* diatom communities of the Great Lota Lake during 2000-2001.

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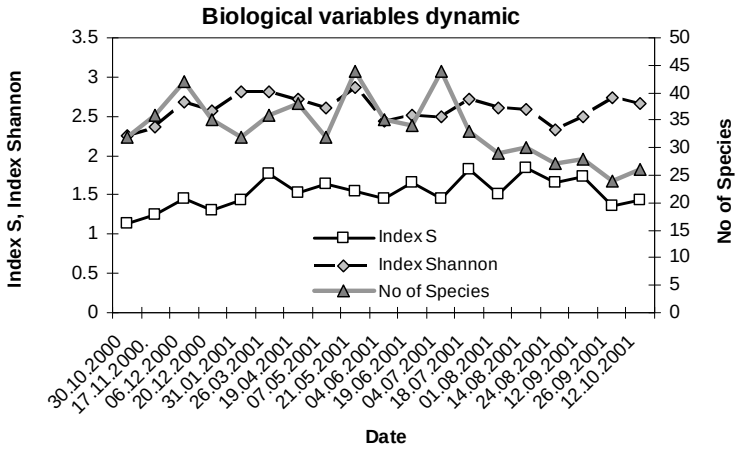

Figure 4. Dynamic of species richness, Index S and Shannon index in experimental diatom communities of the Great Lota Lake over the study period 2000-2001.

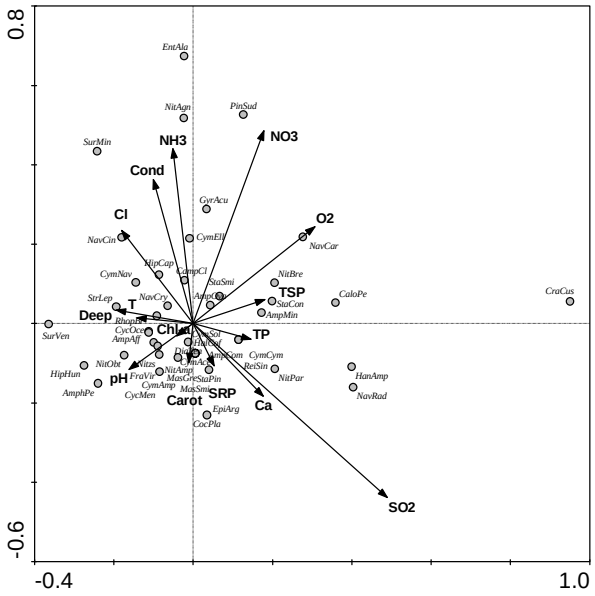

Figure 5.Biplot of Canonical Correspondence Analysis (CCA) of relationship between experimental diatom taxa distributions and environmental variables in the Great Lota Lake in 2000-2001.

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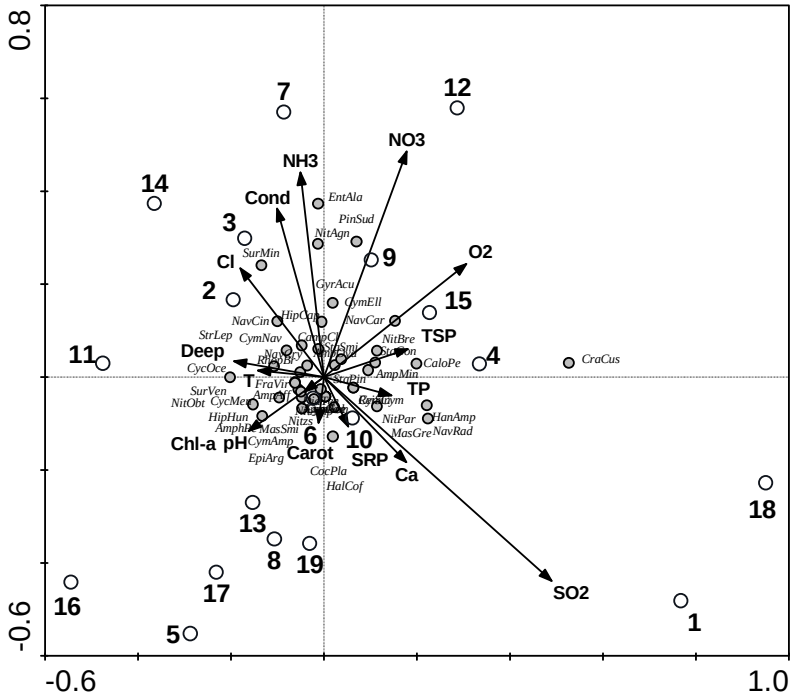

Figure 6.CCA triplot of relationships of diatom species in each community of the Great Lota Lake and environmental variables which were measured on the same dates.

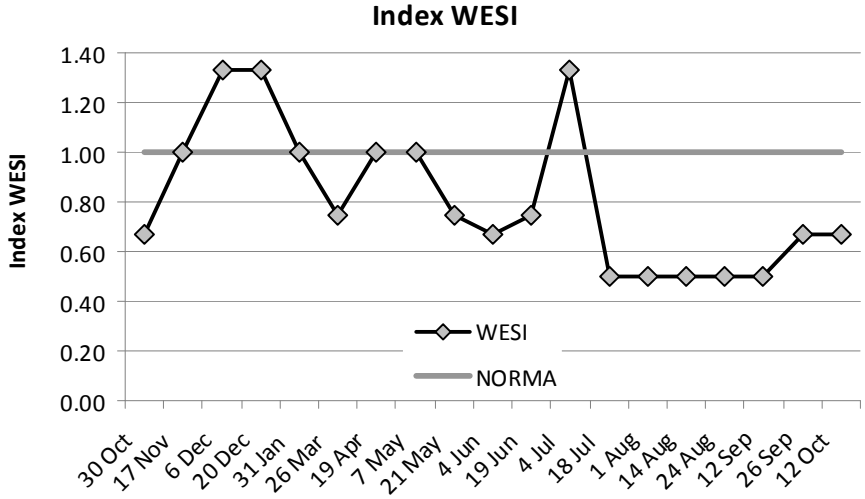

Figure 7.Aquatic Ecosystem State Index WESI fluctuation in the Great Lota Lake during the study period 2000-2001.

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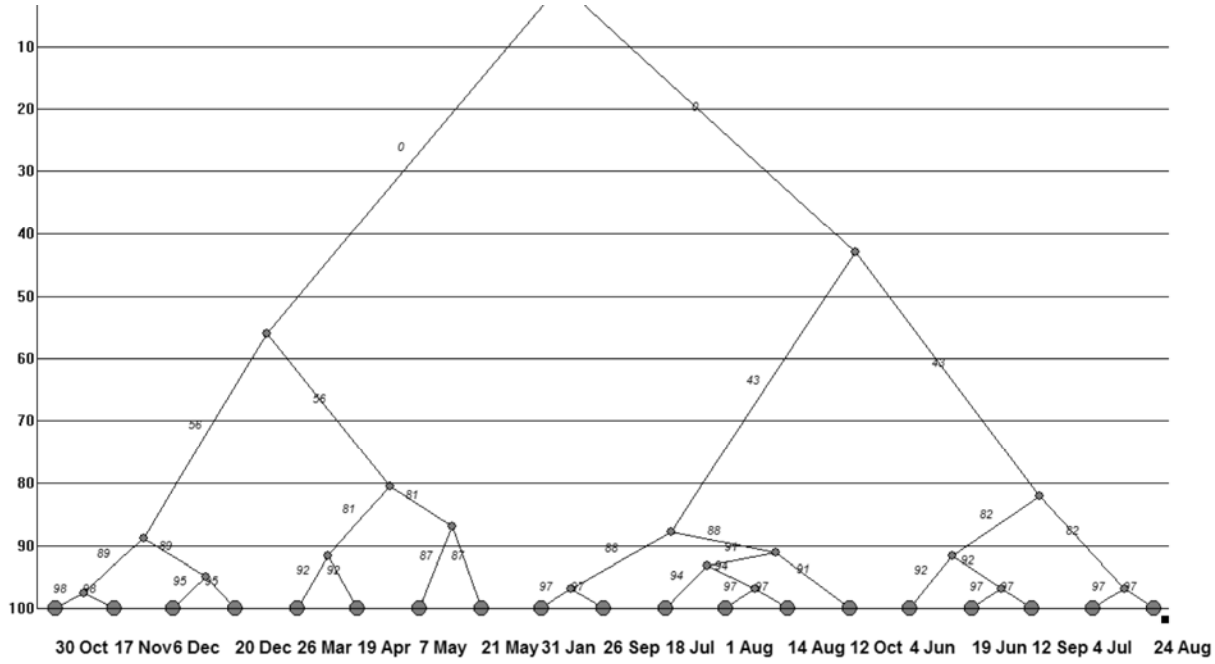

Figure 8.Clustering of the taxonomic structure in the Great Lota Lake *in vitro* diatom communities calculated on the basis of Sørensen-Czekanowski indices. At the similarity level of 50% three clusters are cut off.

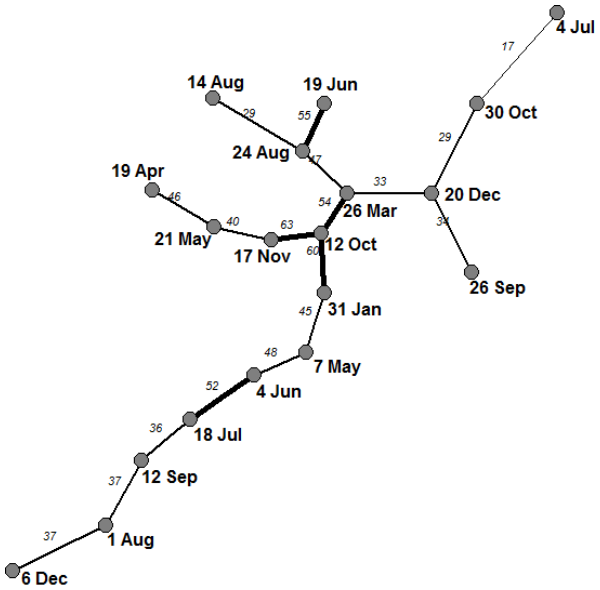

Figure 9. Dendrite of algal species lists comparing similarity levels of more than 50%. The three groups of highest similarity are marked by bold lines.

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CONCLUSIONS

The experimental *in vitro*communities of the Great Lota Lake were inhabited by 48 taxa of diatoms found during monthly monitoring in 2000-2001. Environmental variables of the studied karstic lake are correlated with precipitation-evaporation seasons. All *in vitro*revealed species are indicators of environmental conditions, and *Mastogloia* species are strongly prevail. Bio-indication and statistical approaches help us to assign *Mastogloia* species as bio-indicators for karstic sulfate lakes with high level of resistance.

The *in vitro*diatoms prefer temperate, low salinity, and alkaline high sulfate water. Organic pollution indications showoligo- and beta-mesosaprobic conditions all year-round. Trophic state indicators revealed a eutrophic state of the lake. Seasonal experiments show two major groups of communities – winter and summer, which depend on climatic or anthropogenic environmental conditions.

Experimantal *in vitro* communities assess the same level of organic pollution but in addition show preference of high sulfate water. The *in vitro* experiment show more realistic picture of ecological assessment with normal or slighlty stressed lake ecosystem in summer. It can be related with artificial enriched natural sediments by falling of empty diatom shalls, which are absent on experimental slides.

As a result, we can to conclude that the experimental *in vitro* diatom community as a part of the lake ecosystem reflect its state and most of environmental impacts. The experimental communities can be used as most indicative for water quality and ecosystem state assessment. Bio-indication and comparative statistics methods can help with recognition of the major environmental factors that are important for monitoring of natural lakes in Turkey.

ACKNOWLEDGEMENTS

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