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Full Length Research Paper

Ecological assessment of Great Lota Lake (Turkey) on the base of diatom communities

Rıdvan Erdal Sivaci[1], Sophia Barinova[2], Cüneyt Nadir Solak[3] and Kadir Çobanoglu[4]

[1]Department of Biology, Art and Science Faculty, Adiyaman University, Adiyaman 02000, Turkey.
[2]The Laboratory of Biodiversity and Ecology, the Institute of Evolution, University of Haifa, Mount Carmel, Haifa 31905 Israel.
[3]Department of Biology, Art and Science Faculty, Dumlupınar University, Kütahya, 43100, Turkey.
[4]Department of Biology, Art and Science Faculty, Dumlupınar University, Kütahya, 43100, Turkey.

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The diatoms are very important component for aquatic ecosystems. Turkey has a rich lake potential and many of the lakes have high level of endemism. For this reason, the Great Lota Lake was investigated between October 2000 and October 2001 in sampling periods of approximately per 15 days from one station. Totally, 104 diatom taxa were identified and used for ecological analysis by statistic methods. Chronological analysis, indication in respect to temperature, habitat preferences, streaming and oxygenation, organic pollution by Pantle-Buck and Watanabe's saprobity system, N-uptake metabolism, and trophic states were evaluated, and the aquatic ecosystem state index (WESI) was calculated. As a result, the diatoms in the lake preferred temperate, low saline and alkaline water. The saprobity is oligo- and betamesosaprobic when, the trophic state is eutrophic condition according to Van Dam's system.

Key words*:* Bio-indication, CCA, diatoms, Great Lota Lake, monitoring, organic pollution, Turkey.

INTRODUCTION

Algae (especially diatoms) are useful indicators of water quality because of their rapid response to environmental changes (Kelly and Whitton, 1995; Lowe and Pan, 1996; Schneider et al., 2000; Prygiel et al., 2002; Rimet et al., 2004). 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 owing to habitat and climate diversity and lack of major disturbances (Beklioğlu, 2010). 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. The aims of this study were to assess water quality dynamic, to observe changes in some biotic indices seasonally and to determine ecosystem performance statistically based on diatom community.

The Great Lota Lake (39°83'N, 37°43'E) is located in the middle of Turkey and has a depth of 3 to 4 m approximately. It is formed by the karstic subsidence on the east-west orientated gypsum plateau. The local geology consists of conglomerates, limestone ($CaCO_3$), gypsums ($CaSO_4$ + $2H_2O$), marl and mudstones (Gokce and Ceyhan, 1988; Günay, 2002) (Figure 1).

The environments and epiphytic diatom community of the lake were previously investigated by Sıvacı et al. (2008) by using redundancy analysis methods and the results show that there were strong correlation between diatom distributions and environmental variables such as temperature, Ca, TSP and SO_4 in the lake.

MATERIALS AND METHODS

Descriptive statistics of 14 variables are summarized in Table 1. Dissolved oxygen concentration (DO) and water temperature (YSI 51B Model), conductivity (Jenway 4070 Model) and pH (Orion 250-A Model) were measured in the field. Water for chemical analyses bottles, following filtration through GF/C filters for ammonium,

*Corresponding author. E-mail: rsivacii@gmail.com; rsivaci@adiyamn.edu.tr. Tel: (416)2231775 /2073. Fax: +90 (416)2231774.

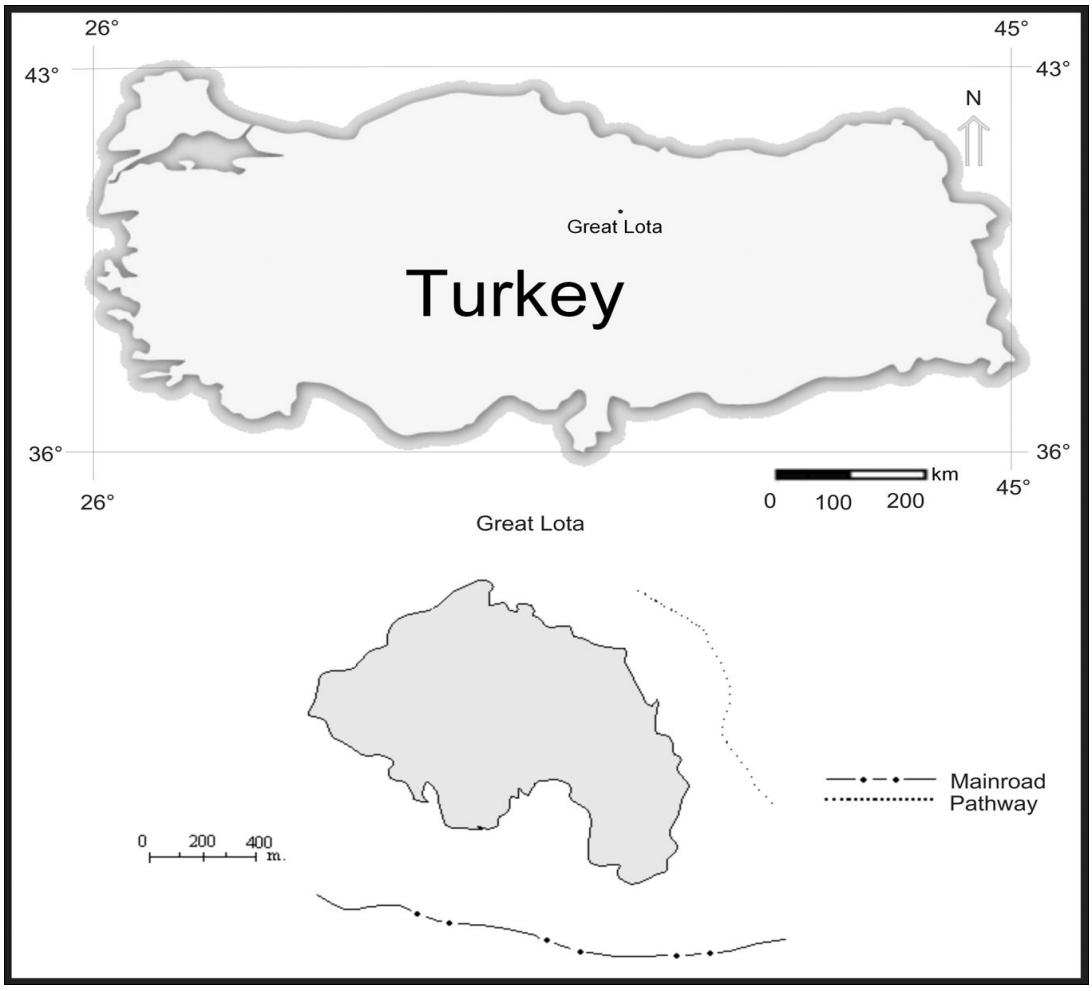

Figure 1. The location of Lake Great Lota in Turkey.

Table 1. Species frequency according to 6-score scale according to Korde (1956).

Score	Visual Estimate	Cell numbers per slide
1	Occasional	1-5
2	Rare	10-15
3	Common	25-30
4	Frequent	1 cell over a slide transect
5	Very frequent	Several cells over a slide transect
6	Abundant	One or more cells in each field of view

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. (1978) 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%.

Measurements were taken from October 2000 to October 2001 in sampling periods of approximately every 15-day (no measurement available in February due to freezing), making up 19 samples from one station. Diatoms were collected by brushing from stones. Then, they were cleaned with HCl and H_2O_2 for microscopic observation at a magnification of 1000X. After preparing three slides for samples, the diatoms were identified according to Krammer and Lange-Bertalot (1986; 1988; 1991a; b).

Autecology and geographic distribution of the diatoms were compiled according to Hustedt (1939; 1957), Sládeček (1986) and Watanabe et al. (1986). Ecological analyses were done based on the indicator species of Hustedt, Sládeček, Van Dam's systems,

Table 2. Correlation of the saprobity, halobity, trophic level, and the water quality classes (according to the study of Dell'Uomo, 1996).

Saprobic degree	Trophic Degree	Halobic Degree	Class of water quality	Water Quality
Xenosaprobic	Hypotrophic	Halophobous	0	Natural, unpolluted water
Oligosaprobic	Oligotrophic	Oligophobous-indifferent	I	Good water quality
α-Mesosaprobic	Mesotrophic	Oligophobous-indifferent	II	Slightly polluted water
β-Mesosaprobic	Eutrophic	Oligophobous-halophilous	III	Strongly polluted water
Polysaprobic	Hypertrophic	mesohalobous	IV	Heavily polluted water

Table 3. Water quality classification from ecological point of view (Barinova et al., 2006b).

Class of water quality	Rank	NO_3^- mg N/l	Saprobity (Pantle-Buck Index) S
I very pure	1	< 0.05	<0.5
II pure	2	0.05-0.20	0.5-1.0
II pure	3	0.21-0.50	1.0-1.5
III medium	4	0.51-1.00	1.5-2.0
III medium	5	1.01-1.50	2.0-2.5
IV polluted	6	1.51-2.00	2.5-3.0
IV polluted	7	2.01-2.50	3.0-3.5
V very polluted	8	2.51-4.00	3.5-4.0
V very polluted	9	> 4.00	>4.0

showing the status of pH, salinity, temperature, habitat preferences, streaming and oxygenation, organic pollution, N-uptake metabolism indicator species. The density scores were calculated by using the 6-score scale (Korde, 1956) (Table 1) for the saprobity index S. Also, the chronological types of the species were revealed according to Sládeček (1986) (Table 5).

Saprobity index (S)

The Saprobity Index (S) was calculated as:

$$S = \sum_{i=1}^{n}(s_i.a_i) \Big/ \sum_{i=1}^{n}(a_i) \quad (1)$$

Where, S is the index of saprobity for the diatom community; S*i* is the species-specific saprobity index and a*i* is the density score.

S value, between 0 and 4 is the "weighted mean" of all individual indices that defines the self-purification zone corresponding to five classes of water quality (Sládeček, 1973) (Table 2). This bio-indication approach is based on the ecological classification, which is widely used in European and Asian countries (Romanenko et al., 1990; Whitton et al., 1991; WFD, 2000). The classification of water quality in European systems is correlated with organic pollution level, salinity and tropic state assessment of aquatic ecosystems.

The saprobity was investigated according to Watanabe's system, which described three indicator groups; "saproxenes (unpolluted water)", "eurysaprobes (moderately polluted water)", and "polysaprobes (polluted water)" in this system (Watanabe et al., 1986).

The aquatic ecosystem state index (WESI)

The index of ecosystem status (Aquatic Ecosystem State Index, WESI) is based on the water quality classes reflecting the self-purification capacities for each of the sampling stations or periods. It is calculated as:

$$WESI = Rank\ S / Rank\ N\text{-}NO_3 \quad (2)$$

Where, Rank S is the rank of water quality based on the Sládeček indices of saprobity; Rank $N\text{-}NO_3$ is the rank of water quality based on the nitric-nitrogen concentration (Table 3).

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 (Barinova et al., 2006a; b; 2010a; b).

Statistical data analysis

The relationship between species diversity (represented in each community) with environmental data can be used for climate-human-environment interaction assessment (as well as saprobity index S) on the sampling stations. For this purpose, Canonical Correspondence Analysis (CCA) was conducted on the sensitivity of species to environmental variables for each sample using CANOCO Program (Statistica 7.0, StatSoft, 1996) (Ter Braak and Šmilauer, 2002).

RESULTS AND DISCUSSION

It should be noted that in natural freshwaters, the expected amount of sulphate is between 3 to 30 mg/L^{-1} and of calcium 6 to 78 mg/L^{-1} (Moss, 1973); the measured values of these ions in the Great Lota Lake were considered extreme, as the average values were above 250 $mg.L^{-1}$ and 500 $mg.L^{-1}$ for sulfate and calcium (Sıvacı et al., 2008) (Table 4).

Totally, 104 epilithic diatom species were found during

Table 4. Abbreviations and units of environmental variables with basic statistical summaries. Sample size n=19.

Environmental variable	Minimum	Maximum	Mean	SE
Soluble reactive phosphorus (µg.L^{-1})	14.80	103.20	46.57	5.7 5
Total soluble phosphorus (µg.L^{-1})	9.20	129.00	46.26	7.24
Total Phosphorus (µg.L^{-1})	8.50	234.60	53.86	11.23
Ammonium (µg.L^{-1})	23.00	416.00	92.16	21.43
Nitrate (mg.L^{-1})	0.12	0.73	0.31	0.04
Silicate (mg.L^{-1})	0.75	3.80	2.40	0.17
Sulphate (mg.L^{-1})	45.30	532.00	269.72	32.46
Calcium (mg.L^{-1})	164.00	641.20	418.17	42.63
Chlorine (mg.L^{-1})	0.60	1.90	1.10	0.07
Temperature (°C)	6.00	28.00	17.51	1.59
pH	7.40	9.60	8.37	0.13
Dissolved oxygen (mg.L^{-1})	48.00	88.00	66.84	2.5
Conductivity	620.00	2108.00	805.37	74.38

the study (Table 5). *Mastogloia* spp. were the most dominant species and was followed by the taxa in decreasing magnitude of dominance; *Gomphonema* spp. (especially *Gomphonema parvulum*), *Cymbella* spp. (particularly *Cymbella affinis*), *Caloneis* spp. and *Nitzschia* spp. in the lake periphyton. Geographic ranges are known for 81 species from the Great Lota Lake; about 75.7% of the total species diversity. The chronological analysis reveals that most of the species were widespread or cosmopolitan (Table 5).

There were 39 (54.9 %) indicator species for oxygenation while, there were only two species (*Halamphora montana* and *H. normannii*) of high oxygen level (Figure 2a). The assessments of organic pollution level based on Watanabe's system revealed 60 indicator species (57.7%) representing all the classes, but with a strong prevalence of eurysaprobionts (Figure 2b). The indicators of salinity (95 species; 91.3%) were assigned to four ecological groups arranged along the gradient of salinity. The numerous ones were the "indifferents" of a broad tolerance of salinity fluctuations (Figure 2c). Five groups of acidification indicators comprised 88 (84.6%) species (Figure 2d). On the diagram, these groups were arranged along the pH gradient. The ratio of the groups reflects the influence of carbonate substrates, and therefore alkaliphiles predominate, with 52 species (59.1%). The ''indifferents'', usually prevailing over silicate substrates, were subordinate here with 23 species. Alkalibiontes and acidophiles are represented by few species, but they are never abundant and acidophile species. The assessments of organic pollution level based on Sládeček's system, class II (oligosaprobic zone) and class III (beta-mesosaprobic zone) species were dominant in the community (36 species; 43.9% and 26 species; 31.7% respectively) (Figure 2e). The N-uptake metabolism indicators include 88 species (84.6%) representing four classes. The group "ats" of photosyntetically active species was significantly dominant in the community (Figure 2f and 2m). The indicators of trophic states revealed 65 species (62.5%). The most representative was eutraphenthic group (31 species) (Figure 2g). The diatoms in the lake inhabited all the available aquatic habitats of the water column, submerged substrates and wet rocky banks. On the diagram, the ecological groups were ordinated according to their relationships with the substrate, and it shows increase in species number. The benthic forms (68 species, 70.1%) prevailed, and the planktobenthic group (25 species, 25.8 %) was next in the species richness (Figure 2h). For temperature, there were 29 species (27.9% of all species). This is not enough for a detailed analysis, although the temperate species obviously prevailed (Figure 2k).

As seen in Figure 3, Species richness in diatom communities is strongly correlated with cells abundance over all investigated period. Both parameters were lower in the winter season whereas increased in summer from April to September when temperature and sunlight intensity were high.

Species richness in diatom communities of the Great Lota Lake had three periods: winter-early spring, spring-early autumn and late autumn. As seen in Figure 4, during the first period the number of species in communities decreased from 75 to 29. In the longest warm period, the maximal species richness increased to 85 species at the end of April and then, the value decreased slowly to 39 species by some fluctuation at the end of September. Finally, the third period was presented in October (66 species). Regarding the yearly fluctuation, we saw only two period of species richness fluctuation in the lake: short winter and long summer. The summer activity of the diatoms can be dependent on photosynthetic radiation as well as increase of the water temperature in the lake. Moreover, the same two periods are shown with number of cells in periphytonic community and the biomass fluctuation in Figure 3. It can be assessed as the insolation-productivity dependent process on climatic

Table 5. The diatom indicators of environments in the Lota Lake with their autoecology and abundance scores in the communities.

Number	Taxa	Code	Score	Hab	T	Reo	D	Sal	pH	S	Sap	Het	Tro	Geo
1	*Achnanthes brevipes* var. *intermedia* (Kütz.) Cl.	ABIN	2	B	-	st	-	mh	-	-	-	-	-	k
2	*Achnanthidium deflexum* (Reimer) Kingston	ADEF	1-2	B	-	-	es	-	-	-	-	-	-	-
3	*A. minutissimum* (Kützing) Czarnecki	AMIN	5-6	B	-	-	-	-	neu	1.5	o-b	-	-	-
4	*A. thermalis* (Rabenhorst) Schoenfeld	ATHE	1-2	B	warm	st-str	-	hl	ind	-	o	-	-	k
5	*Amphipleura pellucida* (Kütz.) Kütz.	APEL	1	B	-	st	-	i	alf	2.6	a-b	ate	o-m	k
6	*Amphora coffeaeformis* (C.Agardh) Kütz	ACOF	1	B	-	st-str	-	mh	alf	-	a	ate	e	k
7	*A. commutata* Grunow in Van Heurck	ACOM	1-3	B	-	-	-	hl	-	-	-	-	e	k
8	*A. obtusa* W.Greg.	AOBT	1	B	-	-	-	mh	-	-	-	-	-	-
9	*A.ovalis* (Kütz.) Kütz.	AOVA	2-3	B	temp	st-str	sx	i	alf	2.7	a-b	ate	e	k
10	*A. ovalis* var. *affinis* Kütz.	AOAF	1	B	temp	st	es	i	alf	-	-	-	-	k
11	*A. pediculus* (Kütz.) Grun.ex A. Schmidt	APED	1	B	temp	st	sx	i	alf	1.8	o-a	ate	e	k
12	*A. veneta* Kütz.	AVEN	1-6	B	-	st-str	es	i	alf	1.0	o	ate	e	k
13	*A. subcapidata* (Kisselev) Hustedt	AVCA	3	B	-	-	-	hl	-	-	-	-	-	-
14	*A. terroris* Ehr.	ATER	1	B	-	-	-	i	-	-	-	-	-	k
15	*Anomoeoneis costata* (Kütz.) Hust.	ANCO	1	B	-	-	-	mh	-	-	-	-	-	-
16	*A. sphaerophora* (Ehr.) Pfitz.	ASPH	1-2	P-B	warm	st-str		hl	alb	0.8	x-b	ate	e	k
17	*Asterionella formosa* Hassall	AFOR	1	P	-	st-str	sx	i	alf	1.0	o	ate	me	k
18	*Brachysira brebissonii Ross*	BBRE	1-3	B	-	-	es	oh	acf	1.0	o	-	-	-
19	*Caloneis amphisbaena* (Bory) Cleve	CAMP	1-6	B	-	st-str	-	hl	alf	1.2	o	ate	e	k
20	*C. amphisbaena* var. *undulata* Krasske	CAUN	1-5	B	-	-	-	hl	-	-	-	-	-	-
21	*C. lewisii* Patrick	CLEW	1	-	-	-	-	-	-	-	-	-	-	-
22	*C. schumanniana* (Grunow) Cleve	CLIM	1-2	P-B	-	st-str	es	i	alf	0.6	o-x	ats	m	k
23	*C. silicula* var. *limosa* (Kützing) Van Landingham	CSGB	1-3	B	-	-	-	i	-	-	-	-	-	-
24	*C. subsalina* (Donkin) Hendey	CSBS	6	B	-	st-str	-	mh	alf	-	a	ate	e	k
25	*Campylodiscus clypeus* Ehr.	CCLY	1-6	B	temp	-	-	mh	alb	-	b	-	e	k
26	*C. bicostatus* W. Smith	CBIC	1-2	B	-	-	-	hl	ind	-	b	-	e	k
27	*Cocconeis pediculus* Ehrenb.	CPED	1	B	-	st-str	sx	i	alf	1.8	o-a	ate	e	k
28	*C. placentula* Ehrenb.	CPLA	1-2	P-B	temp	st-str	es	i	alf	1.4	o-b	ate	e	k
29	*C. placentula* var. *euglypta* (Ehr.) Grunow	CPEU	1-6	P-B	temp	st-str	sx	i	alf	-	b	ate	e	k
30	*Craticula cuspidata* (Kutzing) D.G. Mann	CCUS	1-6	B	temp	st	es	i	alf	1.0	o	-	-	k
31	*Cyclotella antiqua* W.Sm.	CATQ	1-2	P	-	-	-	hb	acf	-	o	ats	ot	a-a
32	*C. meneghiniana* Kütz.	CMEN	1-6	P-B	temp	st	sp	hl	alf	1.8	o-a	hne	e	k
33	*C. striata* (Kütz.) Grunow	CSTR	1-4	-	-	-	es	hl	alf	-	-	-	-	-
34	*Cymatopleura elliptica* (Breb.) W. Sm.	CELL	1	P-B	-	st-str	-	i	alf	1.7	b-o	ate	e	k
35	*C. solea* (Bréb.) W.Sm.	CSOL	2-6	P-B	-	st-str	-	i	alf	1.0	o	ate	e	k
36	*Cymbopleura amphicephala* Krammer	CASP	1	B	-	st-str	es	i	alf	1.6	b-o	ats	o-e	k
37	*Cymbopleura angustata* (W.Smith) Krammer	CCYM	1-2	B	temp	str	sx	i	neu	-	o	ats	o-m	k
38	*C. aspera* (Ehr.) H. Perag.	CCIS	1	B	-	st-str	sx	i	alf	1.5	o-b	ats	e	k
39	*C. cymbiformis* C.Agardh	CHEL	1-2	B	-	str	-	i	alf	1.9	o-a	-	-	a,k

Table 5. Contd.

40	*C. cistula* (Ehrenb.	CTUM	6	B	temp	str	sx	i	alf	0.2	x	ats	me	k
41	*Cymbopleura hauckii* (Van Heurck) Krammer	CAPH	1	B	-	str	sx	i	ind	1.5	o-b	ats	o-m	b
42	*C. helvetica* Kütz.	CANG	1-2	B	-	str	es	i	ind	-	o	ats	ot	b
43	*C.tumida* (Bréb. Kütz.) van Heurck	CHAU	1-3	B	-	-	-	i	ind	-	-	-	-	b
44	*Denticula elegans* Kütz.	DELE	1-3	B	-	-	-	i	alf	1.3	o	-	-	k
45	*D. tenuis* Kütz.	DTEN	3	B	-	str	sx	i	alb	1.8	o-a	ats	m	b
46	*Diatoma anceps* (Ehrenb.) Kirchner	DANC	1-4	P-B	cool	st-str	sx	hl	alf	2.1	b	-	-	a,k
47	*D. vulgaris* Bory de Saint-Vincent	DVUL	1-4	P-B	-	st-str	sx	i	ind	2.4	b-a	ate	me	k
48	*Diploneis ovalis* (Hilse) Cleve	DOVA	1	B	-	str	sp	i	alb	2.0	b	ats	-	b
49	*Encyonema elginense* (Krammer) DG Mann	CTUR	1	B	-	st	sx	hb	acf	-	-	-	-	Ha
50	*E. prostratum* (Berk.) Kütz.	EPRO	1-2	B	-	str	es	i	alb	1.9	o-a	ats	e	k
51	*E. ventricosa* (Kütz.) Grunow	ENVE	1-3	B	-	st-str	sx	i	ind	1.33	x-o	ate	o-e	k
52	*Encyonopsis microcephala* (Grunow) Krammer	ENCM	1	B	-	str	es	i	alf	-	b	ats	me	k
53	*Entomoneis alata* (Ehr.) Ehr.	EALA	1-6	P-B	-	st		mh	alf	-	-	-	-	k
54	*Epithemia argus* (Ehrenb.) Kütz.	EARG	1	P-B	-	st-str	es	i	ind	1.8	o	-	m	k
55	*E. sorex* Kütz.	ESOR	1-2	B	temp	st	sx	i	alf	1.9	o-a	ats	e	k
56	*E. turgida* (Ehrenberg) Kützing	ETUR	2-3	B	temp	st	sx	i	alf	1.1	o	ats	me	k
57	*Eucocconeis flexella* (Kützing) Meister	EUFL	2-6	B	-	-	sx	mh	ind	1.2	o	-	-	a-a
58	*Eunotia monodon* Ehrenberg	EMON	1	B	-	str	-	hb	acf	1.6	b-o	ats	ot	k
59	*Fragilaria Lyngb. sp. 1*	FRAG	1	-	-	-	-	-	-	-	-	-	-	-
60	*F. crotonensis* Kitton	FCRO	1	P	-	st	es	hl	alf	2.7	a-b	ate	m	k
61	*F. capucina* Desm.	FCAP	1	B	-	-	es	i	neu	1.0	o	-	m	k
62	*F. virescens* (Ralfs) D.M. Will. & Rond	FVIR	6	P-B	-	st	es	i	neu	1.3	o	ats	o-m	k
63	*Gomphonema acuminatum* Ehrenb.	GACU	2-6	P-B	-	st	es	i	alf	0.9	x-b	ats	e	k
64	*G. angustatum* (Kütz.) Rabenh.	GANG	1-2	P-B	-	st-str	es	i	alf	2.0	b	-	-	k
65	*Gomphonema dichotomum* Kützing	GINT	6	P-B	-	st-str	es	i	ind	0.4	x-o	-	-	k
66	*G. olivaceum* (Hornemann) Brébisson	GOLI	6	B	-	st-str	es	i	alf	2.5	b-a	ate	e	k
67	*G. parvulum* (Kütz.) Kütz.	GPAR	3-6	B	temp	str	es	i	ind	0.1	x	hne	e	k
68	*G. truncatum* Ehrenb.	GTRU	1-2	P-B	-	st-str	es	i	alf	0.7	o-x	ats	me	k
69	*Gyrosigma acuminatum* (Kütz.) Rabenh.	GYAT	1-3	B	cool	st-str	-	i	alf	0.7	o-x	ate	e	k
70	*Halamphora. montana* Krasske	AMMO	1	B	-	ae	-	i	alf	-	b	ate	e	k
71	*H. normanii* Rab.	ANOR	1	B	-	ae	-	hb	alf	2.4	b-a	ats	m	b
72	*Hantzschia amphioxys* (Ehrenb.) Grunow	HAMP	1	B	temp	st-str	es	i	neu	1.7	b-o	ate	o-e	k
73	*Mastogloia braunii* Grunow	MBRA	6	P-B	-	-	-	mh	alf	-	-	-	-	k
74	*M. grevillei* W. Smith	MGRE	6	B	-	-	-	i	alf	-	o	-	e	-
75	*M. smithii* Thwaites ex W. Smith	MSMI	6	B	-	-	sx	mh	alf	-	b	-	-	k
76	*Melosira varians* C. Agardh	MVAR	1-2	P-B	temp	st-str	es	hl	alf	2.7	a-b	hne	e	k
77	*Meridion circulare* (Greville) C. Agardh	MDIR	1	B	-	str	es	i	alf	1.5	o-b	ate	o-e	k
78	*Navicula Bory sp*	NAVI	1	-	-	-	-	-	-	-	-	-	-	-
79	*N. cincta* (Ehrenberg) Kützing	NCIN	1	B	warm	st-str	es	hl	alf	0.5	x-o	ate	e	k

Table 5. Contd.

80	*N. angusta* Grunow	NCIA	4-6	B		str	sx	hl	acf		o	ats	ot	k
81	*N. cryptocephala* Kütz.	NCRY	3-6	P-B	temp	st-str	es	i	alf	2.7	a	ate	o-e	k
82	*N. exilis* Kützing	NCEX	2-3	P-B	-	-	-	-	-	-	o	-	-	k
83	*N. exigua* var. *capitata* R.M. Patrick	NECT	2-6	B	-	-	sx	-	-	-	-	-	-	-
84	*N. oblonga* (Kütz.) Kütz.	NOBL	1	B	-	st-str	sx	i	alf	2.0	b	ate	e	k
85	*N. radiosa* Kütz.	NRAD	1-2	B	temp	st-str	es	i	ind	1.1	o	ate	me	k
86	*Neidium sp. 1*	NEID	1	-	-	-	-	-	-	-	-	-	-	-
87	*N. dubium* (Ehrenb.) Cleve	NEDU	1	B	-	str	-	i	alf	0.3	x	ats	me	k
88	*Nitzschia amphibia* Grun.	NAMP	2-6	P-B,S	temp	st-str	sp	i	alf	1.3	o	hne	e	k
89	*N. brevissima Grunow*	NBRE	1	-	-	st-str	es	hl	neu	0.4	x-o	-	e	-
90	*N. frustulum* var. *subsalina* Hustedt	NFSS	1	B	-	-	sp	hl	alb	-	b	-	-	k
91	*N. linearis* (Agardh) W. Smith	NLIN	1	B	temp	st-str	es	i	alf	0.0	x	ate	me	k
92	*N. palea* (Kütz.) W. Sm.	NPAL	1	P-B	temp	-	sp	i	ind	2.75	o-x	hce	he	k
93	*N. sigmoidea* (Nitzsch) W. Sm.	NSIO	1-3	P-B	-	st-str	-	i	alf	1.1	o	ate	e	k
94	*Pinnularia Ehrenb. sp. 1*	PINN	1	-	-	-	-	-	-	-	-	-	-	-
95	*P. maior* (Kützing) Cleve	PMAJ	2-6	B	temp	st-str	-	i	ind	0.3	x	ate	me	k
96	*P. sudetica* (Hilse) Hilse	PSUD	1	B	-	-	-	hb	acf	-	o	-	o-m	-
97	*Planothidium frequentissimum* (Lan.-Bert.)R.&Buk.	PFRE	1	B	-	st-str	-	i	alf	1.0	o	ate	o-e	k
98	*Puncticulata bodanica* (Grunow) Håkansson	CBOD	1-6	P	-	st	-	i	ind	0.1	x	ats	ot	a,Ha
99	*Rhopalodia gibba* G.F.O. Müller	RGIB	1	B	temp	-	es	i	alb	0.4	x-o	-	-	k
100	*R. gibberula* (Ehr.) O. Müll.	RGBL	1	B	temp	str	es	mh	ind	-	-	-	-	k
101	*Sellaphora hustedtii* (Krasske) Lang-Bert.&Werum	NHUS	1	B	-	str	sx	i	ind	-	x	-	-	b
102	*Stauroneis smithii* Grunow	SSMI	1	P-B	-	st-str	-	i	alf	0.5	x-o	ate	o-e	k
103	*Staurosira construens*	SCON	1	P-B	temp	st-str	sx	i	alf	1.3	o	-	-	k
104	*Surirella angustata* Kütz.	SANG	1	B	-	-	-	i	alf	2.25	b	-	-	k

Ecological types (Hab): B, benthic; P, planktic; P–B, planktic-benthic; S, soil; Ep, epiphytic. Temperature (T): temp, temperate; eterm, eurythermic; warm, warm-water. Oxygenation (Reo): st, standing water; str, stream; st-str, standing-streaming; ae, aerophil. Saprobity (Watanabe et al., 1986) (D): es, eurysaprob; sx, saproxen; sp, saprophil. Halobity (Sal) (Hustedt, 1939): mh, mesohalobe; oh, oligohalobe; i, oligohalobious-indifferent; hl, oligohalobious-halophilous; hb, oligohalobious-halophobous. Acidity (pH) (Hustedt, 1957): ind, indifferent; neu, neutrophil; alf, alkaliphil; acf, acidophil; alb, alkalibiont. Chorological types (Geo): a, alpine; a-a, arcto-alpine; b, Boreal; k, cosmopolite; Ha, Holarctic, Pt, Paleotropical. Saprobity (Sládeček, 1986) (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, xenosaprob; x-o, xeno-oligosaprob; o-x, oligo-xenosaprob; x-b, xeno-beta-mesosaprob; o-a, oligo-alfa-mesosaprob; o-p, oligo-polysaprob. Nitrogen uptake metabolism (Het) (Van Dam et al., 1994): 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; hce, obligately nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen. Trophic state (Tro) (Van Dam et al., 1994): ot, oligotraphentic; o-m, oligo-mesotraphentic; m, mesotraphentic; m-e, meso-eutraphentic; e, eutraphentic; he, hypereutraphentic; o-e, oligo- to eutraphentic (hypereutraphentic).

impact; also, the fluctuation of the Index Saprobity and Class II of Water Quality, while the minimum at the end S reflects organic pollution affecting the community. The maximum index value was in winter (1.41), and the water was oligosaprobic; self-purification of summer was 1.08 (Tables 2, 3; Figure 4).

The index value decreased over the study period as marked by the linear trend line. Its fluctuation can be also divided in the two periods. The value had the same fluctuation with species richness and cell abundance between April and September,

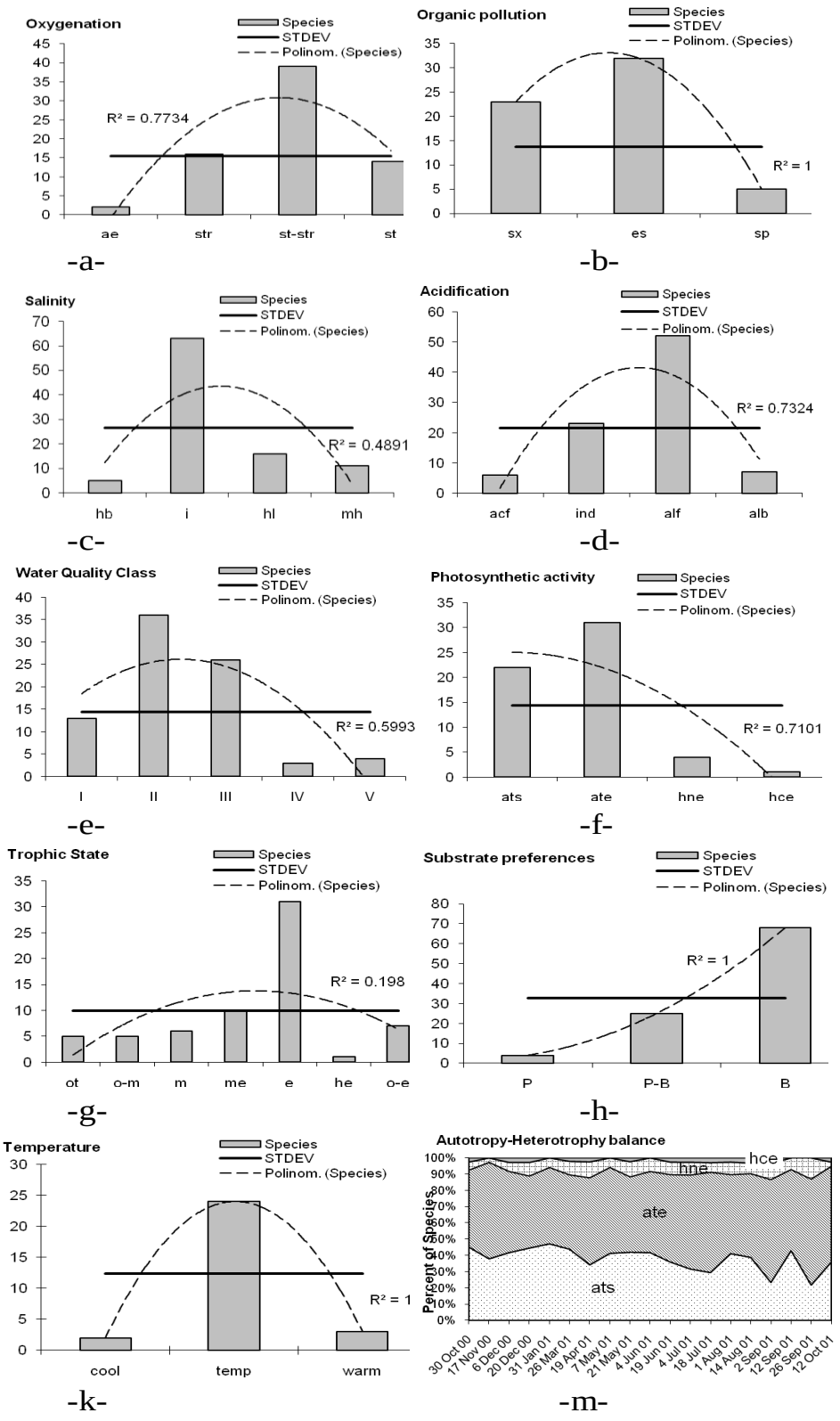

Figure 2. Bio-indication plot for the Great Lota Lake communities: a, oxygenation; b, organic pollution indicators (after Watanabe et al., 1986); c, salinity indicator group; d, acidification groups of indicator species; e, indicators of the Water Quality Class (after Sládeček, 1973); f, photosynthetic activity as a nitrogen uptake metabolism indicators (after Van Dam et al., 1994); g, trophic state indicator groups (after Van Dam et al., 1994); h, substrate preferences; k, temperature; m, dynamic of photosynthetic activity indicators. Symbols as in Table 5.

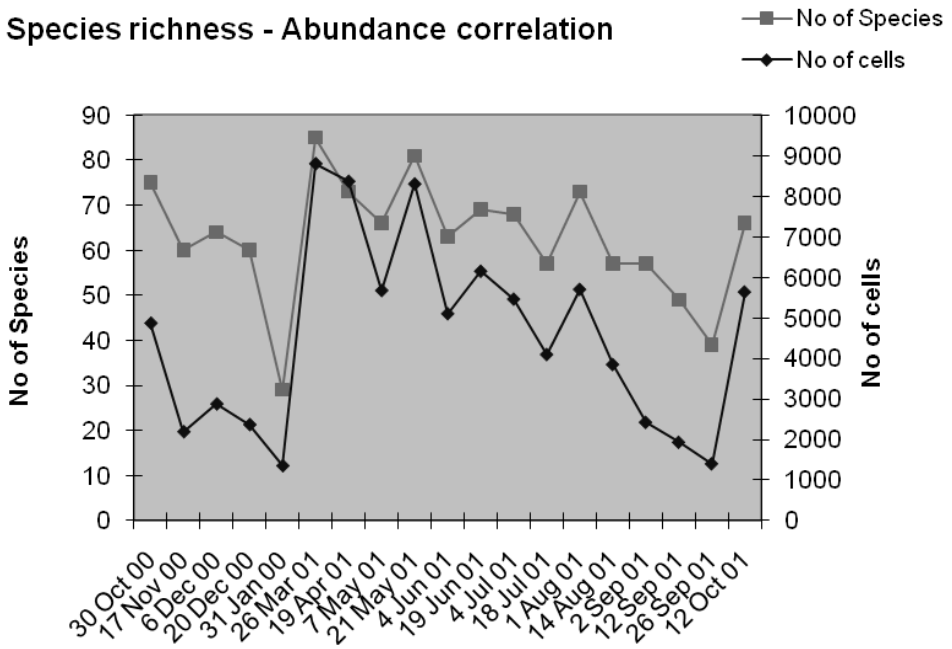

Figure 3. Dynamic of Species richness and abundance of cells in diatom communities of the Great Lota Lake.

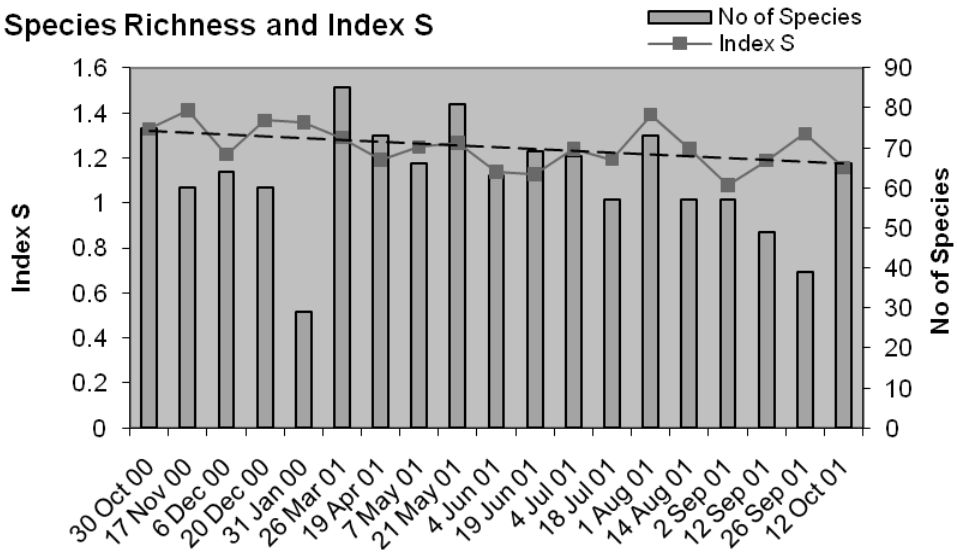

Figure 4. Dynamic of species richness and in diatom communities and Index Saprobity S of the Great Lota Lake.

whereas it had vice versa correlation from September to March. Therefore, species diversity and productivity of diatom communities of the Great Lota Lake are slightly influenced by increasing organic pollution during the autumn-spring period but is stimulated during the warmest summer period because the of the increase of photosynthetic activity (Figure 4).

Regarding CCA analysis (Figure 5), there were four different groups. Group 1 was the group of N-NO_3; conductivity, and chlorides (left down circle) correlated with increasing species richness in communities and depended on anthropogenic influence that stimulates diversity increase. Indicator species was *Pinnularia sudetica* (Hilse) Hilse. Group 2 was the group of pH, DO, chlorophyll and index saprobioty S (left up circle) correlated with increasing organic pollution; mostly nutrients and depended on

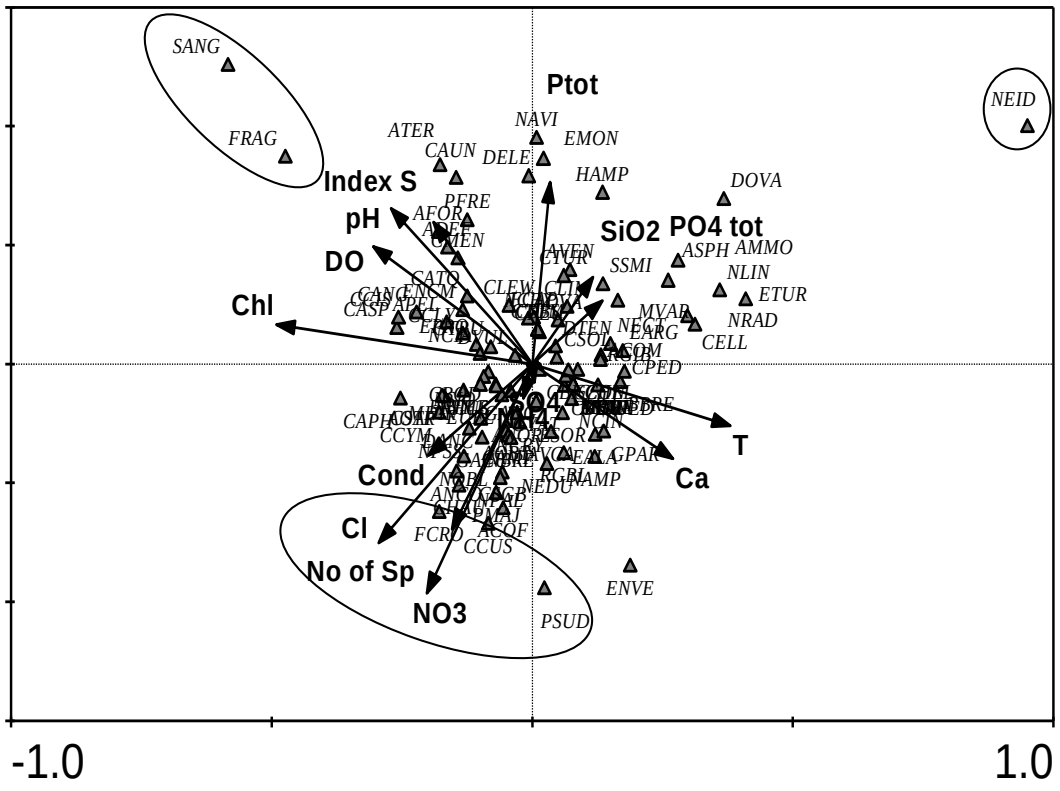

Figure 5. Dynamic of species richness and in diatom communities and Index saprobity S of the Great Lota Lake.

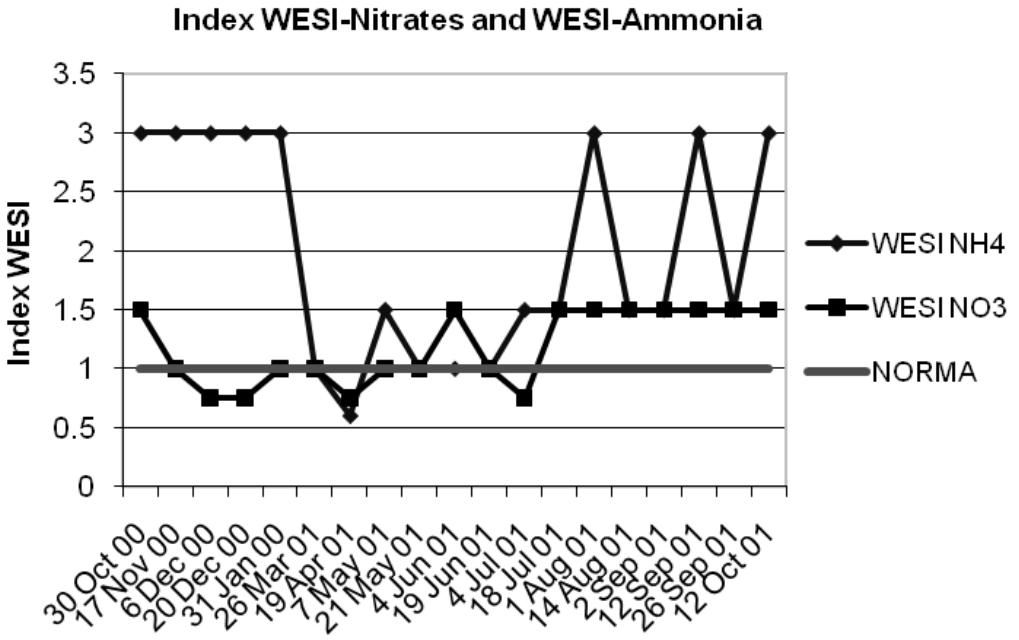

Figure 6. Aquatic ecosystem state index WESI fluctuation in the Great Lota Lake.

on anthropogenic influence that stimulates community productivity. Indicator species were *Surirella angustata* Kütz. and *Fragilaria* sp. Group 3 was the group of phosphorous and silicates (right up circle) from the river bottom carbonates and correlated with natural influences. Indicator species was *Neidium* sp. which survived in the

sediments only. Group 4 was the group of calcium and temperature that depended on climatic seasonal fluctuation. Indicator species could not be revealed. Groups 1 and 3 had antagonistic influence to diatom community, as well as groups 2 and 4. Therefore, species that were indicators for the variables group 1 were bio-sensing and alternative to the variables of group 3 and vice versa, indicators to the variables of group 2 were sensitive to the variables of group 4. In other words, organic pollution stimulated species diversity and biological productivity (left upper and lower triplot quadrants) of diatom community whereas the natural dependent variables (right upper and lower triplot quadrants) were not so impacted by the diatoms. Remarkably, the most abundant species (such as *Fragilaria virescens*, *Gomphonema acuminatum*, *Caloneis subsalina* and many others) had not specific correlations with the environmental variables of the lake.

We calculated Index WESI for diatom communities of the Great Lota Lake on the base of Index saprobity S and the classification of N-nitrate concentration from the ecological point of view (Barinova et al. 2006a). As a result, Figure 6 shows that the ecosystem of the lake was rather healthy with Index WESI more than 1 or slightly lower but not less than 0.75. The community was impacted in winter (December-January), May, and July. It correlated with periods of alternate correlations of species richness, abundance and Index saprobity S, which means that the lake communities were impacted by photosynthetic toxicants during winter, late spring, and peak of summer. These toxic substances can come from organic degradation processes in winter and from algal (usually cyanobacteria) bloom in summer (unpublished data).

In conclusion, totally, 104 diatom taxa were found in this study. Of these, 101 species are indicators of environmental conditions. The diatoms of the lake were low saline, alkaline characteristics and prefer temperate water. According to Watanabe's saprobity system, the lake was oligo- and betamesosaprobic and trophic state was eutrophic condition according to Van Dam's system. As a result, diatom community content is closely related with water quality, which helps for revealing critical periods for the ecosystems, and therefore bio-indicational methods can be used in the monitoring system in Turkey.

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