DIVERSITY OF DIATOMS IN SIKHOTE-ALIN BIOSPHERE RESERVE, FAR EAST RUSSIA

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This paper presents the results of long-term studies on the diatom flora of the Sikhote-Alin biosphere reserve in the Primorsky Region of Far East Russia. The diatom flora consists of 326 species represented by 452 intraspecific taxa (including the nomenclatural type of the species). Taxonomic composition of the diatom flora was analyzed. Diatom communities of different water bodies in the region are described, focussing on dominant taxa.

INTRODUCTION

Given the continual increase of pollution pressure on water quality, it is a matter of urgency to study the intact, natural ecosystems before any possible environmental disturbance. The waters of the Sikhote-Alin biosphere reserve are an ideal example of natural systems unaffected by anthropogenic pollution. Data on diatoms of the Sikhote-Alin reserve were previously published in a number of papers (Medvedeva 1981, 1984, 1986a, b, 1987a, b, 1992, 1994) and this paper aims at an overview of the data sets.

Study area

Sikhote-Alin reserve is located in the middle part of the Primorsky Region, in the Sikhote-Alin mountains (Fig. 1). The Sikhote-Alin Range runs from north to east, bisecting the territory of the reserve into west and east facing slopes. In general, the western slope of the Sikhote-Alin Range is long and gentle, while the eastern slopes are short and steep. The river networks are densely developed dendritic systems. The Serebryanka and Dzhigitovka Rivers are the largest submontane rivers draining the eastern slope of the reserve, while on the western slope the lowland Kolumbe River (Amur River basin) is the largest drainage. There are numerous montane and submontane tributaries to these systems, with V-shaped valleys, narrow channels, 3 to 12 m wide, steep slopes and rapid currents with velocity of 1 to 3 m s^{-1}. Water temperature ranges from 4.5°C to 13.0°C, while pH varies from 6.4 to 7.1. Blagodatnoe Lake is brackish, due to its linkage with the Sea of Japan, while Golubichnoe Lake is a shallow, freshwater system with summer water temperatures as high as 21°C. The alpine wetland Solontsovskie Lakes are located in the headwaters of Solontsovsky Stream at 500 to 800 m above sea level.

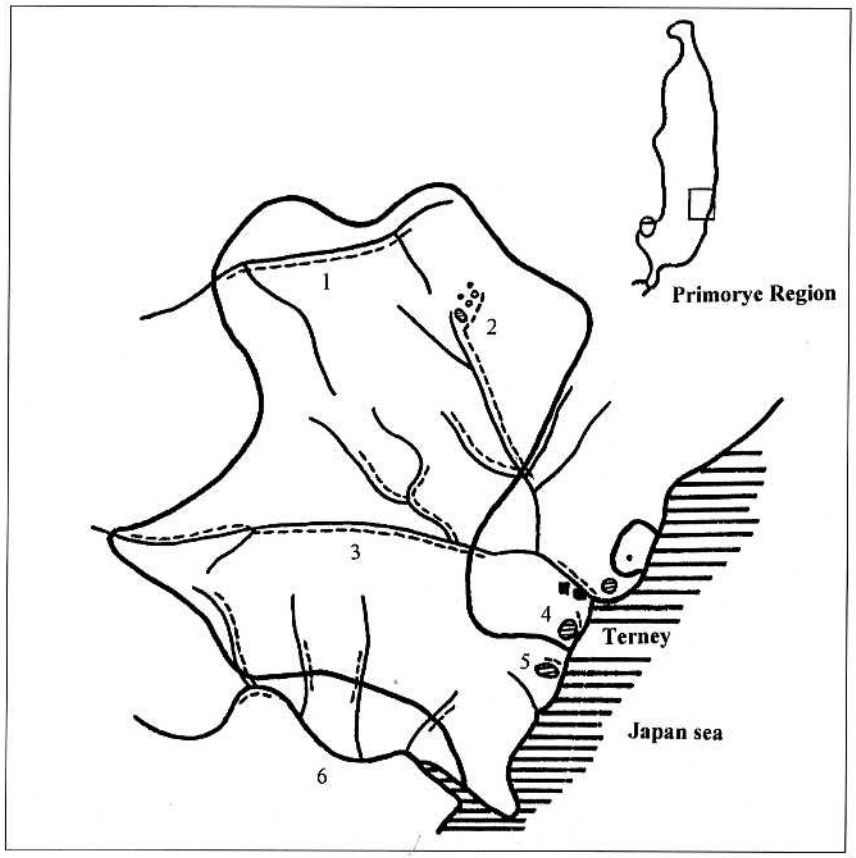

Fig. 1. Water system scheme of Sikhote-Alin biosphere reserve. 1. Kolumbe River, 2. Solontsovskie Lakes, 3. Serebryanka River, 4. Blagodatnoe Lake, 5. Golubichnoe Lake, 6. Dzhigitovka River. ---------- indicates collecting trips.

MATERIALS AND METHODS

The algal samples were collected from June to October 1976 to 1982 at Sikhote-Alin reserve and bordering territories by standard techniques (Vasser 1989). A total of 765 samples of epilithon, epiphyton, epipelon, metaphyton and phytoplankton were collected and processed. For diatom identification, permanent slides were prepared by the peroxide method (Swift 1967, Barinova 1988). The diatom species were identified using Patrick and Reimer (1966, 1975) and Krammer & Lange-Bertalot (1986, 1988, 1991a, b).

RESULTS AND DISCUSSION

Floristic composition

The Sikhote-Alin biosphere reserve recorded some 326 species of diatom flora (452 infraspecific taxa) from 52 genera (Table 1). The five most dominant leading genera were *Navicula* Bory – 47 species (65 intraspecies), *Nitzschia* Hass. - 38 (45), *Eunotia* Ehr. - 26 (37), *Pinnularia* Ehr. - 23 (39) and *Cymbella* Ag. 22 (23).

The families *Naviculaceae* - 110 species (162 infraspecific taxa) and *Nitzschiaceae* - 41 (50) were represented by the largest numbers of taxa (Table 2). Our data are similar to descriptive data from other large regions: water bodies of Northern Russia, Yakutia, Ukraine and Western Siberia (Palamar-Mordvintseva 1982, Saphonova 1984, Getsen 1985, Vassilieva 1989). *Fragilariaceae* and *Eunotiaceae* are also typically northern diatom families. The species within these families reflect holoarctic characteristics of northern hemisphere florae. An increase in the number of single-species families and genera with a small number of species is typical of most northern florae (Getsen 1985).

Diatom communities

Blagodatnoe Lake has not completely lost the link with the Sea of Japan. Depending on the level of precipitation, the lake is occasionally connected to the sea by channels. At such times, there is mixing of the fresh and salt waters.

The diatom flora of brackish Blagodatnoe Lake totals 117 species, with varieties and forms forming 142 taxa. During the saline period, mostly species characteristic of sea and river mouths, such as *Melosira moniliformis* (O. Müll.) Ag., *Licmophora paradoxa* (Lyngb.) Ag., *Tabularia fasciculata* (Ag.) Williams et Round, *Amphora holsatica* Hust. and *Nitzschia reversa* W. Sm., *Rhoicosphenia abbreviata* (Ag.) Lange-Bertalot were dominant. In the less saline period, diatom composition change, resulting in an increase in the number of halophobic and indifferent species. Though *Melosira moniliformis* and *Tabularia fasciculata* are still the most abundant, *Pleurosigma elongatum* W. Sm. and *Melosira juergensii* Ag., *Mastogloia smithii* Thw. are also well-represented.

Many years ago, Golubichnoe Lake was also connected to the sea; however it is now a freshwater lake isolated from the sea. Significant summer warming to 21°C and the availability of nutrients due to destruction of catchment vegetation provide favourable conditions for algal blooms.

The diatom flora of Golubichnoe Lake and small tributary streams totals 133 species (177 intraspecies). The dominant diatoms present in both planktonic and benthic habitats are *Fragilaria construens* (Ehr.) Grun., *F. vaucheriae* (Kütz.) Peters., *Synedra rumpens* Kütz., *Tabellaria fenestrata* (Lyngb.) Kütz., *T. flocculosa* (Roth) Kütz., *Navicula cryptocephala* Kütz., *N. radiosa* Kütz., *Anomoeoneis vitrea* (Grun.) Ross, *Pinnularia gibba* Ehr., *P. viridis* (Nitzsch) Ehr., *Caloneis silicula* (Ehr.) Cl., *Frustulia rhomboides* De Toni, *Achnanthes marginulata* Grun. and species of the genera *Eunotia, Cymbella, Nitzschia* and *Gomphonema*.

The five Solontsovskie Lakes (Tsarskoe, Sokhatinoe, Krugloe, Kamennoe and Mutnoe) are located at 500 - 800 m above sea level, and are marshy, fed by groundwater. The distinctive elevation of this lake system is responsible for the unique diatom flora.

Table 1. The diatom genera of Sikhote-Alin biosphere reserve.

	Genus	Number of species	Number of infraspecific		Genus	Number of species	Number of infraspecific
1	*Thalassiosira*	2	2	27	*Caloneis*	6	10
2	*Stephanodiscus*	2	2	28	*Diploneis*	6	8
3	*Cyclotella*	5	6	29	*Neidium*	7	13
4	*Melosira*	3	6	30	*Amphipleura*	1	1
5	*Aulacoseira*	5	6	31	*Frustulia*	2	4
6	*Actinocyclus*	1	1	32	*Brebissonia*	1	1
7	*Arachnoidiscus*	1	1	33	*Mastogloia*	3	5
8	*Bacteriastrum*	1	1	34	*Cocconeis*	5	8
9	*Fragilaria*	11	21	35	*Achnanthes*	16	21
10	*Synedra*	6	13	36	*Eunotia*	26	37
11	*Tabularia*	1	1	37	*Rhoicosphenia*	1	1
12	*Ctenophora*	1	1	38	*Cymbella*	22	23
13	*Opephora*	2	2	39	*Amphora*	6	6
14	*Asterionella*	1	1	40	*Gomphonema*	17	22
15	*Hannaea*	1	4	41	*Gomphoneis*	1	1
16	*Diatoma*	5	6	42	*Didymosphenia*	1	1
17	*Meridion*	1	2	43	*Entomoneis*	2	3
18	*Tabellaria*	2	2	44	*Epithemia*	2	5
19	*Rhabdonema*	1	1	45	*Denticula*	2	2
20	*Licmophora*	2	2	46	*Rhopalodia*	3	4
21	*Navicula*	47	65	47	*Nitzschia*	38	45
22	*Anomoeoneis*	2	2	48	*Hantzschia*	2	4
23	*Stauroneis*	5	7	49	*Bacillaria*	1	1
24	*Gyrosigma*	4	4	50	*Surirella*	14	22
25	*Pleurosigma*	3	3	51	*Campylodiscus*	2	2
26	*Pinnularia*	23	39	52	*Stenopterobia*	1	1

Table 2. Families most rich in number of species

	Family	Genus	Species	Infraspecific taxa
1	*Naviculaceae*	13	110	162
2	*Nitzschiaceae*	3	41	50
3	*Cymbellaceae*	2	28	29
4	*Eunotiaceae*	1	26	37
5	*Fragilariaceae*	7	23	43

The total diatoms in Solontsovskie Lakes are comprised of 174 taxa and 125 species. Tsarskoe Lake is the largest with an area of 190 000 m^2. Depending on the amount of atmospheric precipitation, the fluctuations of the water level are very significant. In drought periods, the water

surface is a residual puddle at the bottom of the lake depression. Diatoms on the mosses and other macrophytes are numerous and highly variable. *Aulacoseira ambigua* (Grun.) Sim., *Melosira varians* Ag., *Fragilaria bicapitata* A. Mayer, *F. virescens* Ralfs, *Synedra rumpens, S. ulna, Tabellaria fenestrata, T. flocculosa, Stauroneis anceps* Ehr., *Pinnularia borealis* Ehr., *P. microstauron* (Ehr.) Cl., *Diploneis elliptica* (Kütz.) Cl., *Achnanthes lanceolata* (Breb.) Grun., *Eunotia bilunaris* (Ehr.) Mills, *E. flexuosa* Breb. ex Kütz., *E. minor* (Kütz.) Grun., *Amphora ovalis* (Kütz.) Kütz., *Gomphonema clavatum* Ehr., *G. parvulum* (Kütz.) Kütz., *Surirella angusta* Kütz. were abundant. When lake levels were at their highest during our observations (filling half of the depression) *Tabellaria flocculosa* and *Melosira varians* were observed as plankton.

Three of the Solontsovskie Lakes - Sokhatinoe, Kamennoe and Mutnoe - are considerably smaller, variable in their degree of swampiness and have almost constant water levels. The diatom florae of these lakes are similar. The most common diatoms in these water bodies are: *Synedra ulna, Diatoma mesodon, Frustulia rhomboides, Achnanthes lanceolata, Neidium iridis, Amphora ovalis, Surirella pantocsekii, S. angusta*, species of *Pinnularia, Eunotia, Tabellaria, Stauroneis, Cymbella, Fragilaria, Navicula* and *Gomphonema.*

Composition of the diatoms in Krugloe Lake was distinct, characterised by: *Cyclotella radiosa, Tabellaria flocculosa, Stauroneis phoenicenteron, Achnanthes lanceolata, Achnanthidium minutissimum, Gomphonema acuminatum, G. olivaceum, G. productum* and *Surirella robusta.*

In the Serebryanka River, four sites were sampled: upper, middle, lower reaches and the estuary. Tributaries of this river are numerous small montane and submontane streams.

In the Serebryanka River basin, including its tributaries, 266 species were found with 328 varieties and forms.

On the upper segment of the river extending about 15 km, only 30 species (36 taxa) were found. The overgrowths on the stones were formed by rheophilic cold water diatoms: *Synedra inaequalis* H. Kob., *S. ulna, Hannaea arcus, Diatoma mesodon, Cocconeis placentula, Achnanthidium minutissimum, Cymbella minuta, Gomphonema angustatum* and *G. olivaceum.*

The middle segment of the Serebryanka River is approximately 50 km long. In comparison with the upper reaches, the diatom species richness of this part of the river is double (71 species); the most abundant are *Synedra inaequalis, S. ulna, Hannaea arcus, Diatoma hiemalis* (Roth) Heib., *D. mesodon, Meridion circulare, Cocconeis placentula, Achnanthes lanceolata, Achnanthidium. minutissimum, Cymbella cesatii* (Rabh.) Grun., *C. cistula* (Ehr.) Kirchn., *C. minuta, C. sinuata* Greg., *Gomphonema angustatum, G. olivaceum, G. parvulum, Didymosphenia geminata* (Lyng.) M. Schmidt.

The lower section of the Serebryanka River extends from the mouth of the Zabolochennaya River to Terney town. 146 diatom species with 179 varieties and forms were found here. The diatom flora of this river segment is markedly different from that of the upstream segment. There was an abundant diversity of diatoms such as, *Cyclotella meneghiniana* Kütz., *Aulacoseira granulata* (Ehr.) Sim., *Diatoma tenuis* Ag., *D. vulgaris* Bory, *Tabellaria fenestrata, T. flocculosa, Anomoeoneis vitrea, Diploneis elliptica, Eunotia bilunaris, Epithemia adnata* (Kütz.) Breb., *Rhopalodia gibba* (Ehr.) O. Müll., *Bacillaria paradoxa* Gmelin, species of genera *Fragilaria, Synedra, Navicula, Cymbella, Gomphonema* and *Nitzschia.*

Near Terney town, pollution and salinity influence water quality in the estuary of Serebryanka River; with 122 species of diatoms (130 taxa including subspecies). They were the most diverse and numerous and include: *Stephanodiscus hantzschii, Melosira juergensii, Fragilaria bicapitata, Tabularia fasciculata, Diatoma vulgaris, Achnanthes delicatula, Rhoicosphenia abbreviata, Amphora holsatica, Rhopalodia gibba* and species of the genera *Navicula, Pinnularia, Cymbella, Gomphonema, Nitzschia* and *Surirella.*

The range of dominant species in the numerous tributaries of the Serebrjanka River is identical to the diatom composition of the upper and middle segments of the river.

The diatom flora of the Dzhigitovka River basin is represented by 119 species with 141 varieties and forms. The most common species were: *Fragilaria vaucheriae, Synedra inaequalis, S. ulna, Hannaea arcus, Diatoma mesodon, Meridion circulare, Navicula minuscula, N. radiosa, Cocconeis placentula, Achnanthidium minutissimum, Amphora pediculus, Didymosphenia geminata, Denticula elegans*, species of the genera *Cymbella* and *Gomphonema*.

The list of diatoms found in the lowlands Kolumbe River basin contains 120 species (141 taxa). The diatoms were typically numerous and diverse in the Kolumbe River, but the species composition differed greatly from that of the high-velocity cold water streams of the east slope of the Sikhote-Alin Range (Serebryanka, Dzhigitovka and its tributaries). They include *Melosira varians, Fragilaria bicapitata, F. vaucheriae, Synedra ulna, Hannaea arcus, Meridion circulare, Tabellaria fenestrata, T. flocculosa, Stauroneis anceps, Pinnularia mesolepta, Frustulia rhomboides, Eunotia bilunaris, Nitzschia levidensis, N. palea, Surirella angusta, S. brebissonii* and species of the genera *Navicula, Cymbella* and *Gomphonema*. The diatom flora of the Kolumbe's tributaries differs from that of the mainstream and has many species in common with the flora of the east slope rivers. Among the rare species were: *Eunotia rostellata, Gomphoneis eriense, Surirella pantocsekii.* Such species as *Eunotia baicalensis, Diploneis oculata* var. *nipponica, Amphora delphinea* var. *minor* previously were observed only at Lake Baikal (Skvortzow & Meyer 1928, Skvortzow 1937), and *Surirella alisoviana* only at Khanka Lake (Skvortzow 1928).

CONCLUSION

Taxonomic structure of this flora reflects holoarctic characteristics of northern hemisphere florae. Richness of this diatom flora and the differences between community composition (lakes and rivers) are explained by diversity of environmental conditions. Diatom flora of Sikhote-Alin reserve is currently the richest and most diverse among all of nine reserves studied in the Russian Far East.

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