doi: 10.25750/1995-4301-2024-2-175-184

# Diversity of soil diatom communities of Frolikhinsky State Nature Reserve

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The species composition of soil diatoms in Frolikhinsky State Nature Reserve was studied. Flora of diatoms algae was represented with 128 taxa of 4 classes, 12 orders, 23 families and 49 genera. The greatest diversity of species was found on the bank of the Bireya River (77 species), and the lowest – on the Barguzinsky ridge pass (3 species). In most species and intraspecific taxa of diatoms (97%) found in the reserve, the occurrence rate varied from 10 to 40%. An occurrence rate above 40% was noted only in four taxa that were identified as leading: *Pinnularia borealis* (80%), *Adlafia bryophila* (50%), *Gomphonema parvulum* (50%) and *Planothidium lanceolatum* (50%). The complex of dominant species was diverse and included representatives of 15 families. 36 species and intraspecific taxa were classified as dominants, 20 taxa were classified as subdominants. The complex of associated species included 6 taxa, 67 taxa were found singly and occasionally. *Pinnularia borealis* Ehrenberg had the highest occurrence at all sites. The families Fragilariaceae, Achnanthidiaceae, Naviculaceae, Ahnanthaceae, Gomphonemataceae, Cymbellaceae, Cocconeidaceae, Eunotiaceae, Pinnulariaceae, Bacillariaceae, Sellaphoraceae were characterized by high species diversity. Comparison of diatoms complexes (DC) in different plots of the reserve revealed similarities and differences of floristic diversity and taxonomic structure. The main reasons of taxonomic heterogeneity of DC in different areas are the conditions defined by their location within the natural reserve. The largest number of species was found on the shores of water bodies characterized by a high degree of moisture. The least abundant and diverse diatoms were represented in shaded and insufficiently moist areas of coniferous forests with abundant coniferous litter and acidic soils.

***Keywords:*** habitat, diatoms complexes (DC), species composition, Lake Baikal, *Pinnularia borealis*, *Adlafia bryophila*, *Gomphonema parvulum*, *Planothidium lanceolatum*.

УДК 582.232/.275-152.6

# Разнообразие сообществ почвенных диатомовых водорослей Государственного природного заказника «Фролихинский»

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Изучен видовой состав почвенных диатомовых водорослей Государственного природного заказника «Фролихинский». Флора диатомовых водорослей представлена 128 таксонами из 4 классов, 12 порядков, 23 семейств и 49 родов. Выявлены группы наиболее часто встречающихся видов, доминант и субдоминант. Разнообразие и обилие диатомовых водорослей, встреченных в почвах заказника, может быть охарактеризовано как высокое. Таксономическое богатство и разнообразие сообществ диатомовых водорослей исследованных участков существенно отличались друг от друга. Наибольшее разнообразие видов выявлено на участке возле реки Бирея (77), наименьшее – на перевале Баргузинского хребта (3). У большинства видов и внутривидовых таксонов диатомовых водорослей (97%), обнаруженных на территории заказника, показатель встречаемости варьировал от 10 до 40%. Показатель встречаемости выше 40% был отмечен только у четырёх таксонов, которые были выделены в ранг ведущих: *Pinnularia borealis* (80%), *Adlafia bryophila* (50%), *Gomphonema parvulum* (50%) и *Planothidium lanceolatum* (50%). Комплекс доминирующих видов был разнообразным и включал представителей 15 семейств. К доминантам относилось 36 видов и внутривидовых таксонов, к субдоминантам – 20 таксонов. Комплекс сопутствующих видов включал 6 таксонов, 67 таксонов встречались единично и эпизодически. Самую высокую встречаемость на всех участках имела *Pinnularia borealis* Ehrenberg. Высоким видовым разнообразием отличались семейства Fragilariaceae, Achnanthidiaceae, Naviculaceae, Ahnanthaceae, Gomphonemataceae, Cymbellaceae, Cocconeidaceae, Eunotiaceae, Pinnulariaceae, Bacillariaceae, Sellaphoraceae. Сравнение комплексов диатомовых водорослей разных участков на территории заказника выявило черты сходства и различия флористического разнообразия и таксономической структуры. Основными причинами таксономической неоднородности диатомовых комплексов в разных районах являются условия среды обитания, определяемые их расположением в пределах природного заказника. Наибольшее число видов было обнаружено на берегу водоёмов, характеризующихся высокой степенью увлажнения. Наименее обильно и разнообразно диатомовые водоросли были представлены на затенённых и недостаточно увлажнённых участках хвойного леса с обильным хвойным опадом и кислыми почвами.

***Ключевые слова:*** местообитание, комплексы диатомовых водорослей, видовой состав, озеро Байкал, *Pinnularia borealis*, *Adlafia bryophila*, *Gomphonema parvulum*, *Planothidium lanceolatum*.

Nature reserves, national parks and other protected natural areas often serve as “centers of stability” for a given area of the biosphere and have a beneficial effect on habitats far beyond their borders. They make it possible to preserve natural communities and the existing genetic fund of organisms. The role of studying such territories is to accumulate scientific information that can be used to study the structure and functioning of various ecosystems. The biological diversity of protected natural areas is of great value because it represents an important biological indicator of the state of the environment, which sensitively responds to the entire complex of anthropogenic impacts over a long period of time [1]. One component of biological diversity is diatoms. Many species of diatoms are sensitive to the effects of environmental factors, which allows them to be used as bioindicators in monitoring the state of the natural environment [2, 3].

A large number of diverse works are devoted to the study of diatoms in the Baikal region [4–8]. However, the knowledge of diatoms in terrestrial communities in this region remains extremely poor today. In this regard, the study of diatom complexes (DC) is an important element in tracking changes in ecosystems, since the analysis of their species composition provides an integral assessment of the results of all natural and anthropogenic processes.

The purpose of the work was to study the structure of diatom complexes of different biotopes on the territory of the Frolikhinsky State Nature Reserve.

## Objects and methods of research

The state natural reserve of federal significance “Frolikhinsky” is located in the North-Baikal region of the Republic of Buryatia on the north-eastern coast of Lake Baikal, 40 km from the regional center – the township of Nizhneangarsk and 45 km from the city of Severobaikalsk (55°26′13″ N, 110°02′09″ E). The reserve is included in the territory of the Central Ecological Zone of Lake Baikal and is part of the World Natural Heritage Site [9]. The climate of the Northern Baikal region is sharply continental, with a large amplitude of fluctuations in annual and daily temperatures. In January, the minimum average monthly temperature is from −22 to −40 °C, in July the maximum temperature is 17 °C. Atmospheric precipitation falls extremely unevenly. Formed under harsh climate and mountain conditions, the soils in the reserve are characterized by the composition of weathered rocks with certain signs of vertical zonation. Tundra soils dominate. The river valleys are swampy and are represented by humus-peaty-gley soils and, less commonly, alluvial-meadow soils. The territory of the reserve belongs to the coniferous taiga zone. Forests occupy 91.9 thousand hectares. Due to the cooling influence of Lake Baikal, the vegetation here resembles the pre-tundra strip of the northern taiga. The main forest-forming species are larch with an undergrowth of dwarf cedar and shrubby birch species, as well as pine and fir. There are cedar, spruce, aspen, and birch. The dwarf cedar grows both in the undergrowth and in continuous areas [9]. As can be seen from the characteristics of the study area, environmental conditions in the reserve are highly heterogeneous, which was taken into account during sampling.

During the research, four areas on the territory of the reserve were analyzed: 1 – the shore of Lake Levaya Frolikha (LF), 2 – the shore of the

Bireya River (BR), 3 – the Barguzinsky Ridge Pass (BRP) and 4 – the Khakusy sanatorium (KhS).

The material for this study was 10 mixed soil samples, consisting of 5–7 soil monoliths with a volume of 75–100 $cm^3$. Sampling and analysis of species diversity were carried out using methods generally accepted in soil algology [10–12]. Technical preparation of the samples was carried out according to the classical method [13], the cell walls were cleared of protoplasts by boiling in concentrated nitric acid. To prepare the preparations, the cleaned cell walls were placed in Naphrax™ resin [14]. For species identification of diatom taxa, a series of keys were used [15–19].

The names of classes, orders, families, genera, species and intraspecific taxa are given mainly according to the system adopted in the Algaebase database (Table 1) [20]. A Zeiss Axio Imager A2 light microscope was used in this work. To determine the role of individual species and intraspecific taxa in the DC, there was used a method of assessing abundance, which was expressed in points on a modified six-point Kolbe-Wysłouch scale [2]. We included species and intraspecific taxa with abundance from 3 to 6 points into the dominant or main complex. Diatoms with 6 points were recognized as dominants, subdominants had 4–5 points, and representatives with scores below 3 were classified as accompanying. For each species, constancy (occurrence) was calculated using the formula:

$$C\ (\%) = n/N \cdot 100,$$

where $n$ is the number of samples in which the species was found, $N$ is the total number of samples. Taxa containing a higher than average number of species were classified as leading. The similarity of the DC in different parts of the reserve was judged by the coefficient of similarity of the floristic composition of Sørensen-Chekanovsky, which was calculated using the formula:

$$K = 2C/A+B,$$

where $A$ and $B$ are the number of species in each of the compared areas, $C$ is the number of species common to them. The similarity coefficient is expressed in fractions of one; complete similarity is equal to one.

## Results and discussion

The composition of diatoms in the Frolikhinsky State Nature Reserve included 128 taxa from 4 classes, 12 orders, 23 families and 49 genera. Diatoms were observed in all sites examined.

In the sites of Lake Left Frolikha 74 species and infraspecific taxa have been identified. The dominant species were represented: *Achnanthidium helveticum* (Hustedt) Monnier, Lange-Bertalot & Ector in Monnier et al., *A. minutissimum* (Kützing) Czarnecki, *Adlafia bryophila* (J.B. Petersen) Gerd Moser, Lange-Bertalot & D. Metzeltin, *Aulacoseira lacustris* (Grunow) Krammer, *Cavinula cocconeiformis* (Gregory ex Greville) D.G. Mann & A.J. Stickle, *Diatoma mesodon* (Ehrenberg) Kützing, *Encyonema minutum* (Hilse) D.G. Mann in Round, Crawford & Mann, *Eunotia exigua* (Brébisson ex Kützing) Rabenhorst, *Fragilaria arcus* var. *recta* Cleve, *Gomphonema angustatum* (Kützing) Rabenhorst, *G. parvulum* (Kützing) Kützing, *Nitzschia palea* (Kützing) W.Smith, *Pinnularia borealis* Ehrenberg, *P. subcapitata* W. Gregory, *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot, *Stauroneis nobilis* Schumann, *Synedra ulna* (Nitzsch) Ehrenberg and *Tabellaria flocculosa* (Roth) Kützing. Subdomian taxa were equally numerous: *Brachysira vitrea* (Grunow) R. Ross in Hartley, *Cocconeis pseudolineata* (Geitler) Lange-Bertalot in Werum & Lange-Bertalot, *Diatoma vulgaris* Bory de Saint-Vincent, *Encyonema ventricosum* (C.Agardh) Grunow in A. Schmidt et al., *Eunotia praerupta* Ehrenberg, *Fragilaria capucina* var. *gracilis* (Oestrup) Hustedt, *Gomphonema affine* Kützing, *Mayamaea atomus* (Kützing) Lange-Bertalot, *Pinnularia microstauron* (Ehrenberg) Cleve, *Sellaphora pupula* (Kützing) Mereschkovsky, *Stauroneis anceps* Ehrenberg and *Staurosira venter* (Ehrenberg) H. Kobayasi in Mayama et al. Also at the LF site, associated species such as: *Achnanthes marginulata* Grunow in Cleve & Grunow, *A. ventralis* (Krasske) Lange-Bertalot in Lange-Bertalot & Krammer, *Achnanthidium subatomoides* (Hustedt) Monnier, Lange-Bertalot & Ector, *Adlafia minuscula* (Grunow) Lange-Bertalot in Lange-Bertalot & Genkal, *Aulacoseira crassipunctata* Krammer, *A. distans* (Ehrenberg) Simonsen, *Caloneis bacillum* (Grunow) Cleve, *Cocconeis placentula* Ehrenberg, *C. placentula* var. *euglypta* (Ehrenberg) Grunow, *C. placentula* var. *lineata* (Ehrenberg) van Heurck, *Diadesmis contenta* (Grunow ex Van Heurck) D.G. Mann in Round, Crawford & Mann, *D. perpusilla* (Grunow) D.G. Mann in Round, Crawford & Mann, *Diatoma anceps* (Ehrenberg) Kirchner, *Encyonema caespitosum* Kützing, *E. elginense* (Krammer) D.G. Mann in Round, Crawford & Mann, *E. gracile*

Rabenhorst, *E. silesiacum* (Bleisch) D.G. Mann in Round, Crawford & Mann, *Eunotia arcus* Ehrenberg, *E. implicata* Nörpel, Lange-Bertalot & Alles, *Eunotia intermedia* (Krasske) Nörpel & Lange-Bertalot in Lange-Bertalot, *E. paratridentula* Lange-Bertalot & Kulikovskiy, *E. serra* var. *tetraodon* (Ehrenberg) Nörpel, *Fragilaria biceps* Ehrenberg, *F. construens* (Ehrenberg) Grunow, *F. nitzschioides* Grunow in van Heurck, *F. pinnata* var. *acuminata* (A. Mayer) Regenbogen, *Gomphoneis quadripunctatum* (Østrup) P. Dawson ex R. Ross & P.A. Sims, *Gomphonema helveticum* Brun, *G. minutum* (C.Agardh) C. Agardh, *Hannaea arcus* (Ehrenberg) R.M. Patrick in R.M. Patrick & L.R. Freese, *Hantzschia abundans* Lange-Bertalot, *Navicula cryptocephala* Kützing, *N. oppugnata* Hustedt, *N. radiosa* Kützing, *N. subrotundata* Hustedt, *Neidium iridis* (Ehrenberg) Cleve, *Pinnularia appendiculata* (C. Agardh) Cleve, *P. intermedia* (Lagerstedt) Cleve, *Planothidium conspicuum* (Mayer) E.A. Morales, *P. delicatulum* (Kützing) Round & Bukhtiyarova, *Rossithidium petersenii* (Hustedt) Round & Bukhtiyarova, *Sellaphora bacillum* (Ehrenberg) D.G. Mann, *Tabellaria fenestrata* (Lyngbye) Kützing and *Ulnaria delicatissima* (W. Smith) M. Aboal & P.C. Silva.

In soil samples taken from the bank of the Bireya River, the largest number of species and intraspecific taxa of diatoms was discovered – 77 (60% of the total species diversity). The dominant species were: *Achnanthes delicatula* subsp. *septentrionalis* (Østrup) Lange-Bertalot, *A. lanceolata* var. *rostrata* Hustedt, *Achnanthidium helveticum, Adlafia minuscula, Amphora ovalis* (Kützing) Kützing, *A. pediculus* (Kützing) Grunow ex A.Schmidt, *Craticula halophila* (Grunow) D.G.Mann in Round, Crawford & Mann, *Cocconeis placentula* var. *lineata, C. pseudolineata, Encyonema minutum, E. silesiacum, Fragilaria pinnata* var. *acuminate, Gomphonema parvulum, Karayevia laterostrata* (Hustedt) Bukhtiyarova, *Mayamaea atomus, Navicula cincta* (Ehrenberg) Ralfs in Pritchard, *Nitzschia fonticola* (Grunow) Grunow in Van Heurck, *Pinnularia borealis, Planothidium delicatulum, P. lanceolatum* and *Staurosira venter*. Subdominant species were less representative: *Achnanthes lacus-baicali* Skvortzov, *Achnanthidium subsalsum* (J.B. Petersen) M. Aboal, *Caloneis bacillum, Encyonema ventricosum, Fistulifera pelliculosa* (Brébisson) Lange-Bertalot, *Fragilaria nitzschioides, Gomphonema clavatum* Ehrenberg, *Halamphora normanii* (Rabenhorst) Levkov, *Navicula cryptocephala, Nitzschia palea, Opephora mutabilis* (Grunow) Sabbe & Wyverman, *Planothidium frequentissimum* (Lange-Bertalot) Round & L.Bukhtiyarova, *Sellaphora mutata* (Krasske) Lange-Bertalot and *S. pupula*. This site was characterized by the presence of a large number of associated, sporadic species with low abundance scores: *Achnantheiopsis lanceolatoides* (Sovereign) Lange-Bertalot, *Achnanthes flexella* var. *alpestris* Brun, *A. lanceolata* var. *baicalensis* (Skvortzov) Sheshukova, *A. lanceolata* var. *magna* (Straub) Lange-Bertalot, *A. lanceolata* subsp. *robusta* (Hustedt) Lange-Bertalot, *A. lanceolata* subsp. *robusta* (Hustedt) Lange-Bertalot, *A. minutissima* Kützing, *A. obliqua* (Gregory) Hustedt, *A. oestrupii* (Cleve-Euler) Hustedt, *Adlafia bryophila, Amphora sibirica* Skvortzow & Meyer, *Cocconeis placentula* var. *baikalensis* Skvortzov, *Cyclotella striata* (Kützing) Grunow, *Cymbella affinis* Kützing, *C. stuxbergii* (Cleve) Cleve, *Diatoma vulgaris, Didymosphenia geminata* (Lyngbye) M. Schmidt in A. Schmidt, *Diploneis elliptica* (Kützing) Cleve, *D. oblongella* (Nägeli ex Kützing) Cleve-Euler in Cleve-Euler & Osvald, *Encyonema elginense, Eucocconeis flexella* (Kützing) Meister, *Fallacia pygmaea* (Kützing) A.J. Stickle & D.G. Mann in Round, Crawford & Mann, *Fragilaria capucina* Desmazières, *Geissleria paludosa* (Hustedt) Lange-Bertalot & Metzeltin, *Gomphoneis quadripunctatum, Gomphonema affine, G. angustatum, G. angustatum* var. *sarcophagus* (Gregory) Grunow in van Heurck, *G. minutum, G. olivaceum* (Hornemann) Brébisson, *G. vibrio* var. *intricatum* (Kützing) Playfair, *Hannaea arcus, Karayevia clevei* (Grunow) Bukhtiyarova, *Luticola mutica* (Kützing) D.G. Mann in Round et al., *N. lanceolata* Ehrenberg, *N. leptostriata* Jørgensen, *N. subrotundata, Pinnularia* sp. 1, *Planothidium peragalloi* (J.Brun & Héribaud-Joseph) Round & L. Bukhtiyarova, *Psammothidium oblongellum* (Østrup) Van de Vijver in Van de Vijver, Frenot & Beyens, *Rhopalodia gibba* (Ehrenberg) Otto Müller, *Sellaphora bacilloides* (Hustedt) Z. Levkov, S. Krstic & T. Nakov in Levkov, Nakov & Metzeltin, *Synedra ulna* and *Tryblionella angustata* W. Smith.

The diatom complex of the Barguzinsky Ridge site included only three species of algae, two species were classified as subdominants (*Pinnularia borealis* and *Tabellaria flocculosa*) and one accompanying species – *Synedra ulna* (with an abundance score of 2 points).

The soil samples in the area near the hot springs of the Khakusy sanatorium were dominated by: *Achnanthes delicatula* subsp. *septentrionalis, A. lanceolata* var. *rostrate, Achnanthidium helveticum, Amphora pediculus, Cocconeis*

**Table 1**

Taxonomic richness and diversity of the DC in different parts of the Frolikhinsky State Nature Reserve

| Index | LF | BR | BRP | KhS |
|---|---|---|---|---|
| Number of classes | 3 | 4 | 2 | 3 |
| Number of orders | 8 | 9 | 3 | 7 |
| Number of families | 18 | 17 | 3 | 15 |
| Number of genera | 30 | 37 | 3 | 22 |

*Note: LF – Lake Levaya Frolikha, BR – the Bireya River, BRP – Barguzinsky ridge pass, KhS – Khakusy sanatorium.*

**Table 2**

Number of species (diagonal), number of common taxa (under the diagonal) and coefficients of similarity of DC at plots (above the diagonal)

| Plots | LF | BR | BRP | KhS |
|---|---|---|---|---|
| LF | 74 | 0,37 | 0,08 | 0,30 |
| BR | 28 | 77 | 0,05 | 0,50 |
| BRP | 3 | 2 | 3 | 0,08 |
| KhS | 16 | 29 | 1 | 37 |

*Note: LF – lake Levaya Frolikha, BR – the Bireya river, BRP – Barguzinsky ridge pass, KhS – Khakusy sanatorium.*

*placentula* var. *lineata, Hantzschia amphioxys* (Ehrenberg) Grunow in Cleve & Grunow, *Pinnularia borealis, Planothidium delicatulum, P. frequentissimum* and *P. lanceolatum.* The group of subdominants was represented by the following taxa of diatoms: *Adlafia minuscula, Encyonema silesiacum, Fragilaria pinnata* var. *acuminate, Gomphonema minutum, G. parvulum, Mayamaea atomus, Navicula cincta* and *Sellaphora mutata*. The associated species complex was not very specific, all taxa identified were found at previously surveyed sites. This group included: *Achnanthes lacus-baicali, A. oestrupii, Adlafia bryophila, Caloneis bacillum, C. dubia* Krammer in Lange-Bertalot & Krammer, *Craticula halophila, Cocconeis pediculus* Ehrenberg, *C. neodiminuta* Krammer, *C. placentula, Diploneis oblongella, Fistulifera pelliculosa, Fragilaria capucina, Gomphonema clavatum, Navicula leptostriata, Nitzschia palea, Placoneis elginensis* (Gregory) E.J. Cox, *Rhopalodia gibba, Sellaphora bacillum* and *Stephanodiscus minutulus* (Kützing) Cleve & Möller.

The diversity and abundance of diatoms found in the reserve's soils can be described as high. The revealed taxonomic richness and diversity of DC showed their inequality in different areas (Table 1).

For the majority of species and infraspecific taxa of diatoms (97%) found on the territory of the reserve, the occurrence rate varied from 10 to 40%. An occurrence rate above 40% was observed in only four taxa that were identified as leading: *Pinnularia borealis* (80%), *Adlafia bryophila* (50%), *Gomphonema parvulum* (50%) and *Planothidium lanceolatum* (50%). The complex of dominant species was diverse and included representatives of 15 families. The dominants included 36 species and intraspecific taxa, and the subdominants included 20 taxa. The complex of associated species included 6 taxa, 67 taxa were encountered singly and occasionally.

A comparison of the DC of different parts of the natural reserve revealed similarities and differences in a number of their basic parameters. The degree of similarity of the diatom flora of the studied areas was generally low (Table 2).

Its greatest value ($K$=0.50) was noted for sections of bank of the Bireya river and the Khakusy sanatorium, perhaps this is due to their close territorial location (Table 2). The DC of the banks of the Bireya River and Barguzinsky ridge were especially different ($K$=0.05). The number of species in the studied areas also varied greatly depending on the habitat and ranged from 3 to 78 species. A common feature of all sites was the presence of the families Pinnulariaceae and Fragilariaceae. The leading families – Ahnanthaceae, Achnanthidiaceae, Cymbellaceae, Gomphonemataceae and Naviculaceae, each of which included at least 7% of the species composition, were represented differently in DC.

As already mentioned, the communities of diatoms in different areas differed in the set of species and intraspecific taxa. Therefore, diatom complexes are characterized by areas that are determined by local landscape conditions.

**Shore of Lake Levaya Frolikha.** Three biotopes were considered on the site: a section of floodplain forest, the shores of Lake Levaya Frolikha in the splash zone and at a distance of 50 m from the water's edge. Representatives of seven families played a significant role in the

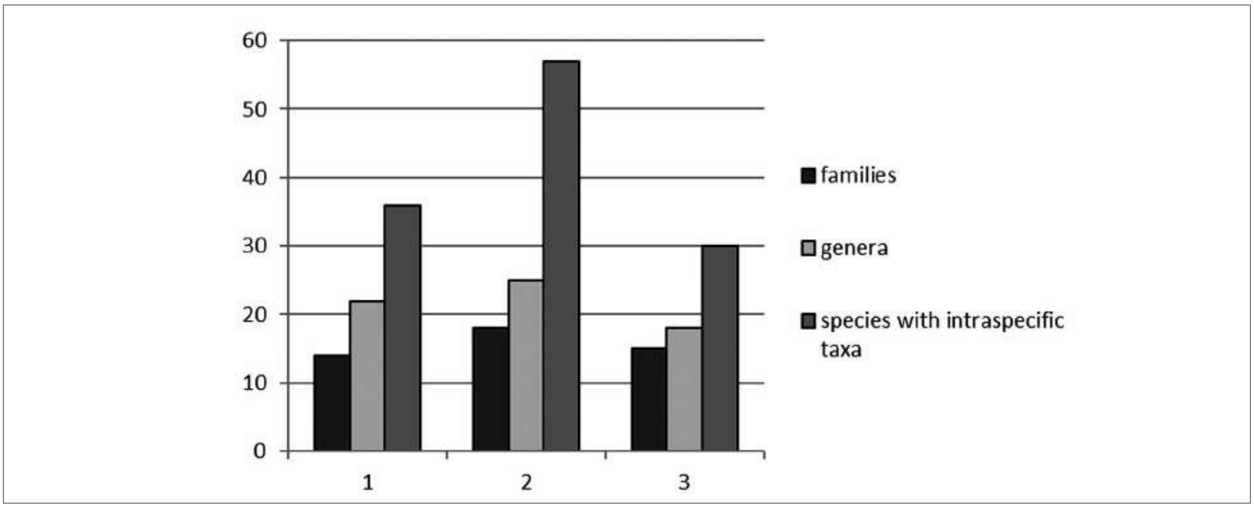


**Fig. 1.** Diversity of DC on the site of the bank of lake Levaya Frolikha:
1, 2, 3 – see the location of sampling sites in see in text (here and in other figures)

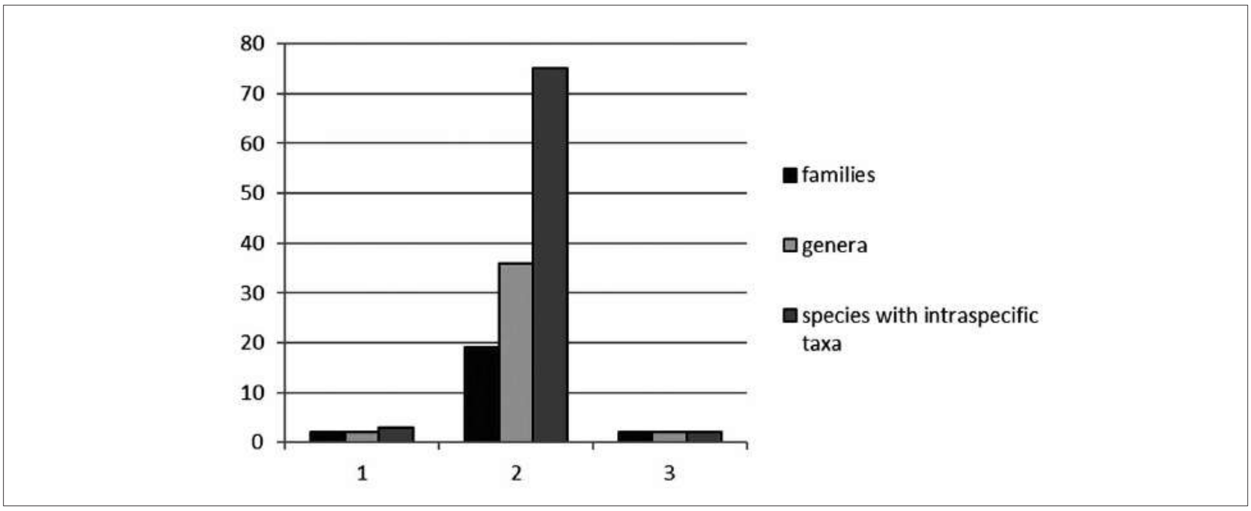


**Fig. 2.** Diversity of DC on the bank of the Bireya River

formation of the DC. The first place was occupied by the family Fragilariaceae with 13 species, in second place there were two families (Naviculaceae and Cymbellaceae), including 8 taxa each, in third place were the families Eunotiaceae and Achnanthidiaceae, with 7 species each. Next were the families Gomphonemataceae (6) and Pinnulariaceae (5). The remaining families accounted for 27% of the total species diversity of this site. In the splash zone, 36 species from 14 families and 22 genera were identified (Fig. 1).

In the soil of a forest area on the lake shore, 57 species were found (44% of the total species diversity), and the number of species increased due to the ecotone effect. The increase occurred due to the introduction of species from aquatic and forest habitats, which is quite natural in aquatic-terrestrial transition spaces [21–23]. In soil samples from a floodplain forest, 30 species of algae from 15 families and 18 genera were identified.

**Bank of the Bireya River.** In the study area, different biotopes were selected for analysis: a section of taiga forest with thickets of elfin pine, a river floodplain in the splash zone, and its terrace above the floodplain. The taxonomic structure of this diatom complex is quite complex. In this area, the first place was occupied by the family Naviculaceae (11 species), followed by families containing 10 taxa: Ahnanthaceae, Achnanthidiaceae and Gomphonemataceae. In third place there is the family Fragilariaceae with 8 species, followed by the family Cymbellaceae with 6 taxa. Soil samples from the forest area and the floodplain terrace were characterized by poor species diversity (Fig. 2).

Three species were found in the taiga: *Gom-*

*phonema affine*, *Pinnularia borealis* and *Pinnularia* sp.1. In the area of the floodplain terrace, two species were identified: *Luticola mutica* and *Pinnularia borealis*. Moreover, in both biomes *P. borealis* acted as a dominant; no subdominants or associated species were identified. The largest number of species and intraspecific taxa (74) was noted in soil samples taken from the coastal strip of the Bireya River (58% of the total).

Soil diatoms found on the territory of Frolikhinsky State Nature Reserve are presented in Figure 3.

**Plot near the Khakusy sanatorium.** Three biotopes were analyzed: a path in the taiga, a section of taiga with thickets of dwarf pine, and the shoreline of the Lake Baikal. The diatom communities of this site were similar in taxonomic structure to the communities of the bank of the Bireya River. The leading position of the families Naviculaceae, Ahnanthaceae, Achnanthidiaceae was also noted, with the exception of the family Gomphonemataceae, which was replaced here by the family Cocconeidaceae. Despite the taxonomic similarity, it is worth noting the difference in the quantitative indicators of diatoms at two adjacent sites. On the territory of the Khakusy

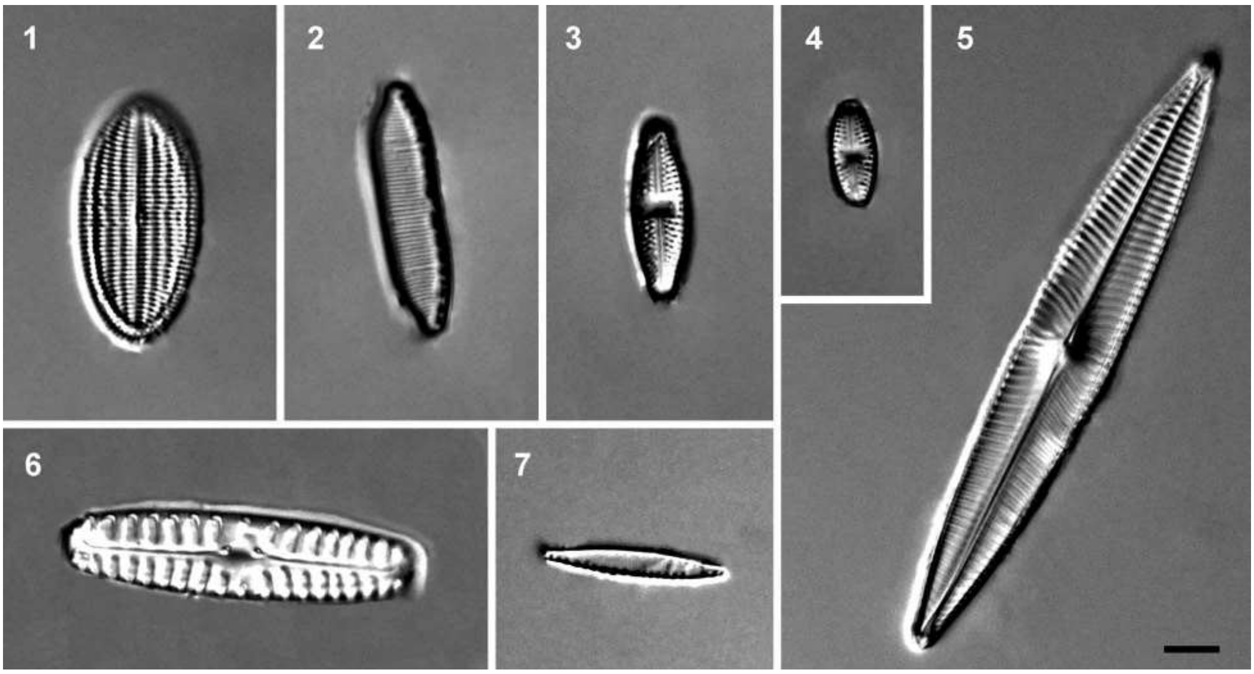


**Fig. 3.** Soil diatoms of Frolikhinsky State Nature Reserve: 1 – *Cocconeis placentula*; 2 – *Hantzschia amphioxys*; 3 – *Luticola mutica*; 4 – *Mayamaea atomus*; 5 – *Navicula radiosa*; 6 – *Pinnularia borealis*; 7 – *Nitzschia fonticola*. Scale bar equals to 10 μm

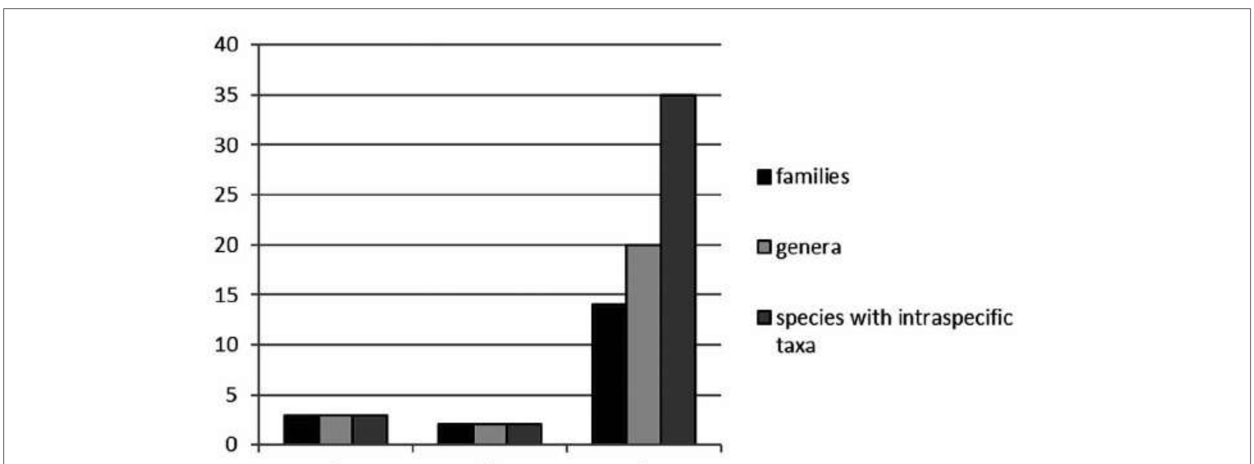


**Fig. 4.** A diversity of DC on the site of the Khakusy sanatorium

sanatorium, there was a clear decrease in the abundance of the three leading families by more than 2 times. In general, the site of the Khakusy sanatorium was characterized by average species richness; 37 species with intraspecific taxa were identified here. The fewest algae species were identified in forest soil (Fig. 4).

This is quite natural, since the flora of the dwarf pine belt is extremely poor, the development of photoautotrophs is largely suppressed, and many species cannot adapt to unsuitable environmental conditions [24]. Two species were found in the soil of the forest plot: *Hantzschia amphioxys* and *Pinnularia borealis*, both taxa dominated in abundance. On the footpath passing through this area, the number of species increased to three. The increase was due to the introduction of *Fragilaria pinnata* var. *acuminata*, which was represented singly in this biotope, and on the coast of the Lake Baikal was a subdominant. *Hantzschia amphioxys* and *Pinnularia borealis* were also dominant here. On the coast of the Lake Baikal, 35 species and varieties of diatoms have been identified.

**Section Barguzinsky ridge.** The smallest DC was identified here. The reason for this is the location of the site – a coniferous taiga zone, with acidic and slightly acidic soils, unfavorable for the development of diatoms. At the Barguzinsky ridge pass, no leading families were identified; three families found here (Fragilariaceae, Pinnulariaceae, Tabellariaceae) each had one species.

The territory of the Frolikhinsky nature reserve, most of which is located in the taiga zone, is characterized by the presence of a typical mountainous terrain. The presence of these two ecological conditions implies insignificant floristic species diversity, which is formed by a monodominant community of cold-loving and acidophilic species of diatoms, characterized by significant abundance, which is usually reflected in a large number of dominants and subdominants [25, 26]. However, our studies showed a high floristic diversity of this territory (128 taxa). This surge in diversity can be explained by the introduction of intrazonal biotopes (in this case, floodplains of rivers and lakes), in which polydominant groups of diatoms with a large number of accompanying and rarely encountered hydrophilic species are formed.

Diatom complexes of the natural reserve have a complex taxonomic structure. The greatest abundance and diversity were noted in areas that are well moistened and located in close proximity to water bodies. The characteristic features of such DC are the predominance of the families Fragilariaceae, Ahnanthaceae, Achnanthidiaceae, Naviculaceae, Gomphonemataceae, Cymbellaceae and Eunotiaceae. However, for certain sections the structure is greatly simplified. The low diversity of diatoms noted in forest biotopes can be explained by the fact that these areas are located in the coniferous taiga zone and are unfavorable for the development of diatoms. Environmental factors limiting the development of diatoms in coniferous forests include the presence of coniferous litter, an acidic reaction of the environment, low illumination, and insufficient moisture [26–28]. An increased role of diatoms was not observed even on paths where more favorable conditions are created for diatoms [29, 30]. The diatom community of the taiga forests of the reserve is predominantly represented by Pinnulariaceae and Bacillariaceae. The species composition of each site is formed from the species of dominant complexes characteristic of the territory as a whole, and specific taxa found only in this particular habitat. Most representatives of the families Achnanthidiaceae, Bacillariaceae, Cymbellaceae, Fragilariaceae, Gomphonemataceae, Naviculaceae, Pinnulariaceae, included in the main complex, are present in the flora of all areas, but they achieve leading positions in communities in different areas. For example, *Adlafia bryophila* dominated only on the shore of the LF, and *Gomphonema parvulum* and *Planothidium lanceolatum* acted as dominants in three sites, and were absent in the BRP site. Against the background of the dominance of individual diatoms being confined to certain habitats, *Pinnularia borealis* stands out. The widespread distribution of *P. borealis* indicates good adaptation of the species to a wide range of environmental conditions and a high ability to compete in diverse diatom communities.

## Conclusion

Studies of the DC of different areas on the territory of the Frolikhinsky nature reserve showed that the species composition and dominant complexes of diatoms in different areas were formed depending on the ecological conditions of the habitats. The largest number of species was found on the shores of reservoirs characterized by a high degree of moisture. The least abundant and diverse diatoms were present in shaded and insufficiently moistened areas of coniferous forest with abundant coniferous litter and acidic soils.

It should be noted that the territory of the Frolikhinsky nature reserve has not yet been well studied, and with an increase in the number of studies, one should expect the discovery of a larger number of taxa of diatoms.

***The study was supported by grant from the partner university "M. E. Evsevyev Mordovian State Pedagogical University" for the year 2022 and the Ministry of Education of the Russian Federation, grant number BWUZ-2023-0006.***

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