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RESEARCH ARTICLE

Characteristics of flora and vegetation of Kolmakhtun Lake – Nature Reserve of local significance of Tomsk Region (West Siberia, Russia)

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Abstract

Kolmakhtun Lake is located in the center of Tomsk Region in a basin of Ob' River. It is Nature Reserve of local significance (OOPT). A complex team of researchers from Tomsk State University performed a multi-years research of hydrology, flora and vegetation of this area. In details have been investigated flora and vegetation of Kolmakhtun Lake and surrounding area. Anthropogenic influence on the lake and surrounding vegetation have been estimated. Applied methods of research were based on multi-years descriptions of vegetation and flora and includes 30 field geobotanical descriptions, herbarium collections, photographs, results of laboratory analyses of floristic lists by elements of flora. The general species composition includes 212 species of vascular plants belonging to 55 families. Angiosperms (Magnolyophyta) dominate the taxonomic spectrum – 201 species from 52 families. The share of 10 leading families accounts for 92 species (43.4%), Asteraceae, Rosaceae and Poaceae dominate. The species composition of adventives totals 40 species, which is 18.9% of the entire flora of the lake. Five types of vegetation are described: forest, meadow, aquatic, shrub and marsh. A classification of vegetation is given, including 6 classes, 7 subclasses, 8 groups of associations and 32 associations are distinguished. Anthropogenic changes, most clearly manifested in grassland-forest and aquatic vegeta-

tion, are described. Rare species listed in the Red Books of Siberia were discovered: *Salvinia natans* (L.) All., *Nymphoides peltata* (S.G. Gmel.) Kuntze, *Nymphaea tetragona* Georgi and *Triglochin palustre* L.

Keywords
Aquatic plants, flora analysis, geobotanical descriptions, lake, vegetation, rare species

Introduction

In the Tomsk Region, special lake complexes (Adam et al. 2001) with significant reserves of fresh water are identified in the system of Nature Reserve of local significance (OOPT).

Kolmakhtun Lake is located in the center of the Tomsk Region (West Siberia, Russia) in the vicinity of Molchanovo, Molchanovsky district. It is surrounded from the south by a fen turning into a swampy forest (sogra), from the north and northeast – by meadows and willow thickets located on the valley wall of the Ob River.

One of the authors of the article (V.P. Amelchenko) has been observing the lake since the 1960s of the last century, for about 50 years. During this period, the general outlines of the lake have hardly changed, but the surroundings have undergone significant changes. First of all, this concerns the swamp vegetation, which has changed greatly due to a change in the water regime. Numerous streams, feeding the lake and the river, began to dry up back in the 1960s. At the same time, the swamp began to dry out, and later, during the construction of a dirt road, a section of the lowland swamp surrounding the lake in its southern part was separated. In some years, the flood was very high and a long flood period was noted until August. During the studied period, the tree canopy changed in height and density. Birches (*Betula pendula* Roth and *B. humilis* Schrank.) grew significantly (2 times). If in the 1960s *B. pendula* barely exceeded 2.5 m, now they reach 5–12 m in height. Moreover, the trunks in diameter are up to 7–10 cm. Shrubs of the genus *Salix*, *Swida alba* (L.) Opiz and *Vaccinium uliginosum* L. were also up to 100–120 cm in height. The sedge thickets of *Carex caespitosa* L. in the center of the fen have significantly decreased in size and diameter; if previously the tussocks of turf sedge reached a height of 50–70 cm, then in 2010 they had practically decreased to 25–30 cm.

The aquatic vegetation has also changed significantly. In the 1960s and 1970s, the water surface was practically clean. In the area of the lake southern part and along the coast, there were water lilies (*Nuphar lutea* (L.) Smith and *Nymphaea tetragona* Georgi). During these years, the lake served not only as a source of clean water, but also of ice, which was prepared in winter for the local fish factory.

In the 1980s, wastewater began to be discharged into the Kolmakhtun fen. The lake is located 2 km from the sewage discharge site.

Probably, the noted changes in vegetation are associated with global warming, but may also be the result of anthropogenic factors, which has been earlier noted by

many authors (Gorchakovsky 1999; Shepeleva 1998; Lapshina 2003; Port et al. 2012; Kirpotin et al. 2021).

The reconstruction of the dynamics of vegetation on the plains of Western Siberia in the postglacial period by T.A. Blyakharchuk (2000) based on pollen analysis data revealed a complex picture of the historical formation of modern vegetation in the south of the forest zone of Western Siberia. The main turning points in this dynamics took place 8 thousand years ago, when the areas of the modern taiga zone, sparsely forested with birch-larch-spruce sparse forests, and the virtually treeless landscapes of the modern birch forest and forest-steppe zone were covered with closed birch forests, and pine forests formed in areas of sandy soils. During the Holocene optimum, the fir formation was most widespread in the modern taiga zone during the entire Holocene, and the role of pine increased in the south of the region. Then, after 5000 years ago, the dominance in the taiga zone shifted from the fir formation to the cedar formation (with *Pinus sibirica* Du Tour). After 4000 years ago, the role of fir in the forests in the southeast of the Western Siberia significantly decreased. Finally, 2500 years ago, cedar forests (*P. sibirica*) reached their maximum distribution in both the middle taiga and southern taiga subzones. In the last millennium, the role of dark coniferous species in taiga forests has sharply decreased, especially in the southern taiga. At the same time, the role of birch in the vegetation cover has increased, and the abundance of wormwood pollen produced by the vegetation cover has noticeably increased everywhere. The described picture of the dynamics of the vegetation cover in the south of Tomsk Region indicates repeated rhythmic changes in climatic conditions.

Materials and methods

The description of the vegetation and flora was carried out by means of long-term research based on 30 geobotanical descriptions as well as annual route studies of the flora of the lake and its surroundings. The herbarium collection, photography and laboratory analysis of floristic lists of flora elements were completed (Flora of Siberia 2003), using both classical approaches (Shumilova 1962; Vegetation cover... 1985; Hellquist 1993) and modern methods (Shepeleva 1998; Lapshina 2003; Sviridenko and Sviridenko 2006; Kharanzhevskaya 2011; Pott 2011). In total, more than 600 herbarium specimens were collected, some of which are kept by the authors and in the collection of the Siberian Botanical Garden. The survey of reference benchmarks was carried out using a GARMIN Etrex Vista Cx GPS Receiver and was used to create a diagram of the lake's water area, which was carried out by digitizing space images of the study area and their geographic referencing.

Kolmakhtun Lake is located within the boundaries of the Kolmakhtun peatlands (cadastral number 785). The area of the deposit is 2421 ha, the average thickness of the peat deposit is 2.6 m. The maximum thickness of the peat deposit is 6.0 m. The total peat stock are 13.5 Tg. The predominant type of peat is eutrophic. The

peat is high-ash (38%) with a high degree of decomposition of 44% and humidity of 79.2% (Peat deposits... 1998). It is likely that the presence of the peat deposit will prevent pollution of the lake (Brown et al. 2000; Kalmykova et al. 2009).

Kolmakhtun Lake is a typical old floodplain lake and is located in the floodplain of the Ob River. The shape of the lake (Fig. 1), in accordance with genetic features, is elongated from the southeast to the northwest, has an isthmus. The distance between the most remote points of the reservoir or its length is 1705 m, the length of the coastline is 3479 m, with a total area of the lake – 59054 m^2. According to the results of the survey, the average width of the lake is 44 m, the maximum is 57 m.

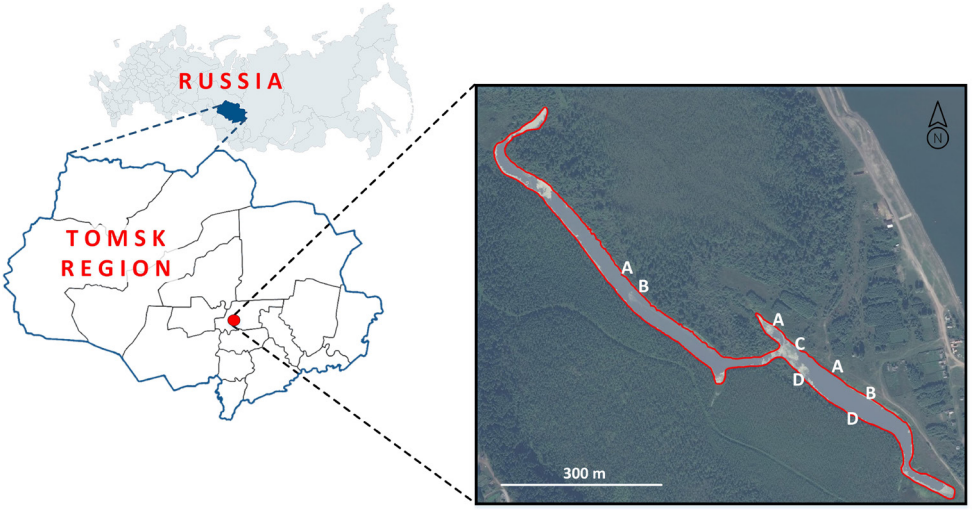

Figure 1. The Kolmakhtun Lake with rare species locations, *Salvinia natans* (A), *Nymphoides peltata* (B), *Triglochin palustre* (C) and *Nymphaea tetragona* (D).

The average depth of the lake, according to our measurements, was 3.1 m, the maximum depth was 5.2 m. The maximum depths are noted in the wider southern part of the lake. The northern shore of the lake is more gentle. The surface of the water mirror of the lake is characterized by significant overgrowth along the banks, especially within its northern and southern parts (Fig. 2). The width of the overgrown line varies from 1–2 to 4–5 m.

Results

Characteristics of vegetation

Vegetation analysis over the past 15 years has shown that changes in the community structure are observed, primarily in the tree layer, as well as in aquatic and meadow vegetation. The reasons for this may be due to global warming.

Within the studied area (about 100 ha) surrounding Kolmakhtun Lake, 5 vegetation types, 6 classes and 7 subclasses, 8 association groups and 32 associations were identified. All the diversity of vegetation characterizes the rich species diversity surrounding the lake.

Vegetation types are identified by the predominant life form: forests, shrubs, swamps, meadow and aquatic vegetation. Classes are described by trophicity: mesotrophic, oligotrophic, etc. Subclasses are described by moisture: damp, swampy, aquatic phytocenoses. Association groups are identified on the basis of dominant species, taking into account the ecological assessment of habitats. Associations are described by the composition of dominant species. The description of the vegetation was carried out according to E.P. Prokopyev (2003).

Figure 2. Overgrowing of Kolmakhtun Lake in the southern (A) and northern (B) parts (Photo by Yu.A. Kharanzhevskaya).

Vegetation classification system of Kolmakhtun Lake:

I Vegetation type – Forest vegetation
1 Vegetation class: Mesoeutrophic forests
Subclass: Mesoeutrophic wet forests
Association group: Tree-like willow forest
1 Association. *Calamagrostis-Salix viminalis* forest
2 Association. *Carex acuta-Salix viminalis* forest
Association group: Birch forests (*Betula pendula*)
3 Association. Shrub-*Betula*-small-grass forests
II Vegetation type – Shrub vegetation
2 Vegetation class: Mesoeutrophic wet shrubs
Association group: *Salix*-shrub forest
4 Association. Mixed grass-*Salix cinerea* forest
5 Association. *Calamagrostis-Carex-Salix cinerea* forest
6 Association. *Equisetum palustre-Salix cinerea-S. pentandra* forest
7 Association. *Carex acuta-Salix viminalis* forest
Subclass: Mesoeutrophic swampy shrubs
8 Association. Swamp-grass-*Carex-Salix* forest
III Vegetation type – Mire vegetation
3 Vegetation class: Meso-oligotrophic mires
Subclass: Meso-oligotrophic damp mires
Association group: Transitional *Carex-Sphagnum* mires
9 Association. *Betula pendula-Carex-Sphagnum* mires
10 Association. *Pinus-Betula*-subshurb-*Carex-Sphagnum* mires
Subclass: Meso-oligotrophic medium-wet mires
Association group: Subshurb-*Sphagnum* mires
11 Association. *Betula pendula-Carex-Sphagnum* mires
4 Vegetation class: Mesotrophic mires
Subclass: Mesotrophic mires
Association group: Woody eutrophic mires (sogry)
12 Association. *Betula-Carex caespitosa* mires
13 Association. *Pinus-Betula-Carex* swamps
Association group: Grassy eutrophic mires
14 Association. *Equisetum*-swamp-grass mires
Association group: *Carex* eutrophic mires
15 Association. *Carex vesicaria* mires
16 Association. *Carex lasiocarpa* mires
IV Vegetation type – Grassland vegetation
5 Vegetation class: Mesoeutrophic grasslands
Subclass: Mesoeutrophic grasslands
Association group: Large-grasses grasslands
17 Association. *Carex caespitosa-C. acuta-Phragmites* grasslands

18 Association. *Calamagrostis arundinaceae* grasslands
Association group: Coarse-*Carex* grasslands
19 Association. *Carex acuta* grasslands
20 Association. Mixed grass-*Carex* grasslands
Association group: Floodplain grasslands
21 Association. *Agrostis clavata* grasslands
22 Association. *Alisma plantago-aquatica* grasslands
23 Association. *Rorippa palustris* grasslands
V Vegetation type – Aquatic vegetation
6 Vegetation class: Mesoeutrophic aquatic vegetation
Subclass: Mesoeutrophic coastal aquatic vegetation
Association group: Coastal aquatic vegetation
24 Association. *Calla palustris-Stratiotes aloides*
25 Association. *Lemna minor-Hydrocharis morsus-ranae*
Association group: Coastal-water vegetation on silty substrates
26 Association. *Alisma plantago-aquatica-Lemna minor*
27 Association. *Lemna minor-Spirodela polyrhiza*
28 Association. *Sparganium erectum-Potamogeton natans*
29 Association. *Utricularia vulgaris*
7 Vegetation class: Eutrophic aquatic vegetation
30 Association. *Sparganium erectum*
31 Association. *Sagittaria natans*
32 Association. *Stratiotes aloides*.

Characteristics of flora

The flora in the vicinity of Kolmakhtun Lake is characterized by a significant diversity of aquatic, marsh and meadow plants. The total species composition includes 212 species belonging to 55 families. Angiosperms dominate the taxonomic spectrum: Magnolyophyta – 201 species from 52 families. The class of dicotyledons (Magnoliopsida) contains 168 species, the class of monocotyledons (Liliopsida) – 33 species. Gymnosperms (Pinophyta) includes 1 family and 5 species. Division 3 – ferns (Polypodiophyta) contains 1 species: *Pteridium pinetorum* subsp. *sibiricum* Gureeva et C.N. Page (Gureeva, Page 2005). Division 4 – horsetails (Equisetophyta) contains 5 species from 1 family Equisetaceae.

The 10 leading families that characterize the lake flora as boreal account for 92 species (43.4%). The following families are the richest in species: Asteraceae (21), Rosaceae (14), Poaceae (14), Fabaceae (11), Apiaceae (10), Brassicaceae (9), Salicaceae (9), Cyperaceae (8), Ranunculaceae (8), Primulaceae (8). A significant number of families: (16) are represented by 2–6 species - Alismataceae, Betulaceae, Scrophulariaceae, Lemnaceae, Potamogetonaceae, etc. The names of the plants are given according to S.K. Cherepanov (1995).

Almost 30% of all families are monospecific: Haloragaceae, Menyanthaceae, Lentibulariaceae, Callitrichaceae, Sparganiaceae, etc.

Adventitious plants deserve special attention. There are 40 species, which is 18.9% of the entire flora. This characterizes the anthropogenic contamination of the flora of the meadows and swamps surrounding Kolmakhtun Lake. In the flora of the meadows there are 8 families containing an adventitious element: Asteraceae - 9 species, Brassicaceae - 6 species. The other 6 families contain 2–3 species each: Apiaceae, Chenopodiaceae, Lamiaceae, Onagraceae, Caryophyllaceae, Plantaginaceae. The analysis of advents was carried out taking into account the materials on the study of the flora of the Tomsk city (Pyak, Merzlyakova 2000; Rybina et al. 2009). We noted ergasiophytes – 6 species: *Asparagus officinalis* L., *Cichorium infybus* L., *Chelidonium majus* L., *Pastinaca sativa* L. and *Sorbaria sorbifolia* (L.) A. Braun. The remaining species are classified as xenophytes. Among them, 2 species (*Artemisia absinthium* L. and *A. sieversiana* Willd.) have recently appeared and are actively settling in the area of the lake along the edges of roads and near housing.

Ecological analysis of flora

Two factors are of the greatest importance – moisture and soil richness (Prokopyev 2001). In the ecological spectrum by trophicity, mesotrophs, mesoeutrophs and eutrophs can be distinguished – 3 groups of species. In percentage terms, mesoeutrophs predominate: 165 species (77.8%), a smaller percentage (21.2%) are mesotrophs and eutrophs: 45 species. Oligotrophs are few in number: only 2 species – *Andromeda polyfolia* L. and *Oxycoccus palustris* Pers.

Mosses were not taken into account in this report.

According to the moisture factor, mesophytes (eumesophytes) were distinguished – 161 species (75.9%), hydromesophytes – 26 species (12.3%), mesoxerophytes – 16 species (7.5%). Hydrophytes make up a group of 9 species: *Myriophyllum verticillatum* L., *Salvinia natans* (L.) All., *Callitriche verna* L., *Stratiotes aloides* L., *Hydrocharis morsus-ranae* L., *Potamogeton natans* L., *Spirodella polyrhiza* (L.) Schleid., *Lemna minor* L., *Lemna trisulca* L.

Biomorphological analysis of flora

The following groups of plants were identified: trees – 9 species (4.2%); shrubs – 13 species (6.1%); dwarf shrubs – 7 species (3.3%); perennial grasses – 157 species (74.1%); annual grasses – 26 species (12.3%).

The most significant group is perennial grasses, dominated by sedges and grasses – 27 species (13.7%).

Particularly valuable botanical objects

For conservation purposes, it is necessary to identify the most valuable objects, primarily rare and endangered plants (Heywood and Iriondo 2003; Pärtel et al. 2005; Vellak et al. 2009). We identified 3 plant species included in the Red Book of Tomsk Region (Red Book… 2013).

Salvinia natans is an ancient aquatic fern (Fig. 3a), concentrated in the southeastern part of the lake and occurs together with *Spirodella polyrhiza*. *Nymphoides peltata*, *Nymphaea tetragona* (Fig. 3b) and *Triglochin palustre* are rarely found in the coastal water strip. All of the listed species are listed in the Red Book of Tomsk Region (Red Book… 2023) and other regions of Siberia.

In the depressions in the meadows surrounding the lake from the north, *Carex vulpina* L. and *Carex riparia* Curt. are rarely found. The last southern Siberian species is located at the northern border of the range in the Tomsk Region. *Triglochin palustre* is indicated only in the vicinity of Tomsk and Malo-Bragino. This is a new location, significantly removed to the north of Tomsk (about 200 km).

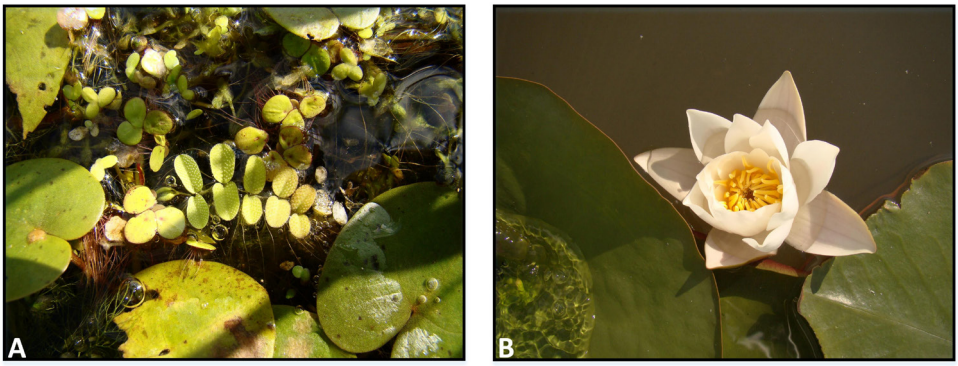

Figure 3. *Salvinia natans* (A) and *Nymphaea tetragona* (B) (Photo by T.N. Kataeva).

Conclusions

The analysis of floristic lists for all years of observations showed that 10 families of boreal flora dominate in the flora surrounding Kolmakhtun Lake, they contain 92 species (46.7%). An intensive increase in the tree and shrub layer surrounding the lake in the southern part was revealed. An increase in the role of advents in the composition of meadow vegetation was noted. An increase in the anthropogenic load on aquatic vegetation led to the contamination of the lake with *Stratiotes aloides*, which currently occupies a fairly wide coastal strip. Over the last decade, the role of advents has increased. Their number has increased to 40 species. Some (6 species) have recently left the culture, other species are spreading following the

increased role of the anthropogenic factor. Five types of vegetation were identified within the studied Kolmakhtun Lake, belonging to 6 classes and 7 subclasses. 8 groups and 32 associations were identified. Rare species listed in the Red Books of Siberia were found: *Salvinia natans*, *Nymphoides peltata*, *Nymphaea tetragona* and *Triglochin palustre*.

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