Flora and vegetation of the Sulem Reservoir (Middle Urals)

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Abstract. The study of biodiversity of anthropogenically disturbed areas is a prerequisite for assessing and predicting species abundance in regions. The present research aims at investigating the aquatic and coastal-aquatic flora and vegetation of the Sulem reservoir, built on the territory of the Visimsky nature reserve. Phytocoenotic material has been processed in accordance with the requirements of ecological-floristic classification of Braun-Blanquet. Flora analysis has been carried out in compliance with standard floristic methods. The study has revealed a variety of vegetation, which has been classified into 2 classes (Potamogetonetea and Phragmito-Magnocaricetea), 5 orders (Potamogetonetalia, Callitricho hamulatae-Ranunculetalia aquatilis, Phragmitetalia, Magnocaricetalia, Oenanthea aquatica), 6 alliances (Nymphaeion albae, Potamogetion graminei), 20 associations and 2 rankless communities. Communities of associations Elodeetum canadensis, Myriophylletum spicati and Callitrichetum hermaphroditicae are the most common in the territory under study. Large areas are covered with Sagittario sagittifoliae- Sparganietum emersi, Typhetum latifoliae and Typha intermedia. Communities of associations Potamo crispi-Ranunculetum trichophylli, Potamogetonetum graminei, Potamo natantis– Polygonetum natantis, Typhetum angustifoliae and Sparganietum erecti are less common. Flora of vascular plants include 66 species from 43 genera and 26 families. Cyperaceae (10 species), Poaceae (8 species), Potamogetonaceae (6 species), Ranunculaceae (4 species), and Typhaceae (4 species) are the leading families. Hydrophytes prevail among ecological groups. Eurasian boreal species prevail in the geographical structure of the flora. 2 species listed in the Red Book of the Sverdlovsk region include Nuphar lutea (L.) Smith and Nymphaea candida J. Presl.

1. Introduction

Study and conservation of biological diversity on regional and on global scale is very important today. This is due to the fact that biodiversity is one of the factors of optimal functioning of ecosystems and the biosphere as a whole [1, 2]. Quite often economic activity leads to changes in structure of biogeocenoses and disturbance of ecological balance. In this regard, the study of biodiversity in anthropogenically disturbed areas is a necessary condition for assessing and predicting species abundance in regions.

The territory of the Sverdlovsk region of the Russian Federation is home to the Visimsky reserve, which was founded in 1946 to preserve and study the typical and unique ecosystems of the South taiga middle Ural lowlands. In 2001, the reserve was granted the status of a biosphere reserve by UNESCO. Most area of the reserve is located in the upper reaches of the Sulem river, part of the vast Volga-
Kama basin. In the 1980s, 4 km² of the Visimsky reserve were transferred to the flooding zone. The reservoir created on the river Sulem was to solve the problem of drinking water supply of the city of Kirovgrad, located 30 km away from the reservoir. However, the water supply system has not been finished, and currently the reservoir is not used for supply of water to the city.

Creation of reservoirs significantly changes the landscape of river valleys, as well as the hydrological regime of the river within reservoirs. Reduction of the river flow speed often causes silting of artificial reservoirs. These factors lead to the emergence of a number of new landscape elements forming a zone of shallow waters, contributing to the formation and further development of aquatic and coastal-aquatic vegetation. Due to the relatively young age of the Sulem reservoir, its vegetation remains poorly studied.

The present research aims at investigating the aquatic and coastal-aquatic flora and vegetation of the Sulem reservoir, built on the territory of the Visimsky nature reserve.

2. Methods and materials

The area under study refers to the temperate continental climatic region. The average annual air temperature is 0.1 °C; the average duration of vegetation period (with average daily temperatures above 5 °C) is 152 days; the number of days with snow cover is 202; the average annual precipitation is 505 mm (with fluctuations from 350 to 700 mm) [3].

Field studies were conducted in July 2013. 34 geobotanical studies have been performed on test sites ranging in size from 2.5 to 100 m². Size of the sample area depends on the size and homogeneity of the community. Location of the geobotanical descriptions has been recorded using a GPS navigator (Fig. 1). Only vascular plants have been taken into account when performing geobotanical descriptions. Species names are given according to S. K. Cherepanov's report [4], as well as other modern taxonomic reports [5].

Figure 1. Map-scheme of the Sulem reservoir with localization of geobotanical descriptions

Phytocenotic material has been processed in accordance with the requirements of ecological and Braun-Blanquet's floristic classification [6, 7]. Geobotanical descriptions have been recorded in the TURBOVEG database [8] and processed using the JUICE program [9]. Works on aquatic and coastal-
aquatic vegetation of Europe and Russia have been used to make syntaxonomic decisions [10–15]. Names of higher syntaxons are given according to "Vegetation of Europe..." [16].

Flora analysis has been carried out according to standard floristic methods. Ecological types are given according to V. G. Papchenkov [17]: hydrophytes, helophytes, hygrohelophytes, hygrophytes, hygromeso- and mesophytes.

3. Results

Research results have shown that the vegetation of the Sulem reservoir is quite diverse and includes 2 classes, 5 orders, 6 alliances, 20 associations and 2 rankless communities. The system of syntaxons has the following form:

Class Potamogetonetea Klika in Klika et Novák 1941
    Order Potamogetonetalia Koch 1926
        Alliance Nymphaeion albae Oberd. 1957
            Acc. Potamo natantis–Polygonetum natantis Knapp et Stoffers 1962
            Acc. Potamogetonum natantis Hild 1959
            Acc. Potamo-Napharetum luteae Müller et Görs 1960
        Alliance Potamogetonion Libbert 1931
            Acc. Elodeetum canadensis Nedelcu 1967
            Acc. Potamo pectinati-Myriophylletum spicati Rivas Goday 1964
            Acc. Potamogetonum graminei Lang 1967
            Acc. Potamogetonum lucentis Hueck 1931
            Acc. Potamogetonum perfoliati Miljan 1933
    Order Callitricho hamulatae-Ranunculetalia aquatilis Passarge ex Theurillat in Theurillat et al. 2015
        Alliance Ranunculion aquatilis Passarge ex Theurillat in Theurillat et al. 2015
            Acc. Potamo crispi-Ranunculetum trichophylli Imchenetzky 1926
            Acc. Callitrichetum hermaphroditicae Černohous et Husák 1986

Community Callitriche palustris
Class Phragmito-Magnocaricetea Klika in Klika et Novák 1941
    Order Phragmitetalia Koch 1926
        Alliance Phragmition communis Koch 1926
            Acc. Equisetum fluviatilis Nowiński 1930
            Acc. Sparganium erecti Roll 1938
            Acc. Typhetum angustifoliae Pignatti 1953
            Acc. Typhetum latifoliae Nowiński 1930
    Community Typha intermedia
    Order Magnocaricetalia Pignatti 1953
        Alliance Magnocaricion elatae Koch 1926
            Acc. Caricetum aquatilis Sambuk 1930
            Acc. Caricetum gracilis Savich 1926
            Acc. Equiseto fluviatilis-Caricetum rostratae Zumpfe 1929
    Order Oenanhtetalia aquatcae Hejný ex Balátová-Tuláčková et al. 1993
        Alliance Eleocharitio palustris-Sagittarion sagittifoliae Passarge 1964
            Acc. Eleocharitetum palustris Savich 1926
            Acc. Sagittario sagittifoliae-Sparganietum emersi Tüxen 1953
            Acc. Scirpetum radicans Savich 1926

The revealed associations and communities in the territory under study have a pronounced intrazonal character and have a simple structure, often monodominant (Tables I and II). Absence of communities of Lemnetea class is typical of the reservoir. Pleistophyte *Lemna minor* L. has been encountered only once in the community of association Elodeetum canadensis.

Cenoses of the association Elodeetum canadensis are the most common in the territory under study, while communities of the associations Potamo pectinati-Myriophylletum spicati and Callitrichetum...
hermaphroditicae are less common. Pondweed communities are mostly represented with *Potamogeton perfoliatus*. *Potamo crispi-Ranunculetum trichophylli*, *Potamogetonetum graminei*, *Potamo natantis-Polygonetum natantis*, *Typhetum angustifoliae* and *Sparganietum erecti* are rare communities of associations. Despite the relatively high syntaxonomic diversity, the described communities, especially those of the class *Potamogetonetea*, are characterized by poor species composition. Major part of the coastal-aquatic vegetation is concentrated along the left bank, which is flat and shallow. In this regard, the left-bank communities *Sagittario sagittifoliae-Sparganietum emersi*, *Typhetum latifoliae* and *Typha intermedia* are characterized by larger areas than the right-bank ones.

66 species of vascular plants from 43 genera and 26 families found in the aquatic environment or in drying shallow waters have been identified in the studied territory. They include 2 species of Equisetales belonging to one family and one genus. Flowering plants are represented with 64 species belonging to 42 genera from 25 families. The monocotyledonous class is represented with 34 species belonging to 17 genera from 9 families. The dicotyledonous class is represented with 30 species belonging to 25 genera from 16 families.

Table 1. Abbreviated overview table of the class Potamogetonetea

| Order | Potamogetonetea | Callitricho hamulatae-Ranunculetalia aquatilis |
|-------|----------------|-----------------------------------------------|
| Alliance | Nymphaeion albae | Potamogetonion |
| Sequence number of syntaxon⁴ | 1 2 | 3 4 | 5 6 | 7 8 | 9 10 | 11 |
| Number of descriptions | 2 | 1 | 4 | 3 | | 2 | 1 | 1 | |
| OPP, % | 90–100 | 80 | 80–100 | 90–100 | 40–70 | 70 | 100 | 100 | 80 | 80–90 | 100 |
| Depth, m | 1.0 | 0.5 | 0.3–0.6 | 0.2–0.4 | 1.6–2.0 | 1.5 | 1.8 | 0.4 | 0.4 | 0.3–0.4 | 0.3 |
| Number of species | 2–3 | 3 | 3–5 | 2–8 | 2 | 3 | 2 | 6 | 3 | 6–7 | 6 |

Diagnostic species of the association Potamo natantis–Polygonetum natantis

*Persicaria amphibia* ₂⁵

*Potamogeton natans* ¹⁵

*Nuphar lutea* ₁

*Elodea canadensis* ₁ ₂ ₁

*Myriophyllum spicatum* ₁ ₂ ₁

*Potamogeton gramineus* ₁ ₁

*Potamogeton lucens* ₁ ₁

*Potamogeton perfoliatus* ₁ ₁

*Batrachium trichophyllum* ₁ ₁

*Callitriche hermaphroditica* ₁ ₁ ₁ ₁

*Callitriche palustris* ₁ ₁ ₁ ₁

*Nuphar lutea* ₁ ₁ ₁ ₁

*Potamogeton pusillus* ₁ ₁ ₁ ₁

*Lemma minor* ₁ ₁ ₁ ₁

*Alisma plantago-aquatica* ₁ ₁ ₁ ₁

*Sparganium emersum* ₁ ₁ ₁ ₁

*Equisetum fluviatile* ₁ ₁ ₁ ₁

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Sequence number of syntaxon: 1 – *Potamo natantis-Polygonetum natantis*; 2 – *Potamogetonetea*; 3 – *Nymphaeion albae*; 4 – *Elodeetum canadensis*; 5 – *Callitrichetum hermaphroditicae*; 6 – *Potamogetonetea*; 7 – *Potamogetonetea*; 8 – *Callitrichetum hermaphroditicae*; 9 – *Potamo crispi-Ranunculetum trichophyllum*; 10 – *Callitrichetum hermaphroditicae*; 11 – *Callitriche palustris*. OPP – total projective cover.
## Table 2. Abbreviated overview table of the class Phragmito-Magnocaricetea

| Order Alliance | Phragmitetalia | Magnocaricetalia | Oenanthealia aquaticae | Eleocharito palustris-Sagittario sagittifoliae |
|----------------|----------------|------------------|------------------------|---------------------------------------------|
|                | Phragmition communis | Magnocaricion elatae | Equisetetum fluviatilis | Sparganietum erecti |
|                |                   |                   |                        |                               |
| Number of descriptions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| OPP, % | 70 | 60 | 50 | 100 | 70 | 100 | 100 | 50-90 | 70-90 | 80 | 100 |
| Depth, m | 0.1 | 0.5 | 0.2 | 0.3 | 0.2-0.4 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 | 0.0 |
| Average height, cm | 90 | 40 | 160 | 160 | 150 | 60 | 60 | 80 | 30 | 25 | 110 |
| Maximum height, cm | 140 | 60 | 180 | 170 | 170 | 110 | 150 | 150 | 70 | 50 | 160 |
| Number of species | 8 | 4 | 3 | 5 | 5–11 | 9 | 10 | 5–8 | 8 | 5–6 | 8 |

**Diagnosis species of the association Equisetum fluviatilis**

1

**Diagnosis species of the association Sparganium erectum**

2

**Diagnosis species of the association Typheto angustifoliae**

1

**Diagnosis species of the community Typha latifolia**

1

**Diagnosis species of the community Typha intermedia**

1

**Diagnosis species of the association Caricetum aquatilis**

1

**Diagnosis species of the association Caricetum gracilis**

1

**Diagnosis species of the association Equiseteto fluviatilis-Caricetum rostratae**

1

**Diagnostic species of the association Eleocharis palustris**

1

**Diagnostic species of the association Eleocharis australis**

2

**Diagnostic species of the association Scirpetum radicantis**

1

**Diagnostic species of the association Oenanthealia aquaticae**

1

**Diagnostic species of the association Caricetum aquatilis**

1

**Diagnostic species of the association Caricetum gracilis**

1

**Diagnostic species of the association Equiseteto fluviatilis-Caricetum rostratae**

1

**Diagnostic species of the association Sagittario sagittifoliae-Sparganietum emersi**

1

**Diagnostic species of the association Scirpetum radicantis**

1

**Diagnostic species of the association Magnocaricetalia**

1

**Diagnostic species of the association Equiseteto fluviatilis-Caricetum rostratae**

1

**Diagnostic species of the association Eleocharis palustris**

1

**Diagnostic species of the association Eleocharis australis**

1

**Diagnostic species of the association Phragmito-Magnocaricetea**

1

**Diagnostic species of the association Potamogeteto perfoliati**

1

**Diagnostic species of the association Littorelletalia uniflorae**

1

**Diagnostic species of the association Littorelletalia uniflorae**

1

**Diagnostic species of the association Bidentetalia tripartitae**

1

**Diagnostic species of the association Molinio-Arrhenatheretea**

1

**Diagnostic species of the association Molinio-Arrhenatheretea**

1

**Diagnostic species of the association Scirpetum radicantis**

1

**OPP – total projective cover. I.**
5 families are characterized by the largest number of species taxa among vascular plants in the flora of the Sulem reservoir (Table III): *Cyperaceae* Juss. – 10 species, *Poaceae* Barnhart – 8 species, *Potamogetonaceae* Dumort. – 6 species, *Ranunculaceae* Juss. – 4 species and *Typhaceae* Juss. – 4 species. Other families are represented with only 1–3 species. 12 families are represented with only one species.

**Table 3.** The number of species in the 5 leading families of flora and their share in the number of vascular plants, %

| Family names and other indicators | Number of species |
|-----------------------------------|------------------|
| 1. *Cyperaceae*                   | 10 (15.2 %)      |
| 2. *Poaceae*                     | 8 (12.1 %)       |
| 3. *Potamogetonaceae*            | 6 (9.1 %)        |
| 4. *Ranunculaceae*               | 4 (6.1 %)        |
| 5. *Typhaceae*                   | 4 (6.1 %)        |
| Total number of species in 5 leading families | 32 (48.6 %) |
| Families with 2–3 species         | 9                |
| Families with 1 species           | 12               |

Such distribution of the leading families in the studied flora, in general, is typical of many other groups of reservoirs described in the literature [12, 14].

At the genera level, *Potamogeton* and *Carex* are leaders in the number of species represented, with 6 species each. Since pondweed refers to species with high migratory activity, the undisputed leadership of the genus *Potamogeton* is observed in the aquatic flora of Russia and the world [18]. The genus *Typha* is represented with 4 species. Most of the genera (40 genera, or 93.0 %) are represented with only 1–3 species and contain 75.8 % of the list of species of the flora under study (50 species).

Analysis of ecological composition of the flora shows the predominance of hydrophytes in the hydrophilic flora of vascular plants of the Sulem reservoir (19 species, or 28.8 %). Hygrohelophytes, hygrophytes, hygromeso- and mesophytes account for 13 species each (or 19.7 %). Helophytes are represented with 8 species (12.1 %).

Geographical structure of the flora under consideration is characterized by the predominance of boreal (37 species, 56.1 % of the flora list) and plurizonal (24 species, 36.4 %) species in zonal distribution. Holarctic (24 species, 36.4 %) and Eurasian (22 species, 33.4 %) species dominate regionally. While taking into account both zonal and regional characteristics of the flora of vascular plants of the Sulem reservoir, it is possible to note a significant predominance of Eurasian boreal species (16 species, or 24.2 % of the total flora list) and, to a slightly lesser extent, Holarctic plurizonal (12 species, or 18.2 %) and Holarctic boreal species (11 species, or 16.7 %). These 3 groups contain more than half of the list of considered flora (59.1 %).

Conservative nature of reservoirs’ aquatic environment creates favourable conditions for widespread plurizonal species. Moreover, the location of the Sulem reservoir determines a significant shift in the geographical spectrum towards Holarctic and Eurasian, as well as boreal species.

The studied flora is also characterized by extremely low presence of adventitious plant species in comparison with similar flora located in the more populated regions of the Urals [19]. Among adventitious plant species, only *Elodea canadensis* probably introduced by waterfowl has been recorded. This factor indicates a weak anthropogenic disturbance of the territory of the Sulem reservoir.

2 species listed in the Red Book of the Sverdlovsk region have been found in the studied water area [20]: *Nuphar lutea* (L.) Smith и *Nymphaea candida* J. Presl.

**4. Conclusion**

Thus, the vegetation of the Sulem reservoir includes 2 classes, 5 orders, 6 alliances, 20 associations and 2 rankless communities. The revealed associations and communities have a pronounced intrazonal character and a simple structure, often monodominant. Communities of associations *Elodeetum canadensis*, *Myriophylletum spicati* and *Callitrichetum hermaphroditicae* are the most
common in the territory under study. Rare associations include Potamo crispi-Ranunculetum trichophylli, Potamogetonetum graminei, Potamo natantis–Polygonetum natantis, Typhetum angustifoliae and Sparganietum erecti.

The flora ofvascular plants includes 66 species from 43 genera and 26 families. The leading families are Cyperaceae (10 species), Poaceae (8 species), Potamogetonaceae (6 species), Ranunculaceae (4 species), Typhaceae (4 species). Hydrophytes dominate among environmental groups, and Eurasian boreal species dominate in the geographical structure. The studied flora is also characterized by extremely low presence of adventitious plant species in comparison with similar flora located in more populated regions of the Urals [19].

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