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## 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. Phytocenotic 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*, *Oenanthetalia aquaticae*), 6 alliances (*Nymphaeion albae*, *Potamogetonion*, *Ranunculion aquatilis*, *Phragmition communis*, *Magnocaricion elatae*, *Eleocharito Palustris-Sagittarion Sagittifoliae*), 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 и *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-



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Kama basin. In the 1980s, 4 km<sup>2</sup> 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 m<sup>2</sup>. 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, 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. *Potamogetonetum natantis* Hild 1959

Acc. *Potamo-Nupharetum luteae* Müller et Görs 1960

Alliance *Potamogetonion* Libbert 1931

Acc. *Elodeetum canadensis* Nedelcu 1967

Acc. *Potamo pectinati–Myriophylletum spicati* Rivas Goday 1964

Acc. *Potamogetonetum graminei* Lang 1967

Acc. *Potamogetonetum lucentis* Hueck 1931

Acc. *Potamogetonetum 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 crispae–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. *Sparganietum 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 *Oenanthetalia aquatica* Hejný ex Balátová–Tuláčková et al. 1993

Alliance *Eleocharito palustris–Sagittarion sagittifoliae* Passarge 1964

Acc. *Eleocharitetum palustris* Savich 1926

Acc. *Sagittario sagittifoliae–Sparganietum emersi* Tüxen 1953

Acc. *Scirpetum radicans* Nowiński 1930

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 crispus-Ranunculetum trichophylli*, *Potamogeton 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	Potamogetonetalia								Callitriche hamulatae-Ranunculetalia aquatilis		
Alliance	Nymphaeion albae				Potamogetonion				Ranunculion aquatilis		
Sequence number of syntaxo <sup>a</sup>	1	2	3	4	5	6	7	8	9	10	11
Number of descriptions	2	1	4	3	2	1	1	1	1	2	1
OPP <sup>b</sup> , %	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											
<i>Persicaria amphibia</i>	2 <sup>5</sup>										
Diagnostic species of the association Potametum natantis											
<i>Potamogeton natans</i>	1 <sup>5</sup>										
Diagnostic species of the association Potamo-Nupharetum luteae											
<i>Nuphar lutea</i>		4 <sup>5</sup>			1						
Diagnostic species of the association Elodeetum canadensis											
<i>Elodea canadensis</i>	2	1	4	3 <sup>5</sup>		1		1		2	1
Diagnostic species of the association Potamo pectinati-Myriophylletum spicati											
<i>Myriophyllum spicatum</i>				3	2 <sup>3-4</sup>	1	1	1		1	
Diagnostic species of the association Potamogetonetea graminei											
<i>Potamogeton gramineus</i>					1 <sup>5</sup>						
Diagnostic species of the association Potamogetonetea lucentis											
<i>Potamogeton lucens</i>						1 <sup>5</sup>					
Diagnostic species of the association Potamogetonetea perfoliati											
<i>Potamogeton perfoliatus</i>	1							1 <sup>5</sup>			
Diagnostic species of the association Potamo crispus-Ranunculetum trichophylli											
<i>Batrachium trichophyllum</i>									1 <sup>5</sup>		
Diagnostic species of the association Callitrichetum hermaphroditicae											
<i>Callitriche hermaphroditica</i>				1					1	2 <sup>5</sup>	1
Diagnostic species of the community Callitriche palustris											
<i>Callitriche palustris</i>				1				1		2	1 <sup>5</sup>
Diagnostic species of the class Potamogetonetea											
<i>Nymphaea candida</i> var. <i>minor</i>		2			1						
<i>Potamogeton pusillus</i>										1	1
Diagnostic species of the class Lemnetae											
<i>Lemna minor</i>				1							
Diagnostic species of the class Phragmito-Magnocaricetea											
<i>Alisma plantago-aquatica</i>	1			1				1		2	1
<i>Sparganium emersum</i>			1	1					1	1	1
<i>Equisetum fluviatile</i>			3	1							

Sequence number of syntaxon: 1 – *Potamo natantis-Polygonetum natantis*; 2 – *Potamogetonetea natantis*; 3 – *Potamo-Nupharetum luteae*; 4 – *Elodeetum canadensis*; 5 – *Potamo pectinati-Myriophylletum spicati*; 6 – *Potamogetonetea graminei*; 7 – *Potamogetonetea lucentis*; 8 – *Potamogetonetea perfoliati*; 9 – *Potamo crispus-Ranunculetum trichophylli*; 10 – *Callitrichetum hermaphroditicae*; 11 – *Callitriche palustris*. OPP – total projective cover.

**Table 2.** Abbreviated overview table of the class Phragmito-Magnocaricetea

Order	Phragmitetalia				Magnocaricetalia			Oenanthetalia aquaticae			
Alliance	Phragmiton communis				Magnocaricion elatae			Eleocharito palustris-Sagittarion sagittifoliae			
Sequence number of syntaxo <sup>a</sup>	1	2	3	4	5	6	7	8	9	10	11
Number of descriptions	1	1	1	1	2	1	1	3	2	1	1
OPP <sup>b</sup> , %	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	5–6	8	15
Diagnostic species of the association <i>Equisetum fluviatilis</i>											
<i>Equisetum fluviatile</i>	1 <sup>4</sup>			1	1			2	2		
Diagnostic species of the association <i>Sparganietum erecti</i>											
<i>Sparganium erectum</i>		1 <sup>3</sup>									
Diagnostic species of the association <i>Typhetum angustifoliae</i>											
<i>Typha angustifolia</i>			1 <sup>3</sup>								
Diagnostic species of the association <i>Typhetum latifoliae</i>											
<i>Typha latifolia</i>				1 <sup>5</sup>				1			1
Diagnostic species of the community <i>Typha intermedia</i>											
<i>Typha intermedia</i>					2 <sup>3,4</sup>						1
Diagnostic species of the association <i>Caricetum aquatilis</i>											
<i>Carex aquatilis</i>						1 <sup>5</sup>					
Diagnostic species of the association <i>Caricetum gracilis</i>											
<i>Carex acuta</i>					1		1 <sup>5</sup>	1			
Diagnostic species of the association <i>Equiseto fluviatilis</i> - <i>Caricetum rostratae</i>											
<i>Carex rostrata</i>						1		3 <sup>3,5</sup>			
Diagnostic species of the association <i>Eleocharitetum palustris</i>											
<i>Eleocharis palustris</i>	1								2 <sup>4,5</sup>		
Diagnostic species of the association <i>Sagittario sagittifoliae</i> - <i>Sparganietum emersi</i>											
<i>Sparganium emersum</i>		1			1				2	1 <sup>5</sup>	
Diagnostic species of the community <i>Scirpetum radicans</i>											
<i>Scirpus radicans</i>											1 <sup>5</sup>
Diagnostic species of the order <i>Magnocaricetalia</i>											
<i>Carex vesicaria</i>						1	1	1			
<i>Galium palustre</i>						1					1
<i>Phalaroides arundinacea</i>											1
<i>Poa palustris</i>	1										
<i>Scutellaria galericulata</i>											1
Diagnostic species of the order <i>Oenanthetalia aquaticae</i>											
<i>Alisma plantago-aquatica</i>	1	1	1	1	2	1	1	3	2	1	1
<i>Eleocharis austriaca</i>						1		1			1
Diagnostic species of the class <i>Phragmito-Magnocaricetea</i>											
<i>Phalaroides arundinacea</i>	1										
<i>Rorippa amphibia</i>											1
Diagnostic species of the class <i>Potamogetonetea</i>											
<i>Elodea canadensis</i>		1	1	1	2					1	
<i>Myriophyllum spicatum</i>					1						
<i>Nymphaea candida</i>					1						
<i>Potamogeton perfoliatus</i>											1
<i>Potamogeton pusillus</i>											1
Diagnostic species of the class <i>Littorelletea uniflorae</i>											
<i>Callitriche palustris</i>	1				1				1	1	
<i>Elatine triandra</i>										1	
Diagnostic species of the class <i>Bidentetea tripartitae</i>											
<i>Persicaria hydropiper</i>	1							1			1
<i>Alopecurus aequalis</i>	1				1						
<i>Rorippa palustris</i>					1						
Diagnostic species of the class <i>Molinio-Arrhenatheretea</i>											
<i>Agrostis gigantea</i>							1				
<i>Lathyrus pratensis</i>							1				
<i>Vicia cracca</i>							1				

Sequence number of syntaxon: 1 – *Equisetum fluviatilis*; 2 – *Sparganietum erecti*; 3 – *Typhetum angustifoliae*; 4 – *Typhetum latifoliae*; 5 – *Typha intermedia*; 6 – *Caricetum aquatilis*; 7 – *Caricetum gracilis*; 8 – *Equisetum fluviatilis*-*Caricetum rostratae*; 9 – *Eleocharitetum palustris*; 10 – *Sagittario sagittifoliae*-*Sparganietum emersi*; 11 – *Scirpetum radicans*.

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. <i>Cyperaceae</i>	10 (15.2 %)
2. <i>Poaceae</i>	8 (12.1 %)
3. <i>Potamogetonaceae</i>	6 (9.1 %)
4. <i>Ranunculaceae</i>	4 (6.1 %)
5. <i>Typhaceae</i>	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 crisp-Ranunculetum trichophylli*, *Potamogetonum graminei*, *Potamo natantis-Polygonetum natantis*, *Typhetum angustifoliae* and *Sparganietum erecti*.

The flora of vascular 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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