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The Study of the Higher Aquatic Flora of the Middle Don Basin within Rostov Region

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Abstract: Middle Don basin is recognized as a biodiversity hotspot, characterized by high diversity of vascular terrestrial plants. However, the significance of its freshwater biodiversity is not well understood now. In the given paper we present the results of the investigation of higher aquatic flora of basin streams and reservoirs within the Middle Don, Rostov region. 90 species of 53 genera and 32 families belonging to the four departments of higher plants were identified. The biodiversity of the Middle Don aquatic flora is discussed using the previously obtained herbal and biogeographic data and considering ecological, geographical and human factors. A systematic, ecological and geographical analysis of the regional aquatic flora has been conducted.

Keywords: Aquatic Flora, Ponds, Streams, Middle Don, Ecological Groups, Hydrophytes, Helophytes, Hygrohelophytes

Introduction

Studies of higher aquatic flora are an important part of ecological and biogeographic investigations in different regions of the world (Chambers *et al*., 2008; Bella *et al*., 2008; Chappuis *et al*., 2011; Figueroa *et al*., 2013; Davies and Stewart, 2013). It includes studies of macrophytes occupying higher levels of biocenosis as well as the researches of biodiversity in general (Murphy *et al*., 2003; Shi *et al*., 2010; Chappuis *et al*., 2012; Bosiacka and Pienkowski, 2012; Afanasyev *et al*., 2012; Bolpagni *et al*., 2013; Lukacs *et al*., 2013). Aquatic flora and riparian habitats of the north of Rostov region have begun to be studied-in the middle of the XX century. The basic investigations of this field were performed by Balazs (1955) and Fedjaeva (2004).

Don River basin is bordered by the Voronezh region in the west and by the Volgograd region in the east (Fig. 1).

This area is a part of the basin of the Middle Don, which upper border lies over the inflow Point of voronezh River (Fig. 1).

The climate of the territory is a temperate continental with insufficient moisture, hot and dry summers and relatively mild winters. The average annual temperature is 6.5°C. The annual range of air temperature is 77°C on average. The coldest month is January (-8.8°C). The warmest month is July (23°C). The duration of the warmest period is 76 days. The average annual relative air humidity is 72%. The rainfall is about 400-450 mm of precipitation during a year. According to the hydrochemical indices, the reservoirs of Middle Don river basin are characterized by a medium mineralization: 0.5-1.0 mg L^{-1}. The surface water can be attributed to the hydrocarbon class and the calcium group (Khrustalyov *et al*., 2002). Middle Don River basin in some places has a width up to 400 m, average depth of 5-10 meters, but sometimes its depth reaches 15 meters (Bazkovsky khutor). The depth of rivers is constantly changing as a result of uneven deposition of river sediment in the river bed and their movement. The right bank of the Don is significantly higher than the left. Almost everywhere there are high chalk mountains adjoining to the riverbed. In many aquatories, the sediment deposits cover large areas. Sometimes there are sand bars and beaches in the downstream, especially in the corners of the riverbeds. Major tributaries of the Don are shallow rivers: Peskovatka, Tihaya, Elan. The largest lakes are Ostrovnoye, Chiganak, Gremyach'ye, Rassohovo. They are also the deepest (3, 5-4 m). These lakes and the 500 m zone around them have a nature conservation status. The soil is uliginous or rocky-uliginous, sandy-uliginous, sometimes sandy. The Middle Don basin is a part of the Black Sea steppe province of Eurasian steppe region (Isachenko and Lavrenko, 1980).

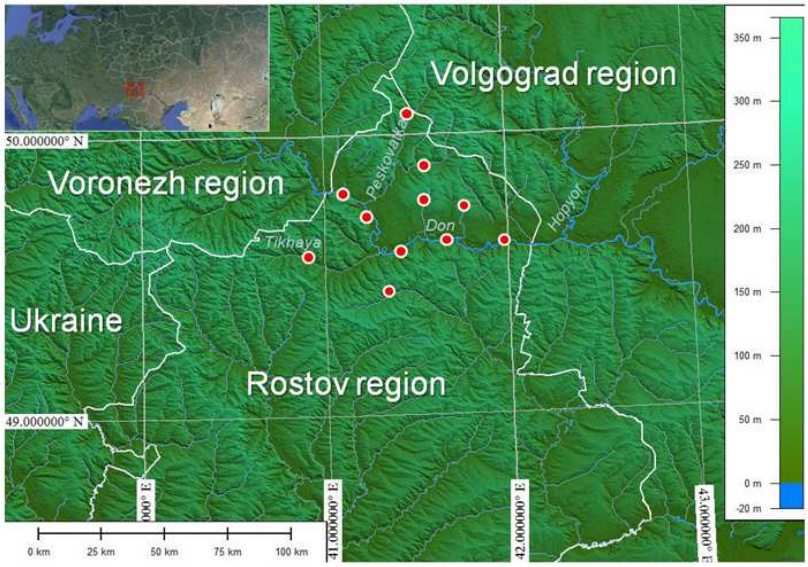

Fig. 1. Locations of test plots (red circles) within the Rostov region part of Middle Don basin

The purpose of this work is to analyze the flora of higher plants of lakes and rivers of the Middle Don basin within the Rostov region. Here we examine biodiversity of aquatic flora of Middle Don basin, the influence of geographical, climatic *and* biotic processes on the patterns of distribution of aquatic species. We have compared taxon diversity of the studied region with other regions of Russian federation and Canada.

Materials and methods

The Material for this work was obtained as a result of field works during the summers of 2009-2012. The study area included the pool area of the Middle Don, within Rostov region, i.e., the segment of the Don River from the border with the Voronezh region to the border with the Volgograd region, with streams and ponds, hydrologically linked into one system. Location of test plots is shown in the Fig. 1. On purpose to compare the floristic data correctly there was used the scheme of floristic analysis adduced by Papchenkov (2001). Here (in the present work) we take in consideration a group of aquatic plants, which, according to Papchenkov, are hydrophytes (I), helophytes (II) and hygrohelophytes (III), i.e., this species are belonging to the aquatic flora in the broadest sense. Also it should be noted that algae is not considered in present work.

Results and Discussion

In total 90 species of higher plants from 53 genera and 32 families which are belonging to the four departments were identified in the studied lakes (Table 1).

Most the number of the species are referred to the angiosperms (78 species, 86%), the rest of the species are represented by species from departments of Bryophyta (9 species, 10%), Polypodiophyta (2 species) and Equisetophyta (1 species). The ratio between classes of Magnoliopsida and Liliopsida in number of species is 1: 1.7, i.e., 29 species and 49 species respectively. Liliopsida is a dominating class in the department of flowering plants that is due to the presence of large water families, such as Potamogetonaceae, Cyperaceae, Sparganiaceae.

A considerable domination of monocot class in a number of species (and a lesser domination in a number of genera and families) is typical for the aquatic flora of reservoirs and watercourses of CIS countries (Papchenkov 2001; Sviridenko, 1997; Dubina, 2006; Weisberg, 2007).

Leading families have been estimated by the number of species comparing to the total number of species of the studied family. They are: Cyperaceae (13 species, 14% of the total number of species), Potamogetonaceae (10 species, 11%), followed by Ranunculaceae (6 species, 7%). The fourth place is occupied by five families, which are represented by 4 species in each. They are Alismataceae, Apiaceae, Lemnaceae, Ricciaceae, Sparganiaceae. Other families are scared. It is likely that the family Potamogetonaceae is more plentiful, but, unfortunately, we have not considered Potamogetonaceae hybrids, which are now described in a significant amount (Kaplan and Fehrer, 2013). The largest genera estimated by number of species of the studied flora is Potamogeton-10 species (11%), followed by Carex-5 species (6%), the third place is occupied by two kinds of 4 species (3%) in each-these are Eleocharis and Sparganium. Group of 7 genera is in fourth place, each of them includes 3 types: Alisma, Batrachium, Ceratophyllum, Myriophyllum, Riccia, Scirpus, Typha. One of informative indicators of diversity of flora is a generic factor (Papchenkov, 2001), i.e., the average number of species at the genus, which

was founded to be 1.7 for the studied flora. For comparison, the same index in a similar flora of streams and ponds upstream of the Samara River basin (Bobrov, 1999) is also equal to 1.7. The flora taken to compare was described in a similar area, climatic and hydrochemical conditions of the territory. Aquatic flora widely distributed in the more northern latitudes is characterized by generic coefficients more than 1.9 (Sviridenko, 1997; Weisberg, 2007; Bobrov, 1999; Starodubtseva, 1999). Aquatic flora of the forest zone in the middle current of the Don basin is also richer, estimating by data, obtained with the Voronezh Reserve flora (Papchenkov, 2013). The aqueous core of the studied flora is an effective index and it is used in many hydrobotanical studies (Starodubtseva, 1999; Papchenkov, 2013; Landolt, 1986).

In our studies the aqueous core is represented by 43 species from 25 genera and 18 families. For comparison, an aqueous core of the flora of reservoirs and streams of the Middle Sura basin is represented by 55 species 24 genera and 19 families, excluding mosses.

The level of the aqueous core of the studied flora seems to be depleted when compared (by the number of species) to its more northern analogs. Thus, the aquatic core of the Central Canada flora includes 69 species of higher aquatic plants (Pip, 1979) that is richer than the flora of the river Don. This region is located further north than Middle Don basin.

Ecological analysis of the aquatic flora showed the dominance of hydrophytes-39 or 43% of the total species. Almost half of them belong to the ecological group of rooting submerged hydrophytes, represented by 20 species, most part of which belongs to the genus Potamogeton. There were the hygrohelophytes in the second place-29 species (32%) *and* there were only 22 species of helophytes (24%) among them. Furthermore, short grass helophytes are represented by 14 species, whereas tall grass helophytes are represented only by 8 species. Interestingly, that the similar ratios were obtained by the authors (Papchenkov, 2001; Weisberg, 2007; Kaplan and Fehrer, 2013) who have studied aquatic flora of regions of similar climate (Table 2).

The geographical composition of flora of the Middle Don Basin is characterized by predominance of the species of Holarctic plurizonal type-21 species, then pluriregional plurizonal-16 species, the third type is the Eurasian plurizonal type-10 species, followed by Eurasian boreal-meridional type-9 species. Other types are not numerous. This distribution of species by geographical types is also distinctive for aquatic flora of other regions (Papchenkov, 2001). We should also point out the fact of finding Wolffia arrhiza in the studied region which is a floating hydrophyte with tropical origin (Pip, 1979). Earlier this thermophilic species were not adduced for ponds of Rostov region, although known from more northern locations, such as Bryansk region (Braslavskaya, 2000). Perhaps, Wolffia arrhiza is brought here by animals during warm seasons *and* so, forms temporary coenopopulations.

Most species are met both in rivers and in lakes: 41 species (46% of total). About 32 species were found only in lakes (35%) and only 17 species (19%) were identified for rivers. The aforementioned authors (Papchenkov, 2001; Weisberg, 2007) also note that, as a rule, there is a much smaller number of species belonging to the aquatic flora in streams than in the reservoirs. In our case, this can be explained by sharp character of the bottom topography of the studied rivers, which, in turn, leads to a narrow band of shallow water. Hygrohelophytes can also be deprived of the opportunity to dwell where the high right bank forms cliffs. The analysis of the species composition of aquatic flora based on the frequency of occurrence allows identifying the predominance of rare species-30 species (33%), identifying a group which includes sporadically encountered species (24 species-27%), rarely found species (20 species-22%), frequent species (15 species-17%) and the category of “very rare species” which was referred only to one species (1%).

In general, the study of aquatic flora in the Middle Don basin within Rostov region have revealed a low level of floristic diversity in lakes and rivers of this region compared to other similar areas. At the same time, this flora is a little richer than the aquatic flora of south territories of Russia. Thus, considering a number of the listed in this study floristic indicators, the wealth of aquatic flora of Middle Don basin can be judged to be increased in the meridional direction from south to north. Perhaps, this is due to the change of landscape-climatic features within the studied area, where the zone of steppes gradually turns into forest area.

To summarize, the present study have revealed the following main characteristics of Middle Don basin:

- Higher aquatic flora of reservoirs and streams of the Middle Don basin within Rostov region consists of 90 plant species from 32 families
- In the spectrum of ecological groups of plants the hydrophytes are dominant, numbering 39 species. The group of hygrohelophytes (29 species) is in the 2nd place and the helophytes is in the 3rd place (22 species)
- The species of a wide geographical distribution are dominating in the flora of the basin: Holarctic flora- 21 species, pluriregional-16 species, Eurasian-10 species
- The biggest diversity of species was found in the lakes-73 species and in the rivers-58 species
- Generic coefficient for the studied flora is 1.7, that indicates a relatively low species richness comparing with the floras described in the neighboring regions of the European part of Russia

Table 1. List of aquatic plants encountered in the lakes and rivers of the Middle Don basin within the Rostov region

	Ecological characteristics of plant groups*			
Species	1	2	3	4
	Bryophyta			
	Ricciaceae			
Riccia cavernosa Hoffm.	III	Hp	R	Oc
R. fluitans L.	I 1	Hp	R	Of
R. frostii Austin	III	Hp	R	R
Ricciocarpus natans (L.) Corda	II 6	Pp	R	R
	Bryaceae			
Leptobryum pyriforme (Hedw.) Wilson	II 6	Hp	R	R
	Amblystegiaceae			
Amblystegium serpens (Hedw.) Bruch, Schimp and W. Guembel	II 6	Pp	R	R
Hygroamblystegium humile (P.Beauv.) Vanderp.	II 6	Pp	R	R
Leptodictium riparium (Hedw.) Warnst.	III	Pp	R	S
	Brachytheciaceae			
Brachythecium rivulare Bruch, Schimp and W. Guembel	III	Pp	R	R
	Equisetophyta Equisetaceae			
Equesetum fluviatile L.	II 6	Hp	R, L	Of
	Polypodiophyta Thelypteridaceae			
Thelypteris palustris Schott	III	Hp	R, L	Of
	Salviniaceae Dumort			
Salvinia natans All.	I 5	Htm	L	S
	Magnoliophyta Magnoliopsida Nymphaeaceae			
Nymphaea alba L.	I 4	E:bm	L, R	R
N. candida J.& C.Presl	I 4	EAbm	L	R
Nuphar lutea Smith.	I 4	ESbsm	L, R	Oc
	Ceratophyllaceae			
Ceratophyllum platyacanthum Cham.	I 2	EAbm	L	Oc
C. submersum L.	I 2	EAbm	L	Of
C. demersum L.	I 2	EAbm	L, R	Of
	Ranunculaceae			
Batrachium circinatum (Sibth.) Spach	I 3	EAbsm	L, R	Oc
B. rionii (Lagger) Mym.	I 3	EAtm	L	R
B. trichophyllum (Chaix) Bosch	I 3	Hp	R	Oc
Caltha palustris L.	III	Hp	L	V
Ranunculus lingua L.	III	EAbsm	L	S
R. polyphyllus Waldst. Et Kit. Ex Willd.	III	ESbsm	L	R
	Polygonaceae			
Persicaria amphibia (L.) S. F. Gray	I 4	Hp	L, R	S
Rumex hydrolapathum Huds	III	ESbm	L, R	R
	Elatinaceae			
Elatine alsinastrum L.	I 3	EAbm	L	R
	Brassicaceae			
Rorippa amphibia Bess.	III	EAp	L	Oc
	Lythraceae			
Lythrum salicaria L.	III	Pp	L, R	S
	Trapaceae			
Trapa natans L.	I 5	ESbsm	L	R
	Haloragaceae			
Myriophyllum sibiricum Kom.	I 3	ESbm	L, R	R
M. spicatum L.	I 3	Hp	L, R	Oc
M. verticillatum L.	I 3	Hp	L, R	R
	Apiaceae			
Cicuta virosa L.	III	EAp	L, R	Oc
Oenanthe aquatic (L.) Poir.	III	EAp	R	R
Sium latifolium L.	III	EAp	R	Oc
S. sisaroideum DC.	III	EAtm	R	Oc
	Menyanthaceae			
Menyanthes trifoliata L.	III	Hbm	L	R

Table 1. Continue

Nymphoides peltata (S.G.Gmel.) O. Kuntze	I 5	EAtsm	L	Oc
	Scrophulariaceae			
Veronica anagallis-aquatica L.	III	Pp	L, R	Of
	Lentibulariaceae			
Utricularia vulgaris L.	I 2	Hp	L	R
	Liliopsida			
	Butomaceae			
Butomus umbellatus L.	II 6	EAp	R, L	S
	Alismataceae			
Alisma plantago-aquatica L.	II 6	EAp	R, L	S
A. lanceolatum With.	II 6	EAtm	L	Oc
A. *gramineum* Lej.	II 6	Hbm	L	R
Saggitaria sagittifolia L.	II 6	EAp	L	R
	Hydrocharitaceae			
Elodea canadensis Michx	I 3	Pp	L, R	R
Hydrocharis morsus-ranae L.	I 5	Hbm	L, R	S
Stratiotes aloides L.	I 2, 3	ESbsm	L	R
	Potamogetonaceae			
Potamogeton berchtoldii Fieb.	I 3	Hp	L, R	S
P. compressus L.	I 3	Hbt	L, R	Oc
P. crispus L.	I 3	Pp	L, R	Of
P. gramineus L.	I 4	Hbt	L, R	S
P. lucens L.	I 3	ESp	L, R	Of
P. natans L.	I 4	Hbsm	L, R	Of
P. nodosus Poir.	I 3	Hp	L, R	Oc
P. pectinatus L.	I 3	Pp	R	Of
P. perfoliatus L.	I 3	Pp	R	Of
P. pusillus L.	I 3	Hp	L, R	S
	Zannichelliaceae			
Zannichellia palustris L.	I 3	Hbsm	L, R	R
	Najadaceae			
Caulinia flexilis Willd.	I 3	Hbt	L	R
Najas major All.	I 3	EAtm	L	R
	Iridaceae			
Iris pseudocorus L.	III	EAbm	L	R
	Cyperaceae			
Eleocharis acicularis (L.) Roem. & Schult.	III	Hp	R, L	Oc
E. palustris R. Br.	III	Hp	R, L	S
E. mammilata Lundb.	III	EAbt	R	Oc
E. uniglumis (Link) Schult.	III	EAp	L	R
Scirpus sylvaticus L.	II 7	EAbm	L	S
S. lacustris L.	II 7	EAp	L	S
S. tabernaemontani C.C. Gmel.	II 7	Hbm	L	S
Bolboschoenus maritimus Palla	III	Hp	L, R	Oc
Carex acuta L.	III	ESasm	L, R	S
C. acutiformis Ehrh	III	EAbm	L, R	Oc
C. melanostachya Bieb. ex Willd.	III	EAtm	R, L	S
C. riparia Curt.	III	EAbm	R, L	S
C. *visicaria* L.	III	EAp	R, L	S
	Poaceae			
Agrostis stolonifera L.	III	Hp	R, L	S
Gliceria maxima (C. Hartm.) Holmb.	II 7	ESbsm	R	Oc
Phragmites australis (Cav.) Trin. ex Steud.	II 7	Pp	R, L	Of
	Lemnaceae			
Lemna minor L.	I 5	Pp	L	Of
L. trisulca L.	I 2	Pp	L	Of
Spirodela polyrhisa Schleid.	I 5	Pp	L	S
Wolffia arrhiza (L.) Horkel. Ex Wimm.	I 5	Eatrt	L	R
	Sparganiaceae			
Sparganium emersum Rehm.	II 6	Hp	L	S

Table 1. Continue

S. erectum L.	II 6 Countinew	ESbm	L	R
S. neglectum Beeby	II 6	EAtm	L	S
S. minimum Wallr.	II 6 Typhaceae	Hbsm	L	Oc
Typha angustifolia L.	II 7	Pp	L, R	Of
T. latifolia L.	II 7	Hp	L, R	S
T. laxmannii Lepech.	II 7	EAtm	L, R	R

Notes: Column count number 1
* I. Hydrophytes: 1. Aquatic mosses, 2. Hydrophytes, freely floating in the water thick, 3.
Submerged hydrophytes rooted, 4. Rooting hydrophytes with floating leaves on the water, 5.
Hydrophytes, freely floating on the water surface.
II. Helophytes: 6. Low grass helophytes, 7. Tall grass helophytes.
III. Hygrohelophytes.
*Column count number 2.
Region geographical status: P-pluriregional (widespread species, covering several geographical areas), H-Holarctic, EA-Eurasian, ES-Eurosiberian, E-European, zonally: p-plurizonal, asm-arktosubmeridional, bm-boreal-meridional, bsm-boreal-submeridional, bt-boreal-temperatnye, tm-temperatno-meridional, tsm-temperatno-submeridional, ttr-temperatno-tropical (Papchenkov, 2001).
*Column count number 3.
Water object type: L-lake, R-River.
*Column count number 4.
Frequency of occurrence: V-very rarely, R-rarely, O-occasionally, S-sporadically, O-often.

Table 2. Ratio of the number of species in ecological groups of aquatic flora in the European part of Russia

Ecological Groups	Aquatic flora studied in the present work (%)	Hydrophilic flora of lakes of Chelyabinsk region (Weisberg, 2007) (%)	Aquatic flora of the middle current of the Sura River basin (Kaplan and Fehrer, 2013) (%)	Aquatic flora of the Basin of the upper current of Samara River (Papchenkov, 2001) (%)
Hydrophytes	43	51	49	54
Helophytes	24	23	16	18
Hygrohelophytes	32	26	35	28

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Author's Contributions

Michael M. Sereda: Participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript, designed the research plan and organized the study.

Olga A. Kapralova: Coordinated data-analysis and contributed to the writing of the manuscript.

Vlada A. Sereda: Participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

Boris L. Kozlovskiy, Vladimir S. Lysenko and Tatyana V. Varduni: Designed the research plan and contributed to the writing of the manuscript.

Pavel A. Dmitriev: Designed the research plan and contributed to the writing of the manuscript, coordinated the data-analysis.

Olesya G.Lysenko: Participated in the experiments.

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