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Article

Floristic diversity in the small rivers with different morphology in the zone affected by backwater of a lowland reservoir

Elena G. Krylova[1]*, Alexander V. Tikhonov[2], Eduard V. Garin[1]

[1] *I.D. Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences, Borok 109, Nekouz District, Yaroslavl Region, 152742 Russia*

[2] *Yaroslavl Scientific Research Institute of Livestock Breeding and Forage Production – Federal Williams Research Center of Forage Production and Agroecology, ul Lenina 1, Mikhailovskiy village, Yaroslavl District, Yaroslavl Region, 150517 Russia*

**panovaeg@mail.ru*

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Abstract. A comparative study of the floristic diversity of small rivers is of great importance in the assessment of their environmental state, which allows assessing the degree of pollution of the environment. The floristic diversity of the estuaries of the small rivers Korozhechna, Latka, Il'd', and Chesnava, has been studied with special attention to the ecological groups and biological peculiarities of certain species. All the studied rivers flow into the Rybinsk Reservoir and have different morphology of the studied estuaries. The largest number of species has been recorded for the Chesnava River, the lowest, for the Il'd' River. The representatives of families Poaceae, Cyperaceae, and Juncaceae evidence on the active overgrowing of shallow waters and periodically flooded coasts. Most of the species can grow on various soils, they are typical for water bodies with an oscillating water level and weak flow. The species-to-genus ratio, which is inversely proportional to the diversity of ecological conditions, is the highest in the Korozhechna River and the smallest in the Chesnava and Latka rivers. On the rivers Hydrophytes and hygrophytes dominated in the Korozhechna and Latka rivers; hygrophytes, hydrophytes, and hydrogelophytes, in the Il'd' River; hygrophytes, mesophytes and hydrophytes, in the Korozhechna River. Such differences are explained by the peculiarities of environmental conditions. The highest similarity, by the absolute number of common species and by Jaccard coefficient, is found between the Chesnava River and the Latka River and between the Il'd' River and the Latka River. According to hydrophytic cover index (HCI), near-water species dominated in the Chesnava River, a slight advantage in the proportion of the aquatic component of the flora was observed in the other rivers.

Keywords: floristic diversity, species-to-genus ratio, ecological groups, species activity, hydrophytic cover index (HCI).

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Introduction

River systems occupy significant territories in Russia. The springs, streams, and small rivers are the most numerous water bodies and the primary elements of any hydrographic network. Recent hydrobiological studies, devoted to small rivers, are of great relevance (Ekologicheskoe sostoyanie.., 2003; Ekosistema maloi reki.., 2007). They have been studied less than other water bodies, although they serve as a natural filter, protecting large rivers from excessive income of river sediments. Many small rivers, flowing into and out of reservoirs, precondition the structural and functional characteristics of ecosystems significantly. The reservoirs may radically change the microclimate and landscape, and hence the structure and functioning of related aquatic and terrestrial ecosystems. Under the technogenic load, both quality and quantity of the water of the small rivers change much faster than in the medium-size and large rivers, so small rivers may serve as model objects for studying the processes of structure formation, biological productivity, the flows of energy, matter and information, and various ecosystem links.

The state of small rivers is one of the indicators of the environmental well-being. Therefore, it is highly relevant to assess the ecological status of small rivers nowadays in order to improve their state and to prevent further pollution. The rivers selected for study belong to the class of small rivers according to the classification suggested by A.V. Ogievsky; this classification system is based on the river length, catchment area, and the average water discharge (Papchenkov, 2008; Sytnik et al., 1994).

The assessment of species richness at various spatial scales is the keystone of biodiversity studies, it is the most significant criterion for assessing the ecological changes occurring in aquatic ecosystems (Ricklefs and Schluter, 1993; Rosenberg and Resh, 1993). The floras of the studied rivers were described earlier by the authors (Garin and Krylova, 2017; Krylova, 2007, 2015; Krylova et al., 2018).

The study aims to compare the floristic diversity of the small rivers (Korozhechna, Latka, Il'd', and Chesnava) flowing into the Rybinsk Reservoir and characterized by different morphology of estuarine areas.

Materials and methods

The flora was studied in 2004–2018 by the route survey method in the ecotopes of the estuarine zone of the Korozhechna, Latka, Il'd', and Chesnava rivers flowing into the Rybinsk Reservoir (Papchenkov, 2001) (Fig. 1). The morphological parameters of the rivers were studied earlier (Zakonnova and Litvinov, 2003).

A synopsis of the flora of vascular plants was compiled, six ecological groups were assigned according to the classification proposed by V.G. Papchenkov (1985): hydrophytes (floating and submerged forms), helophytes (air-water), hygrohelophytes (plants of highly waterlogged habitats), and hygrophilous species, nemaly, hygrophytes, hygromesophytes (plants of swamp and temporarily flooded coasts) and mesophytes (plants growing on the soils with sufficient, but not excessive moisture degree) (Table 1). All species found in the aquatic environment and along the water's edge, as well as on the gently sloping parts of the coast flooded during a significant part of the growing season, were recorded. The taxonomy of herbarium specimens was determined using the "Flora of the Central zone of the European part of Russia" (Maevskii, 2014) and "Flora of the water bodies of the Volga River basin" (Lisitsyna et al., 2009). The dominant species in the communities, i.e. the edificator plants, were indicated. The activity of the species was assessed by the frequency of occurrence when compiling geobotanical descriptions according to generally accepted methods during the route survey, as well as by their role in communities: 1 – inactive, 2 – weakly active, 3 – active, 4 – highly active.

A matrix of absolute and relative similarity was developed. The absolute similarity was calculated as the number of common species. The relative similarity was determined by the Jaccard coefficient:

$$K = N_{A+B}/(N_A+N_B–N_{A+B})\ 100\%,$$

where N_{A+B} is the number of common species, N_A, the number of species in flora A, N_B, the number of species in flora B.

The structure of the studied flora is given according to the APG IV system with minor changes proposed for the flora of the Yaroslavl Region (Byng et al., 2016; Garin, 2016). The hydrophytic cover index (HCI) proposed by B.F. Sviridenko (1997) was calculated as:

$$I_{hd} = (2A/B) – 1,$$

where A is the number of aquatic species, B is the number of all species of the considered flora.

The value of the index varies from +1, when the flora is represented by hydrophytes only, to –1, when the hydrophytes are absent in the sample; zero value means equal share of the aquatic and near-aquatic components of the analyzed flora. Here, we have calculated HCI for the entire flora, considering the number of aquatic plants in a broad sense, i.e., hydrophytes, helophytes and hygrohelophytes (by classification of V.G. Papchenkov (Sviridenko, 1997)), as belonging to A.

In addition to vascular plants, Bryophyta were noted, which were found in an insignificant number both in biomass and in the number of species: *Blasia pusilla* L., *Drepanocladus aduncus* (Hedw.) Warnst., *Leptodictyum riparium* (Hedw.) Warnst., and *Riccia fluitans* L. in shallow water and on swamp soil, and *Orthotrichum speciosum* Nees., on the trunks of trees and shrubs sticking out of the water. Also, the filamentous alga *Cladophora fracta* (Vahl.) Kütz was noted in small numbers in shallow waters.

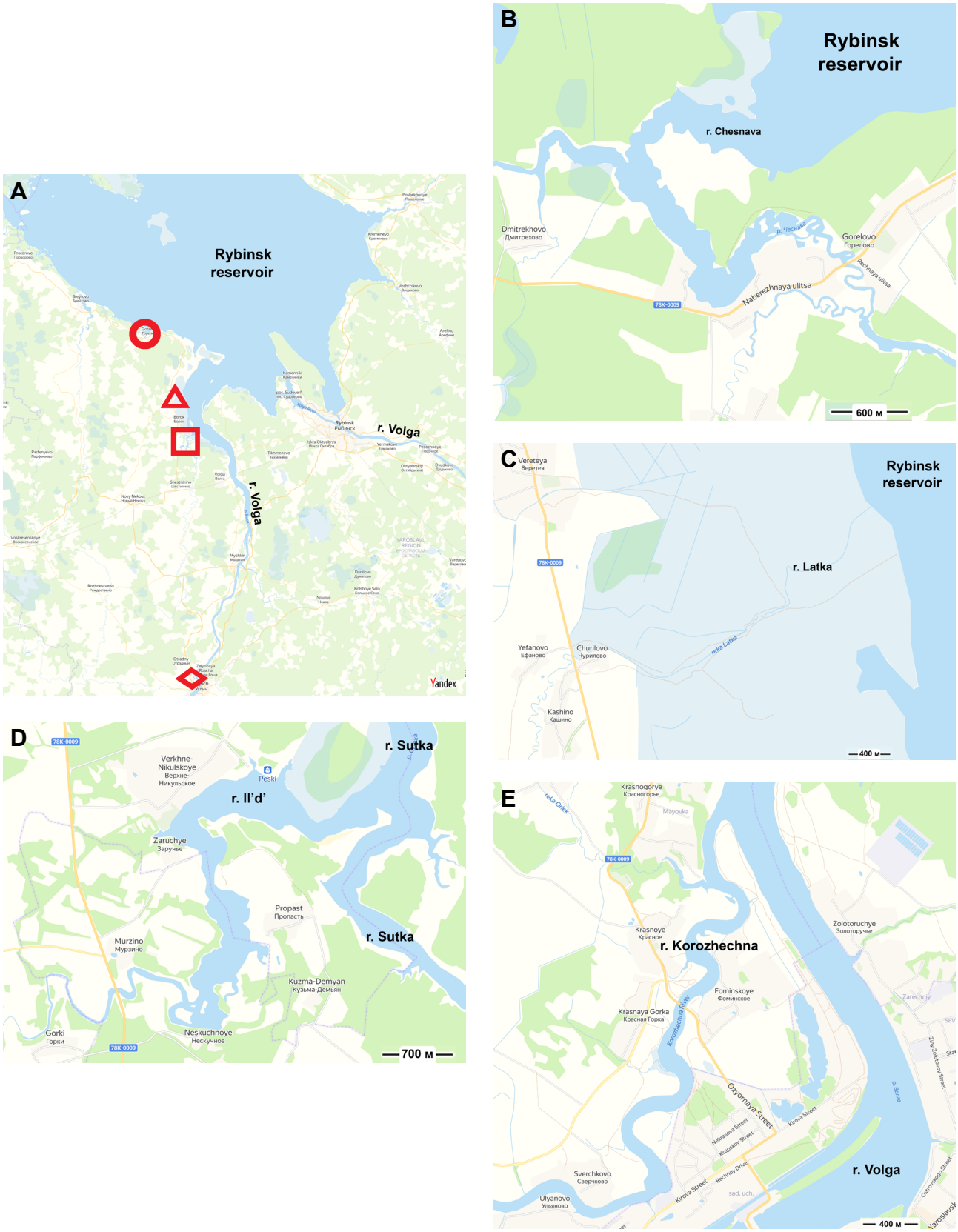

Fig. 1. Schematic map of the location of the studied rivers. **A** – Rybinsk Reservoir, figures indicate the estuaries of the studied rivers; **B** (circle) – Chesnava River; **C** (triangle) – the Latka River; **D** (square) – the Il'd' River (including the area after confluence with the Sutka River); **E** (rhombus) –the Korozhechna River.

Table 1. Species composition of flora of the studied rivers: I – the Chesnava River; II – the Latka River; III – the Il'd' River, IV – the Korozhechna River; "–" – the species is absent.

Species	Ecological group	Species activity			
		I	II	III	IV
Division Polypodiophyta					
Class Equisetopsida					
Order Equisetales					
Family Equisetaceae Michx.					
Equisetum arvense L.	mesophyte	1	1	1	–
E. fluviatile L.	helophyte	3	2	4	3
E. sylvaticum L.	mesophyte	2	–	–	–
Division Spermatophyta					
Class Magnoliopsida					
Order Nymphaeales					
Family Nymphaeaceae Salisb.					
Nuphar intermedia Ledeb.	hydrophyte	–	–	1	–
N. lutea (L.) Sm.	hydrophyte	3	4	4	4
N. × *spenneriana* Gaudin	hydrophyte	–	1	–	–
Nymphaea candida C. Presl	hydrophyte	–	–	4	4
Order Alismatales					
Family Juncaginaceae Rich					
Triglochin palustris L.	hygrophyte	–	1	–	–
Family Potamogetonaceae Bercht. et J. Presl					
Potamogeton compressus L.	hydrophyte	–	–	–	1
P. gramineus L.	hydrophyte	1	2	–	1
P. lucens L.	hydrophyte	–	3	3	3
P. natans L.	hydrophyte	–	–	–	2
P. perfoliatus L.	hydrophyte	1	3	4	4
P. salicifolius Wolfg.	hydrophyte	–	–	–	1
Stuckenia pectinata (L.) Börner	hydrophyte	1	3	3	4
Family Hydrocharitaceae Juss.					
Elodea canadensis Michx.	hydrophyte	2	4	3	–
Hydrocharis morsus-ranae L.	hydrophyte	4	4	3	2
Family Butomaceae Mirb.					
Butomus umbellatus L.	helophyte	2	4	3	2
Family Alismataceae Vent.					
Alisma gramineum Lej.	helophyte	4	–	–	3
A. plantago-aquatica L.	helophyte	4	4	4	4
Sagittaria sagittifolia L.	helophyte	3	4	3	3
Family Araceae Juss.					
Lemna minor L.	hydrophyte	4	4	3	2

Species	Ecological group	Species activity			
		I	II	III	IV
L. trisulca L.	hydrophyte	4	4	3	2
Spirodela polyrrhiza (L.) Schleid.	hydrophyte	4	4	3	2
Order Asparagales					
Family Iridaceae Juss.					
Iris pseudacorus L.	hygrohelophyte	–	–	1	–
Order Poales					
Family Poaceae Barnhart					
Agrostis gigantea Roth	mesophyte	–	1	1	–
A. stolonifera L.	hygrohelophyte	3	4	3	4
Alopecurus aequalis Sobol.	hygrophyte	3	3	3	2
A. geniculatus L.	hygrophyte	–	2	–	–
A. pratensis L.	mesophyte	1	–	–	–
Calamagrostis canescens (Weber) Roth	hygrophyte	2	2	–	–
C. epigeios (L.) Roth	mesophyte	1	–	–	–
Deschampsia caespitosa L.	hygromesophyte	2	–	–	1
Glyceria fluitans (L.) R. Br.	hygrohelophyte	2	4	2	3
G. maxima (Hartm.) Holmb.	helophyte	4	4	4	–
G. notata Chevall	hygrohelophyte	–	1	–	–
Phalaris arundinaceae L.	hygrophyte	3	4	4	4
Phragmites australis (Cav.) Trin. ex Steud	helophyte	4	4	4	4
Poa palustris L.	hygrophyte	3	3	–	1
Order Ceratophyllales					
Family Ceratophyllaceae Gray					
Ceratophyllum demersum L.	hydrophyte	3	4	–	1
Family Juncaceae Juss.					
Juncus articulatus L.	hygrophyte	1	–	1	–
J. bufonius L.	hygrophyte	2	1	–	1
J. conglomerates L.	hygrophyte	2	–	–	–
J. effusus L.	hygrophyte	1	–	–	–
J. filiformis L.	hygrophyte	1	–	–	–
Family Typhaceae Juss.					
Typha angustifolia L.	helophyte	3	–	–	–
T. latifolia L.	helophyte	2	3	4	–
Sparganium emersum Rhem.	helophyte	3	3	2	3
S. erectum L.	helophyte	–	3	–	–
*S. microcarpum (*Neum.) Domin	helophyte	–	–	1	1
Family Cyperaceae Juss.					
Carex acuta L.	hygrohelophyte	4	4	4	4
C. aquatilis Wahalb.	hygrohelophyte	–	4	3	–

Species	Ecological group	Species activity			
		I	II	III	IV
C. bohemica Schreb.	hygrohelophyte	–	–	1	–
C. diandra Schrank	hygrohelophyte	1	–	–	–
C. hirta L.	mesophyte	–	1	1	1
C. leporina L.	hygrophyte	1	1	1	–
C. nigra (L.) Reichard	hygrophyte	–	1	–	–
C. rostrata Stokes	hygrohelophyte	–	–	2	–
C. vesicaria L.	hygrohelophyte	2	3	–	–
C. vulpina L.	hygrophyte	1	–	–	–
Eleocharis acicularis (L.) Roem. et Schult.	hygrohelophyte	3	3	3	4
E. palustris (L.) R. Br.	hygrohelophyte	4	4	4	3
Scirpus radicans Schkuhr	hygrohelophyte	1	1	–	–
S. sylvaticus L.	hygrophyte	2	4	2	2
Schoenoplectus lacustris (L.) Palla	helophyte	3	3	4	3
Order Ranunculales					
Family Ranunculaceae Juss.					
Thalictrum flavum L.	hygrophyte	3	2	2	1
T. lucidum L.	hygrophyte	2	–	1	–
Ranunculus circinatus Sibth.	hydrophyte	2	3	3	4
R. trichophyllus Chaix ex Vill.	hydrophyte	1	3	2	–
R. sceleratus L.	hygrophyte	3	–	–	3
R. repens L.	hygrophyte	2	–	1	–
R. reptans L.	hygrophyte	1	–	1	1
R. flammula L.	hygrophyte	1	–	–	–
Caltha palustris L.	hygrohelophyte	1	1	–	1
Order Saxifragales					
Family Haloragaceae R. Br.					
Myriophyllum verticillatum L.	hydrophyte	1	3	–	–
M. sibiricum L.	hydrophyte	–	–	–	1
M. spicatum L.	hydrophyte	–	2	1	–
Order Fabales					
Family Fabaceae Lindl.					
Trifolium hybridum L.	mesophyte	1	–	–	–
T. repens L.	mesophyte	1	–	–	–
Order Rosales					
Family Rosaceae Juss.					
Filipendula ulmaria (L.) Maxim.	hygrophyte	–	3	–	1
Potentilla reptans L.	mesophyte	–	1	–	1
P. erecta (L.) Raeusch.	mesophyte	1	–	–	–
Comarum palustre L.	hygrohelophyte	1	–	–	–

Species	Ecological group	Species activity			
		I	II	III	IV
Order Malpighiales					
Family Elatinaceae Dumort.					
Elatine hydropiper L.	hydrophyte	–	2	–	1
Order Fagales					
Family Betulaceae Gray					
Alnus incana (L.) Moench	hygrophyte	1	2	2	1
Family Salicaceae Mirb.					
Salix triandra L.	hygrophyte	3	3	3	2
S. cinerea L.	hygrophyte	2	–	–	–
S. myrtilloides L.	hygrophyte	2	–	–	–
Order Myrtales					
Family Onagraceae Juss.					
Epilobium adenocaulon Hausskh.	hygrophyte	1	–	–	1
E. palustre L.	hygrophyte	2	–	–	–
Family Lythraceae J. St.-Hil.					
Lythrum salicaria L.	hygrohelophyte	3	3	3	1
Order Brassicales					
Family Brassicaceae Burnett					
Rorippa amphibia (L.) Bess.	hygrohelophyte	3	4	4	3
R. palustris (L.) Bess.	hygrophyte	1	2	–	1
R. sylvestris (L.) Bess.	hygromesophyte	–	–	–	1
Cardamine pratensis L.	hygrophyte	–	–	1	1
Order Cariophyllales					
Family Polygonaceae Juss.					
Persicaria amphibia (L.) S.F. Gray	hygrophyte	4	4	4	3
P. hydropiper (L.) Spach	hygrophyte	–	2	–	–
P. lapatifolia (L.) S.F. Gray	hygrophyte	–	–	–	1
P. minor Huds	hygrophyte	1	–	1	–
Rumex aquaticus L.	hygrohelophyte	3	3	3	–
R. confertus Willd.	hygrohelophyte	–	2	–	1
R. crispus L.	hygrohelophyte	–	1	–	1
R. maritimus L.	hygrohelophyte	1	–	1	1
R. pseudonatronatus Borb.	hygrohelophyte	–	–	–	1
Family Amaranthaceae Juss.					
Chenopodium album L.	mesophyte	2	–	–	1
Oxybasis rubra (L.) Fuentes, Uotila et Borsch	hygrophyte	1	–	1	1
Family Caryophyllaceae Juss.					
Myosoton aquaticum (L.) Moench	hygrophyte	–	–	1	1
Sagina subulata L.	mesophyte	1	–	–	–

Species	Ecological group	Species activity			
		I	II	III	IV
Silene flos-cuculi (L.) Greuter et Burdet	mesophyte	1	–	–	–
Stellaria palustris Ehrh. ex Retz.	hygrophyte	1	1	–	–
Order Ericales					
Family Primulaceae Batsch ex Borkh.					
Androsace filiformis L.	hygrophyte	–	–	–	1
Lysimachia nummularia L.	hygrophyte	1	3	3	1
L. thyrsiflora (L.) Reichenb.	hygrohelophyte	1	1	–	
L. vulgaris L.	hygrophyte	2	3	3	1
Order Gentianales					
Family Rubiaceae Juss.					
Galium palustre L.	mesophyte	1	2	2	1
G. uliginosum L.	hygrophyte	1	–	–	1
Order Boraginales					
Family Boraginaceae Juss.					
Myosotis caespitosa K.F. Schultz.	hygrophyte	1	1	–	–
M. palustris L.	hygrophyte	1	3	2	1
Order Lamiales					
Family Lentibulariaceae Rich.					
Utricularia vulgaris L.	hydrophyte	1	1	1	1
Family Lamiaceae Martinov					
Galeopsis tetrahit L.	hygrophyte	–	–	–	1
Lycopus europaeus L.	hygrophyte	1	3	2	–
Mentha arvensis L.	hygrophyte	1	–	1	1
Prunella vulgaris L.	mesophyte	1	–	–	–
Scutellaria galericulata L.	hygrophyte	1	–	–	–
Stachys palustris L.	hygrophyte	2	3		1
Family Scrophulariaceae Juss.					
Limosella aquatica L.	hydrophyte	3	2	–	–
Family Plantaginaceae Juss.					
Callitriche cophocarpa Sendther	hydrophyte	–	–	1	–
C. palustris L.	hydrophyte	1	2	1	–
Hippuris vulgaris L.	hydrophyte	–	–	–	4
Plantago major L.	mesophyte	1	2	1	1
Veronica anagalis-aquatica L.	hygrohelophyte	–	3	2	3
V. baccabunga L.	hygrohelophyte	1	–	1	1
V. longifolia L.	mesophyte	–	–	1	–
V. spicata L.	mesophyte	1	–	–	–

Species	Ecological group	Species activity			
		I	II	III	IV
Order Asterales					
Family Asteraceae Bercht. et J. Presl					
Bidens cernua L.	hygrophyte	2	–	–	1
B. frondosa L.	hygrophyte	1	–	–	–
B. radiata Thuill.	hygrophyte	3	2	–	–
B. tripartita L.	hygrophyte	2	2	–	–
Cirsium palustre (L.) Scop.	mesophyte	1	–	–	–
Erigeron canadensis L.	mesophyte	–	–	–	1
Hieracium umbellatum L.	mesophyte	1	–	–	–
Ptarmica cartilaginea (Ledeb. ex Reichenb.) Ledeb.	mesophyte	2	2	–	–
Sonchus arvensis L.	mesophyte	1	1	–	1
Tanacetum vulgare L.	mesophyte	1	–	–	–
Tussilago farfara L.	mesophyte	–	–	–	1
Order Apiales					
Family Apiaceae Lindl.					
Cicuta virosa L.	hygrohelophyte	1	–	–	–
Oenanthe aquatica (L.) Poir.	hygrohelophyte	3	3	2	–
Sium latifolium L.	hygrohelophyte	4	3	3	2
Всего		**108**	**83**	**71**	**80**

The species-to-genus ratio has been calculated to assess the diversity of ecological conditions; this ratio considers the ratio of the number of genera to the number of species, which is inversely proportional to the species diversity (Alyokhin, 1944).

Characteristics of rivers

The Chesnava River flows in the Nekouz and Breitovo districts of the Yaroslavl Region, Russia. Its length is 37 km, the catchment area, 256 km^2, the width varies from 25 to 250 m. The riverbed is strongly meandering; during floods, both banks are significantly flooded, “straightening” the channel, so the river width increases up to 300 m. The right bank is steep. Villages and recreation centers locate on both banks; the river is actively used for hobby fishing.

The Latka River flows into the Volzhsky Reach of the Rybinsk Reservoir, its length is 18.8 km, the catchment area, 35 km^2. The river basin is located in the Nekouz district of the Yaroslavl Region, in the southern taiga subzone. The riverbed is clearly expressed, meandering, surrounded by fields. The banks are sloping, they are flooded only during high water in the zone, where it flows into the Rybinsk Reservoir. The width of the river varies from 3 to 7 meters. The estuary section of the river is used for hunting and hobby fishing, as well as by animals for watering.

The Il’d’ River is a tributary of the Sutka River, which flows into the Volzhsky Reach of the Rybinsk Reservoir. Its length is 46 km, the catchment area, 240 km^2. The riverbed is meandering, the left bank is steep; bays are formed along the right bank, covering significant areas. Villages are situated along the both banks.

The Korozhechna River flows through the territory of the Yaroslavl and Tver regions. The mouth of the river is located on the left bank of the Volga River (Volzhsky channel section of the Rybinsk Reservoir). The length of the river is 147 km, the catchment area, 1690 km^2. The riverbed is winding, surrounded by fields; several villages are situated along the banks. This river is affected by anthropogenic load (storm runoff) from the bridge of the Uglich-Nekouz Highway. The velocity of current is low; the width of the river increases to 25 m closer to the mouth due to the backwater of the reservoir; the last 4-km section of the river is navigable.

The water regime of the four studied watercourses belongs to the Eastern European type, which is characterized by a pronounced spring flood, summer-autumn low dry season, interrupted by floods, and

winter low water. The duration of the flood is 36 days (Ekosistema maloi reki.., 2007).

Results and discussion

All found vascular plants belong to two divisions: Polypodiophyta (1, 2, 2, and 3 species in the Chesnava River, the Latka River, the Il'd' River, and the Korozhechna River, respectively) and Spermatophyta (79, 81, 69, and 105 species, respectively) (Table 1).

The Chesnava River

The flora of the Chesnava River estuary comprises 108 species belonging to 33 families and 68 genera. Dominant families are Poaceae (11 species / 10.2% of the total number of vascular plants), Cyperaceae (10 / 9.3%), Asteraceae and Ranunculaceae (9 / 8.3% each), Juncaceae and Lamiaceae (5 / 4.6% each). These families account for 45.3% of the total flora. The species-to-genus ratio is 62.9%. The main edificators are *Persicaria amphibia, Phragmites australis, Eleocharis palustris*, *Glyceria maxima*, *Schoenoplectus lacustris, Ceratophyllum demersum, Typha angustifolia, Hydrocharis morsus-ranae, Lemna minor*, *L. trisulca*, and *Spirodela polyrrhiza.*

In total, 48 species of aquatic plants, 41 species of waterlogged and humid habitats, as well as 19 species of mesophytes (Table 2).

The Latka River

The flora of the Latka River comprises 83 species belonging to 32 families and 53 genera. The dominant families are Poaceae and Cyperaceae (11 / 13.2% each), Polygonaceae (5 / 6.0%), Ranunculaceae, Asteraceae, and Potamogetonaceae (4 / 4.8% each). These families account for 48% of the total number of species. The species-to-genus ratio is 63%. The main edificators are *Nuphar lutea*, *Elodea canadensis, Phalaroides arundinacea*, *Potamogeton perfoliatus, P. lucens, Carex acuta*, *Glyceria maxima, G. fluitans, Equisetum fluviatile, Rorippa amphibia*, *Sagittaria sagittifolia, Alisma plantago-aquatica*, *Eleocharis palustris,* and *Sparganium emersum.*

In total, 48 species of aquatic plants, 27 species of waterlogged and humid habitats, as well as 8 species of mesophytes (Table 2).

The Il'd' River

The flora of the Il'd' River estuary comprises 71 species belonging to 28 families and 48 genera. The dominant families are Cyperaceae (10 / 14.1%), Poaceae (7 / 9.8%), Ranunculaceae and Plantaginaceae (6 / 8.5% each), Polygonaceae (4 / 5.6%); altogether, they account for 38% of the total flora. The species-to-genus ratio is 67.6%. The main edificators are *Phragmites australis, Phalaroides arundinacea, Schoenoplectus lacustris, Rorippa amphibia*, *Equisetum fluviatile, Glyceria maxima*, *Typha latifolia*, *Eleocharis palustris*, *Persicaria amphibia,* and *Carex acuta*.

In total, 46 species of aquatic plants, 19 species of waterlogged and humid habitats, as well as 6 species of mesophytes were registered (Table 2). A rare species for the region, *Carex bohemica*, has been recorded, protection category III (Krasnaya Kniga..., 2015).

The Korozhechna River

The flora of the Korozhechna River estuary is represented by 80 species belonging to 32 families and 59 genera. The dominant families were Potamogetonaceae and Poaceae (7 species / 11.2% of the total flora list), Cyperaceae and Polygonaceae (6 / 7.5% each), Ranunculaceae (5 / 6.3%), Asteraceae, Brassicaceae (4 / 5.0% each); altogether, they account for 53.7% of the total number of species. The species-to-genus ratio is 73.7%. The main edificators are *Phragmites australis*, *Phalaroides arundinacea*, *Scirpus lacustris, Alisma plantago-aquatica*, *Carex acuta*, *Nymphaea candida*, *Nuphar lutea*, *Potamogeton perfoliatus, P. pectinatus*, *Eleocharis acicularis*, *Hippuris vulgaris*, *Batrachium circinatum*, and *Agrostis stolonifera*.

In total, 42 species of aquatic plants, 29 species of waterlogged and humid habitats, as well as 9 species of mesophytes have been found (Table 2).

A matrix of absolute and relative similarity has been developed based on the data on the species composition (Table 3).

The main part of the flora is represented by perennial grasses, which is typical for most aquatic ecosystems. In all rivers, Poaceae and Cyperaceae are the dominant families. Their presence indicate active overgrowing of the studied areas, which is facilitated by the presence of certain ecotopes, i.e. shallow waters and periodically flooded coasts. The species of the Juncaceae family (dominant family in the Chesnava River), are part of the meadow vegetation and partially penetrated into the water. This is associated with the active overgrowing of wide belts of the river coastal areas, which are drained during the low-water period. Many species of hydrophytes, characterized by wide ecological range, are highly active in all rivers; this is explained by the presence of areas with a certain depth required for their development. Among the coastal aquatic species, both shallow and coastal riverside species have been noted; these species have the opportunity to develop actively on periodically flooded and drained areas of the shores and along the water edge of all studied rivers.

All species found in the riverbeds and along flooded banks are indicators of water bodies with fluctuating water levels and weak currents; they are able to grow on different types of soil. Thirty-three species (22.2% of the total number of species) are found singly in only one of the studied rivers. Among them, 2% are true aquatic species, since the conditions necessary for their development are noted on all rivers. Most of such unique species are found in the Chesnava River (24 species; 72%). Meantime, hygrophytes and mesophytes dominate here; this indicates on temporarily flooded coasts and areas with sufficient moisture, which are characteristic for their growth and which are absent in other rivers. Only in the Chesna-

Table 2. Spectrum of environmental groups of flora studied rivers. Total number of species is indicated outside the brackets, the percentage of the total number (%), in the brackets.

	Chesnava	Latka	Il'd'	Korozhechna
Hydrophytes	17 (15.7)	20 (25.0)	18 (25.4)	20 (25.0)
Helophytes	12 (11.1)	10 (11.9)	10 (14.1)	9 (11.3)
Hygrohelophytes	19 (17.6)	18 (21.4)	18 (25.4)	13 (16.3)
Hygrophytes	40 (37.0)	25 (29.8)	19 (26.8)	25 (31.3)
Hygromesophytes	1 (0.9)	2 (2.4)	0 (0.0)	4 (5.0)
Mesophytes	19 (17.6)	8 (9.5)	6 (8.5)	9 (11.3)

Table 3. Similarity of the floras of the studied rivers. Absolute similarity are shown below the diagonal, relative similarity (%), above the diagonal (in italics). Values in diagonal are the number of species (in bold).

River	Chesnava	Latka	Il'd'	Korozhechna
Chesnava	**108**	*50%*	*45%*	*39%*
Latka	64	**83**	*51%*	*46%*
Il'd'	55	52	**71**	*45%*
Korozhechna	53	52	47	**80**

va River, most species of bulrush and narrow-leaved cattail, some sedges and willows are found. Several species of hydrophytes and hygrophytes are recorded exclusively in the Latka River (*Triglochin palustris*, *N.* × *spenneriana, Glyceria notata, Persicaria hydropiper*, and several sedge species). The Latka River and the Chesnava River are similar in channel tortuosity and soil types; they are also characterized by similar degree of anthropogenic load in their catchment areas. The presence of similar ecotopes on these rivers is confirmed by the largest number of common species (64 species), as well as similar values of species-to-genus ratios.

The smallest number of common species is found for the Korozhechna River and the Il'd' River (47). The Korozhechna River had the lowest ecotope diversity due to differences in the magnitude of water level fluctuation (expressed much more in the Latka and Chesnava rivers) and the degree of overgrowth (higher in the Latka and Il'd' rivers). Several species of pondweed, *Hippuris vulgaris, Myriophyllum sibiricum, Rumex pseudonatronatus*, hygrophytes, hygromesophytes, and mesophytes dominate only here. The sloping banks, flooded much better than the steep ones, precondition active development of these plants. The Il'd' River has the least number of unique species. These are *Iris pseudacorus*, several sedge species, *Veronica longifolia, Callitriche cophocarpa*, which are mainly hygrohelophytes and hygrophytes. The favorable conditions for their development exist in the large bay-like expansions. The Il'd' River and the Korozhechna River do not have such meandering as the Chesnava River and the Latka River, that is why the flora composition is less similar in these rivers.

A high Jaccard coefficient for the flora has been found between the Latka River and the Il'd' River (51%), as well as between the Latka River and the Chesnava River (50%). In first case, it is explained by the similarity of the degree of overgrowth, in the second, by similar range of water level fluctuations. The HCI is +0.05 for the Korozhechna River, +0.17, for the Latka River, +0.3, for the Il'd' River, and −0.1, for the Chesnava River. This evidences that semi-aquatic species slightly dominate in the Chesnava River, while the share of the aquatic component of the flora prevails slightly in all the other rivers.

Conclusions

The largest number of species is recorded in the Chesnava River, the lowest, in the Il'd' River. The species-to-genus ratio, inversely proportional to the diversity of ecological conditions, is the highest in the Korozhechna River and the lowest in the Chesnava River and the Latka River. Hydrophytes and hygrophytes dominate in the Korozhechna River and the Latka River; hygrophytes, hydrophytes, and hygrohelophytes, in the Il'd' River; hygrophytes, mesophytes, and hydrophytes, in the Korozhechna River; this is explained by the peculiarities of the ecological conditions. The highest similarity, by the

absolute number of common species and by Jaccard coefficient, is found between the Chesnava River and the Latka River and between the Il'd' River and the Latka River. The hydrophytic cover index indicates a slight predominance of semi-aquatic species in the Chesnava River, while the share of aquatic flora is the highest in other studied rivers.

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ORCID

Elena G. Krulova 0000-0002-9367-2732
Alexander V. Tikhonov 0000-0002-6857-484X
Eduard V. Garin 0000-0002-0199-9405

References

Alyokhin, V.V., 1944. Geografiya rastenij [Geography of plants]. Uchpedgiz, Moscow, USSR, 455 p. (In Russian).

Byng, J.W., Chase, M.W., Christenhusz, M.J.M., Fay, M.F., Judd, W.S. et al., 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* **181**, 1–20.

Ekologicheskoe sostoyanie malykh rek Verkhnego Povolzh'ya [Ecological status of small rivers of the upper Volga region], 2003. Krylov, A.V., Papchenkov, V.G. (eds.). Nauka, Moscow, Russia, 389 p. (In Russian).

Ekosistema maloi reki v izmenyayushchikhsya usloviyakh sredy [Ecosystem of a small river in changing environmental conditions], 2007. Krylov, A.V., Bobrov, A.A. (eds.). KMK, Moscow, Russia, 372 p. (In Russian).

Garin, E.V., 2016. Struktura flory sosudistykh rastenii Yaroslavskoi oblasti [Structure of vascular plant flora of the Yaroslavl region]. *Mezhdunarodnyi Zhurnal Prikladnykh i Fundamental'nykh Issledovanij [International Journal of Applied and Fundamental Research]* **8** (2), 188–193. (In Russian).

Garin, E.V., Krylova, E.G., 2017. Predvaritel'nye itogi issledovaniya flory ust'evogo uchastka maloi reki Chesnavy (Yaroslavskaya oblast) [Preliminary results of the study of the flora of the estuarine area of the small Chesnava River (Yaroslavl region)]. *Sbornik statej XIV Mezhdunarodnoj nauchno-prakticheskoj konferentsii "World Science: Problems and Innovations" [Collection of articles of the XIV International Scientific and Practical Conference "World Science: Problems and Innovations"]. Part 1.* International center for scientific cooperation "Nauka i prosveshchenie", Penza, Russia, 54–56. (In Russian).

Krasnaya kniga Yaroslavskoj oblasti [Red Data Book of the Yaroslavl Region], 2015. Akademiya 76, Yaroslavl, Russia, 472 p. (In Russian).

Krylova, E.G., 2007. Osobennosti struktury i dinamiki rastitel'nogo pokrova ust'evogo uchastka [Features of the structure and dynamics of the vegetation cover of the estuarine area]. In: Krylov, A.V., Bobrov, A.A. (eds.), *Ekosistema maloi reki v izmenyayushchikhsya usloviyakh sredy [The ecosystem of a small river in changing environmental conditions].* KMK, Moscow, Russia, 87–95. (In Russian).

Krylova, E.G., 2015. Struktura rastitel'nogo pokrova [Structure of vegetation cover]. In: Krylov, A.V (ed.), *Gidroehkologiya ust'evykh oblastei pritokov ravninnogo vodokhranilishha [Hydroecology of estuarine areas of tributaries of the lowland reservoir].* Filigran', Yaroslavl, Russia, 109–123. (In Russian).

Krylova, E.G., Tikhonov, A.V., Ivanova, E.S., 2018. Zona vremennogo zatopleniya malykh rek kak uchastok povyshennogo floristicheskogo raznoobraziya [The zone of temporary flooding of small rivers as an area of increased floristic diversity]. *Biosystems Diversity* **26** (1), 30–36. (In Russian).

Lisitsyna, L.I., Papchenkov, V.G., Artemenko, V.I., 2009. *Flora vodoyomov Volzhskogo basseina. Opredelitel sosudistyh rastenii [Flora of water bodies of the Volga river basin. Identification guide of vascular plants]* KMK, Moscow, Russia, 219 p. (In Russian).

Maevsky, P.F., 2014. *Flora srednei polosy Evropeiskoi chasti Rossii [Flora of the temperate zone of the European part of the Russia]*. 11th edition. KMK, Moscow, Russia, 640 p. (In Russian).

Papchenkov, V.G., 1985. O klassifikatsii makrofitov vodoyomov i vodnoj rastitel'nosti [On the classification of macrophytes of the water bodies and aquatic vegetation]. *Ekologiya [Ecology]* **6**, 8–12. (In Russian).

Papchenkov, V.G., 2001. *Rastitel'nyi pokrov vodoemov i vodotokov Srednego Povolzh'ya [Vegetation cover of reservoirs and watercourses*

of the Middle Volga River region]. International Academy of Business and New Technologies, Yaroslavl, Russia, 214 p. (In Russian).

Papchenkov, V.G., 2008. Osobennosti rastitel'nogo pokrova malykh rek [Features of vegetation cover of small rivers]. In: Papchenkov, V.G. et al. (eds.), *Lektsii i materialy dokladov konferentsii "Ekosistemy malykh rek: bioraznoobrazie, ehkologiya, okhrana" [Lectures and abstracts of the conference "Ecosystems of small rivers: biodiversity, ecology, protection"]. Borok, November 18–21, 2008.* Printkhaus, Yaroslavl, Russia, 368 p. (In Russian).

Ricklefs, R., Schluter, D., 1993. Species diversity in ecological communities: historical and geographical perspectives. University of Chicago press, Chicago, USA, 414 p.

Rosenberg, D.M., Vincent, H.R., 1993. Freshwater biomonitoring and benthic macroinvertebrates. *Journal of the North American Benthological Society* **12** (2), 220–222.

Sviridenko, B.F., 1997. Struktura vodnoi flory Severnogo Kazakhstana [The structure of the aquatic flora of the Northern Kazakhstan]. *Botanicheskij zhurnal [Botanical Journal]* **82** (11), 46–57. (In Russian).

Slovar'-spravochnik po ehkologii [Reference book on ecology], 1994. Sytnik, K.M. et al. (eds.). Naukova Dumka, Kiev, Ukraine, 664 p. (In Russian).

Zakonnova, A.V., Litvinov, A.S., 2003. Geomorfologiya, pochvennyj i rastitel'nyj pokrov [Geomorphology, soil and vegetation cover]. In: Krylov, A.V., Papchenkov, V.G. (eds.), *Ekologicheskoe sostoyanie malykh rek Verkhnego Povolzh'ya [Ecological status of small rivers of the Upper Volga River region].* Nauka, Moscow, Russia, 5–9. (In Russian).