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Alien Species of Plants in Aquatic and Semiaquatic Ecosystems of the Vyatka-Kama Cis-Urals

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Abstract—In the territory of the Vyatka-Kama Cis-Urals, 22 species of alien macrophytes are recorded. They compose 6.5% of the number of known macrophyte species known for the region. Most of them do not play an active role in formation of vegetative communities and constitute a part of aquatic communities as accompanying elements (*Amaranthus retroflexus, Chenopodium glaucum, C. rubrum, Xanthium strumarium, Epilobium pseudorubescens, Juncus gerardii, Senecio vulgaris, Typha laxmannii, Mimulus guttatus, Butomus junceus, Scirpus tabernaemontani*, and *Zannichellia repens*). They grow in secondary and open natural ecotones and do not pose a serious threat to aquatic ecosystems in the region because of their low activity in aquatic communities. Among alien species of macrophytes, invasive species are encountered. Some of them (*Najas major, Vallisneria spiralis, Phragmites altissimus, Juncus tenuis*, and *Echinochloa crusgalli*) have become a constant part of secondary biotope communities but pose a threat to indigenous macrophyte species only in specific biotopes where ecological conditions differ significantly from normal ones. Other species (*Elodea canadensis, Epilobium adenocaulon, Impatiens glandulifera, Mentha longifolia*, and *Lemna gibba*) have successfully naturalized in natural ecosystems or have been penetrating into them. The overwhelming majority of alien macrophyte species within the region are plants which do not refer to aquatic plants: hygrophytes (ten species or 45.5%) and hygromesophytes (three species or 13.6%). Only five species (22.7%) belong to hydrophytes and four species are helophytes (18.2%). Six species of alien macrophytes are characterized by transcontinental (North America) drift, 12 species (54.5%) are characterized by transzonal drift, and four species (18.2%) have been introduced from adjacent natural zones.

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INTRODUCTION

The Vyatka-Kama Cis-Ural region covers the territory of the Udmurt Republic and adjacent regions of Perm krai, Kirov oblast, the Republic of Tatarstan, and the Republic of Bashkortostan. The Vyatka-Kama Cis-Ural region belongs to the Volga River basin. The region has an advantageous economic and geographical position. Two large navigable rivers (Kama and Vyatka), two railway branch lines with large junctions crossing the region in the latitudinal direction in the north and in the south, and a dense network of primary roads are favorable for economic ties with other regions of the country. Such conditions, as well as a high degree of anthropogenic transformation of the Vyatka-Kama Cis-Ural region, create the prerequisites for penetration of nonindigenous plants into this territory. The composition of the adventive fraction of the regional flora has been well studied (Tuganayev and Puzyrev, 1988; Baranova et al., 1992; Bakin et al., 2000; Tarasova, 2007). In this respect, we should mention the territory of the Udmurt Republic, where at the beginning of the 21st century more than 940 species of adventive plants have been documented (Puzyrev, 2006). The overwhelming majority of alien species in the region are terrestrial plants. The species of aquatic vegetation growing in waterbodies and watercourses are not numerous. The aim of the study is to analyze the distribution of adventive species of aquatic and semiaquatic plants (macrophytes) in the Vyatka-Kama Cis-Ural region and to make a preliminary assessment of the potential threat of their invasions into freshwater ecosystems.

MATERIALS AND METHODS

The work is based on floristic and geobotanical data obtained by the author in the course of studies conducted in the Vyatka-Kama Cis-Ural region from 1995 to 2010. The published data on findings of adventive species of aquatic and semiaquatic plants in this territory (Tuganayev and Puzyrev, 1988; Baranova et al., 1992; Ovesnov, 1997; Bakin et al., 2000; Puzyrev, 2008, 2009], oral presentations of Puzyrev, and botanical collections of Kapitonov have also been analyzed. The description of the species according the time and way of their immigration and the degree of their naturalization, as well as the relation to a florogenetic element, is presented according to Tuganayev and Puzyrev (1988).

The names of ecobiomorphic groups are given according to Papchenkov (2001).

RESULTS AND DISCUSSION

The analysis of the obtained data and of literature sources shows that the adventive fraction of the flora of aquatic and semiaquatic plants in the territory of the Vyatka-Kama Cis-Urals includes 22 taxa (table), constituting 6.9% of the number of macrophyte species known for the region. According to our data, there are about 320 macrophyte species in the region. The group includes macroalgae, water mosses, and vascular plants, but at present, adventive species are known only among flowering plants.

Most of the alien macrophyte species do not play an active role in formation of the cenoses and are secondary elements in communities of aquatic and semiaquatic plants. Such species as *Amaranihus retroflexus*, *Chenopodium glaucum*, *C. rubrum*, *Xanthium strumarium*, *Epilobium pseudorubescens*, *Juncus gerardii*, *Senecio vulgaris*, and *Typha laxmannii* grow mainly in secondary (puddles along roads, ditches, disturbed banks, flooded open pits, eutrophic shoals) and open natural ecotopes (exposed shoals, beaches). Apparently, these species do not pose a serious threat to ecosystems of waterbodies and watercourses in the region since their activity in aquatic and semiaquatic communities is extremely low. The first four species mentioned above are annual plants and appear in mass on exposed substrates, but they leave the habitats when the environmental conditions change. *E. pseudorubescens* and *T. laxmannii* prefer open habitats. The latter can penetrate into natural cenoses represented mainly by nongrassy moist or wet floodplain meadows on alluvia but do not spread in natural habitats. At the initial stages of overgrowing of disturbed moist habitats *S. vulgaris* is common, but it does not form large populations and is not a competitive species. *J. gerardii* also grows on secondary moist habitats (Tuganayev and Puzyrev, 1988; Puzyrev, 2008, 2009), though its small population was recorded in natural communities of the Kama River bottomland in the south of the region (Kapitonova and Papchenkov, 2003). This species does not demonstrate a high cenotic activity in the region and cannot be classified as an invasive species.

Mimulus guttatus, *Butomus junceus*, *Scirpus tabernaemontani*, and *Zannichellia repens* are rare for the Vyatka-Kama Cis Ural region and, in particular, for semiaquatic ecosystems in the region. Only one finding of the first species was recorded on a floating mat in the Izhevsk Pond (city of Izhevsk) in the region (Efimova, 1972), and after that the species was not collected. The distribution of *B. junceus* in the region is limited: it was found only in the vicinity of the city of Glazov (Baranova et al., 1992) and on islands in the Nizhnekamsk Reservoir (Bakin et al., 2000). *S. tabernaemontani* is rarely found in the southern part of the region, mainly in artificial waterbodies with high water mineralization (e.g., waterbodies on slag piles). *Z. repens* occurs in some waterbodies of the region as small unstable populations formed as a result of periodic introductions. These species do not spread from the sites of their introduction and do not pose a threat to floodplain ecosystems of the Vyatka-Kama Cis-Urals.

However, this group includes species that take an active part in formation of overgrowths of higher aquatic and semiaquatic vegetation, contribute to the process of closure of waterbodies and water courses, and are naturalized in natural or anthropogenic ecosystems. Such species are *Elodea canadensis*, *Najas major*, and *Vallisneria spiralis*. Only the first species has been completely acclimatized and now is a common component both in artificial and transformed ecosystems and in natural ecosystems which are not subjected to anthropogenic effect. In some artificial waterbodies, for example, in flooded open pits, *E. Canadensis* can dominate and form dense stands at depths up to 1 m. Communities with domination of *E. Canadensis* are formed also in polluted waterbodies and water courses. We can consider this species as a polytopic mesoeutrophic ecologically plastic and competitive species. One more species naturalized in natural ecosystems is *Epilobium adenocaulon*. It is a common component in semiaquatic communities, though it does not form its own associations. The other species compete successfully with aboriginal species in secondary habitats.

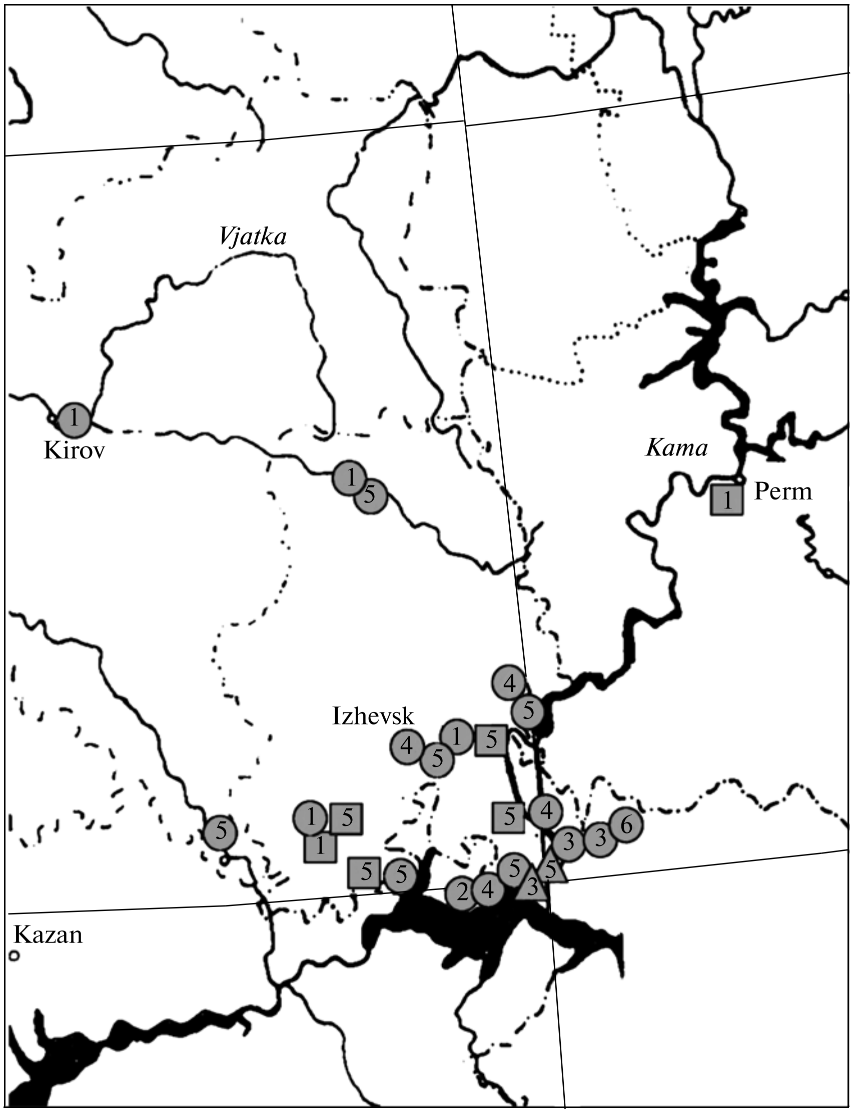
Najas major was recorded in the region in the Bui River (a left tributary of the Kama River) and in the Karmanovsky Reservoir (Fig. 1) 5 years ago. It forms one- or few-species communities where it is a dominant species growing together with *Elodea canadensis* and narrow-leaved pondweed (Kapitonova et al., 2006). The species forms dense stands and flowers and bears fruit actively. Artificial heating of the water in the Bui River and the reservoir caused by the input of warm discharge waters from the Karmanovsky Power Plant is favorable for development of the species. In other rivers lacking the influence of warm waters, the species was not recorded except in the Kama River (within the limits of the Nizhnekamsky Reservoir), where the species was found downstream of the site of the Bui River inflow. Thus, we can consider this species as an invasive one within the limits of the Vyatka-Kama Cis-Ural region, where it could penetrate from its natural habitats, for example, from southern regions of the Republic of Tatarstan, where it is a rare and disappearing species (Bakin et al., 2000). Our observations show that, at the present time, *Najas major* has spread all the way to the Bui River mouth, entered the Kama River, and spread along shoals of the Nizhnekamsky Reservoir. It actively penetrates into natural freshwater cenoses and can be classified as an invasive species; i.e., the species is able to spread over a large territory (Gel'tman, 2006).

Only in the warm water discharge canals of the Karmanovsky Power Plant is one more thermophilous

The main characteristics of alien species of aquatic and semiaquatic plants in the Vyatka-Kama Cis-Urals

	Species name	Ecobiomorphic group	Time of immigration	Way of immigration	Degree of naturalization	Type of range	Florogenetic element
1.	*Amaranthus retroflexus* L.	Hygromesophyte	2	1	3	Hemicosmopolitan	North American
2.	*Butomus junceus* Turcz.	Lowgrass helophyte	2	1	2	Eastern European–Asian	Central Asian
3.	*Chenopodium glaucum* L.	Herbaceous hygrophyte	2	1	1	Holarctic	Irano-Turan
4.	*C. rubrum* L.	Hygromesophyte	1	1	1	Holarctic	Irano-Turan
5.	*Echinochloa crusgalli* (L.) Beauv.	Herbaceous hygrophyte	1	1	3	Holarctic	North American
6.	*Elodea canadensis* Michx.	Submersed rooting hydrophyte	2	1	1	Hemicosmopolitan	North American
7.	*Epilobium adenocaulon* Hausskn.	Herbaceous hygrophyte	2	1	1	Holarctic	North American
8.	*Epilobium pseudorubescens* A. Skvorts.	Herbaceous hygrophyte	2	1	3	Holarctic	North American
9.	*Impatiens glandulifera* Royle	Herbaceous hygrophyte	2	3	1	Cultivated	South Asian
10.	*Juncus gerardii* Loisel.	Herbaceous hygrophyte	2	1	3	Eurasian	Irano-Turan
11.	*Juncus tenuis* Willd.	Herbaceous hygrophyte	2	1	3	Holarctic	North American
12.	*Lemna gibba* L.	Floating, not rooting hydrophyte	2	2(?)	2	Hemicosmopolitan	Tropical
13.	*Mentha longifolia* (L.) Huds.	Herbaceous hygrophyte	2	3	2	Cultivated	Caucasian
14.	*Mimulus guttatus* DC.	Herbaceous hygrophyte	2	3	4	Cultivated	North American
15.	*Najas major* All.	Submersed rooting hydrophyte	2	1	3	Erasian	European–West Asian
16.	*Phragmites altissimus* (Benth.) Nabille	Tallgrass helophyte	2	2	2	Eurasian	Irano-Turan
17.	*Scirpus tabernaemontani* C.C. Gmel.	Lowgrass helophyte	2	1	2	Eurasian	Irano-Turan
18.	*Senecio vulgaris* L.	Herbeceous hygrophyte	2	1	3	Eurasian	Mediterranean
19.	*Typha laxmannii* Lepechin	Lowgrass helophyte	2	1	3	Eurasian	East Asian
20.	*Vallisneria spiralis* L.	Submersed, rooting hydrophyte	2	1	3	Hemicosmopolitan	Tropical
21.	*Xanthium strumarium* L.	Hygromesophyte	2	1	3	Hemicosmopolitan	Irano-Turan
23.	*Zannichellia repens* Boenn.	Submersed rooting hydrophyte	2	1	4	Holarctic	Mediterranian–West Asian (?)

Note: Conventions: time of immigration: 1—archeophyte; 2—kenophyte; means of immigration: 1—xenophyte; 2—akolutophyte, 3—ergasiophygophyte; degree of naturalization: 1—agriophyte, 2—colonophyte, 3—epecophyte, 4—ephemerophyte.



Locations of findings of some invasive macrophyte species in the territory of the Vyatka-Kama Cis-Urals. The numbers indicate (1) *Impatiens glandulifera*, (2) *Lemna gibba*, (3) *Najas major*, (4) *Phragmittes altissimus*, (5) *Typha laxmannii*, (6) *Vallisneria spiralis*. The author's data are denoted by circles, published data and oral presentations by A.N. Puzyrev are denoted by squares, and Kapitonov's collections are denoted by triangles.

species, *Vallisneria spiralis*, recorded (Kapitonova et al., 2006). Vallisneria forms vast thick stands at large depths up to several meters, replacing other species of submersed macrophytes. In warm waters discharged from the power plant, Vallisneria behaves aggressively; it has been naturalized but occurs only in waters where the temperature is higher than values natural for the subtaiga natural zone. This species can pose a threat to native macrophyte species only in specific habitats where the parameters differ from normal ones.

A different mode of behavior is typical of *Impatiens glandulifera*, *Mentha longifolia*, *Phragmites altissimus*, *Juncus tenuis*, *Echinochloa crusgalli*, and *Lemna gibba*. These species have successfully naturalized in secondary habitats and actively occupy natural habitats as well. Probably, in the future, their broad expansion into aquatic and semiaquatic ecosystems of the region can be expected.

The first two of these introduced species have become wild. *I. glandulifera*, escaping from cultivation, occupies moist dense thickets, ravines, small streams, and other moist sites, sometimes forming rather thick one-species stands. In some cities of the region, for example, Izhevsk and Mozhga, as well as in the territory of Kirov oblast (Tarasova, 2003), the species enters the communities of natural biotopes. *I. grandulifera* can be considered as a potential competitive species able to spread within aquatic ecosystems of a region subjected to anthropogenic load. A high invasive potential of the species was mentioned by other authors (Mirkin and Naumova, 2002; Krylov and Reshetnikova, 2009; etc.).

M. longifolia belongs to the group of colonophytes. The species occupies exposed moist banks of small rivers, brooks, and reservoirs and settles in sites of introduction in natural and transformed biotopes. The species can form dense thickets, competing successfully with aboriginal species, but does not leave the sites of its introduction.

The growth of *P. altissimus* in semiaquatic ecosystems of the Vyatka-Kama Cis-Urals was first recorded in 2004 (Kapitonova, 2006), though its penetration into the territory occurred earlier. At present, the species is recorded in several sites in the region (Fig. 1). The obtained data support its status of an adventive species within the territory of the Vyatka-Kama Cis-Urals, where it grows in various disturbed natural and artificial ecotopes forming dense, often one-species thickets. *P. altissimus* is a strong competitor; it flowers and bears fruit and is able to reproduce by seeds. The populations of the species are able to keep their position for a long time and inhabit moist banks and water, sometimes at large depths.

J. tenuis is considered to be a species spreading rapidly in the European part of Russia. Within the Vyatka-Kama Cis-Urals, it occurs in moist sites along roads and can form dense thickets (Tuganayev and Puzyrev, 1988; Puzyrev, 2008, 2009). The large number of findings of the species in recent years attests to its wide dispersal in the region.

L. gibba also spreads rapidly in the Volga River basin (Lisitsyna et al., 2009), and its growth in the territory of the Vyatka-Kama Cis-Urals was documented in 2002 (Kapitonova and Papchenkov, 2003). A local population of the species inhabiting shoals of the Nizhnekamsky Reservoir is found near the northeastern boundary of the European part of the range, but we can expect further expansion of the species into anthropogenically disturbed and eutrophic ecosystems as well as into natural communities.

A persistent weed in fields with hemicosmopolitan range, *Echinochlodea crusgalli* is now a common component of hygrophilous communities of disturbed banks and has been successfully naturalized in secondary habitats.

Thus, the overwhelming majority of alien macrophyte species in the Vyatka-Kama Cis-Urals are plants that are not aquatic ones: hygrophytes (ten species, or 45.5%) and hygromesophytes (three species, or 13.6%). Alien hydrophytes include only five species (22.7%) and helophytes include four species (18.2%). Among 22 species of alien aquatic and semiaquatic plants in the Vyatka-Kama Cis-Ural region, six species of alien macrophytes (27.3%) are characterized by transcontinental (North America) drift, 12 species (54.5%) are characterized by transzonal drift, and four species (18.2%) (*Juhcus gerardii*, *Najas major*, *Scirpus tabernaemontani*, and *Zannichellia repens*) have been introduced from adjacent natural zones. Ten taxa can be regarded as invasive ones. These species have overcome not only the geographical but also the reproductive barrier, have naturalized both in anthropogenically transformed and natural ecosystems, and pose a threat to their structural and functional uniqueness. They successfully compete with indigenous macrophyte species and can, apparently, hybridize with closely related species and form hybrid progeny with even more aggressive characteristics as demonstrated by the conducted studies (Schierenbeck and Ellstrand, 2009).

CONCLUSIONS

High anthropogenic transformation of the natural environment in the Vyatka-Kama Cis-Urals and construction of artificial aquatic and semiaquatic ecotopes create the prerequisites for introduction of alien macrophyte species into aquatic communities. Many of the invasive species are characterized by a high degree of competitiveness and adaptability, thus posing a threat to the integrity and uniqueness of aquatic and semiaquatic ecosystems in the region. In order to make a decision for minimizing possible ecological damage to ecosystems caused by introduction of alien macrophyte species, a system of biological monitoring of waterbodies and watercourses should be organized that should include systematic long-term observations and analysis of information on spreading of this group of plants. Such an information system should include the characteristics of each adventive species using different parameters according to a unified point scale (Lapina, 2006) or by other means, for example, by the method of analysis of ecological ranges suggested by Seledets (Seledets and Probatova, 2007; Seledets, 2010) that makes possible visualization and mathematical treatment of the results of field studies. Such complex assessment will make it possible to reveal the syndrome of the invasive species (Mirkin and Naumova, 2002) using a set of typical features allowing the introduction of the alien species into recipient ecosystems and to develop the concept of the invasive potential of alien species within the territory under consideration.

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