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**СООБЩЕНИЯ**

# ALIEN AQUATIC PLANT SPECIES IN EUROPEAN RUSSIA

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The intense hydrobotanical investigations and high activity of international ornamental trade contributed to the list of the alien aquatic plant species in European Russia during several last decades (late 20th – early 21st centuries). However, the records from the Herbaria were not included in these reports. Our study aimed to complete this inventory by using multiple herbarium sources, our own field observations, and all publicly available references. In this region we identified 26 species of alien aquatic plants species by reporting multiple new localities and status of their invasiveness. Two species from Eastern Asia (*Wolffia globosa*, *Monochoria korsakowii*) have not been observed previously in Western, Central or Southern Europe. Ten species (53%) were originated from North and Central America, four species (21%) – from South America, three species (16%) – from tropics and subtropics of the Old World, one species (5%) – from the Far East, and one species (5%) – from Southeast Asia. We found that the aliens grow predominantly in the rivers with thermal inputs and artificial water bodies. Invasive species occasionally can be found in the non-disturbed aquatic communities, although most of these species have been established in the surroundings of the cities with dense population where they were introduced from aquarium and ornamental culture. According to the classification of invasive plants (Pyšek et al., 2004), twelve species (46%) are the outside cultivation casual plants, and eleven species (42%) are the alien outside cultivation naturalized non-invasive plants. *Elodea canadensis* Michx. and *Lemna minuta* Kunth are characterized by high invasiveness. *Elodea nuttallii* (Planch.) H. St. John most recently also showed more signs of being invasive.

*Keywords:* alien plant, aquatic vascular plant, biological invasion, water body, European Russia
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Currently, the problem of dispersal of plants outside of their natural habitats is very important (Pyšek et al., 2017). Because of the expansion of economic and cultural international relations, the organisms associated with the human activity have been often found beyond their native range (Pyšek et al., 2015; van Kleunen et al., 2015). The alien species often take over the natural habitats, which leads to the loss of the biodiversity in the ecosystems (Dumalisile, Somers, 2017, Pyšek et al., 2017; Starodubtseva et al., 2017; Wagner et al., 2017, Helsen et al., 2018). Many recent studies focus on biological invasion and its management (e.g., Pergl et al., 2016).

The number of new records and resettlement of alien species constantly increased over the past 200 years (Seebens et al., 2017). The most recent high activity of the international ornamental trade accelerates this process (Hüssner, 2012). The investigations of alien plant species have been intensified in many regions worldwide (e.g., Medvecká et al., 2012; Pyšek et al., 2015; Wang et al., 2016; Tuniyev, Timukhin, 2017; Vinogradova et al., 2018). These studies provided the valuable insights on biodiversity in the local (partial) floras, and invasive biology and plant geography in general. The investigations of the alien aquatic plants have been carried out in China (Wang et al., 2016), Japan (Kadono, 2004), Ukraine (Dubina et al., 2017),

and Slovakia (Hrivnák et al., 2019). Information on invasive aquatic plants in Europe has been constantly accumulated (Hüssner, 2012; Anđelković et al., 2016; Lukács et al., 2016; Oertli et al., 2018; Hrivnák et al., 2019), and updated (European and Mediterranean Plant Protection Organization) EPPO, https://www.eppo.int/.

However, the above sources provided incomplete, and in some cases, inaccurate information about the list and distribution of the alien hydrophytes in European Russia. The EPPO was mainly referencing to the study by Vinogradova et al. (2018), although this source along with the earlier publication by the same authors (Vinogradova et al., 2009) did not focus on the exhaustive studying of the alien aquatic species and did not report the status of the invasive species in European Russia, such as: *Eichornia crassipes* (Mart.) Solms and *Pistia stratiotes* L. (EPPO A1/A2 Lists of pests recommended for regulation as quarantine pests); *Cabomba caroliniana* A. Gray, *Egeria densa* Planch. and *Hydrilla verticillata* (EPPO List of invasive alien plants). Moreover, two native species to the European part of Russia (*Lemna gibba* L. and *Zannichellia repens* Boen) were treated as the alien species for this territory (Hüssner, 2012).

A lot of new information about the alien aquatic species in European Russia was accumulated in late 20$^{th}$ – early 21$^{st}$ centuries due to detailed hydrobotanical investigations carried out during this period (Shcherbakov, 1990, 2010; Papchenkov, 2001; Petrova, 2006; Solovyeva, 2008; Vargot, 2009; Laktionov et al., 2014). Unfortunately, most of these results were reported in Russian which made it less accessible to the non-Russian speaking peers.

Our study was aimed to provide more complete and up-to-date inventory of the alien aquatic vascular plants in European Russia. We present an overview of the alien aquatic plant species within European Russia, including their taxonomic composition, habitat preferences, data on the introduction sources and the invasion pathways, as well as their population dynamics and extent of naturalization. Importantly, we hope that our publication in English will help to assimilate this information in the international peer-accessible online sources for the alien plant species.

## MATERIALS AND METHODS

### *Terminology*

We considered as aquatic plants those species which grow only in the aquatic habitats (Papchenkov et al., 2007). The hygrophyte plants which can be found not only in water but also in the terrestrial habitats have not been included in this study.

To define the species of different origin, we used the following terms:

– *native species* – a species originated, evolved, and established on a given territory;

– *alien species* – a species, which has been introduced into a given territory due to the human activity (intentionally) or spread without human influence from a territory where it is considered as alien (unintentionally) (Pyšek et al., 2004);

– *range-expanding native species*, which are currently expanding their geographical ranges (up to several hundred of kilometers during a few decades) due to climate changes or natural reasons.

*Invasive species* are naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from the parent plants, and thus have the potential to spread over a large area (Pyšek et al., 2004).

We differentiated range-expanding native species and alien species on the basis of the following criteria: i) a species invades the area directly from its primary range; ii) propagules are transported by natural agents; iii) a species invades natural habitats or in anthropogenically transformed habitats having natural analogues, such as ponds recognized as analogues of lakes. If a species fits all three criteria, then it could be classified as a range-expanding native species. If one or more criteria are not fulfilled, a species is classified as alien (Shcherbakov, 2014).

In the study, we categorized the alien species according to Pyšek et al. (2004).

### *Area of the study*

In present study, we use the interpretation of the borders of European Russia according to the Wikipedia (https://en.wikipedia.org/wiki/European_Russia). The northern border passes along the coast of the Barents Sea and White Sea, the eastern follows along the main boundary between the East European Plain and West Siberian Lowland (along the Ural Mountains up to the headwaters of the Ural River), then it passes along the Ural River, the boundary between Russia and Kazakhstan, and coast of the Caspian Sea up to the mouth of the Kuma River. The southern border passes along the Kuma River, Manych River, Don River and the coast of the Sea of Azov up to the boundary between Russia and Ukraine. The western boundary is formed by the Russian state border from the Sea of Azov in the south to the Barents Sea in the north.

The European Russia is predominantly located in the temperate climatic zone, but is also represented by the arctic, subarctic, temperate and subtropical zones. It provides a lot of natural (rivers, oxbow lakes, karst, thermokarst, suffosion, karst-suffosion, aeolian, glacial lakes, swamps) and artificial (canals, reservoirs, ponds, treatment facilities, quarries, ditches, flooded ditches, rice paddies, ephemeral water bodies) habitats for the aquatic plant species.

The present study summarized the floristic data on alien aquatic plant species in 43 regions in European

Russia. We did not consider the regions with more than 25% of their area located outside of Europe: i.e., the Sverdlovsk region, Chelyabinsk region, Orenburg region, or Republic of Dagestan. We also did not analyze data from the Kaliningrad region located outside of the main part of European Russia, and the Crimea peninsula where the alien aquatic plant species were studied earlier by Alexandrov et al. (2007).

Due to its large area and heterogeneity of natural conditions, we divided the territory of European Russia into eight macro regions on the basis of similarity of climatic and socio-economic characteristics of regions included in them:

**North (N):** Arkhangelsk, Vologda, Murmansk regions, Republic of Komi, Republic of Karelia, Nenets Autonomous Okrug.

**North-West (NW):** Leningrad, Novgorod, Pskov regions.

**Central Industrial (CI):** Moscow, Bryansk, Vladimir, Ivanovo, Kaluga, Kostroma, Ryazan, Smolensk, Tver, Tula, Yaroslavl regions.

**Volga-Vyatka (VV):** Kirov, Nizhny Novgorod regions, Permsky Krai, Republic of Mari El, Udmurt Republic, Republic of Bashkortostan.

**Central Chernozemny (CC):** Belgorod, Voronezh, Kursk, Lipetsk, Orel, Tambov regions.

**Middle Volga (MV):** Penza, Samara, Ul'yanovsk regions, Republic of Mordovia, Republic of Tatarstan, Chuvashian Republic.

**Lower Volga (LV):** Astrakhan, Volgograd, Saratov regions, Republic of Kalmykia.

**Lower Don (LD):** Rostov-on-Don region.

### *Sourced Data*

The following data were used to determine the distribution of alien aquatic plant species in the macro regions of European Russia.

We used our own field observations of the changes of the aquatic flora during the last 30 years for the following macro regions: CI, CC, LD, LV, MV, VV (see Appendix 1 for the full names of the herbaria). Most of our herbarium vouchers are kept in the MW, MHA, GMU herbarium collections. Some herbarium vouchers were transferred to the herbarium depositories in LE, IBIW and other publicly accessible collections. The additional data were obtained from the publicly available sources (Tzynger, 1885; Sukachev, 1903; Syreischikov, 1914; Rychin, 1948; Krasovskaya, 1955; Maevskii, 1964; Tikhomirov, 1964; Fedorov, 1979; Katanskaya, 1979; Skvortsov, 1982; Ignatov et al., 1990; Alexandrova et al., 1996; Reshetnikova, 1997; Shvetsov, 1997; Klinkova, Sagalaev, 1999; Braslavskaya, 2000; Tzvelev 2000; Plaksina, 2001; Grigoryevskaya et al., 2004; Poluyanov, 2005; Petrova, 2006; Skvortsov, 2006; Khlyzova et al., 2008; Solovyeva, 2008; Kapitonova, 2011; Khlyzova, 1984; Sukhorukov, 2010; Mayorov et al., 2012; Saksonov, Senator, 2012; Seregin, 2012; Laktionov et al., 2014; Maevskii, 2014; Agafonov et al., 2015; Panasenko, Anischenko, 2018; Zarubo, Mayorov, 2020). We also analyzed published data from ten specialized national conferences on aquatic plants (Borok, 1977, 1988, 1992, 1995, 2000, 2003, 2005, 2010, 2015, 2020), six national conferences on alien and synanthropic flora (Tula, 2003; Izhevsk, 2006, 2012, 2017; Moscow, 2012, 2014), and multiple-regional and macro-regional floristic meetings (for example, the meeting in Moscow, 1983; Kursk, 1983). We searched the appropriate sources by using bibliographic data on the floras of USSR (Lipshits, 1975), Central Russia (Syreishchikov, 1914; Gubanov et al., 2002; Kalinichenko et al., 2006, 2011, 2016) and hydro-botanical literature (Garin, 2006). Latin names of alien aquatic plants were employed from the World Flora Online (http://www.worldfloraonline.org/, last visited October 14, 2021).

The following herbarium collections were analyzed: BRSU, BSU, GMU, HERZ, HMNR, IBIW, IVGU, KURS, LE, LECB, MHA, MOSP, MW, MWG, NNSU, OHHI, OKA, PKM, PVB, RSU, RV, RWBG, SARAT, TU, TUL, TVBG, UPSU, VOR, VORG, VU, as well as the Herbarium of P.P. Semenov-Tyan-Shanskiy Lipetsk State Pedagogical University, the Herbarium of Russian State Agrarian University – Moscow Timiryazev Agricultural Academy (see the full names of the herbaria used in this study in the Appendix 1 (Thiers, 2017). We have worked out about 3000 herbarium vouchers. The most important of them are given in Appendix 3.

## RESULTS

We identified 26 alien aquatic plant species and their hybrids from 21 genera and 11 families in European Russia (Table 1, Appendix 2).

Table 1 includes the species listed as alien at least in one region within one of the distinguished macro regions. We included *Lemna gibba* and *Zannichellia repens* in this list, which we consider as native to European Russia by the criteria described above. Nineteen species and one hybrid from 16 genera and seven families are recognized as alien in European Russia. Seven species are alien only in some macro regions, while they are recognized as native species or range-expanding native species in other macro regions. Two species (*Wolffia globosa*, *Monochoria korsakowii*) (MW; MHA; Skvortsov, 2006; Mayorov et al., 2012) have not been observed previously in Western, Central or Southern Europe. Twenty-one species and one hybrid out of 26 species reported in this study for European Russia are new to the latest treatment of the European alien aquatic species (Hüssner, 2012), and to the EPPO website (https://www.eppo.int/). Families Hydrocharitaceae and Araceae contained the largest number of alien aquatic plants (eight and five species, respectively) in European Russia. Families Alismataceae

**Table 1.** The alien aquatic plant species in European Russia
**Таблица 1.** Список чужеземных водных растений Европейской России

| Species | Status | Macro regions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | NW | CI | VV | CC | MV | LV | LD |
| Azollaceae | | | | | | | | | |
| *Azolla caroliniana* | NI | – | – | – | – | – | – | A/2009 | – |
| Nymphaeaceae | | | | | | | | | |
| *Nelumbo nucifera* | NI | – | – | – | – | A/2013 | – | A/18th century | – |
| *Nuphar advena* | C | – | – | A/1914 | – | – | – | – | – |
| ***Nymphaea* × *marliacea*** hort. | NI | – | – | A/1960 | – | – | – | – | – |
| Cabombaceae | | | | | | | | | |
| *Cabomba caroliniana* | NI | – | – | A/1997 | – | – | – | – | – |
| Trapaceae | | | | | | | | | |
| *Trapa natans* | C | – | N | N; A/ late 1950s | N | N | N | N | N |
| Elatinaceae | | | | | | | | | |
| *Elatine triandra* | C | N | N | N | N | REN | – | – | A/1931 |
| Menyanthaceae | | | | | | | | | |
| *Nymphoides peltata* | InH** | A/1886 | A/1952 | N; A/1905 | A/1928 | A/1989 | A/1940s | N | N |
| Araceae | | | | | | | | | |
| ***Lemna minuta*** | C | – | – | A/2008 | – | A/2010 | A/2004 | A/2010 | – |
| *Pistia stratiotes* | C | – | – | A/1998 | – | A/2002 | A/2006 | A/1986 | A/2013 |
| ***Wolffia arrhiza*** | NI** | – | – | REN; ?A/2011 | – | REN; A/ early 1980s | ? | A/1988 | – |
| ****Wolffia globosa*** | C | – | – | A/2002 | – | A/2010 | – | – | – |
| Hydrocharitaceae | | | | | | | | | |
| ***Egeria densa*** | NI | – | – | A/1983 | – | – | – | – | A/1991 |
| *Elodea canadensis* | T | A/1905 | A/1881 | A/1885 | A/1897 | A/1910 | A/1914 | A/1920 | A/1917 |
| ***Elodea nuttallii*** | InH | – | – | A/2017 | – | – | – | – | |
| *Hydrilla verticillata* | C | – | – | A/1972 | – | – | – | – | A/1989 |
| ***Najas graminea*** | NI | – | – | – | – | – | – | A/1993 | A/2007 |
| ***Najas major*** | C** | – | – | REN; A/2011 | REN; A/2005 | REN | N | N | N |
| ****Vallisneria neotropicalis*** | NI | – | – | A/2010 | – | – | – | – | – |
| ***Vallisneria spiralis*** | C | – | – | A/1979 | A/1968 | A/1910 | ? | N | N |
| Alismataceae | | | | | | | | | |
| ***Sagittaria latifolia*** | NI | – | A/1927 | – | – | – | – | – | – |
| ***Sagittaria platyphylla*** | NI | – | – | A/2002 | – | – | – | – | – |
| ***Hydrocleys nymphoides*** | C | – | – | – | A/2009 | – | – | – | – |
| Potamogetonaceae | | | | | | | | | |
| ***Potamogeton nodosus*** | NI** | – | N | REN; A/2010 | A/1968 | REN | REN | N | N |
| Pontederiaceae | | | | | | | | | |
| ***Eichhornia crassipes*** | C | – | – | A/2002 | – | – | – | – | – |

**Table 1.** (Contd.)

| Species | Status | Macro regions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | NW | CI | VV | CC | MV | LV | LD |
| **Monochoria korsakowii* | C | – | – | – | – | – | – | A/1997 | – |
| *Total number of taxa in a macro region:* | | | | | | | | | |
| A | | 2 | 2 | 14 | 5 | 7 | 6 | 8 | 6 |
| N | | 1 | 3 | 1 | 2 | 1 | 3 | 5 | 5 |
| REN | | – | – | – | – | 3 | 1 | – | – |
| N; A | | – | – | 2 | – | – | – | – | – |
| REN; A | | – | – | 3 | 1 | 1 | – | – | – |

*Notes*. Macro regions: N – North, NW – North-West, CI – Central Industrial, VV – Volga-Vyatka, CC – Central Chernozemny, MV – Middle Volga, LV – Lower Volga, LD – Lower Don. Status of invasiveness in the European Russia: A – alien species (/dates of the first registrations); N – native species; REN – range-expanding native species. A sign "?" is used, if the status is assumed. *Alien aquatic plants, have not been observed previously in Western, Central or Southern Europe. **Bold** is used for the names of the species which were not indicated by Hüssner (2012) for European Russia. Status of the alien aquatic plants in European Russia (Pyšek et al., 2004): NI – alien naturalized non-invasive plant, C – alien casual plants, outside cultivation, InH – alien naturalized invasive not harmful plants, outside cultivation, T – alien naturalized invasive transformer plants, outside cultivation. ** – data on alien locations in the regions.

and Nymphaeaceae contained four and three species respectively. The other families included 1–2 species.

The native ranges of the alien aquatic plant species found in European Russia are demonstrated in the Table 2.

Seven plant species are alien regionally (Table 1, Appendix 2). Two regionally alien species *Valissneria spiralis*, and *Nymphoides peltata* are recognized as native plants in the LV and LD macro regions. They are alien in all other macro regions. The range-expanding native species *Wolffia arrhiza*, *Trapa natans*, *Najas major* and *Potamogeton nodosus* started shifting to the north due to climate warming, but some sporadic alien locations are in the CI, VV. The exception was *Elatine triandra*, whose native range is confined mainly to the forest zone. This species was found in the rice paddies in the surroundings of Rostov (LD). In European Russia, this is the only case of alien species invading in a northern direction instead a southern one.

The aliens predominantly grow in the rivers with thermal inputs and artificial water bodies, such as canals, reservoirs, ponds, rice paddies, treatment facilities. Two species (*Elodea canadensis*, and *Lemna minuta*) also grow in the natural water bodies (oxbow lakes, karst, thermokarst, suffosion, karst-suffosion, aeolian, glacial lakes).

The date of the first records, status of invasiveness and invasive activity, and degree of naturalization (Pyšek et al., 2004) are represented in the Table 1. Only two alien aquatic plant species (*Nelumbo nucifera* and *Elodea canadensis*) recorded in 18$^{th}$ and 19$^{th}$ centuries. Six species were found in 1914–1989 years. Most of the localities of aliens in Europaean Russia were recorded in 1990–2020 years (Fig. 1).

Our results demonstrated that the most of the alien aquatic plants belonged to the categories of the outside cultivation casual plants and alien outside cultivation naturalized non-invasive plants (Pyšek et al., 2004).

**Table 2.** Native ranges of the alien aquatic plant species found in European Russia.
**Таблица 2.** Первичные ареалы чужеземных водных растений, отмеченных в Европейской России

| Native range | Number of species | % | Species |
|---|---|---|---|
| North and Central America | 10 | 53 | *Azolla caroliniana*, *Cabomba caroliniana*, *Elodea canadensis*, *E. nuttallii*, *Lemna minuta*, *Nuphar advena*, *Nymphaea* × *marliacea hort.*, *Sagittaria latifolia*, *S. platyphylla*, *Vallisneria americana* |
| South America | 4 | 21 | *Egeria densa*, *Eichhornia crassipes*, *Hydrocleys nymphoides*, *Pistia stratiotes* |
| Tropics and subtropics of the Old World | 3 | 16 | *Najas graminea*, *Nelumbo nucifera*, *Wolffia globosa* |
| Far East | 1 | 5 | *Monochoria korsakowii* |
| Southeast Asia | 1 | 5 | *Hydrilla verticillata* |

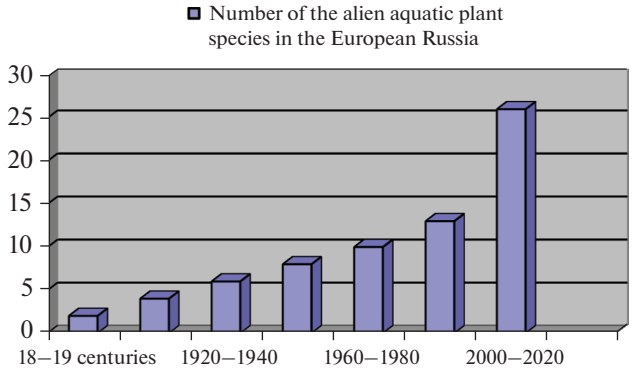


**Fig. 1.** The accumulation of the records of the alien aquatic plant species during the 18th–21st centuries.

**Рис. 1.** Динамика численности чужеземных водных растений в 18–21 веках.

## DISCUSSION

The majority of the alien aquatic plant species (19 species, 73%) were recorded in the CI macro region, predominantly in the rivers and urban ornamental ponds in Moscow region (Table 1, Appendix 2). This massive occurrence of the alien hydrophytes can be explained by presence of multiple water bodies with thermal inputs, and high population density in Moscow region and Moscow city, in particular. The presence of sites with discharge of warm wastewaters makes conditions suitable for existence of hydrophytes (especially in winter) originated from subtropics and tropics of the Old and New Worlds, Southeast Asia and the Far East. Affluent populations in the Moscow region also contributes to the invasion of alien thermophile ornamental plant species from aquarium culture or ornamental waters into these water bodies.

Eight alien species (31%) were found in the CC macro region. Four of them are aquarium plant species (*Pistia stratiotes*, *Wolffia arrhiza*, *Wolffia globosa*, *Vallisneria spiralis*), and have also been found in thermal water bodies in the Voronezh (Appendix 2). Two species (*Nelumbo nucifera*, *Nymphoides peltata*) were potentially cultivated as ornamental plants. *Elodea canadensis* and *Lemna minuta* have been unintentional resettled by means of natural agents.

Six (23%), six (23%), eight (31%) and six (23%) alien plant species were registered in the VV, MV, LV, LD macro regions, respectively. Most of them are aquarium and ornamental plans. The plants originated from the subtropical regions of the Old and New Worlds, as far as from the Far East invaded relatively well-heated waters. They were commonly found in Nizhny Novgorod, Samara, Astrakhan, and Rostov (Appendix 2). Interestingly, *Monochoria korsakowii* and *Najas graminea*, which are known as the typical weeds in the cultivation of rice, began to be found in the LV and LD macro regions in 1997 and 1993, 2007 respectively (Table 1).

The least number of alien aquatic plant species (two, 8%) were recorded in the NW macro region, despite the fact that this Saint-Petersburg is the second largest urban agglomeration in Russia with intensive landscape design. There are numerous discharges of thermal waters similar to those in the surroundings of Moscow and Nizhny Novgorod. It may be explained by the fact that this area belongs to the different biogeographic zone. However, we suggest that a focused study of the flora of water bodies in St. Petersburg may reveal more findings of the alien plant species.

Thus, most of the aliens invade water bodies of European Russia from aquarium culture, similarly to the records from other countries in Eurasia (Kadono, 2004; Hüssner, 2012; Dubina et al., 2017; Wang et al., 2016; Hrivnák et al., 2019; EPPO website). Based on our observations, the thermal inputs majorly contribute to the establishing of the alien aquarium vascular hydrophytes in natural and artificial water bodies of European Russia. The optimal conditions for the invasion of alien aquatic plants were set up in the water bodies at or near the large urban agglomerations.

The most of the alien aquatic species were first recorded in European Russia in the 20th–21st centuries. However, by contrast to the native species, which populations are more established for the longer period of time (Le Roux et al., 2019), the alien species experience constant changes of their ranges. Some of the early findings have been successfully established for centuries since they were recorded (*e.g.*, *Nelumbo nucifera* and *Elodea canadensis*), while others have been reported occasionally in early 20th century, and have never been re-discovered later (e.g., *Nuphar advena* and *Sagittaria latifolia*, Table 1, Appendix 2). Introduced species *Nuphar advena* and *Sagittaria latifolia* were registered only in early 20th century, but have not been re-discovered later. Similarly, *Egeria densa* and *Hydrilla verticillata* were recorded in 1970–1990s (Table 1, Appendix 2). Currently *Egeria densa* has been only found in the surroundings of Moscow (CI; Mayorov et al., 2012), possibly due to the inflow of thermal water into the river Pekhorka. The current status the species population in the LD macro region was not confirmed. The same is applied to *Hydrilla verticillata*, which according to our records, has disappeared from the known locations. However, we do not exclude its possible re-discovery in water bodies of European Russia. Some of the ranges of the alien species have the tendency to expand. For example, in the 2000s, the number of records of *Pistia stratiotes* increased. In addition to the recent records in MV, LV, LD, this species has also been found in the Caucasus (Shapovalov, Saprykin 2016). In most cases (with the exception of a population located in the river Pekhorka, CI), this species behaves as an ephemerophyte (Solovyeva, 2008; Mayorov et al., 2012; Shapovalov, Saprykin, 2016).

Throughout the history of the introduction of the alien aquatic plants in European Russia, different species naturalized with various success. According to the available data (Syreishchikov, 1914; Kaden, 1951; Fedorov, 1979), the introduced species *Nuphar advena* and *Sagittaria latifolia* have not become naturalized in planting sites. We attributed *Nuphar advena*, *Trapa natans* (a population from Moscow), *Elatine triandra*, *Nymphoides peltata*, *Pistia stratiotes*, *Wolffia globosa*, *Hydrilla verticillata*, *Najas major* (a population from Udmurtia), *Vallisneria spiralis*, *Eichhornia crassipes*, and *Monochoria korsakowii* to the alien casual plants, occurring outside cultivation. In the sites where these species were introduced, they did not form the stable populations. Their number, abundance and vitality strongly depended on the weather climatic conditions in the area. *Azolla caroliniana*, *Nelumbo nucifera*, *Nymphaea* × *marliacea* hort., *Cabomba caroliniana*, *Wolffia arrhiza*, *Egeria densa*, *Najas graminea*, *Vallisneria americana*, *Sagittaria platyphylla*, and *Potamogeton nodosus* (the populations from the surroundings of Moscow and Nizhny Novgorod) are the alien naturalized non-invasive plants, occurring outside cultivation. These species formed well-established populations which existed in the known locations for more than ten years. The generative reproduction contributed to establishing of the populations of *Azolla caroliniana*, *Nelumbo nucifera*, *Najas graminea* and *Potamogeton nodosus*. *Cabomba caroliniana*, *Wolffia arrhiza*, *Egeria densa*, and *Vallisneria americana* maintained their populations only due to vegetative reproduction. Among the non-invasive alien plants, the populations of *Cabomba caroliniana*, *Egeria densa*, *Vallisneria spiralis*, *Vallisneria americana* and *Eichhornia crassipes* almost entirely depended on the inflow of heated wastewater to their sites.

Based on our own observations, herbarium and publicly available references (https://www.eppo.int, last time visited October 14, 2021), three species should be determined as invasive (*Elodea canadensis*, *Elodea nuttallii*, and *Lemna minuta*). *Elodea canadensis* is a well-known alien naturalized invasive transformer, which occurred outside its cultivation (Vinogradova et al., 2009). We consider *Lemna minuta* and *Elodea nuttallii* as the alien naturalized invasive species, but not harmful plants, which occurred outside cultivation. The North American species *Lemna minuta* appeared in the flora of European Russia over the past two decades. This species is able to successfully establish in the existing locations as well as invade the other water bodies with the help of birds and aquatic mammals. In 2017, *Elodea nuttallii* has been recorded for the first time in European Russia. However, we expect that, similarly to Europe, this species will actively invade the water bodies and watercourses of Europea Russa, as it did in Europe. The other aliens have been shown low invasiveness, despite the fact that in many countries of Europe (https://www.eppo.int, last time visited October 14, 2021; Hüssner, 2012; Dubina et al., 2017), China (Wang et al., 2016), and Japan (Kadono, 2004) they have been identified as invasive plant species.

Our study identified primarily two ways in which alien aquatic plant invade the water bodies of European Russia. The first way is the intentional introduction: *Nuphar advena* (Syreishchikov, 1914; Kaden, 1951), *Nymphaea* × *marliacea* hort. (Reshetnikova, 1997), *Nelumbo nucifera* (Agafonov et al., 2015; Laktionov et al., 2019), *Trapa natans* (Tikhomirov, 1964), *Pistia stratiotes* (Majorov et al., 2012; Shapovalov, Saprykin, 2016), *Sagittaria latifolia* (Fedorov, 1979), *S. platyphylla* (Majorov et al., 2012), or invasion from an aquarium culture: *Cabomba caroliniana*, *Wolffia arrhiza*, *W. globosa*, *Pistia stratiotes*, *Egeria densa*, *Vallisneria americana*, *V. spiralis*, *Eichornia crassipes* (Majorov et al., 2012), *Hydrocleys nymphoides* (Zarubo, Majorov, 2020), *Monochoria korsakowii* (Skvortsov, 2006). The second way is unintentional resettlement by means of natural agents (waterfowl and aquatic mammals) into water bodies with suitable living conditions: *Azolla caroliniana*, *Elatine triandra*, *Nymphoides peltata*, *Lemna minuta*, *Elodea canadensis*, *E. nuttallii*, *Wolffia arrhiza*, *Najas graminea*, *Najas major*, *Potamogeton nodosus*.

The data provided in this study contributes to more accurate and complete information about the distribution and status of invasiveness for the alien aquatic plants in the Eastern Europe.

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# ЧУЖЕЗЕМНЫЕ ВОДНЫЕ РАСТЕНИЯ ЕВРОПЕЙСКОЙ РОССИИ

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Наша работа посвящена обзору чужеземных водных сосудистых растений Европейской России. На указанной территории выявлено 26 таксонов (25 видов и 1 гибрид); 2 вида (*Wolffia globosa*, *Monochoria korsakowii*) ранее не были учтены в Европе. Десять видов (53%) произошли из Северной и Центральной Америки, четыре вида (21%) – из Южной Америки, три вида (16%) – из тропиков и субтропиков Старого Света, один вид (5%) – с Дальнего Востока и один вид (5%) – из Южной Азии. Преимущественно чужеземные виды произрастают в искусственных водоемах и водотоках с поступлением подогретых сточных вод. Оптимальные условия для вселения чужеземных гидрофитов складываются в водных объектах крупных городских агломераций. Основной источник чужеземных водных растений – аквариумная культура и торговля декоративными видами. Бóльшая их часть выявлена в Европейской России в конце 20 – начале 21 столетия. Это связано с активизацией гидроботанических исследований и развитием международной торговли декоративными растениями в этот период. Чужеземные водные гидрофиты заселяются в водные объекты Европейской России двумя путями: во время намеренной интродукции и непреднамеренного заноса с помощью природных агентов. Большинство выявленных видов обладают низкой степенью инвазивности, являются эфемерофитами и колонофитами. Из 26 видов только *Elodea canadensis* и *Lemna minuta* отнесены к инвазионным растениям. Также мы, на основании анализа вторичного ареала вида, предполагаем в будущем проявление высокой инвазионной активности *Elodea nuttallii*.

*Ключевые слова:* чужеземные виды, водные сосудистые растения, биологические инвазии, водные объекты, Европейская Россия