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Alien invasive species in Siberia: current status and problem

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Abstract: Although alien and invasive plant species have been researched extensively in the European part of Russia, the situation in Siberia is another matter. Hitherto, alien and invasive species in Siberia have not received much attention because this problem was not especially acute in Siberia. The lack of attention on alien and invasive species in Siberia is attributed to three major reasons: 1) Low vegetative productivity and sparse human populations in the Siberian territory have limited botanical research interest in the area. 2) Severe Siberian climate likely prevents many alien and invasive species from increasing their distribution into Siberia. 3) Most Siberian plant communities have not been human-transformed and thus may be resistant to newcomers. Nevertheless, recent increased economic activities have resulted in increasing plant migration to Siberia, and this process should be monitored. Furthermore, global environmental changes may also have made Siberia more favorable for more alien and invasive species. Currently, research on alien and invasive species has begun in the Altai-Sayan region (Western Siberia) and the Magadan region (Northeastern Asia).

Keywords: alien invasive plants; global climate change; economic development; Siberia

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Alien invasive species are species that are accidentally or intentionally introduced by human activities outside of their natural distribution areas to a new geographic area. All too often, invasive species establish themselves, proliferate and disseminate to the detriment of human interests, ecological services and biodiversity. Species migration is a natural process, caused by climate change over geological periods and associated alterations of land and its surface. Nevertheless, species mobility is known to be increasing. One reason for the recent increase of species mobility is globalization, which features the circulation of peoples across the Earth and oceans, high economical activity and complex commercial exchange (McKinney, 2002). Another reason is recent global environmental change, which has provided new opportunities for invasive species to enter and establish in new areas and regions, leading to sustained changes in habitat conditions.

Invasive species have different influences on nature, economies and humans. Besides their negative influences in agriculture that lead to significant economic losses (Elton, 1958), alien invasive species often change species composition within and among plant community types. Through the hybridization of alien invasive species with native relatives, they may alter the gene pool of the latter. Continued introgressive hybridization can result in the complete loss of native species. Alien invasive species directly or indirectly cause the transformation in habitat quality (Heffernan, et al., 2001; Largiadèr, 2007). They can substantially

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change physical and chemical conditions of the environment or seriously alter ecological aspects including geomorphic and hydrologic processes, carbon storage patterns, nutrient cycling, and composition of soil biota. Alien invasive species are an important cause of biodiversity loss worldwide, second only to habitat destruction. The problem of invasive organisms is so important that the Convention on Biological Diversity has accepted the special recommendation that concerns alien invasive species (Convention on Biological Diversity, 2012). In accordance with Guiding Principle 1 for implementation of Article 8(h) of the Convention, every country should prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species. Thus, the Convention binds signatory countries to prevent invasion, evaluate the risk of introduced species, control or eradicate aggressive alien species, and avoid the introduction of the most aggressive alien plants with goods and baggage. This Convention was signed by many countries, including Russia.

1 Situation in Russia

Being located in different natural zones, Russia has a numerous ecological niches for the invasion of alien plants. The preliminary list of invasive species of Russia contains about 1,000 plant species. In the regional flora of the European part of Russia, about 20% of species are invasive. This percent is much greater in towns (Afonin et al., 2008). Most alien species in Eastern Europe are observed along railways and in other ruderal habitats. In Eastern Europe, many naturalized alien species occur in riparian habitats, where alien species naturalize most easily (Vinogradova, 2009). Because many invasive species are also considered to be weeds, the Federal Service for Veterinary and Phytosanitary Surveillance of Russia, the Ministry of Agriculture of the Russian Federation, and the Agricultural Academy of the Russian Federation are involved in the research and control of these species. Scientific Institutes of the Russian Academy of Science also pay a great deal of attention to alien species. Agroecological atlas of Russia and adjacent countries (Afonin et al., 2008) is devoted to weeds, many of which are known to be invasive. The last significant work that was devoted to research of invasive plants in Russia was by Vinogradova (2009). This work contains full information for 52 of the most dangerous alien invasive species.

Different species have different abilities for invasion in natural communities. Some of them, after being introduced, cannot grow out of fields and gardens, whereas others, having been introduced occasionally, can distribute themselves very quickly and invade communities, replacing native species. Thus, predicting the potential risk of accidentally or intentionally introduced alien plants is very important. The primary tool for screening the potential for invasion by weeds has been developed by Moskalenko (2002). This primary screening is based on the potential of concurrent ability, potential harm, and the area of potential distribution of the species. Potential of concurrent ability is based on the biological features of plants. Moskalenko (2002) recognized 12 characters that could reveal potentially aggressive species. These characters include: seed formation, vegetative reproduction, minimum generation time, early and rapid seed germination in broad temperature limits, root system with storage potential, capability to affect other plants by inhibitors, herbicide resistance, and distribution of seeds and fruits by wind, water, or animals. Potential harm may be evaluated using such characters as decreasing the yield of agricultural plants, decreasing the technological quality of production, making harvesting more difficult, decreasing productivity of meadows and pastures, danger to humans and animals, ability to transmit organisms that cause diseases of agricultural plants, and ability to host fungi and insects. The area of potential distribution is the area where climatic conditions match those for species occurrence (Rabotnov, 1983), which is often determined using bioclimatic models based on GIS technologies. The integrative evaluation can reveal potentially invasive species. Revealing alien and invasive species and developing the database on these species have been done by Russian scientists (Morozova, et al., 2008; Morozova and Borisov, 2010). The AliS database (Morozova and Borisov, 2010) is the basis for the monitoring and bioclimatic modeling of possible distributions of 1,295 alien (adventive) plant species in the European part of Russia, based on GIS technologies. This database includes data on morphology, biology, dis-

tribution, period of invasion, and lists of synonyms (Morozova, 2005). Their research on the potential impacts of alien species on the structure and diversity of local floras in European part of Russia suggests that alien species do not significantly alter taxonomic structure. Research of urbanized flora, which contains many more alien species, has similar conclusions. The number of alien species increases from North to South in Russia according to the data of Morozova (2005). Nevertheless, significant correlations between the number of alien species and latitude was not significant (r= –0.23, P=0.18), whereas the correlation between species diversity and latitude was significant (r=0.55, P<0.01). Overall, the distribution of alien species, and their biology and influence on local flora have been researched quite intensively and effectively in the European part of Russia.

Unfortunately, all these achievements concern the European part of Russia only. Siberia forms the greatest proportion of Russia's geographical area and is highly variable both in topography and natural vegetation. Nevertheless, the problem of invasive species in the Asian part of Russia, and in Siberia particularly, has not yet been researched properly, and literature devoted to invasive and other alien species in this territory is scarce.

2 Situation in Siberia

The most recent and detailed research on the alien species in Siberia was made by Ebel (2001, 2011), who studied the flora of the northwestern part of Altai-Sayan province. In his papers, due regards were given to adventive and alien species, and 10 new adventive species, *Amaranthus povelii* S. Watson, *Chenopodium atripliciforme* Murr, *Erucastrum gallicum* (Willd.) O.E. Schulz., *Euphorbia peplus* L., *Geum macrophyllum* Willd., *Ipomea purpurea* (L.) Roth, *Nonea versicolo* (Steven) Sweet, *Persicaria bungeana* (Turcz.) Nakai in T. Mori, *Setaria faberi* Herrm., *Veronica agrestis* L. have been documented throughout Siberia. Of species investigated by Ebel (2011), 487 (19.5%) are likely to be human-induced migrants. These species belong to 299 genera and 76 families, with 221 introduced accidentally and 266 introduced intentionally. Ebel (2011) proposed a new detailed classification for these species:

(1) Adventive (inducing) element–species that have been introduced accidentally.

1) Archeophytes. Th e most ancient group of alien plants in this area, which were introduced while Russia developed this land. The main evidence of their age is the presence of their diasporas in archeological remains. About 20 species belong to this group– *Cannabis sativa* L., *Bunias orientalis* L., *Pastinaca sativa* L., *Avena sativa* L., and *Panicum ruderale* Kitag are some examples.

2) Neophytes (coenophytes). Ebel recognized 3 groups among the neophytes based on their time of migration.

(a) Hemicoenophytes (17–19 centuries before railway building). It contains about 19 species.

(b) Eucoenophytes (after the beginning of the 20th century until the 1980s). This group consists of 130 species.

(c) Ultracoenophytes (introduced after 1980s). This migration was caused by alteration of transport and migration directions and changing agricultural management. This group includes 63 species. Some of them are successful settlers (*Centaurea stoebe* L., *Geum macrophyllum*), whereas others still only occur as points of distribution (*Arctium leiospermum* Juz. et C. Serg., *Lotus corniculatus* L.).

(2) Introduced element. These plants have been introduced intentionally.

1) Non-naturalized. The plants cannot complete their whole life cycles under natural Siberian conditions. Most of them are annuals, and they are present for only one of the following seasons:

(a) Occasional. Species that appear in this area but not every year: *Callistepus sinensis* (L.) Nees, *Papaver somniferum* L., and *Tagetes patula* L. are examples.

(b) Regular. Species that occur in the same places every year (road sides, field sides, wetlands): *Solanum tuberosum* L., *Helianthus annuus* L., and *Avena sativa* are examples.

2) Naturalizing (non-developing).

(a) Relics of culture. Plants that have been growing in the same place (old parks, locations of old settlements, cemeteries) for a long time without human

disturbance: *Aronia mitchurinii* Skvortsov et Maitulina and *Phlox paniculata* L. are two examples. Some of these species propagate vegetatively (*Dianthus barbatus* L.), whereas others propagate by seeds (*Syringa vulgaris* L.).

(b) Colonophytes. Plants that can propagate in the same place and persist for more than one year without the arrival of new propagules from outside: *Acer tataticum* L., *Convallaria mayalis* L., *Helianthus tuberosus*, *Armoracea rusticana* (Lam.) Gaertner, and *Malus domestica* Borkh. are examples.

3) Naturalized (developing). Species that develop and complete their life cycles without human disturbance and *Malus baccata* (L.) Borkh. and *Impatiens glandulifera* Royle. are two examples.

(a) Epectophytes. Settle themselves mainly in anthropogenic areas: species include *Ulmus laevis* Pall., *Amelanchier spicata*, Lupinus *polyphyllus* Lindl., *Saponaria officinalis* L., and *Echinoyistis lobata.* (Michx.) Torr. et Gray.

(b) Agriophytes (invasive species). Plants that settle themselves actively, and sometimes even aggressively, within natural communities and have the capacity to change ecosystems by forcing out the native species: species include *Acer negundo* L., *Calystegia subvolubilis*, and *Malus baccata*.

Based on his research on the flora of the northwestern part of Altai-Sayan province, Ebel (2011) recognized widely distributed invasive species in this area (i.e. those that occur in at least 1/2 of the regions of the research area), such as *Bunias orientali*s, *Echinochloe crus galli* (L.) Beauv., *Pastinaca sativa*, *Tripleurospermum inodorum* (L.) Sch. Bip., *Coniza canadensis* (L.) Cronq., *Lepidotheca suaveolens* (Pursh.) Nutt., *Trifolium hybridum* L., *Acer negundo*, *Echinocystis lobata*, *Impatiens glandulifera*, and *Malus baccata*. Ebel (2011) also noted potentially invasive species that have not settled widely. Although this classification is detailed and readily adaptable to other regions, Ebel's research covers only a restricted area of the huge Siberian territory, the remainder of which is poorly investigated concerning alien and invasive species.

When analyzing the situation of alien and invasive species in the Asian part of Russia, what should be mentioned is the research of Lysenko (2010a, b) which devoted to the alien plants of the Magadan oblast (Northeastern Asia). This region is one of the least populated areas in Russia, and its industrial development began less than 100 years ago. Moreover, because of the extremely severe climate, agriculture, and consequently the inflow of alien species associated with crop planting, is very restricted. Poor development of road networks allowed the control of alien plant migration both with goods and along roadsides. Lysenko inferred that, in spite of agriophytes being present in the Magadan region, invasive species are absent. This absence may be due to the severe climate, and the age of the adventives flora of this region, i.e. alien plants merely have not had sufficient time to become invasive. Lysenko's research provides a list of alien species, prevailing routes of plant migrations, and patterns of naturalization.

Nevertheless, in spite of the real achievements in some specific Siberian areas, a comprehensive list of the alien species of Siberia has not yet been completed, which is mainly because the invasive species in Siberia appear quite stable. A number of reasons may explain this situation. One is a low density of the human population and roads. These factors likely limit the distribution of alien species along roads. Another reason is the severe Siberian climate, which prevents the establishment and naturalization of most invasive species. Because of the severe climate, population densities of alien species are much lower in Siberia than in the European part of Russia, and their potential impact is also smaller. The main reason is that Siberia has not ever invaded by aggressors like other countries and even the European part of Russia. In fact, alien species such as *Acer negundo*, *Impatiens glandulifera*, *Hordeum jubatum* L., and *Echinocystis lobata* (Mich.) Torr. et Gray are rather welcome in Siberian settlements because they cover trash dumps, making them look like flowerbeds, and do not need human care.

As in other areas, the presence of alien species in Siberia is related to the history of economic development in the region. Very low economic activities and mobility of human population until the 16^{th}–18^{th} centuries, i.e. before ethnic Russians penetrated this land, caused a low level of "attendant" plants. A new epoch

of plant migration (mainly from the West to the East) began during 1891–1905, when the Trans-Siberian railway was built. Although construction of the Trans-Siberian railway is considered to be the outset of greatest plant invasion into Siberia, two main periods of plant immigration along this railway are recognized. Both are associated with human migrations. The first took place after the railway was built, when, due to Stolypyn's economic reforms, many people moved from European Russia to Siberia. The second great migration of people and technical equipment was during the first years of the Great Patriotic war (1941–1945), when people and factories were evacuated from the occupied European part of Russia to Siberia.

The recent history of economic development in Siberia also has implications for plant community disturbance and stability. Diverse, well-balanced plant communities use natural resources quite completely and effectively and generally are more resistant to invasions than human-transformed communities with restricted biodiversity. Thus, established natural vegetation, which is typical to most of Siberia, is usually resistant to new-comers. Nevertheless, the economic development of Siberia resulted in plant community disturbance and increased plant immigration. To help understand plant invasions, Siberian botanists are starting to pay more attention to invasive species, especially at Siberian botanical gardens where they evaluate the risk of alien species escape and their potential to become naturalized. Botanists at the botanical gardens determine which alien species escape and which become naturalized, and they try to prevent horticulturists from introducing potentially invasive species. Thus, despite the overall lack of research in Siberia, the appearance of new species is usually registered by botanists. Thus, some new species that are primarily distributed along roads were observed near Tomsk, Siberia during the last 25–30 years. These species include: *Echium vulgare* L., *Impatiens glandulifeera*, *Pastinaca sativa*, *Coniza canadensis*, *Hordeum jubatum*, and *Poa compressa* L. One species of special concern is *Poa compressa*, which is considered by some botanists to be invasive. This species occurs throughout most of Europe, the Far East and North America. Recently, it appeared near Tomsk (Olonova, 2003) and some other Siberian towns. *Poa compressa* hybridizes easily with *Poa palustris* L. in disturbed habitats and can alter the balance between the two species, resulting in the loss of native biodiversity.

Some ornamental plants, such as *Amaranthus*, are known to be potentially invasive. The Siberian Botanical Garden and the Department of Ecological Management of Tomsk State University have begun to research potentially invasive species. Species of special interest are *Heracleum sosnowskii* Manden., *Amaranthus rethroflexus* L., *A. albus* L., *A. cruentus* L., and *Helianthus tuberosus* L. These potentially invasive species occur in Siberia, but most of them have not been introduced into natural communities yet and do not cause visible economic losses. Thus, because the status of invasive species in Siberia appears quite stable, research on biodiversity in Siberia focused mainly on the conservation of rare and vulnerable native species and their communities.

3 Conclusions

Although invasive species in Siberia do not currently appear to be a major issue, we must be cautious. Initially after introduction, increases in the distribution of alien plants is usually quite slow (some potentially invasive species in Siberia may merely be in this latent period), but after a lag of perhaps 10–20 years, spread of invasive species can increase dramatically (Lacey, 1957). Although Siberian natural ecosystems are typically sustainable and resistant to invasions, disturbance caused by industrial development of this region may result in both the loss of native species and plant communities and the invasion of alien species. Analysis of the distributions of new invasive and weedy species that have migrated into the Tomsk area during the last few years indicates that most of these species are of southern origin (*Urtica cannabina* L., *Leersia orizoides* (L.) Sw., *Eriochloe villosa* (Thunb.) Kunth., and *Sorgo sudanence* (Piper) Stapf.). Although lower temperatures can stop their northward migration, published models of climate change suggest that future global warming will no longer climatically limit their distribution in Siberia. Furthermore, some species are able to adapt to climatic

changes, such as the Colorado potato beetle that has appeared in potato fields of the Tomsk oblast despite the severe Siberian climate. However, some botanists have proposed that day length could prevent the range expansion of some potentially invasive species, but this hypothesis needs to be verified.

Thus, although the status of alien species in Siberia is now stable, more research and control efforts should be made, because the current status could rapidly change for a number of reasons.

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