Invasive species in Kamchatka: distribution and communities

Larisa M. Abramova 1, Olga A. Chernyagina 2, Elizaveta A. Devyatova 3*

ABSTRACT
This paper presents information about the distribution of invasive plant species in the Kamchatka Peninsula and the communities formed by these species in the urban areas. Some of these species are from the "black list" of invasive plants of Russia and some plants are usual for central Russia. These species were introduced to the Kamchatka Peninsula and actively spread over the urban area in recent years. We assign communities with the dominance of the species under study to 2 classes of vegetation: Galio-Urticetea and Molino-Arrhenatheretea. The paper presents the prodromus of vegetation communities with the dominance of the invasive species and a brief description of the syntaxa. The invasive species successfully invade synanthropic habitats, including the natural communities. It is necessary to observe their ecological status and find ways to prevent their further spread in the Kamchatskii Krai.

Keywords: Kamchatka, synanthropic vegetation, alien plants, invasive species, invasion focal points

The previous examination of synanthropic flora of the Kamchatka was only fragmentary and now requires an overall inventory. Some alien species actively spread due to the development of housing construction, road networks and transport systems (Devyatova et al. 2015). Among them there are problematic invasive species. These species produce numerous progenies, spread over the region and often invade into natural habitats. We started the examination of the urban areas of Petropavlovsk-Kamchatskiy and other settlements in 2012. This paper presents data concerning the communities formed by some alien species: Heracleum sosnowskyi Manden., Impatiens glandulifera Royle, Symphytum caucasicum Bieb., Lupinus polyphyllus Lindl., Reynoutria sachalinensis (Fr. Schmidt) Nakai, Tussilago farfara L., Vicia cracca L., Arctium tomentosum Mill. They include both species of Russia's invasive plants “Black List” (Vinogradova et al. 2015) and the plants of the temperate zone of Russia.

MATERIAL AND METHODS
The Kamchatskii Krai is a federal entity of the Russian Federation. It occupies the territory of the Kamchatka Peninsula with the continental adjacent part of the mainland, Karaginsky island and Commander Islands. The administrative center is the city of Petropavlovsk-Kamchatskiy; with a population of about 180 000 people.

Petropavlovsk-Kamchatskiy stretches along 25 km of the eastern coast of Avacha Bay which is a part of the Pacific Ocean (53°01’ N 158°39’ E). The city has a strong

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mountainous relief ranging from 0 to 380 m a.s.l. The territory of Petropavlovsk-Kamchatskiy covers the eastern coastal sub-region and has a maritime climate with excess humidity. Intensive cyclonic activity is the basic climate-forming process especially during autumn and winter (Kondratyuk 1983). The average annual temperature is +2.1°C. The average daily temperature in January is -8.7°C, in August +14°C. The active growth period of vegetation lasts from the 22nd of May to the 14th of October. The average annual precipitation is 1300 mm with 56% during winter. The number of days with snow cover is 177 with an average maximum height of snow cover of 136 cm.

Since 2012, we observed the territories of Petropavlovsk-Kamchatskiy, Yelizovo, Vilyuchinsk and 9 villages: Paratunka, Apacha, Sosnovka, Esso, Anavgay, Klyuchi, Iwashka, Palana and Ossora.

For the investigation of Petropavlovsk-Kamchatskiy territory, we made geobotanical survey of synanthropic communities formed by alien species and obtained 66 relevés. We estimated the abundance of species according to the Braun-Blanquet scale as follows: r – the occurrences of species are single, the cover-abundance rating is insignificant; + – the species occurs rarely, the cover-abundance rating is low; 1 – the number of the species is high but the cover-abundance rating is low, up to 5 %; 2 – the cover is 5–25 %; 3 – the cover is 25–50 %; 4 – the cover is 50–75 %; 5 – the cover is more than 75 %. The constancy of species in the communities was estimated according to five-grade scale: I – 1–20 %; II – 21–40 %; III – 41–60 %; IV – 61–80 %; V – 81–100 %.


We preceded the relevés in accordance with the principles of ecological-floristic classification (Braun-Blanquet 1964) with the application of the deductive method of Kopecký-Hejny (Kopecký 1974). This allowed us to classify depauperate, seral and derivative (replacement) communities with the participation of alien species. This method has been often used in Russia in recent years for the classification of various communities with invasive plant species (Bulokhov et al. 2008, 2011, Abramova 2011a, 2015, Golovanov & Abramova 2012, Abramova et al. 2013, Panasenko et al. 2013, Arepjeva 2015).

We included relevés into the database of TURBOVEG (Hennekens 1995) and processed with an aid of the Juice program (Tichy 2002).

RESULTS

As a result of the investigation 8 alien species are found in the city of Petropavlovsk-Kamchatskiy, which can be considered invasive for the Kamchatka region in the whole. We studied communities with the dominance of these species and classified them as derivative i.e. replacement communities. The communities belong to 2 classes: the class of nitrophilic communities of shady habitats Galio-Urticetea and the class of meadow vegetation Molinio-Arrhenatheretea.

We present the prodromus of vegetation communities with the dominance of the invasive species and short description of the revealed syntaxa below.

Class GALIO–URTICETEA Passarge ex Kopecký 1969
Derivative communities:
- Heracleum sosnowskyi [Galio-Urticetea]
- Reynoutria sachalinensis [Galio-Urticetea]
- Symphytum caucasicum [Galio-Urticetea]
- Tussilago farfara [Galio-Urticetea/Polygono arenstri-Poëtea annuae]
- Arctium tomentosum [Galio-Urticetea]
- Impatiens glandulifera [Galio-Urticetea]

Class MOLINIO-ARRHENATHERETEA R.Tx 1937
Order Arrhenatheretalia R.Tx 1937
 Alliance Cynosurion R.Tx 1947
Derivative communities:
- Lupinus polyphyllus [Molinio-Arrhenatheretea]
- Vicia cracca [Molinio-Arrhenatheretea]

Derivate community Heracleum sosnowskyi [Galio-Urticetea] (Table 1, cluster 1)

Sosnovsky hogweed is one of the most aggressive invasive species of the European part of Russia (Vinogradova et al. 2010, 2015). It is one of priority targets for research and control (Dgebuadze 2014), because it is a serious threat to ecosystems.

Initially, Sosnovsky hogweed was introduced into Kamchatka as a silage crop. In 1985 thickets of H. sosnowskyi appeared on the experimental plots of Kamchatka Agricultural Research Station in Sosnovka. Moreover, H. sosnowskyi nowadays covers extensive areas of lawns and grows on heated soils near the thermal pools, wells and pipelines of the Paratunka resort area in Yelizovsky district. We recorded the focal point of invasion of Sosnovsky hogweed in Petropavlovsk-Kamchatskiy in 2010 near the pipeline in “Seroglazka” district (Chernyagina & Strecker 2012). The plants reach a height of 3.5–4.0 m, have good vitality and abundant fruiting. Nowadays we note an active expansion of Sosnovsky hogweed about the territory of the city.

Composition. H. sosnowskyi dominates in the community and forms practically monodominant thickets. Species of the class Galio-Urticetea mainly occur in the community. The number of species is from 5 to 12, with the average species abundance of 8 species.

Structure. The community has a 2-layer structure. H. sosnowskyi plants form the upper layer (from 1 to 3 m), while other plants occupy the lower layer and have a small height (up to 30 cm). The total cover is 100 %.

Ecology. We observed the community on well-lit slopes of southern exposure, near heating pipelines, along road-sides (Fig. 1A).

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<th>Cluster</th>
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<td>Reynoutria sachalinensis</td>
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<td>Impatiens glandulifera</td>
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<td>Lapinus polyphyllus</td>
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<td>Vicia cracca</td>
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D.s. of Galio-Urticetea Class

Artemisia opulenta IV IV IV IV V IV V
Rumex longifolius III IV IV IV V V I III
Cirsium setosum III II II II III III
Festuca repens V II III IV IV IV I V
Brassica inermis | | I | I | | | | |
Urtica pilulifera | | I | I | | | | |
Acer pseudoplatanus | | I | I | | | | |
Hordeum lanatum | | I | I | | | | |
Impatiens noli-tangere | | | I | | | | |
Galeopsis bidentata | | | I | | | | |
Rumex acetosella | | | | | | | |
Taraxacum officinale | I IV III V IV V V

D.s. of Molinio-Arkhenatheretea Class

Rumex acetosella | I II | I | I |
Taraxacum officinale | I IV III V IV V V

Note. Beside above mentioned, the following species were observed: Rumex acetosella 4 (I), Barbarea orthorea 4 (II), Salix alba 1 (I), Ranunculus arvensis 4 (I), Rumex crispus 6 (I), Alnus incana 2 (I). Species of the community with great constancy. The quantity of species in the community is 7–11, with an average of 9 species.

Structure. The community has a 2-layer structure. The sprouts of Reynoutria sachalinensis form the upper layer (from 1 to 3 meters high). Also there are rare sprouts of Artemisia opulenta, Rumex longifolius in this layer. Low-growing species occur in the lower layer (Taraxacum officinale, Stellaria media).

The total cover is 100%.

Ecology. Yards, front gardens, abandoned kitchen gardens, lawns, often in the shade (Fig. 1B).

Derivate community Symphytum caucasicum [Galio-Urticetea] (Table 1, cluster 3)

Blue comfrey, or Caucasian comfrey, is a species of “Black Book of the flora of Russia’s Temperate Zone” (Vinogradova et al. 2014). Species of the class Galio-Urticetea (Artemisia opulenta, Rumex longifolius) and the class Molinio-Arkhenatheretea (Taraxacum officinale, Poa angustifolia) occur in the community with great constancy. The quantity of species in the community is 7–11, with an average of 9 species.

Structure. The community has a 2-layer structure. The sprouts of Reynoutria sachalinensis form the upper layer (from 1 to 3 meters high). Also there are rare sprouts of Artemisia opulenta, Rumex longifolius in this layer. Low-growing species occur in the lower layer (Taraxacum officinale, Stellaria media).

The total cover is 100%.

Ecology. Yards, front gardens, abandoned kitchen gardens, lawns, often in the shade (Fig. 1B).

Derivate community Symphytum caucasicum [Galio-Urticetea] (Table 1, cluster 3)

Blue comfrey, or Caucasian comfrey, is a species of “Black Book of the flora of Russia’s Temperate Zone” (Vinogradova et al. 2014). Species of the class Galio-Urticetea (Artemisia opulenta, Rumex longifolius) and the class Molinio-Arkhenatheretea (Taraxacum officinale, Poa angustifolia) occur in the community with great constancy. The quantity of species in the community is 7–11, with an average of 9 species.

Structure. The community has a 2-layer structure. The sprouts of Reynoutria sachalinensis form the upper layer (from 1 to 3 meters high). Also there are rare sprouts of Artemisia opulenta, Rumex longifolius in this layer. Low-growing species occur in the lower layer (Taraxacum officinale, Stellaria media).

The total cover is 100%.

Ecology. Yards, front gardens, abandoned kitchen gardens, lawns, often in the shade (Fig. 1B).
The plant is used as an ornamental in the gardens of apartment buildings and private houses. *S. caucasicum* grows wild in lawns, dumps, and spreads in hillsides and meadows. The plant begins to grow under the winter snow cover and has early flowering pattern. It is commonly found not only in the city of Petropavlovsk-Kamchatskiy but also in Esso (Bystrinsky district).

**Composition.** The species dominates in the communities. In Petropavlovsk-Kamchatskiy, it is cultivated on the sites near cottage-houses and in the front gardens of blocks of flats as an unpretentious plant which is easy to control. Species of the class Galio-Urticetea (*Artemisia opulenta*, *Rumex longifolius*) often occur in the community. The species abundance is from 4 to 16 species, on average 9 species.

**Structure.** Community has mainly a two-layer structure. In some cases there is a shrub layer with *Rosa auxifolia* or *Rubus idaeus*. In the upper layer the comfrey dominates. Also sprouts of *Artemisia opulenta*, *Rumex longifolius* can be observed. In the lower layer *Stellaria media*, *Taraxacum officinale*, *Plantago major* and other low-growing plants prevail. The total cover is 100 %.

**Ecology.** The community occupies the plots near the walls of blocks of flats, front gardens and often grown in the shade. It also occurs along the slopes of the hills in residential areas of the city (Fig. 1C).

**Derivate community Tussilago farfara**
*Galio-Urticetea/Polygony arenstri-Poëtea annuae* (Table 1, cluster 4)

Coltsfoot in central Russia is an ordinary native ruderal species. In Kamchatka it is a progressive invasive plant. Plant seeds were brought for cultivation in 1970–80’s. *T. farfara* soon became a weed observed in gardens and flower-beds. The species became common in Petropavlovsk-Kamchatskiy during last 10 years. Plants begin to grow and form flower buds under the winter snow cover. *T. farfara* now is widespread in Yelizovsky district, Esso (Bistrinsky district) and Palana (Tigilsky district of Koryak Okrug).

**Composition.** *T. farfara* dominates in the community. It grows in disturbed habitats (refuse piles of ground, new roadsidess) (Chernyagina et al. 2013). Species of the class Galio-Urticetea (*Artemisia opulenta*, *Elytrigia repens*) mainly form the community. *Plantago major* and *Taraxacum officinale* occur frequently. The number of species in the community is from 9 to 16 with an average species abundance of 11 species.

**Structure.** One layer which is represented by low-growing plants. The average height of the herbage is 30 cm. The total cover is 70–100 %.

**Ecology.** The community occupies open sites: lawns, yards, slopes of southern exposure, roadsides (Fig. 1D)

**Derivate community Arctium tomentosum**
*Galio-Urticetea* (Table 1, cluster 5)

Cotton burdock is a common species of ruderal habitats in the temperate zone of Russia. It is an introduced species for Kamchatka. *A. tomentosum* forms replacement communities on the lawns and in the city yards. First found in 1989 in Klyuchi in the Ust-Kamchatsk district, the species established to the south due to road improvements. Nowadays it occupies lawns, dumps and yards. The plant has a good vitality and abundant fruiting. It actively spreads in Petropavlovsk-Kamchatskiy and Yelizovo, villages of Yelizovsky district, Klyuchi (Ust-Kamchatsk district), and Palana (Tigilsky district of Koryak Okrug).

**Composition.** *A. tomentosum* is the dominant species of the community. Species of the class Galio-Urticetea (*Artemisia opulenta*, *Rumex longifolius*, *Elytrigia repens*) occur with high constancy. The intensity of cotton burdock spreading increased in recent years. It is facilitated by regular lawn mowing in the city and is further assisted with the appearance of vacant habitats in eroded sites (Chernyagina et al. 2013). The species number is 7–15; the average is 11.

**Structure.** The structure of the community depends on the nature of the occupied habitats. In the city yards the community has a two-layer structure. The upper layer which is 100–110 cm high is formed by the sprouts of *Arctium tomentosum*, *Rumex longifolius* and *Artemisia opulenta*.

Low-growing plants, such as *Stellaria media*, *Por annua*, *Plantago major* form the lower layer (15–20 cm). On the lawns and along the roadsides the height of the herb layer depends on the frequency of mowing procedures and constitutes 20–30 cm. In this case the community has one layer. The total cover is 70–100 %.

**Ecology.** The community occupies open sites: yards, roadsides, lawns (Fig. 1E).

**Derivate community Impatiens glandulifera**
*Galio-Urticetea* (Table 1, cluster 6)

Ornamental jewelweed is another aggressive species from the “Black Book” and “black-list” of the flora of Russia (Vinogradova et al. 2010, 2015). As in other regions of Russia, *I. glandulifera* was used as an ornamental garden plant. It grows in wet areas, moist roadsides, osier-beds, streams and competes with the native *I. noli-tangere* L. It has good vitality and abundant fruiting. We commonly find the plant in the settlements of southern and central Kamchatka, and in Ivashka (Karaginsky district of the Koryak Okrug).

**Composition.** This invasive species dominates in the community. It becomes invasive, spreading from front gardens of apartment blocks and single detached houses and penetrates the natural habitats. Species of the class Galio-Urticetea (*Artemisia opulenta*, *Rumex longifolius*) occur with high constancy. The species number is 7–15, average 10.

**Structure.** The community has one-layer or two-layer structure. The upper layer which is up to 80 cm in height and represented by the sprouts of *Impatiens glandulifera*, *Artemisia opulenta*, *Cirsium setosum*. The lower layer which is up to 30–40 cm in height and formed by *Taraxacum officinale*, *Stellaria media*. The total cover is 70–100 %.

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Figure 1 Derivative communities of invasive alien plants in Kamchatka. A – Heracleum sosnowskyi; B – Reynoutria sachalinensis; C – Symphytum camassianum; D – Tussilago farfara; E – Arctium tomentosum; F – Impatiens glandulifera; G – Lupinus polyphyllus; H – Vicia cracca.
Ecology. The community occurs on shady slopes in the residential areas, along streams, on well-lit sites: abandoned front-gardens, yards, along the roads (Fig. 1F).

Derivate community *Lupinus polyphyllus* [Molinio-Arrhenatheretea] (Table 1, cluster 7)

Bigleaf lupine is an alien species from the “Black Book of the Flora of Russia’s Temperate Zone” (Vinogradova et al. 2010) and the “black-list” (Vinogradova 2015). For a long time it was cultivated in Petropavlovsk-Kamchatskiy as an ornamental plant. Over past years we observed the spread of *L. polyphyllus* in osier-beds and meadows along roads. It has active seed reproduction. The species is common in Petropavlovsk-Kamchatskiy and Yelizovsky districts. The lupine commonly occurs in the city near the foundations of multi-storey buildings, on untended lawns, in weedy places, in abandoned kitchen-gardens and plots. The species is a “refugee” from the cultivated plants group. It starts blooming in July on the slopes of city hills (in the “Sergolazka” and “Horizon” districts) and along Khalaktyrskoye Highway.

Composition. Lupine is the dominant in the community. Meadow species of the class *Molinio-Arrhenatheretea* (*Taraxacum officinale*, *Psyllium pratense*, *Achillea millefolium*) and the class *Galio-Urticetea* (*Artemisia opulenta*, *Cirsium setosum*) occur with high constancy. The number of species in the community is 6–18, the average is 12.

Structure. There is mainly one layer. In some cases there is a shrub layer formed by *Rosá amóphiotes*, *Grassuária nua-crispa* or *Rubus idaeus*. The average height is 90 cm. The total cover is 100%.

Ecology. Open slopes of hills, roadsides, yards (Fig. 1G).

Derivate community *Vicia cracca* [Molinio-Arrhenatheretea] (Table 1, cluster 8)

Bird vetch is one more common meadow species of the Temperate zone in Russia. The plant became an invasive species for Kamchatka. Nowadays we observe the intensive spread of the species in Kamchatskiy (Chernyagina & Strecker 2012). In Alaska *V. cracca* is a species with a high invasive rank. The plant is known in the Kamchatka Peninsula since the early 20th century. Komarov (1954) first recorded *V. cracca* in Ust-Bolsheretskoy district as a weed of field crops. Today the species is widespread over the territory of Kamchatskiy.

Composition. *Vicia cracca* determines the appearance of the community. Species of the alliance *Gynosurion* and the class *Molinio-Arrhenatheretea* (*Taraxacum officinale*, *Psyllium pratense*, *Amoría repens*), as well as of the class *Galio-Urticetea* (*Cirsium setosum*, *Elytrigía repens*) occur with high constancy. The species composition consists of from 7 to 14 species; the average number is 11 species.

Structure. The community mostly possesses a twolayer structure. The main layer is represented by the sprouts of *Artemisia opulenta*, *Elytrigía repens*, *Cirsium setosum*, *Rumex longifolius*, which are densely entangled by *V. cracca*. The second layer which is up to 20 cm in height is represented by low-growing plants, such as *Plantago major*, *Amoría repens*, *Taraxacum officinale*. The height of the herbage varies from 20 to 90 cm. The total cover is from 60 to 100%.

Ecology. The community occurs on well-lit sites: lawns, roadsides, yards (Fig. 1H).

DISCUSSION

Nowadays, the problem of alien species invasion is a part of the global change of ecosystems. The world scientific communities have widely discussed the impact of the alien species on the natural communities and their interaction with the native species (Johnstone 1986, Biological invasions... 1990, Thompson 1997, Tilman 1997, Falinskii 1998, Lonsdale 1999, Parker et al. 1999, Richardson et al. 2000, Kowarik 2003, Didham et al. 2005, Hulme 2007, Pyšek et al. 2012, Anačkov et al. 2013). Alien plants are able to compete with the native species and even displace them from the natural communities. This causes dystrophication and simplification of phytocenoses structure by breaking the ecological ties in the community. Understanding the processes of invasion is important for the development of effective ways of controlling invasive species and the damage they can do to native species and ecosystems (Gurevitch & Padilla 2004). The explosive expansion of alien species may be caused by anthropogenic transformation of habitats, climate change, absence of pests and pathogens etc. Alien plants often form monodominant communities and hybridize with native species. Besides, alien plants perform the role of new host-plants for parasites and pathogenic agents (involving stronger infections) and as well they can exert a specific influence on pollinating insects (King & Sargent 2012, Engelkes & Mills 2013). Comparing alien floras and invasive species of different regions is necessary for understanding general patterns of invasion process (Pyšek et al. 1998, 2004).


The weed flora of Kamchatskiy was not previously sufficiently studied. For the first time Komarov (1954) investigated alien flora during his travel within Kamchatka in 1908-1909. Fedorchenko (1971) presented further data of weed flora of the region. In 1973 Ulyanova (1976, 1982) examined weed infestation of Kamchatskiy’s agricultural crops. She noticed that the Kamchatka weed flora was rather poor in comparison with other regions of the Far East and the species composition of weed plants was not stable and depended on the introduction of alien plans. She revealed only 75 species. In recent years Chernyagina studied alien flora and invasive plant species of the region (Chernyagina et al. 2012, 2013, 2014). She revealed that in Kamchatka weed plant species frequently expand in the areas of thermal springs.

Our research shows that the most of the invasive species concentrated in the Yelizovsky district (Fig. 2). This re-
The investigation of invasion processes is especially important for such a unique region as Kamchatka. Aesthetically valuable landscapes attract lots of tourists whose activity may cause a chain reaction of mass spreading of species that are undesirable for the regional ecosystems. For this reason monitoring of invasive species condition is necessary as well as seeking ways of restraining their spread across the Kamchatka Krai.

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LITERATURE CITED


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