Invasive species in phytocenosis of Sterlitamak town (Republic of Bashkortostan, Russia)

Ya M Golovanov¹, L M Abramova¹ and S S Petrov²

¹ Botanical Garden-Institute Ufa Scientific Centre RAS, Ufa, Russia
² Sterlitamak Branch of Bashkir State University, Sterlitamak, Russia

E-mail: jaro1986@mail.ru, abramova.lm@mail.ru

Abstract. There were 69 invasive and potentially invasive species in the flora of Sterlitamak in the Bashkortostan Republic (Russia). Eight are in the most dangerous types of invasive species. The greatest danger is represented by: Acer negundo, Ambrosia trifida, Elodea canadensis and Xanthium albinum. Within the boundaries of Sterlitamak, 21 syntaxa (13 associations and 8 derivated communities) are invasive species. This phytocenosis in an urban environment can be prime targets for plant quarantine actions.

1. Introduction
Invasions of alien species have long been a global ecological problem, and therefore interest in the study of invasion processes has increased in the whole world. Papers dedicated to penetration of invasive species are numerous and diverse [1, 2, 3, 4, 5]. The dispersal of alien plants is one of indicators of a drastic change in the ecological situation in the modern period and the result of anthropogenic transformation of the natural vegetation [6]. As Ch. S. Elton [7] stressed, the main cause of mass distribution of invasive species is anthropogenic disturbance of self-regulation processes of ecosystems in the absence of antagonist species. In recent years, research of invasions of alien species in Russia has increased [8, 9, 10, 11], and intensification of invasions of aggressive new species, mainly of North American origin, has been noted.

Currently in the Republic of Bashkortostan (South Urals), expansion and naturalization has been observed of North American invasive species of the family Asteraceae Dumort, from genera Ambrosia L., Xanthium L., Bidens L., Galinsoga Ruiz & Pav., Cyclachaena (Iva) Fresen, and others [8, 12, 13]. Naturalization, i.e. the introduction of new plant species into communities, is considered the highest degree of acclimatization and adaptation to a new habitat.

Cities are the first and largest locations of invasion by new species, which leads to «floristic pollution of the territory». Big cities, such as Sterlitamak in the Republic of Bashkortostan (RB), with their developed transport network and large areas of disturbed territories occupied by ruderal communities, are the locations for introduction and fixing of new synanthropic species, from which they extend further into agricultural ecosystems [14, 15].

2. Material and methods
We studied the flora and vegetation of Sterlitamak during 2014–2016. Sterlitamak is located in the south of Cisurals of the Republic of Bashkortostan in the fluvial plain of the Belaya River. The
territory of the town is characterized by a continental climate. The average temperature in January is –14.7°C, the average temperature of July – +19.2°C, and the average annual amount of precipitation is 410–460 mm. A large branch of a federal highway from Ufa to Orenburg passes through Sterlitamak. The town also possesses a developed industrial complex.

During the research, areas of invasive species were noted, and vegetation plots of these communities were analyzed. Data were sampled according to the methods of Zürich-Montpellier school [16].

Invasive plants of the «black list» of flora of RB, were maintained in a regional «Black book», as recommended, and divided into 4 groups of different invasive status.

Status 1. Species that actively penetrate natural and semi-natural communities, change the shape of ecosystems, disturb syngenetic communications, act as dominants, form homotypical thickets of area, and force out and/or interfere with reproduction of natural flora species.

Status 2. Alien species that actively settle and naturalize in disturbed semi-natural and natural habitats.

Status 3. Alien species that settle and naturalize in disturbed habitats and after further naturalization some of them, apparently, will be able to penetrate semi-natural and natural communities.

Status 4. Potentially invasive species capable of reproduction and demonstrated to drift into adjacent regions as invasive species [17].

3. Result and discussions
In the flora of Sterlitamak, several invasive and potentially invasive species of plants (table 1) are noted. Eight species are placed in the most dangerous types of new invasive status. Mostly similar species penetrate various floodplain habitats, frequently meeting on the shores of reservoirs, and they are characteristic of disturbed habitats. The greatest danger, currently, to ecosystems of the town comes from Acer negundo, Ambrosia trifida, Elodea canadensis and Xanthium albinum. The first 3 species belong to priority species for research and control [18], and Ambrosia trifida for plant quarantine in all territory of the Russian Federation.

The second group (10 species) of invasive species of plants are in Status 2. Similar species commonly occur in various disturbed habitats and are less widely found in natural, undisturbed habitats. The highest invasive potential in Sterlitamak is possessed by Echinochloa crusgalli and Fraxinus pennsylvanica, which are commonly found in disturbed habitats.

The third group (24 species) contains species commonly found in various ruderal habitats and not naturalized in undisturbed plant communities. Most of the species of this group are the widespread weeds often forming a monodominant phytocenosis. These are such species as: Atriplex tatarica, Conyza canadensis, Kochia scoparia, Lactuca serriola, etc.

The most numerous group contains potentially invasive species of plants – 27 species. In the future, these species can occupy Status 1 – 3 in their danger of invasiveness.

Analysis of occurrence of invasive species in the highest levels of disturbed habitats (table 2) has shown that 2 invasive species are the most widespread: Acer negundo and Conyza canadensis which occur in almost all sinantropic vegetation classes. The most significant fact is presence of juvenile individuals and young growth of Acer negundo in practically all investigated coenofloras. That speaks about the very strong invasive potential of this species in anthropogenic transformed coenofloras [19].

Often, invasive species of plants are not only a component of coenofloras, but also form monodominant communities. Currently, 21 syntaxa (13 associations and 8 derivated communities) have been identified in the territory of Sterlitamak, with domination by the above-named species. Similar communities are easily identified by the characteristic invasive species acting in a role of dominant. Similar phytocenosis in the urban environment can be prime targets for phytoquarantine actions.
## Table 1. Invasive and potentially invasive species in Sterlitamak town.

| N  | Species                  | Family     | Invasive status | Occurrence | Habitat                                           |
|----|--------------------------|------------|-----------------|------------|---------------------------------------------------|
| 1. | Acer negundo             | Aceraceae  | 1               | Frequent   | Disturbed habitats, afforestation, floodplains    |
| 2. | Ambrosia trifida         | Asteraceae | 1               | Occasional | Disturbed habitats, floodplains                    |
| 3. | Bidens frondosa          | Asteraceae | 1               | Occasional | Banks of rivers, disturbed habitats               |
| 4. | Xanthium albinum         | Asteraceae | 1               | Occasional | Banks of rivers, disturbed habitats               |
| 5. | Cyclachaena xanthifolia  | Asteraceae | 1               | Occasional | Disturbed habitats                                |
| 6. | Echinocystis lobata      | Cucurbitaceae | 1            | Frequent   | Banks of rivers, osiers                          |
| 7. | Elytrigia juncea         | Poaceae    | 1               | Frequent   | Rivers, ponds                                     |
| 8. | Hordeum jubatum          | Poaceae    | 1               | Occasional | Road borders, railways                            |
| 9. | Carda acaenoides         | Asteraceae | 2               | Common     | Disturbed habitats                                |
| 10. | Solidago canadensis      | Asteraceae | 2               | Frequent   | Abandoned gardens                                 |
| 11. | Alyssum turkestanicum    | Brassicaceae | 2              | Very rare  | Disturbed steppe                                 |
| 12. | Cardaria draba           | Brassicaceae | 2             | Occasional | Road borders                                     |
| 13. | Lupinus polyphyllus      | Fabaceae   | 2               | Rare       | Abandoned gardens                                 |
| 14. | Fraxinus pennsylvanica   | Oleaceae   | 2               | Frequent   | Floodplains, disturbed habitats                   |
| 15. | Echinocystis crusgalli   | Poaceae    | 2               | Frequent   | Banks of rivers, disturbed habitats               |
| 16. | Collomia linearis        | Polemoniaceae | 2            | Very rare  | Railways                                          |
| 17. | Portulaca oleracea       | Portulacaceae | 2           | Occasional | Flower gardens, railways                         |
| 18. | Saponaria officinalis    | Caryophyllaceae | 2          | Occasional | Meadows, disturbed habitats                       |
| 19. | Amaranthus albus         | Amaranthaceae | 3            | Occasional | Railways, disturbed habitats                      |
| 20. | A. bidentis              | Amaranthaceae | 3            | Occasional | Disturbed habitats                                |
| 21. | A. retroflexus           | Amaranthaceae | 3            | Common     | Disturbed habitats                                |
| 22. | Artemisia sieversiana    | Asteraceae | 3               | Occasional | Disturbed habitats                                |
| 23. | Conyza canadensis        | Asteraceae | 3               | Frequent   | Disturbed habitats                                |
| 24. | Galinsoga ciliata        | Asteraceae | 3               | Rare       | Flower gardens                                    |
| 25. | G. parviflora            | Asteraceae | 3               | Rare       | Flower gardens, disturbed habitats                |
| 26. | Helianthus tuberosus     | Asteraceae | 3               | Occasional | Abandoned gardens, flower gardens                 |
| 27. | Lactuca serriola         | Asteraceae | 3               | Common     | Disturbed habitats                                |
| 28. | Lepidium densiflorum     | Brassicaceae | 3            | Occasional | Trampled habitats                                 |
| 29. | Onopordum acanthium      | Asteraceae | 3               | Rare       | Disturbed habitats                                |
| 30. | Senecio vernalis         | Asteraceae | 3               | Rare       | Road borders                                      |
| 31. | S. viscosus              | Asteraceae | 3               | Rare       | Railways                                          |
| 32. | Lepidium densiflorum     | Brassicaceae | 3            | Occasional | Trampled habitats                                 |
| 33. | Atriplex tatarica        | Chenopodiaceae | 3         | Common     | Disturbed habitats                                |
| 34. | Kochia scoparia          | Chenopodiaceae | 3        | Frequent   | Disturbed habitats                                |
| 35. | Cuscuta campestris       | Cuscutaceae | 3               | Occasional | Disturbed habitats                                |
| 36. | Hippophae rhamnoides     | Elaeagnaceae | 3            | Rare       | Abandoned gardens                                 |
| N  | Species           | Family    | Invasive status | Occurrence | Habitat                   |
|----|------------------|-----------|-----------------|------------|----------------------------|
| 37 | *Medicago sativa* | Fabaceae  | 3               | Occasional | Disturbed habitats         |
| 38 | *Elsholtzia ciliata* | Lamiales  | 3               | Very rare  | Road borders               |
| 39 | *Bromus japonicus* | Poaceae   | 3               | Occasional | Disturbed habitats         |
| 40 | *B. squarrosus*   | Poaceae   | 3               | Frequent   | Disturbed habitats         |
| 41 | *Setaria japonica* | Poaceae   | 3               | Occasional | Disturbed habitats         |
| 42 | *S. viridis*      | Poaceae   | 3               | Frequent   | Disturbed habitats         |
| 43 | *Acroptilon repens* | Asteraceae | 4               | Very rare  | Disturbed habitats         |
| 44 | *Phalacroloma septentrionale* | Asteraceae | 4              | Very rare  | Road borders               |
| 45 | *Symphyotrichum novi-belgii* | Asteraceae | 4              | Occasional | Abandoned gardens         |
| 46 | *S. × salignum*   | Asteraceae | 4               | Rare       | Abandoned gardens         |
| 47 | *Impatiens glandulifera* | Balsaminaceae | 4        | Rare       | Banks of streams         |
| 48 | *I. parviflora*   | Balsaminaceae | 4             | Very rare  | Flower gardens            |
| 49 | *Symphytum caucasicum* | Boraginaceae | 4           | Rare       | Flower gardens            |
| 50 | *Armoracia rusticana* | Brassicaceae | 4          | Occasional | Abandoned gardens, dumps, meadows |
| 51 | *Sisymbrium volgense* | Brassicaceae | 4          | Very rare  | Road borders               |
| 52 | *Sambucus racemosa* | Caprifoliaceae | 4       | Rare       | Riparian forests          |
| 53 | *Bryonia alba*    | Cucurbitaceae | 4           | Rare       | Abandoned gardens         |
| 54 | *Caragana arborescens* | Fabaceae | 4             | Occasional | Afforestation, road borders, railways |
| 55 | *Galega orientalis* | Fabaceae | 4             | Rare       | Road borders, railways, abandoned gardens |
| 56 | *Epilobium pseudorubescens* | Onagraceae | 4           | Very rare  | Moist habitats            |
| 57 | *Xanthoxalis stricta* | Oxalidaceae | 4          | Very rare  | Lawns                     |
| 58 | *Anisantha tectorum* | Poaceae | 4             | Rare       | Railways                  |
| 59 | *Digitaria sanguinalis* | Poaceae | 4             | Rare       | Railways, flower gardens  |
| 60 | *Lolium perenne*   | Poaceae   | 4             | Frequent   | Lawns                     |
| 61 | *Aquilegia vulgaris* | Ranunculaceae | 4          | Occasional | Abandoned gardens         |
| 62 | *Amelanchier alnifolia* | Rosaceae | 4             | Rare       | Afforestation, railways   |
| 63 | *Cerasus vulgaris*  | Rosaceae  | 4             | Frequent   | Abandoned gardens, railways |
| 64 | *Malus domestica*  | Rosaceae  | 4             | Rare       | Abandoned gardens         |
| 65 | *Rosa pimpinellifolia* | Rosaceae | 4         | Occasional | Abandoned gardens, afforestation, railways |
| 66 | *Populus balsamifera* | Salicaceae | 4       | Occasional | Afforestation, disturbed habitats |
| 67 | *Typha laxmannii*  | Typhaceae | 4             | Very rare  | Moist habitats             |
| 68 | *Ulmus pumila*     | Ulmaceae  | 4             | Occasional | Road borders, railways, afforestation |
| 69 | *Parthenocissus quinquefolia* | Vitaceae | 4           | Occasional | Abandoned gardens, riparian forests, disturbed habitats |
Table 2. Representation of invasive species in units of vegetation of the disturbed habitats of Sterlitamak town.

| Species/Syntaxa | S. m. | Art. | P- | G- | Bid. |
|-----------------|------|-----|----|----|-----|
|                 | Sis. | A-C.| A. | On.| Ag. | P. | U. |
| Xanthium albinum| I    | -   | I  | -  | -  | -  | V |
| Bidens frondosa | I    | -   | -  | -  | -  | -  | IV|
| Acer negundo    | I    | -   | IV | II | I  | -  | III|
| Ambrosia trifida| I    | -   | -  | -  | -  | -  | II|
| Conyza canadensis| I  | II  | II | I  | I  | -  | II|
| Echinocystis lobata| I | I   | -  | -  | -  | -  | II|
| Cuscuta campestris| I  | -   | I  | -  | I  | -  | II|
| Cyclachaena xanthiifolia| I | -   | -  | -  | -  | -  | I |
| Lepidiothea suaveolens| I  | -   | I  | -  | -  | -  | I |
| Hordeum jubatum  | -    | -   | -  | I  | -  | -  | I |
| Anisantha tectorum| -  | -   | -  | I  | -  | -  | I |
| Galinsoga ciliata| I   | -   | -  | -  | -  | -  | - |
| G. parviflora    | I    | II  | -  | -  | -  | -  | - |
| Lepidium densiflorum| I  | -   | -  | -  | -  | -  | - |
| Fraxinus lanceolata| I  | -   | -  | -  | -  | -  | - |
| Portulaca oleracea| I  | -   | I  | -  | -  | -  | - |
| Impatiens glandulifera| - | -   | -  | -  | -  | -  | I |
| Total            | 13   | 4   | 2  | 5  | 2  | 6  | 7 |

**Note.** I–V — Classes of constancy.

Classes of vegetation: S.m. — *Stellarietea mediae* (Orders: Sis. — *Sisymbrietalia*, A-C. — *Atriplici-Chenopodietalia albi*, Art. — *Artemisietea vulgaris* (Orders: A. — *Artemisietalia vulgaris*, On. — *Onopordetalia acanthii*, Ag. — *Agropyretalia repens*), P-P. — *Polygono arenastri–Poëtea annuae*, P-A. — *Polygono-Artemisietea austriacae*, G-U. — *Galio–Urticetea*, Bid. — *Bidentetea tripartitae*.

Table 3. Sytaxis with dominating invasive and potentially invasive species in Sterlitamak town.

| Syntaxa                        | Occurrence |
|--------------------------------|------------|
| **Sytaxis with dominating of 1 group species** |            |
| Association *Elodeetum canadensis* Nedelcu 1967 | Frequent   |
| Association *Chelidonio-Aceretum negundi* Ishbirdina et Ishbirdin 1989 | Frequent   |
| Association *Polygonetum hydropiperis* Passarge 1965 variant *Bidens frondosa* | Occasional |
| Association *Salici-Populetum* (R. Tx. 1931) Meijer Drees 1936 variant *Acer negundo* | Occasional |
| Derivated community *Xanthium albinum* [Potentillion anserinae/Bidentetea tripartitae] | Occasional |
| Derivated community *Ambrosia trifida* [Potentillion anserinae] | Occasional |
| Association *Ivaetum xanthiifoliae* Fijałkowski 1967 | Rare       |
| Association *Polygono avicularis–Hordeetum jubati* Abramova, Golovanov 2016 | Rare       |
| **Sytaxis with dominating of 2 group species** |            |
| Association *Carduetum acanthoidis* Felföldy 1942 | Frequent   |
| Derivated community *Cardaria draba* [Artemisietea vulgaris] | Occasional |
| Association *Setario pumilae–Echinochloëtum crus-galli* Felföldy 1942 corr. Mucina in Mucina et al. 1993 | Rare       |
| **Sytaxis with dominating of 3 group species** |            |
| Association *Conyzo canadensis–Lactucetum serriolae* Lohmeyer in Oberdorfer 1957 | Frequent   |
| Association *Convolvulo arvensis–Amaranthetum retroflexi* Abramova et Sakhapov in Ishbirdin et al. 1988 | Frequent   |


Syntaxa | Occurrence
---|---
Association *Atriplicetum tataricae* Ubryszy 1949 | Frequent
Association *Kochietum densiflorae* Gutte et Klotz. 1985 | Occasional
Derived community *Cuscuta campestris* [Polygono arenstri–Poëtea annuae] | Rare
Derived community *Bromus squarrosus* [Sisymbrietalia/Onopordetalia acanthii] | Rare
Derived community *Galinsoga ciliata* [Stellarietea mediae/Molinio-Arrhenatheretea] | Rare
Derived community *Galinsoga parviflora* [Stellarietea mediae/Molinio-Arrhenatheretea] | Rare

Sytaxa with dominating of 4 group species

Derived community *Digitaria sanguinalis* [Stellarietea mediae] | Rare
Association *Calystegio sepium–Impatientetum glanduliferae* | Rare

4. Conclusions
The intensification of anthropogenic impact within the urban area leads to the formation of a greater number of habitats, favorable for invasions, and active penetration and naturalization of aggressive invasive species of plants. The most vulnerable to this process are areas near railway stations and, in general, railways, highways with adjacent habitats, elevators and banks of water bodies (especially the banks of the Ashkadar and Belaya rivers).

But practically all phytocenoses within city lines contain up to 74% of the alien species [19] which can become further invasive. Therefore, territories of the large cities have to be objects of continuous monitoring of penetration and formation of invasion centers of aggressive, new plant introductions, and these areas demand measures to decrease their numbers by using all suppression methods possible.

Acknowledgment
The reported study was funded by RFBR according to the research project № 17-04-0037.

References
[1] Lonsdale M 1999 *Ecology* **80** (5) 1522–36
[2] Richardson D M and Pysek P 2006 *Progr. Phis. Geogr* **30** (3) 409–431
[3] Chytry M, Maskell L, Pino J, Pyšek P, Vila M, Font X and Smart S 2008 *J. Appl. Ecol.* **45** (2) 448–458
[4] Lambdon P W et al. 2008 *Preslia* **80** 101–149
[5] Pyšek P et al. 2009 *Diversity and Distributions* **15** 891–903
[6] Burda R I 1991 *Anthropogenic Transformation of Flora* (Kiev: Naukova Dumka)
[7] Elton C 1958 *The Ecology of Invasions by Animals and Plants* (London: Methuen)
[8] Abramova L M 2012 *Russian Journal of Ecology* **43** (5) 352–357
[9] Abramova L M 2014 *Bull. Acad. Sci. Rep. Bashk.* **19** (4) 16–27
[10] Vinogradova Yu K, Mayorov S R and Horun L V 2010 *Black book of flora of Central Russia* (Moscow: GEOS)
[11] Panasenko N N 2014 *Ross. Zhurn. Biol. Invas.* **2** 127–132
[12] Abramova L M 1997 *Bot. Journ.* **82** (1) 66–74
[13] Abramova L M 2003 *Bot. Journ.* **88** (4) 67–76
[14] Golovanov Ya M and Abramova L M 2011 *Bull. Voronezh State Univ.* **1** 173–176
[15] Golovanov Ya M and Abramova L M 2013 *Bull. Altai State Univ.* **1** (3) 27–30
[16] Braun-Blanquet J 1964 *Pflanzensociologie* (Wien)
[17] Abramova L M and Golovanov Ya M 2016 *Proc. Ufa Sci. Center RAS* **2** 54–61
[18] Dgebuadze Y Y 2014 *Ross. Zhurn. Biol. Invas.* **1** 2–8
[19] Golovanov Ya M and Abramova L M 2016 *Vegetation of Russia* **28** 28–36