Period of Blooming in the Plant Community as an Indicator of Human Impact (by Example of Komsomolsk-on-Amur)

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Abstract. Currently, phenology is actively used to display and study the effects of climate factors and human impacts on ecosystems. Researchers described phenological responses of plants to climatic and anthropogenic changes, as well as phenological features of alien species, as a factor determining the success of the invasion. In Komsomolsk-on-Amur (Khabarovsk region, The Far East of Russia) a database on the blooming of plants for the city residential areas and Silinsky forest was compiled on the basis of photo archive of plants. Silinsky forest is undisturbed woodland in the city. The flora of the Silinsky forest consists of 378 species of blooming plants, of which 329 plants are native species, 49 ones are alien species. The flowering plants flora of the residential areas of Komsomolsk-on-Amur consists of 518 species: 264 species are native, 254 ones are alien. Blooming was counted for decades. Comparative assessment of blooming periods was conducted for native and alien species taking into account their range and eco-phytocenotic preferences. There is a smoothing of typical features for the region in the more disturbed residential area. The alien fraction contributes to this. The June peak of blooming is disappearing, there is a shift of blooming to the end of summer. Thus, the phenological characteristics of the community can be used as an indicator of anthropogenic pressures.

1. Introduction
Phenology as a science has been existing for almost 200 years. For most of this time, its main goal was to solve narrowly applied tasks in agriculture. Phenology as a fundamental direction had application in plant systems and ecology of communities. A new surge in interest in phenology has been sparked by a study of the effects of global climate change [1-4]. The blooming time is a shift in to an earlier period in the conditions of warming [5]. On the one hand, the early blooming of entomophilic plants is a competitive advantage [6, 7]. It promotes a more active visit of flowers by pollinator insects. Also in dry years early blooming contributes to more efficient use of moisture. On the other hand, the shift in blooming time forms the asynchrony of the life cycles of plants and insects. In addition to the temperature in the dry areas, the amount of precipitation is a significant factor in the shift in blooming times [5]. The dependence of the phenological stages on climatic factors have been proven. It led to new areas of research. Botanists and ecologists have begun to study the effects of anthropogenic influence on phenology. In addition to the impact of global warming, the authors consider the impact of other factors. For example, the grazing also leads to earlier blooming of plants [8]. The researchers described the features of phenology in the dominant species of communities of different stages of successions. In the early stages of the succession, dominance is determined by the nature of pollination...
and distribution of fruits and seeds. The benefits are of long-distance species. In the later stages of the successions, early and long blooming species were benefited [9].

Phenological stages have been used to identify factors in the expansion of alien species. One of the noted factors is the adaptability of blooming dates to climatic factors [10-12].

The papers note that the most successful strategy for infiltration into natural communities is to differentiate environmental niches[13]. Early blooming and fruiting is the best strategy to resist late-blooming alien species [14].

Thus, existing research has formed the basis for the use of phenological observations to identify anthropogenic changes in communities, especially which are associated with the penetration of adventive species.

2. Materials and methods
In 2008 - 2018, a photo archive of plants of Komsomolsk-on-Amur was compiled. It includes more than 23,000 pictures of plants in different phenological stages now. The time of the images is fixed in the EXIF data block. This array of information was supplemented by decade-old phenological observations from May to September, which were conducted in the residential area in 2016 and the Silinsky park in 2018. Thus, empirical observations were obtained on blooming dates for 98.2% of species growing in the residential area and 81.7% of species of the Silinsky Park. For the remaining types, phenological observations were based on literary data based on expert assessments. Blooming was recorded for decades, from May to September. Comparative assessment of the blooming periods of plants of the residential areas of Komsomolsk-on-Amur and the Silinsky Park was conducted for native and alien species taking into account their range and ecological and phytocenotic preferences.

3. Results and discussion
Komsomolsk-on-Amur is a municipal entity of Khabarovsk Region (Russia). It is located at the junction of the taiga area and the area of cedar-broad-leaved forest. The climate is sharply continental. Winter is cold, snowy, summer is hot, with maximum precipitation in August. The city is located on the terrace of the Amur River. A forest area “the Silinskysky Park” is in the administrative boundaries of the city, in its geographical center. Its area is about 7.5 km2. Part of its territory is closed to the public. Vegetation is undisturbed. According to the latest estimates, it has 378 species of blooming plants, of which 329 species belong to native flora, 49 ones are skids. The flora of flowering plants of the residential areas of Komsomolsk-on-Amur consists of 518 species, of which 264 species are native ones, 254 species are alien. The relief, climatic and hydrological characteristics of the residential area of the city and the Silinsky Park are similar, which allows making correct comparisons of the functioning of urbophytocenosis with the forest plant community.

Analysis of absolute and relative flora indicators shows clear differences between aboriginal and alien fractions in both the Silinsky park and residential communities. Aboriginal flora is characterized by an earlier blooming. Early blooming grasses such as Chrysocysthysus amurensis, Corydalis ambigua, Hylomecon vernalis, Anemonoides amurensis, thanks to blooming before the full dissolution of the tree leaves go away from competition for light. Early blooming species also include wind-pollinated trees and shrubs such as Populus suaveolens, Salix schwerinii, Populus maximowiczii, Ulmus japonica, as well as some wind-pollinated grasses such as Carex reventa, Carex pallida, Carex vanheurckii. Both groups of plants have a predominantly Asian and Far Eastern range. The aboriginal flora in both The Silinsky park and the residential area clearly shows two peaks of blooming. The first peak is in mid-June, the second one is in the middle to the end of July. The species that make up the June peak are mainly forest species with Asian and Far Eastern distribution areas. The June peak is formed by typical inhabitants of cedar-wide-leaf forests, such as Maianthemum bifolium, Convallaria keiskei, Clematis fusca, Lonicera maximowiczii, etc. In the monsoon climate, June is the driest month of summer, and many species bloom while spring water is preserved in the soil.
In the middle of July, species with wider ranges: Eurasian and Eurasian-North American species are actively added to Asian and Far Eastern blooming species. They are forming the second peak of blooming.

There is less homogeneity of the picture in the alien flora of the Silinsky park and the residential area. However, most likely, this is due to the small number of alien species in the Silinsky park. Most of the alien species have a wide range, mainly Eurasian and Eurasian-North American. They are characterized by a shift in blooming time to August.

Figure 1. The number of flowering species in communities by decade.

Figure 2. The share of flowering species from the total community flora by decades.

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Figure 3. The share of flowering species from the community flora by decades. RA – residential area, SP - Silinsky Park.
4. Conclusion
A comparison of the flowering curve of the flora of Silinsky Park and the residential zone of the city as a whole shows that due to the adventive fraction in a more disturbed residential zone with a high level of adventization, smoothing of the features typical for the region is observed (Fig. 3). The June peak of flowering disappears, there is a shift in flowering at the end of summer. Thus, the phenological characteristics of the community can be used as an indicator of anthropogenic stress. The flowering shift towards the end of summer not only among adventive, but also native species with a wide distribution area, is explained by the effective differentiation of niches and the accumulation of resources throughout the summer for active flowering and fruiting. These competitive advantages, combined with environmental plasticity, have enabled these species to expand their range.

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**Acknowledgments**
The authors are grateful to V.M. Van (Komsomolsky State Nature Reserve) for the idea of research.