Recreation of Biotic Community from Native Early-Flowering Plants in Greening Urban Lands as a Factor in Preserving the Region’s Biodiversity (the Case of Primorsky Krai)

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Abstract. One of the effective ways of preserving native early flowering plants is their introduction, as a result of which it is possible to recreate plant communities in the form of a model similar to the natural prototype according to dominant characters. An analysis of the species biodiversity of herbaceous early flowering native plants for Primorsky Krai made it possible to identify associations taking into account their morphological traits and color scheme, flowering periods, preservation of ornamental qualities during the seasons, and to develop cenosis models for their use in greening urbanized landscapes.

1. Introduction

Primorsky Krai, located in the South of the Far East, covers 164.7 thous. km² (about 1% of the area of the Russian Federation) and is the zone of the northernmost subtropics on the planet, which pass into the southernmost taiga. Forests occupy almost three quarter of the area in Primorye and are the most important element of the region forming landscapes.

Primorye has no equal in terms of species diversity of flora and fauna among all regions of Russia. The biodiversity of the region has international significance [27]. The richness of flora, distinctness of the climatic regime at the "junction" of the vast continent of Eurasia and the greatest Pacific Ocean on the Earth, a wide range of ecotopes - from mountain peaks till wide river valleys of the flat part of the region, create conditions for the existence of very diverse vegetation and, very often, exotic combinations of its elements.

In the flora of Primorye, there are more than two thousand species of higher plants, early-flowering perennial plants are numerous and diverse. Appearing in early spring, they attract attention and have
long been used by humans - as medicinal [8,38], food [7,26], as indicators that characterize the degree of disturbance of the territory under the influence of anthropogenic load [2].

Life forms and rhythms of seasonal development of early-flowering plants in Primorsky Krai [6], reproduction and distribution of primroses [4,5,10,11,15], physiological and biomorphological features of primroses [6,32,35] are described and studied, as well as evolution and distribution patterns [39], their significance as honey-bearing and medicinal plants [19].

The issues of introduction and propagation of ornamental early-flowering plants were also considered by both Russian [34] and foreign authors [40].

The idea of using ornamental native plants for greening urbanized landscapes is not new, but, unfortunately, only general issues of introduction to the culture of individual species and taxa of plants are considered in most materials on introduction [12,13,37].

In recent years, there have been ideas of using wild plants for landscaping in communities [3,18], which will certainly enhance durability of such artificial cenoses. The reproduction of natural cenoses, native to this territory of plants, in urbanized landscapes, can be considered as a method of conservation of biological diversity.

The aim of the work is to create models of coenoses from native ornamental early-flowering herbaceous plants for their use in greening urbanized landscapes.

The following tasks were highlighted:
1. To analyze the species biodiversity of herbaceous early-flowering native plants for Primorsky Krai and identify associations with similar environmental requirements.
2. To study the plant communities of early-flowering herbaceous perennials formed on the territory of the Botanical Garden of FEB RAS, to analyze the taxonomic composition of artificial communities, to conduct their ecologo-phytocenotic analysis
3. To consider associations of herbaceous early-flowering native plants for Primorsky Krai and, taking into account their morphological traits and color scheme, the time of flowering, preservation of decorative qualities during the seasons, to develop models of cenoses for their use in greening urbanized landscapes.

2. Objects and methods of research
The study object was both natural plant communities of early-flowering perennials and plant communities of early-flowering plants native to Primorsky Krai, artificially created on the territory of the Botanical Garden of the FEB RAS, and the species represented in them.

The material for the work was both live samples of plants of natural communities in Primorsky Krai, and plants growing in the Botanical Garden of FEB RAS, as well as data from price lists of nurseries that cultivate decorative perennials.

The study of plant communities was carried out by us according to the generally accepted method [25, 33].

The model community was created based on the ecologo-phytocenotic method of plant introduction according to N V Trulevich [36], which includes the use of all the main data obtained from the analysis of the species composition, phenology, structure and environmental conditions of plant growth on the studied areas.

Phenological observations of perennial early-flowering ornamental plants were conducted according to the generally accepted method of phenological observations in the Botanical Gardens [1] and according to the observations of G N Zaitsev [16].

3. Results and discussion
A special role in the conservation of rare and endangered plant species belongs to the Botanical Gardens as the centers for increasing species diversity. The main function of Botanical Gardens is to preserve collections of living plants and use them for scientific research, biodiversity conservation, show, and educational purposes. Of the 92 Botanical Gardens in Russia, only five of them propagate
and sell open-ground plants, including early-flowering herbaceous plants. The ratio of native species and cultivated early-flowering herbaceous perennials in prices is shown in figure 1.

![Figure 1](image-url)

**Figure 1.** Number of early-flowering native species in the price lists of the Botanical Gardens in Russia in relation to the total number of sold early-flowering plants and the total number of species of herbaceous perennials offered for open ground.

1 – The Botanical Garden - Institute of FEB RAS
2 – Amur branch Botanical Garden - Institute of FEB RAS
3 – The South Siberian Botanical Garden of Altai State University
4 – Ekaterinburg Botanical Garden - UB RAS
5 – Kemerovo - Kuzbass Botanical Garden

Thus, out of 80 species of ornamental early-flowering perennials that grow in natural communities of Primorsky Krai, the Botanical Garden of FEB RAS propagates and offers less than 20 species for greening. The list can be increased (table 1) and one may use native plants to create compositions in parks, arboretums, for landscaping slopes (in Vladivostok), for strengthening screes and dividing strips along highways in combination with decorative tree-shrubby native plants for Primorsky Krai, such as *Deutzia parviflora* var. *amurensis* Regel, *Philadelphia temulifolius* Rupr. & Maxim., *Weigela praecox* (Lemoine) L. H. Bailey, *Lonicera maximowiczii* (Rupr.) Regel, *Crataegus pinnatifida* var. major N.E.Br., *Padus asiatica* Kom., *Syringa wolffii* Schneid., (Oliv.) Oliv., *Rosa rugosa* Thunb., *Rosa maximowicziana* Regel and others. The use of native species in culture will solve not only the problems of their conservation and expansion of areas, but also increase the stability of artificial plantations, provided that the ecological and biological characteristics of the species are taken into account.

**Table 1.** List of early spring flowering plants in Primorsky Krai.

| No. | Species | Morphology traits used in creating compositions | Time of flowering (month of the year) | Ecological features | Biotope                          |
|-----|---------|-------------------------------------------------|--------------------------------------|---------------------|---------------------------------|
| 1   | *Adonis* *(Chysocyathus)* *amurensis* | During flowering up to 12 cm, after | III-IV | Mesophyte | Deciduous forests and forest edges, |
| **Regel et Rde** | Flowering up to 35 cm | Mixed-grass slopes of sea coasts |
|------------------|-----------------------|---------------------------------|
| **2** | *Aquilegia parviflora* Ledeb., *Aquilegia* | 20-45 cm | V | Meso-petrophyte | Dry meadows, rocky hills |
| **3** | *Arsenjevia glabrata* (Maxim.) Starod., *Arsenjevia* | 15-25 cm | IV-V | Mesophyte | Wet soils in valley forests, riverine terraces |
| **4** | *Arisaema amurense* Maxim., *Arisaema robustum* | Up to 60 cm | V-VI | Mesophyte | Moist soils of mixed valley forests, along the banks of rivers and streams |
| **5** | *Bergenia pacifica* (L.) BSP. | 15-50 cm | V-VI | Meso-petrophyte | Rocks, scree, old moraines and rocky slopes, coniferous and deciduous forests |
| **6** | *Petasites fominii* Bordz. | 15-50 cm | IV-V | Mesophyte | Sand and pebbles along rivers |
| **7** | *Calla palustris* L. | 10-25 cm | V-VI | Hygrophyte | Water and moist habitats with rich inorganic nutrition: swamps, lakes, streams, shallow waters |
| **8** | *Eranthis stellata* Maxim. | Up to 20 cm | III-IV | Mesophyte | Cedar-broad-leaved and mixed forests, edges |
| **9** | *Anemonoides amurensis* (Korsh.) Holu | 25-30 cm | IV-V | Mesophyte | Cedar-broad-leaved forests, |
| No. | Species                                                                 | Height    | Life Form | Habitat Description                                                                 |
|-----|-------------------------------------------------------------------------|-----------|-----------|-------------------------------------------------------------------------------------|
| 10  | *Epimedium koreanum* Nakai                                             | 40-60 cm  | V         | Mesophyte, riverine shrubs and stone birch forests                                |
| 11  | *Iris uniflora* Pall. ex Link*                                          | 10-15 cm  | V         | Meso-petrophyte, dry stony and open grassy slopes, pine forests, white birch and oak sparse forests |
| 12  | *Caltha palustris* L.                                                  | Up to 60 cm | V-VI     | Hygrophyte, around springs and along rivers and streams, lakes, swamps and wetlands in forests and meadows |
| 13  | *Asarum Sieboldii* Miq                                                 | 10-15 cm  | IV-V     | Mesophyte, mixed coniferous-broad leaved forests, river valleys                    |
| 14  | *Polygonatum odoratum* (Mill.) Druce                                   | Up to 90 cm | V         | Mesophyte, forest slopes, river valleys, screes                                    |
| 15  | *Polygonatum humile* var. *humillimum* (Nakai) *Y.N. Lee*              | Up to 40 cm |           | Meso-petrophyte, dry stony slopes, pebbles, dry meadows, sandy soils               |
| 16  | *Polygonatum involucratum* (Franch. & Sav.) Maxim. *                   | 5-50 cm   |           | Mesophyte, mixed coniferous-broad leaved forests, slopes, edges                    |
| 17  | *Hylomecon vernalis* = *H. Japonicum.*                                 | 40 cm     | V         | Mesophyte, forests, under a tree canopy                                            |
| 18  | *Lloydia triflora* (Ledeb.) Baker.                                     | Up to 30 cm | V-VI     | Mesophyte, edges, glades,                                                         |
| No. | Species                          | Height        | Environmental Conditions |
|-----|---------------------------------|---------------|--------------------------|
| 19  | *Allium ochotense* Prokh.*      | Up to 70 cm   | shrubby thickets in mixed forests in mixed forests, valleys of rivers and streams |
| 20  | *Papaver amurense* (N. Busch) H. Chuang* | 40-60 cm      | Forests, edges, valleys of rivers and streams |
| 21  | *Euphorbia komaroviana* Prokh.* | Up to 45 cm   | River valleys, lake banks, dry stony slopes |
| 22  | *Primula patens* (Turcz.) E.A. Busch* | Up too 40 cm  | Slopes of hills covered with forest, sea shores |
| 23  | *Pulsatilla dahurica* Fisch. ex DC.* | Up to 45 cm   | Wet meadows, coastal shrubs in the flood-plain of rivers |
| 24  | *Pulsatilla chinensis* (Bunge) Regel, Tent. Fl.-Ussur. | 12 cm         | Pebbles, stony and rocky slopes, dry meadows |
| 25  | *Anemone cernua* Thunb.*        | Up to 25 cm   | Dry slopes |
| 26  | *Fritillaria camschatensis* (L.) Ker Gawl.* | 35-65 cm      | Stony rock slopes, dry meadows |
| 27  | *Symlocarpus renifolius* Schott ex Tzvel. | Up to 40 cm   | Forest edges, forbs, wet meadows |
| 28  | *Chrysosplenium pilosum* Maxim. | Up to 10 cm   | Mixed forests, wet areas |

26 | *Fritillaria camschatensis* (L.) Ker Gawl.* | 35-65 cm      | Forest edges, forbs, wet meadows |
27 | *Symlocarpus renifolius* Schott ex Tzvel. | Up to 40 cm   | Mixed forests, wet areas |
28 | *Chrysosplenium pilosum* Maxim. | Up to 10 cm   | River banks, wetlands in mixed deciduous forests |
| No | Species | Height | Growth Period | Life Form | Habitat |
|----|---------|--------|---------------|-----------|---------|
| 29 | Smilacina hirta Maxim. | Up to 40 cm | V | Mesophyte | Moist rich soils of forests, river banks and streams, swamps |
| 30 | Viola xanthopetala Nakai | 15 cm | IV-V | Mesophyte | Mixed and deciduous forests, dry and rocky slopes |
| 31 | Viola mandshurica W. Beck. | Up to 20 cm | V | Mesophyte | Sandy or stony soils, dry slopes |
| 32 | Corydalis buschii Nakai | Up to 25 cm | V | Mesophyte | Wet and temporary waterlogged valleys of ash trees and wet meadows |
| 33 | Corydalis repens Mandl & Muehld. | Up to 10 cm | IV-V | | Cedar-broad-leaved and hardwood forests on rich humus soils |
| 34 | Corydalis ambigu Cham. et Schelecht | 15-25 cm | IV-V | | Forests, underbrushes river and stream banks, slopes along the sea coast |

Forming associations of plants that are close to environmental requirements and preserving decorative effect not only for three months, during flowering, and also until late autumn, will increase the species diversity of plants in parks, the aesthetics of some areas, especially shaded because some of them, after flowering and growing, form a dense blanket of leaves with nuances of color, texture, shape. More-layered community will be more stable than single plantings.

About 20 species of early-flowering perennials can be used as groundcover plants under conditions of Primorsky Krai, using layering when forming plantings (table 2).
Table 2. Groundcover plans for enriching the biodiversity of herbaceous plants in parks.

| Ranking in the association | Names of species |
|----------------------------|------------------|
| First row, shortgrowing    | Common moschatel, large-sepal barrenwort, blunt-leaved sandwort, naked mitrewort, Asiatic liverleaf, Manchurian rue anemone, hairy golden saxifrage, Sakhalin violet, creeping corydalis, ambiguous corydalis |
| Middle row                 | Truncate-leaflet sorrel, common woodsorrel, Siebold's wild ginger, Japanese poppy, Okhotian onion |
| Back row, tall grass       | Shaggy Solomon’s seal, blue cohosh, Komarov’s trillium, Radde’s false rue anemone |

To frame the paths in purpose of preventing the trampling of the herb layer in the park zone, we also suggest using a multilayered mixborder of native decorative perennials (table 3).

Table 3. Associations of early flowering ornamental perennials for mixborders in parks.

| Ranking in the association | Names of species |
|----------------------------|------------------|
| First row, shortgrowing    | Amur Adonis, Asian twin flower, hollow primrose, spreading primrose, Asiatic liverleaf |
| Middle row                 | Uda anemone, aromatic Solomon's seal, Asian lily-of-the-valley, may lily, amphi-Pacific two-leaf Solomon’s seal, s parse corydalis |
| Back row, tall grass       | Japanese chloranthus, common brachybotrys, nettle-leaved Meehan’s mint, Amur Jack-in-the-pulpit, peninsular Jack-in-the-pulpit, large-sepal primrose, Kamchatka fritillary |

Large plants such as Caulophyllum robustum, Arisaema, and Symlocarpus can be used to design mixborders or as solitaires.

Due to the decorative nature of leaves, some plants remain quite attractive even after flowering. The size of plants is also very important when forming a mixborder. Tall plants can be perfectly combined with short ones. We will consider options for grouping early-flowering herbaceous perennials native to the flora of Primorsky Krai below.

Several groups of perennials are distinguished by height:
- very tall plants - more than 2 m (there are no early-flowering plants in Primorsky Krai);
- tall – from 1 to 2 m (Thalictrum, Actaea acuminata, Polygonatum odoratum, Caulophyllum robustum), such plants are usually planted as solitaires or along paths in mixborders;
- medium-grown - from 0.5 to 1 m (Aquilegia parviflora, Petasites tatewakianus, Aruncus parvulus, Epimedium koreanum, Brachybotrys paridiformis Maxim. ex Olivier, Papaver amurense), these plants are usually used for forming flower beds, color spots on the background of other perennials to create emphasis;
- shortgrowing – from 0.25 to 0.5 m (Bergenia, Chloranthus japonicus, Polygonatum), they are usually used for the design of flower beds, slides, trunk circles;
- dwarf - no more than 0.25 m (Waldsteinia, Caltha, Primula, Adoxa, Gentiana zollingeri, Gagea nakaiana), such plants can be used as groundcover, to create a decorative beautiful-blooming spring lawn.

To enrich the biodiversity of plants in the shaded corners of parks, on the Northern side of buildings, we suggest using such shade-tolerating plants as: Gagea lutea and Lloydia triflora, Chrysosplenium pilosum, Corydalis repens and C. Yanhusuo - ephemerals appear in the early spring and form a bright carpet for a short time. Adoxa moschatellina preserves green stems and leaves for 2-3 months, until mid-summer. Waldsteina ternata, Eranthis stellata and Anemonoides amurenensis, A. extremorientalis, A. reflexa, A. raddeana, A. udensis bloom until mid-May forming groups of plants.
under the canopy of trees. Actaea acuminata vegetates on shady or semi-shady areas until the beginning of October. Chloranthus japonicus, Asarum sieboldii are planted in mixborders as background plants. Polygonatum, Convallaria, Smilacina grow well on fertile soils in the shade (table 4).

### Table 4. Associations of early-flowering herbaceous perennials for shaded areas of parks.

| Ranking in the associations | Names of species                                      |
|-----------------------------|-------------------------------------------------------|
| First row, shortgrowing     | Maximowicz's barren strawberry, stellate springflower, Nakai’s star-of-Bethlehem, Amur Adonis, three-flowered alpilily, Franchet’s buttercup, Asiatic liverleaf |
| Middle row                  | Glabrate arsenyevia, petaloid-filament meadow-rue, Amur anemone, Far East anemone, Japanese poppy |
| Back row, tall grass        | Asiatic baneberry, robust Jack-in-the-pulpit, shaggy Solomon’s seal, blue cohosh |

To create picturesque small glades Fragaria orientalis, Potentilla fragarioides, Ranunculus franchetii, Mochringia lateriflora, Pulsatilla, Viola can be used on dry areas (table 5).

### Table 5. Community composition of early-flowering herbaceous perennials for dry slopes.

| Ranking in the associations | Names of species                                      |
|-----------------------------|-------------------------------------------------------|
| First row, shortgrowing     | Amur Adonis, Far East strawberry, one-flowered iris, Chinese anemone, golden violet |
| Middle row                  | North Pacific strawberry cinquefoil, false scape groundsel, large-sepal primrose, Manchurian violet, hill violet |
| Back row, tall grass        | Japanese gerbera, showy corydalis                      |

For stony gardens and mixborders Bergenia pacifica is used in combination with Juniperus Microbiota which preserves its decorative value all seasons, even under snow. Aquilegia parviflora, Gentiana zollingeri, Papaver amurense, Pulsatilla chinensis and R. Corydalis species bloom at different times (table 6).

### Table 6. Associations of early-flowering perennial herbaceous plants for rocky hills and alpine scree gardens.

| Ranking in the associations | Names of species                                      |
|-----------------------------|-------------------------------------------------------|
| First row, shortgrowing     | Pacific bergenia, Zollinger's gentian, Asiatic liverleaf, golden violet, variegated violet, Pacific violet |
| Middle row                  | Small-flowered columbine, dwarf goatsbeard, one-flowered iris, rock primrose, Daurhian pasqueflower, nodding pasqueflower |
| Back row, tall grass        | Dentate dentostemon, Amur poppy, showy corydalis          |

To frame water bodies and current of water you can use Petasites tatewakianus, Caltha palustris and C. silvestris, Oxalis, Chrysosplenium, Corydalis buschii, as emergent plants - Calla palustris, Menyanthes trifoliata, in May they form original flowers with dense inflorescences (table 7).
Table 7. Community of early-flowering perennial herbaceous plants for moistened lower areas, framing streams and water bodies.

| Ranking in the associations | Names of species                                      |
|-----------------------------|-------------------------------------------------------|
| Emergent plants             | Marsh calla, water shamrock                           |
| Edges of water bodies       | Cowslip, forest marsh marigold, long-beaked sedge,    |
|                             | Busch’s corydalis                                     |
| Moisty lowlands             | Tatewaki’s coltsfoot, Komarov’s arisaema              |

Thus, the proposed associations of early-flowering plants in Primorsky Krai allow will allow creating sustainable artificial communities when greening urbanized territories. Such plants as Arsenjevia glabrata, Adonis amurensis, Semiaquilegia manshurica, Anemonoides raddeana are decorative in the first half of summer. It is better to plant ephemers and ephemeroids with summer-green species that begin their vegetative season later and preserve decorative qualities until autumn. Brachybotrys paridiformis, Thalictrum filamentosum, Mitella nuda are decorative throughout the season and form a dense cover in shady places, as well as Meehania urticifolia which flowers splendidly.

4. Conclusion
One of the most effective ways to preserve native early-flowering plants is their introduction, as a result of which it is possible to recreate plant communities in the form of a model similar to the natural prototype in basic features. The analysis of the species biodiversity of herbaceous early-flowering native plants for Primorsky Krai allowed us to identify associations taking into account their morphological traits and color scheme, the time of flowering, the preservation of decorative qualities during the seasons, and to create models of communities for their use in greening urbanized landscapes.

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