Morphological and biological characteristics of some anthropogenic plant communities in the lower Irtysh floodplain

E Popova

Tobolsk Complex Scientific Station, Ural Branch of the Russian Academy of Sciences
15 Akademik Yu S Osipov Street, Tobolsk 626152, Russian Federation

E-mail: popova-3456@mail.ru

Abstract. The study examined six sites in the right-bank floodplain of the lower reaches of the Irtysh River, Russia, in the part located near the riverbed. The sites were spaced at a considerable distance from each other. The species composition of plants was analyzed. Forty-four species of vascular plants were identified at the studied sites. In terms of the number of species, the sites were ranked as follows: 1 → 3 → 6 → 5 → 2 → 4. The plants at sites 2 and 4 are under anthropogenic pressure and stress, which affect the species composition, density, biological productivity, oxygen productivity, and morphometric indicators of plant communities. The assessment of the productivity of floodplain communities performed in this study can be further used to determine the natural resources potential of floodplain areas and to ensure the rational use of their natural resources.

1. Introduction

A floodplain of any large river, including the Irtysh floodplain, is a special landscape well isolated from the surrounding areas. The flora of such a landscape is likely to have a certain integrity and deserves to be studied as a natural phenomenon in its own right.

At present, plant communities of the Irtysh floodplain are under high anthropogenic loads arising from the fast development of the oil and gas industry, as well as from the urbanization of the region [1].

The Irtysh River originates from China and flows through Kazakhstan with its industrial enterprises discharging waste water with heavy metals into the Irtysh River [1]. The excessive human impact on the flora causes a number of adverse effects by disrupting the ecological balance and undermining the resource potential of the floodplain area [2]. As a result, floodplain ecosystems have begun to degrade: the biological productivity of the floodplain, including the yield of meadow grasses, has declined [3,4].

The floodplain of the Irtysh River is a unique natural system, which stands out by its rich flora and geographical landscape. Being a renewable source and regulator of natural processes, the vegetation is the most important component of the floodplain [1].

The peculiarity of the floodplains is their flooding with hollow waters, from which silt precipitates in river valleys, which leads to the formation of fertile floodplain soils and meadow vegetation [5,6]. However, the current productivity of floodplain meadows does not match their potential. The study of the horizontal structure of floodplain phytocenoses makes it possible to determine the interannual variability, the change of dominant species, and the stability of the species composition. Currently, researchers pay considerable attention to the analysis of the structure of phytocenoses, since its study is of great theoretical and practical importance in the analysis of phytoecenotic relations [7,8].
This study examined six sites located on the floodplain terrace of the Irtysh River at a significant distance from each other. The research was conducted in July, in the period when the water level was falling and the water remained only in depressed areas.

The aim of the research is to study the productivity of floodplain plant communities for the long-term determination of the natural resource potential of floodplain territories in order to ensure their rational nature management.

2. Materials and Methods

2.1. Selection of sites
In order to select geobotanical test sites and describe the vegetation, the author followed the common phytosociological methods and approaches that are widely used in geobotanical studies. In accordance with the geobotanical research methodology, the description of ground vegetation communities was used as the main method at the field stage of the study.

The species composition of vascular plants at geobotanical sites was identified at the time of the description. Dimensions and configuration of each site: 4 m × 4 m = 16 m². In total, six geobotanical descriptions were performed during the field stage of the study. The abundance of species was estimated visually according to the Drude scale (a system of visual score-based estimates) [9,10].

In addition, the degree of anthropogenic impact (no impact, weak, moderate, strong, very strong) and its nature (air pollutants, inorganic and organic household waste, petroleum products, recreation, grazing, etc.) were visually assessed at the geobotanical sites.

The sites were located at a significant distance from each other, along the floodplain terrace of the Irtysh River.

Site 1. The plant community is located on the left bank of the Irtysh River. The floodplain lies three kilometers from the village of Isenevskaya, Tobolsky District, Tyumen Region, Russia. Its geographical coordinates (the center of the site) are N 58º09.779', E 068º18.215'. The terrain is even and flat. The total projective cover of ground vegetation reaches 100%. The average height of the grass stand is 80 cm. The composition of vascular plants at the site is represented by 20 species: *Lysimachia vulgaris*, *Ranunculus acris*, *Achillea cartilaginea*, *Vicia cracca*, *Plantago media*, *Rosa majalis* Herrm., *Artemísia vulgaris*, *Cirsium arvense* (L.) Scop., *Lathyrus pratensis*, *Prunella vulgaris*, *Leontodon autumnalis*, *Stellaria graminea*, *Plantago major*, *Trifolium medium*, *Agrostis gigantea* Roth., *Pimpinella saxifraga*, *Leucanthemum vulgare*, *Phleum pratense*, *Rhinanthus serotinus*.

Site 2. The plant community is located on the right bank of the Irtysh River, ten kilometers from a ferry service of the town of Tobolsk, Tyumen Region, Russia. Floodplain. Its geographical coordinates (the center of the site) are N 58º07.538', E 068º08.362'. The terrain is even and flat. The total projective cover of ground vegetation reaches 100%. The average height of the grass stand is 70 cm. The composition of vascular plants at the site is represented by twelve species: *Stellaria graminea*, *Taraxacum officinale*, *Artemísia vulgaris*, *Lysimachia vulgaris*, *Ranunculus acris*, *Trifolium medium*, *Cirsium arvense*, *Veronica longifolia*, *Poa pratensis*, *Potentilla anserina*, *Plantago major*, *Trifolium repens*.

Site 3. The plant community is located near a country road, on the right bank of the Irtysh River, between the village of Savinsky Zaton and the village of Ovsyannikova, Tobolsky District, Tyumen Region, Russia. Floodplain. Its geographical coordinates (the center of the site) are N 58º19.042', E 068º07.017'. The terrain is even and flat. The total projective cover of ground vegetation reaches 100%. The average height of the grass stand is 70 cm. The composition of vascular plants at the site is represented by twelve species: *Hypericum perforatum*, *Carum carvi*, *Veronica chamaedrys*, *Tanacetum vulgare*, *Hieracium umbellatum*, *Lathyrus pratensis*, *Vicia sepium*, *Artemísia vulgaris*, *Ranunculus acris*, *Gallium mollugo*. The grass layer is dominated by *Plantago major*, *Poa angustifolia*, *Pimpinella saxifraga*, *Trifolium medium*, *Elytrigia repens*, *Plantago media*, *Taraxacum officinale*.
Site 4. The plant community is located on the right bank of the Irtysh River, five kilometers north of the village of Eksteser, Vagaysky District, Tyumen Region, Russia. Floodplain. Its geographical coordinates (the center of the site) are N 57º59.486', E 069º16.445'. The terrain is even and flat. The total projective cover of ground vegetation reaches 90%. The average height of the grass stand is 90 cm. The composition of vascular plants at the site is represented by ten species: *Cirsium arvense*, *Lathyrus pratensis*, *Centaurea sibirica* L., *Veronica longifolia* L., *Vicia cracca* L., *Lysimachia vulgaris*, *Achillea cartilaginea* L., *Trifolium medium*, *Artemisia vulgaris*, *Lathyrus pratensis*. The grass layer is dominated by *Calamagrostis arundinacea* (L.) Roth.

Site 5. The plant community is located on the steep bank of the Irtysh River near the village of Inzhura, Vagaysky District, Tyumen Region, Russia. Terrace above the floodplain. Its geographical coordinates (the center of the site) are N 58º02.924', E 069º07.701'. The terrain is even and flat. The total projective cover of ground vegetation reaches 90%. The average height of the grass stand is 90 cm. The composition of vascular plants at the site is represented by 14 species: *Artemisia vulgaris*, *Pimpinella saxifraga*, *Vicia cracca*, *Origanum vulgare* L., *Achillea millefolium* L., *Centaurea sibirica*, *Picris hieracioides* L., *Polygonum aviculare* L., *Trifolium medium*, *Plantago media*, *Lathyrus pratensis*. The grass layer is dominated by *Calamagrostis epigeios* (L.) Roth., *Epilóbium angustifolium* L.

Site 6. The plant community is located on the bank of the Irtysh River near the village of Medvedchikovo, Tyumen Region, Russia. Floodplain. Its geographical coordinates (the center of the site) are N 58º24.230', E 068º22.109'. The terrain is even and flat. The total projective cover of ground vegetation reaches 70%. The average height of the grass stand is 80 cm. The composition of vascular plants at the site is represented by 16 species: *Potentilla anserina*, *Trifolium repens* L., *Vicia sepium* L., *Crepis tectorum* L., *Lysimachia vulgaris*, *Trifolium medium*, *Inula bréttannica* L., *Potentilla anserina*, *Lathyrus pratensis*, *Artemisia vulgaris*, *Carex acuta* L., *Plantago major*, *Ranunculus acris* L. The grass layer is dominated by *Poa pratensis*, *Melilotus albus* Medik., *Mentha arvensis* L.

2.2. The density of the plant community
The density of the plant community was determined by counting all individual vascular plants on the test sites. For this purpose, three squares (record plots) of 1 m² were set out within the sites. All grasses on the record plots were cut up to the soil level. In laboratory conditions, the phytomass was sorted by species. Then, the number of shoots was counted [11].

2.3. The biological productivity
The biological productivity is the ability of living organisms to create, preserve and transform the organic matter. The productivity of a biological community is the amount of organic matter synthesized per unit time and unit area. The biological productivity of a plant community is composed of products of individual plant species making up this community or, more precisely, their coenopopulations. Thus, the biological productivity of individual plant species making up the plant community is the rate of phytomass accumulation over a certain time interval [12].

The grasses cut from three record plots were packaged in separate labeled bags. The bags were hermetically sealed to prevent evaporation of water. In laboratory conditions, the phytomass was weighed. It was dried in the open air, and the air-dried phytomass was weighed again. The collected material also served as the basis for calculating the oxygen productivity.

2.4. The morphometric parameters
The morphometric parameters of plants were studied according to the generally accepted methods. The following morphological indicators were taken into account: shoot height, leaf blade length, leaf blade width, total number of living and dead leaves (hereinafter referred to as the number of leaves), plant weight (without root) in grams. The measurements were made using a caliper and an electronic Compact Scale [13].
The results were statistically processed in the Statistica 10.0 (Statsoft, USA) software package. Differences between the samples were considered significant at $p < 0.05$ (Student Test). The mean and standard deviation ($X \pm SD$) are indicated in the text and tables below.

3. Results and Discussion
The plant communities of the Irtysh River floodplain are characterized by a great diversity in terms of species composition, structure and morphostructural characteristics. They form fragile vegetation groups, up to well-developed communities. The analysis of the studied sites identified forty-four species of vascular plants. Twenty species were common and could be found at many studied sites: *Lysimachia vulgaris* L. (1,2,4,6), *Ranunculus acris*, *Plantago major* (1,2,3,6), *Trifolium medium*, *Artemisia vulgaris*, *Lathyrus pratensis* (1-6), *Achillea cartilaginea* (1,4), *Vicia cracca* (1,4,5), *Plantago media*, *Pimpinella saxifraga* (1,3,5), *Cirsium arvense* (1,2,4), *Stellaria graminea* (1,2), *Tanacetum vulgare* (1,3), *Taraxacum officinale* (2,3), *Poa pratensis*, *Potentilla anserina*, *Trifolium repens* (2,6), *Veronica longifolia* (2,4), *Centaurea sibirica* (4,5), *Vicia sepium* (3,6).

The remaining twenty-four species were found only at certain sites: *Agrostis gigantea* Roth., *Rosa majalis*, *Leucanthemum vulgare*, *Prunella vulgaris*, *Leontodon autumnalis*, *Phleum pratense*, *Rhinanthus serotinus* (site 1), *Poa angustifolia*, *Hypericum perforatum*, *Veronica chamaedrys*, *Hieracium umbellatum*, *Elytrigia repens*, *Galium mollugo* (site 3), *Origanum vulgare*, *Calamagrostis epigeios*, *Achilléa millefólium*, *Picris hieracioides*, *Epilóbium angustifolium* (site 5), *Melilotus albus*, *Crepis tectorum*, *Inula britannica*, *Carex acuta*, *Mentha arvensis* (site 6).

The test sites (1, 3, 6) with the largest number of species were identified. In terms of the number of species, the sites are ranked as follows: 1 → 3 → 6 → 5 → 2 → 4. Plant communities of sites 2 and 4 are under severe stress, which affects the species composition of the vegetation cover, as well as the density, biological productivity and oxygen productivity (Table 1).

| Site | Biological productivity | Oxygen productivity | Density |
|------|-------------------------|---------------------|---------|
|      | Fresh phytomass | Dry phytomass |              |          |
| 1    | 1,986.84 | 849.06 | 1,231.12 | 488 |
| 2    | 743.26 | 355.23 | 515.08 | 254 |
| 3    | 1,109.13 | 482.06 | 698.99 | 321 |
| 4    | 466.71 | 212.27 | 307.78 | 186 |
| 5    | 933.42 | 424.53 | 615.56 | 279 |
| 6    | 1,078.82 | 469.23 | 680.38 | 295 |

The density of plant communities at the observation sites includes the total average number of plants in three-meter test squares – 488 (1), 254 (2), 321 (3), 186 (4), 279 (5), 295 (6) shoots per 1 m$^2$.

The amount of phytomass at site 1 (fresh phytomass — 1,986.84 g/m$^2$, dry phytomass — 849.06 g/m$^2$) is more than four times higher than that at site 4 (466.71 g/m$^2$ and 212.7 g/m$^2$, respectively) and two times higher than the amount of phytomass at site 2 (743.26 g/m$^2$ and 355.23 g/m$^2$, respectively). The oxygen productivity of the plant community at site 1 (1,231.12 g) is also significantly higher than that at sites 2 and 4 (515.08 g and 307.78 g, respectively).

Most plant species of these test sites can be attributed to the meadow type of vegetation. These species dominate the meadow plant community. Another group with a large number of species is represented by weeds. The presence of this group indicates an anthropogenic impact on the natural meadow. These are ballast plants that do not have a decisive influence on the quality of the meadow plant community.

The morphometric analysis of the plants found at all sites showed that the plants at sites 2 and 4 are smaller. First of all, the assimilation surface is reduced. For example, the leaf length of *Trifolium medium*...
varies from 6.45±0.36 cm (2) and 5.40±0.27 cm (4) to 9.60±0.15 cm (1). The average leaf width and shoot height at sites 2 and 4 are usually reduced as well. Accordingly, a decrease in the plant weight and certain changes in the dimensions of the studied plants can be observed. The studied patterns of changes in morphometric indicators show a reliable, but insignificant decrease in the leaf blade of the plants at these test sites. It should be noted that the number of leaves does not vary significantly from site to site (Table 2).

### Table 2. Morphometric Characteristics of Plants at the Test Sites 1–6, (X ± SD)

| Morphometric indicator, x±m | Shoot height, cm | Leaf length, cm | Leaf width, cm | Plant weight, g | Number of leaves, pcs |
|-----------------------------|------------------|-----------------|----------------|-----------------|----------------------|
| **Trifolium medium** L.     |                  |                 |                 |                 |                      |
| 1                           | 39.23±0.62       | 9.60±0.15       | 3.42±0.67       | 3.42±0.67       | 6.90±0.56            |
| 2                           | 25.60±2.19*      | 6.45±0.36       | 2.29±0.10       | 2.35±0.04*      | 5.00±0.50*           |
| 3                           | 31.84±2.09       | 8.40±1.44***    | 3.14±0.27**     | 2.78±0.51       | 5.60±1.04*           |
| 4                           | 15.80±2.33**     | 5.40±0.27*      | 2.12±0.21*      | 1.76±0.32***    | 5.00±0.35            |
| 5                           | 29.60±4.51       | 7.40±0.57*      | 2.35±0.04**     | 2.67±0.41       | 5.20±0.82***         |
| 6                           | 30.20±4.01***    | 8.20±0.42**     | 3.08±0.36       | 2.52±0.09***    | 5.54±0.18            |
| **Artemisia vulgaris** L.   |                  |                 |                 |                 |                      |
| 1                           | 98.12±1.28       | 7.60±0.57       | 4.80±0.41       | 5.81±0.57       | 8.00±0.87            |
| 2                           | 82.49±0.29**     | 5.58±0.43***    | 4.08±0.19*      | 3.44±0.24       | 5.00±0.35***         |
| 3                           | 95.53±0.41*      | 6.26±0.79*      | 4.60±0.57       | 5.68±0.54*      | 7.96±0.27*           |
| 4                           | 65.51±5.08*      | 4.32±0.13***    | 3.00±0.71**     | 3.10±0.69***    | 4.92±0.07*           |
| 5                           | 90.27±0.55*      | 6.04±0.79*      | 4.50±0.21       | 5.00±0.47       | 6.18±0.71**          |
| 6                           | 93.46±4.05       | 6.20±0.42**     | 4.56±0.87**     | 5.20±0.42**     | 7.83±0.23            |
| **Lathyrus pratensis** L.   |                  |                 |                 |                 |                      |
| 1                           | 121.32±2.10      | 9.30±0.22       | 5.22±0.48       | 5.36±0.51       | 5.04±0.29            |
| 2                           | 82.49±0.29       | 6.92±0.95*      | 2.78±0.38       | 3.54±0.13***    | 3.22±0.42            |
| 3                           | 96.23±9.54**     | 8.60±0.91**     | 3.64±0.76       | 3.20±0.29*      | 4.28±1.04**          |
| 4                           | 55.28±1.50**     | 5.92±0.80*      | 2.24±0.42*      | 2.51±0.35      | 3.20±0.22**          |
| 5                           | 91.38±4.09       | 7.45±0.35       | 3.02±0.16**     | 2.60±0.44**     | 3.64±0.34***         |
| 6                           | 95.68±0.95       | 7.96±0.40**     | 3.62±0.16       | 2.76±0.13       | 3.60±0.45            |

Note: *,**,*** – differences from the control group are significant at P <0.005, 0.01, and 0.001, respectively.

This article was prepared with the financial support of the Ministry of Education and Science of the Russian Federation in the framework of the theme of fundamental scientific research "Anthropogenic transformation of the floodplain ecosystems of the Ob-Irtysh basin" (No. AAAA-A19-119012190088-0).

### 4. Conclusion

The results of the conducted studies suggest that the floodplain plant communities of the Irtysh River are influenced by external anthropogenic factors, which lead to the disruption of natural ecosystems, including a decrease in species diversity, density and biological productivity at the test sites.

It has been demonstrated that the ecosystems located at sites 2 and 4 are most severely stressed. The conditions at sites 1, 3, 5 and 6 are more favorable.

The morphometric analysis of the plants has shown that the plants at sites 2 and 4 are smaller. First of all, the assimilation surface is reduced. Accordingly, a decrease in the plant weight and certain changes in the dimensions of the plants can be observed.
The findings can be used in environmental monitoring and assessment of the vegetation cover in floodplain areas.

References

[1] Khamzina Sh Sh 2015 Ecological evaluation of the meadow community of the irtysh river flood. Basic research [Fundamental'nyye issledovaniya – in Russian] 2 (23) 5145

[2] Novikov Yu V 2002 Ecology, environment and man (Moscow: Education) p. 217

[3] Burda R I 1991 Anthropogenic Transformation of Flora (Kiev: Naukova Dumka)

[4] Abramova L M 2012 Expansion of invasive alien plant species in the republic of Bashkortostan, the Southern Urals: Analysis of causes and ecological consequences. Russian Journal of Ecology 43 (5) 352 DOI: 10.1134/S1067413612050037

[5] Flanagan N E, Richardson C J and Ho M 2015 Connecting differential responses of native and invasive riparian plants to climate change and environmental alteration. Ecological Applications. 25 753 https://doi:10.1890/14-0767.1

[6] Tabacchi E, González E, Corenblit D, Garófano-Gómez V, Planty-Tabacchi A M, Steiger J 2019 Species composition and plant traits: Characterization of the biogeomorphological succession within contrasting river corridors. River Res Applic. 113 https://doi.org/10.1002/rra.3511

[7] Johnson S E, Amatangelo K L, Townsend P A and Waller D M 2016 Large, connected floodplain forests prone to flooding best sustain plant diversity. Ecology. 97 3019 https://doi:10.1002/ecy.1556

[8] Lisius G L, Snyder N P, Collins M J 2018 Vegetation community response to hydrologic and geomorphic changes following dam removal. River Res Applic. 34 317 https://doi.org/10.1002/rra.3261

[9] Polozghiy A V and Vydrin S N 1996 Flora of Siberia (Novosibirsk: Science) p. 208

[10] Golovanov Ya M and Abramova L M 2016 Regularities of sainantropization processes of the vegetation cover in the towns of the south Cis-Urals (Bashkortostan Republic). Vegetation of Russia [Rastitel'nost' Rossii – in Russian] 28 28

[11] Tsyganov DN 1983 Phytoindication of ecological regimes in the subzone of coniferous-broadleaf forests (Moscow: Nauka) p. 196

[12] Menning WJ, Feder UA 1985 Biomonitoring of atmospheric pollution with the help of plants (Leningrad: Gidrometeoizdat) p. 143

[13] Lakin G F 1990 Biometrics (Moscow: Higher School) p. 105