Epiphytic mosses in urban sites and the possibility of their use in biomonitoring (Yuzhno-Sakhalinsk)

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Abstract The article presents the study results on epiphytic mosses. The research area is Yuzhno-Sakhalinsk and its surroundings. To assess the epiphytic cover the method of occurrence measuring on the tree trunks with the help of a frame 10×40 cm (400 cm²) was used at 15 locations within the study region. 15 species of epiphyte moss and their distribution characteristics were identified. *Populus maximowiczii* A. Henri was selected as a substrate because it predominates in urban vegetation and grows naturally in floodplain areas where control plots were set up.

1. Introduction

*Populus maximowiczii* was selected as a substrate as it is most widely represented in the plantings of the city [1]. This species was massively introduced into landscaping in the 1960’s and 1970’s of the last century. To date, those trees are about 70 years. Poplars were mainly planted in courtyards, city squares and along roadside edges. This species was chosen because of its availability. In river valleys, wild poplar forms pure poplar, willow-poplar and other mixed forests. Poplar is of low maintenance, takes root when planted in the city, and grows very fast. Taking into account all the above factors, it was decided to select *Populus maximowiczii* as the most affordable and successful substrate for bioindication.

Recently, the study of urban flora has attracted considerable interest due to the issue of preserving biological diversity. For the first time, high sensitivity of epiphytic bryophytes to contamination with sulfur oxides was noted at the beginning of the 20th century [2, 3]. With moss as indicators, the following characteristics are often defined by researchers: habitat, species composition, life forms, plant cover, abundance, spore-bearing specimens, etc. One of the main conditions for biomonitoring is assessing and comparing indicators within a single control plot [4].

The study was aimed at assessing the species structure of epiphytic bryophytes inhabiting *Populus maximowiczii* bark.

2. Study Region

Geographically, the study took place in Yuzhno-Sakhalinsk, its surroundings and the valley of Belaya river (Sokol settlement of Dolinsky district). Yuzhno-Sakhalinsk is located in the south-eastern part of Sakhalin Island in the central part of Susunaiskaya lowland elongated longitudinally between two ridges: the Mitsulsy in the west, and the Susunaisky in the east.
The area belongs to Yuzhno-Sakhalinsk climatic region with humid monsoon climate, relatively significant rainfall of about 860 mm per year, warm southern winds in summer and cold northern and north-westerly winds in winter. The average annual temperature is 2–3°C, the average minimum of -13,5°C being observed in January and the average maximum of 17,2°C being recorded in August. Frequent fogs and significant clouds characterize the climate of Yuzhno-Sakhalinsk as chilly and humid [5]. Specific geographical location and climatic conditions prevent the area from dispersal and removal of air pollutants from various sources, both stationary and mobile (rail and road transport, solid fuel boilers, etc.). As a result, a dense long-lasting smog layer is formed in the lower atmosphere. This phenomenon is often observed in cool seasons.

3. Materials and Methods
The study touches upon some distribution peculiarities of leaf-stemmed epiphytic moss in various conditions of anthropogenic impact. The research area was roughly divided into the following plots: strong impact zones (public gardens), a buffer park zone, and woodlands including control plots located at a distance from urban buildings. This distribution is due to the remoteness from the dense road network [1]. In urban areas, five plots were set up in public gardens, which are characterized by close proximity to public roads and are located in vicinity to intersections of major city roads: Sakhalinskaya Street – Mira Avenue, Lenina Street – Pogranichnaya Street, Lenin Street – Pobedy Avenue, Komsomolskaya Street – Sakhalinskaya Street. Another four plots were organized in the park zone in the Yuri Gagarin City Park of Culture and Recreation. All in all, five plots remote from major public roads were arranged on the territory of the Institute of Marine Geology and Geophysics of the Far Eastern Branch of the Russian Academy of Sciences, floodplain areas along Krasnoselskaya, Rogatka and Belaya rivers. Control plots are shown in figure 1.

Moss cover studies were conducted in the summer of 2020–2021 in two stages:

1. reconnaissance operations including test areas (plots) arrangement and herbarium materials collection for subsequent identification;
2. measurement of the cover characteristics.
Sample trees were selected to be of the same diameter, approximately the same age, with at least ten trees in the plot, without inclination and/or with inclination not exceeding 10° relative to the ground. To assess the moss cover, the number of species and species occurrence frequency were measured. To determine the frequency, a 10×40 cm (400 cm²) frame was used divided into 4 micro-sites, 10×10 cm each. The frame was applied from four sides of the tree trunk at height from 1.1 to 1.5 m. The frame image is shown in figure 2. The total of more than 2 400 micro-sites were set up in the research area. Based on these measurements, the occurrence frequency was calculated.

![Figure 2. Frame image 10×40 (400 cm²) on a tree trunk.](image)

Samples were collected with location coordinates fixed. Garmin eTrex 30 GPS navigator system was used. The altitude above sea level was recorded and the exposure was marked. Samples were gathered in paper envelopes made of wrapping paper. 10x and 15x magnifying lenses were used. Particular attention was paid to samples with sporophytes for reliable subsequent samples identification.

Samples were dried by means of generally accepted methods described in modern literature. The collected species were placed in paper envelopes with a field label indicating: collection area (site point number), substrate, collection date, cardinal direction and other data. Identification was carried out using conventional bryophytes techniques [6, 7, 8]. When identifying the samples, the following microscopes were used: Biolam, Micromed-2, MBS-10, preparation needles, tweezers, slides and cover glasses for microscopy. Materials were processed and identified in Phyto- and Geo-Ecology Laboratory of the Institute of Marine Geology and Geophysics of the Far Eastern Branch of the Russian Academy of Sciences.

4. Findings of the Study

15 species with different participation share in poplar epiphytic cover formation were identified. The species identified were assigned to two orders, 12 families and 13 genera. Most species belong to the order Hypnales Dumort. (14 species), only one species was assigned to the second order Orthotrichales Dixon (Orthotrichum sordidum cf. obtusifolium Hedw.).

Among 12 identified families, the dominant ones are Pylaiasiaceae Schimp. (3 species), two species in each of the families Anomodontaceae Kindb., Brachytheciaceae Schimp., Neckeraeaceae Schimp. The families Entodontaceae Kindb., Leskeaceae Schimp., Leucodontaceae Schimp., Orthotrichaceae Arn., Hylocomiaceae (Broth.) M.Fleisch., Scorpidiaceae Ignatov & Ignatova include one species each.

The dominant genera are presented by Anomodon Hook. & Taylor и Pylaisia Bruch et al. (two species each). The other genera have one species each: Brachythecium Bruch et al., Entodon Müll.Hal., Homalia Brid., Leskea Hedw., Leucodon Schwägr., Myuroclada Besch., Neckera Hedw., Orthotrichum Hedw., Pleurozium Mitt., Sanionia Loeske, Stereodon (Brid.) Mitt.
Typical boreal leaf-stemmed moss species are dominant for the entire study area, such as *Leskea polycarpa* Hedw. (more than 60%), *Orthotrichum sordidum* cf. *obtusifolium* Hedw. (about 32%), *Brachythecium salebrosum* (F.Weber & D.Mohr) Bruch et al. (23,55%) and *Anomodon thaustus* Mull.Hal. (19,13%). The following species are the least common: less than 1% – *Entodon* sp., *Myuroclada maximowiczii* (G.G. Borshch.) Steere & W.B.Schofield; from 1 to 3% – *Neckera pennisata* Hedw., *Sanionia uncinata* (Hedw.) Loeske, *Leucodon sciouroides* (Hedw.) Schwagr., *Pylaisia* sp., *Pleurozium schreberi* (Brid.) Mitt., *Stereodon vaucheri* (Lesq.) Lindb. ex Broth., *Anomodon longifolius* (Brid.) Hartm.

The table 1 below shows identified species with an average total occurrence for the entire study area and by anthropogenic impact zones. A dash indicates a species absent in the zone. For convenience, the types of bryophytes are placed in alphabetical order.

| Mosses species | Occurrence, % | zone type |
|----------------|---------------|-----------|
|                | Average mount | Public gardens | Park | Woodlands |
| *Anomodon longifolius* (Brid.) Hartm. | 2,71 | 5,63 | – | 2,08 |
| *Anomodon thaustus* Mull.Hal. | 19,13 | 29,38 | 22,03 | 8,65 |
| *Brachythecium salebrosum* (F.Weber & D.Mohr) Bruch et al. | 23,56 | – | 78,91 | 6,30 |
| *Entodon* sp. | 0,37 | – | – | 0,93 |
| *Homalia trichomanoides* (Hedw.) Bruch et al. | 3,54 | – | 1,14 | 8,10 |
| *Leskea polycarpa* Hedw. | 60,88 | 14,38 | 74,22 | 90,74 |
| *Leucodon sciouroides* (Hedw.) Schwagr. | 1,55 | – | 2,08 | 2,49 |
| *Myuroclada maximowiczii* (G.G. Borshch.) Steere & W.B.Schofield | 0,38 | – | – | 0,94 |
| *Neckera pennisata* Hedw. | 1,04 | – | – | 2,60 |
| *Orthotrichum sordidum* cf. *obtusifolium* Hedw. | 31,88 | 22,5 | 23,44 | 45,31 |
| *Pleurozium schreberi* (Brid.) Mitt. | 2,22 | – | 6,25 | 1,39 |
| *Pylaisia polyantha* (Hedw.) Bruch et al. | 8,18 | – | 5,47 | 16,81 |
| *Pylaisia* sp. | 2,08 | 0,63 | 6,25 | 0,52 |
| *Sanionia uncinata* (Hedw.) Loeske | 1,25 | – | – | 3,13 |
| *Stereodon vaucheri* (Lesq.) Lindb. ex Broth. | 2,50 | – | 1,00 | 5,59 |

5 species of epiphytic mosses were identified in public gardens. The highest occurrence is in *Anomodon thaustus* (29,38%) and *Orthotrichum sordidum* cf. *obtusifolium* (22,5%). The lowest occurrence is in *Pylaisia* sp. (0,63%). Samples layers are of small size and with oppression. In some zones, sporophytes were absent. Most likely, the species reproduction was mainly vegetative in such conditions. The occurrence analysis in this zone showed that urban settlements of mosses have not been completed yet. This can be influenced by a number of factors. However, one of the key factors is the degree of moisture content in epiphyte habitats.

In parks, the number of mosses increased and amounted to 10 species. Here, the dominant species are *Brachythecium salebrosum* and *Leskea polycarpa*. The species listed are highly vital. Low occurrence (no more than 3%) was observed in the following species: *Stereodon vaucheri*, *Homalia trichomanoides*, *Leucodon sciouroides*. The species have an average vitality, with sporogones being present abundantly.
15 species were recorded in woodlands. The most common species are *Leskea polycarpa* and *Orthotrichum sordidum* cf. *obtusifolium* build an epiphytic moss cover. The lowest occurrence in this zone was noted in such species as *Pyralia* sp., *Myuroclada maximowiczii*, *Entodon* sp., and *Pleurozium schreberi*. Their occurrence is not more than 2% of each. Since the control plots were located in places of natural poplar growth (such as valley forests and riverine areas), mosses are much more vital here. Poplar trunks are abundantly covered both at the upper level of bryophyte settlement and on flanges (butt ends).

For the total study area, *Leskea polycarpa* species was singled out enabling to conduct short-term monitoring and having small area coverage. This species is present in all zones. Its vitality is average and it can be recommended as a subject item for regular monitoring studies.

5. Conclusion

*Populus maximowiczii* was selected as a phorophyte prevailing in public gardens and growing naturally in floodplains areas, where study plots were set up as control ones. 15 species with different participation share in poplar epiphytic cover formation were identified on poplars. The species identified were assigned to two orders, 12 families and 13 genera. Among the 12 identified families, the dominant ones are *Pyralia*aceae (3 species) and 2 species each in the family *Anomontaceae*, *Brachytheciaceae*, *Neckeraceae*.

The research area was roughly divided into three zones (public gardens, parks and woodlands), where different numbers of epiphytic mosses were identified on poplars. 5 species were recorded in public gardens, 10 species were noted for parks, and 15 species were identified in woodlands. In each zone, a characteristic set of species was identified that prevail in the upper distribution of epiphytic cover.

At this stage, they cannot be considered resistant to anthropogenic pollution for a number of reasons, such as short-term monitoring, or poor bryophyte species study for poplars. Moss oppression was noted for all control areas. Bryophytes remote from water sources seem to directly affect their occurrence, especially in urban environment. Therefore, moss studies on the banks of open reservoirs, such as rivers, lakes, water basins and other objects, are common in the literature. Research should be continued in this direction.

References

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