Ecological bioindication-based zoning of the urbanized area in arid conditions

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Abstract. One of the most important problems is the study and conservation of biological diversity of our planet. The study of the flora species composition of any territory is the basis for the botanical and ecological research. One of the ways to control the environment is environmental monitoring. Fungi bacteria, complex symbiotic associations which include lichens, can be indicators of the state of the environment and its components. When predicting the state of the environment, especially air, representatives of lichen biota are widely used: species composition, distribution of lichens in cities, industrial centers, regions and states. Registration of indicators of lichen biota is part of the observation program of many stations of the global environmental monitoring network. It is important to study lichens in areas subject to the excessive economic impact, which includes Kalmykia.

1. Introduction
The need to study the system of interrelated natural elements that make up biogeocenoses is obvious. However, the influence of technogenic and anthropogenic factors on urban lichens has been studied for the first time: zoning based on the identified indicator species and mapping were carried out; the influence of heavy metals on woody plants and epiphytic lichen biota of Elista was studied.

The study of lichen biota in various countries, including the local (regional, zonal) one, is of great theoretical and practical importance, and represents a wide field of activity for a taxonomist-evolutionist, ecologist, geobotanist, physiologist, practitioner-forester, pharmacist, etc.

In the steppe communities of Kalmykia, epiphytic lichens and their groups are indicators of air pollution. The response of lichens to atmospheric pollution is different. This allows them to be used as environmental indicators [1].

2. Problem statement
The Republic of Kalmykia is one of the regions that has not been studied by lichenologists. Meanwhile, in the steppe conditions of Kalmykia, lichens and lichenosynusia play a special role in the mechanism of succession, being indicators of the abiotic environment and recovery (demutational) dynamics. When technical tools allow us to control the degree of gas at stations, interest in epiphytic lichens as indicators of atmospheric pollution has not weakened. The use of lichens as indicators is relevant and often more profitable [2], since the lichen indication method has a great potential (it allows us to survey large areas - regions of the country) and gives satisfactory results.

An increase in the concentration of any substances (pollutants) does not have a noticeable effect on the development of natural systems, including steppes. Under these conditions, the indicator role of lichens, the component of ecosystems which are sensitive to pollution, increases. The presence or absence of changes reflects the nature of impact of the pollutant on the ecosystems, i.e. shows whether its action is still harmless or causing changes.
3. Materials and methods
Based on the original materials collected on the territory of Kalmykia, studies of lichen biota were carried out. At the beginning, a systematic study of the survey area was undertaken using the route-stationary method. During the study, all the main natural areas were included. On the sample plots, in addition to the composition of lichen flora, the distribution and confinement of various groups of lichens to the main types of plant communities and substrates were studied. Individual associations were studied in multiple replications along the same routes. Various ecotopes were studied within the study area.

The identification of lichen species was carried out according to "Keys", "Floras" and monographs of Russian and foreign authors [3, 4, 5, 6, 7, 8]. The nomenclature of taxa is given in accordance with modern summaries [9, 10].

The study of the diversity of epiphytic lichens was carried out in all medium-sized parks, squares, forest plantations of parks, cemeteries, streets. We studied the distribution of lichens by substrates, including introduced tree species used in the urban landscaping.

Currently, there are a lot of lichenology methods. There are several classifications of these methods.

Here is the classification of Kh.Kh. Trace [11] which groups the methods as follows:

- Physiological and biochemical methods. They are used to study metabolism, the photosynthetic apparatus, and chemical composition of species.
- Anatomical and morphological methods. They are used to study changes in the internal and external structures of thalli, fruiting bodies, diasporas.
- Floristic and autecological methods. They are used to study specific species, their population, specific groups of species (ecological groups: epiphytes, epilites, epigeids; taxonomic groups: genera, families, etc.) and complete lists of species of certain habitats, substrates, territories.
- Price-synecological methods. These methods are based on the descriptions of lichen groupings as phytocoenological phenomena.

4. Discussion
It was found that the lichen biota of Kalmykia consists of 80 species belonging to 32 genera, 17 families, and six orders. The volumes of orders and families are presented according to O. Eriksson and D. Hawksworth [12], the volumes of genera are presented according to the latest reports [13, 14].

All the variety of lichen species belongs to the Ascomycota division. The basis is the order Lecanorales, which is characteristic of the temperate Holarctic. It includes 60 species from 25 genera and 12 families, or 75.0%. The remaining five orders account for 20 species from seven genera and five families (Table 1).

| Order         | Number of families | Number of genera | Number of species | % of the total number of species |
|---------------|--------------------|------------------|-------------------|---------------------------------|
| Lecanorales   | 12                 | 25               | 60                | 75,0                            |
| Teloschistales| 1                  | 3                | 14                | 17,5                            |
| Peltigerales  | 1                  | 1                | 1                 | 1,25                            |
| Dothideales   | 1                  | 1                | 1                 | 1,25                            |
| Ostropales    | 1                  | 1                | 3                 | 3,75                            |
| Verrucariales | 1                  | 1                | 3                 |                                  |
| Total         | 17                 | 32               | 80                | 100%                            |

On the territory of Elista, we divided lichens into three groups according to their distribution: resistant, medium sensitive and sensitive.
• Resistant species. They grow on the entire territory of the city, including areas with industrial facilities. These include: Caloplaca cerina, C. holocarpa, Candelariella aurella, C. reflexa, Lecanora hagenii, Phaeophyscia orbicularis, Xanthoria paretina.

• Medium sensitive species. These species are common in the peripheral areas of the city. These include: Caloplaca carpinea, C. ferruginea, C. lobulata, Lecanora chlorina, Physconia distorta, P. enteroxantha, Xanthoria candelaria, X. policarpa.

• Sensitive species. These species are found only in artificial forest plantations outside the city. This group includes Caloplaca chlorina, Parmelia sulcata, Xanthoria fallax.

The generalized boundaries of the distribution of the species of these three groups divide the territory of Elista into tree zones of pollution.

• Zone I - moderate level pollution (SO$_2$ 0.02 - 0.03 mg / sq. m.). This zone covers the central part of the city with parks and alleles. There are seven species resistant to pollution.

• Zone II - low level pollution “competition zone” (SO$_2$ less than 0.02 mg/sq. m.). It includes the zone of private houses and gardens around the city. There are 15 species which are resistant and moderately sensitive to pollution.

• Zone III - the least level pollution - artificial forest plantations outside the city. 18 species resistant and moderately sensitive to pollution were found. Species sensitive to pollution were found as well.

In addition to zoning according to the distribution of species, the city territory was mapped based on the index of atmospheric purity index (I.A.P.). Three zones of pollution were identified in Elista. The interval estimates of the index were determined taking into account the distribution of indicator species I (1-5); II - (6-10); III - (11-18). An analysis of the distribution of lichens in areas with different degrees of the anthropogenic load made it possible to compile a regional scale of the sensitivity of indicator species to pollution (Table 2.). According to the degree of sensitivity, three groups of lichens were distinguished: resistant, medium sensitive and sensitive [15] (Zakutnova, 2004).

### Table 2. Regional scale of sensitivity of indicator species to pollution

| Stable          | Medium sensitive | Sensitive        |
|-----------------|------------------|------------------|
| Caloplaca cerina| Caloplaca carpinea| Caloplaca chlorina|
| Caloplaca saxicola| C. ferruginea   | Parmelia sulcata |
| Candelariella aurella| C. lobulata     | Xanthoria fallax |
| Candelariella reflexa| Tephromela atra |                 |
| Lecanora hagenii| Physconia distorta|                |
| Phaeophyscia orbicularis| Physconia enteroxantha |   |
| Xanthoria paretina| Xanthoria candelaria |   |
|                 |                  | Xanthoria paretina |

5. Conclusion
The distribution of lichens on the territory of cities is due to ecological characteristics, including air pollution. For the first time, urbanized territories have been investigated and a comparative analysis of urban lichen biota has been carried out. Indicator species of lichens have been identified, a regional scale of sensitivity of indicator species to pollution has been compiled. According to the degree of sensitivity of species, three groups of lichens have been identified: resistant, medium sensitive and sensitive.

On the basis of their distribution and the index of atmospheric purity (I.A.P.), zones of pollution have been identified. In urban plantings, Xanthoria paretina is a common species; sensitive species are replaced by those resistant to atmospheric pollution. However, stress anthropogenic factors decrease the number and size of apothecia, cause deaths and early deaths of thalli, and delay in the development of X. paretina. Groups of the generative period are disappearing, and the population of
X. parietina is becoming reduced due to the high anthropogenic impact of vehicles, electric power facilities, oil and gas production enterprises, gas and oil product transport, construction enterprises, and processing industries.

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