

Using the lichen *Parmelia sulcata* Taylor in the urban environment monitoring

N. Istomina, O. Likhacheva,
Pskov State University, Russia

Abstract. The article presents the results of the long-term research of the lichen species population in urban environment. The tolerant species *Parmelia sulcata* Taylor was chosen as an indicator of urban conditions. The study was conducted in different parts of the city of Pskov (Russia) varying in degree of air pollution. The analyses of species' urban habitats, substrate diversity, thalli location in relation to the points of the compass, abundance and projective cover are discussed. Attention is also focused on the morphological parameters of the lichen's thalli (thalli size, presence or absence of apothecia, vegetative propagules, thalli color and presence of necro spots on the lichen individuals etc.) in different environmental conditions. Received data will serve as a base for monitoring *Parmelia sulcata* population change continuously.

Keywords: tolerant lichen species, *Parmelia sulcata*, urban environment, population state.

I INTRODUCTION

Parmelia sulcata Taylor is one of the most common species of lichens with cosmopolitan distribution [3].

Parmelia sulcata is considered to be one of the lichen species tolerant to the effects of atmospheric pollutants in the city environment [7], [12], [13], [14], and along with other species it is used as an indicator of environment conditions, e.g. [12], [14]. However, in the city of Pskov, where large industrial enterprises are absent, but the amount of motor transport annually increases [10], there has been a tendency of *Parmelia sulcata* population size reduction in recent years.

The aim of this work was to study the population state of the lichen *Parmelia sulcata* in the city of Pskov.

II MATERIALS AND METHODS

Parmelia sulcata was studied in 9 green areas, located in 5 districts of Pskov city (Fig. 1).

All selected areas were located in different part of the city and were under different anthropogenic pressure.

The present study was conducted during the field seasons in 2004-2012. In every stand, the tree trunks were examined. The presence of *Parmelia sulcata* was recorded up to a 3 m height all around the tree. The total number of investigated stems, number of stems with the thalli of *Parmelia sulcata*, and the number of detected thalli are presented in Table I.



Fig. 1. Studied areas in Pskov city: 1 – Parks in the city center (1 – Detskiy park, 2 – Kutuzov park, 3 – “Botanical garden”, 4 – “Letniy garden”, 5 – Finskiy park); 2 – Zapskov’e (plantings along Truda street); 3 – Zavelich’e-1 (1 – planting around the regional hospital, 2 – plantings around military hospital, 3 – Mirozhskiy dendropark); 4 – Zavelich’e-2 (planting around the city hospital); 5 – public garden near the railway station

TABLE I
NUMBER OF INVESTIGATED TREES AND LICHEN THALLI

City district	Number of trees	Number of tree trunks with thalli of <i>Parmelia sulcata</i>	Number of thalli
Center of the city	1587	484	747
Zapskov’e	386	64	234
Zavelich’e-1	131	73	243
Zavelich’e-2	59	30	69
Near the railway station	807	122	186

ISSN 1691-5402

For every phorophyte species belonging was identified, tree diameter at breast height (cm) was measured, type of bark was defined according to V. Peciar [9].

For every sample of *Parmelia sulcata* the exposure, height, thallus size, the color of thallus, the presence (or absence) of reproductive organs, and the presence of necro spots were recorded.

III RESULTS AND DISCUSSION

In total *Parmelia sulcata* was discovered on the bark of 13 tree and shrub species (Table II).

However, it more frequent settled on the trunks of broad-leaved species, in particular on the bark of lime, which is dominant in urban green areas.

TABLE II
DISTRIBUTION OF *PARMELIA SULCATA* BY TREE SPECIES (IN %)

Green areas	Parks in the city center					Zapkov'e	Zavelich'e-1			Zavelich'e-2	Public garden near the railway station
	Detskiy park	Kutuzov park	"Botanical garden"	"Letniy garden"	Finskiy park	Plantings along Truda street	Planting around the regional hospital	Plantings round the military hospital	Mirozhskiy dendropark	Planting around the city hospital	
<i>Acer platanoides</i> L.	10.3	4.6	1.5	26.2		6.3	32.4	5.2	35.0	23.3	1.1
<i>Tilia cordata</i> L.	82.1	81.4	81.5	69.7	72.7	87.5	32.4			46.7	85.0
<i>Quercus robur</i> L.	4.7	14.0	4.5		1.8	4.7	5.8			6.7	0.5
species of <i>Populus</i>				1.4	1.8		2.9	94.8	10.0		4.8
<i>Fraxinus excelsior</i> L.			8.1	2.1			17.6		55.0	3.3	
<i>Aesculus hippocastanum</i> L.	1.8		1.5				2.9				1.6
<i>Betula pendula</i> Roth					23.6	1.6					6.4
<i>Sorbus aucuparia</i> L.							5.8			3.3	0.5
<i>Ulmus glabra</i> Huds.	0.9			0.7							
<i>Malus domestica</i> Borkh.										3.3	
<i>Crataegus sanguinea</i> Pall.										13.3	
<i>Corylus avellana</i> L.			1.5								
<i>Padus avium</i> Mill.			0.7								

Tree age and age-related parameters of the tree (size of trunk) influence the lichen species composition and distribution of lichen thalli on the phorophytes, e. g. [5]. In our study, tree size was assessed by measuring the stem diameter at breast height. The measurement data of the surveyed trees are presented in Table III.

TABLE III
CHARACTERISTICS OF TREES WITH *PARMELIA SULCATA*, RECORDED IN DIFFERENT CITY DISTRICTS

City district	Tree diameter at breast height, cm		
	mean	min.	max.
Center of the city	35.4	10	120
Zapkov'e	31.2	10	50
Zavelich'e-1	38.1	10	210
Zavelich'e-2	27.4	12	60
Near the railway station	41.5	19	64
Mean	34.7	10	210

The analysis of habitat preference showed that in the city of Pskov *Parmelia sulcata* occurred on phorophytes with different trunk diameter (from 10 to 210 cm). However, it is mainly found on trees with the average stem diameter (34.7 cm).

In the literature, there is information about the vertical distribution patterns of lichens on the trunk of phorophytes [1]. Some species of epiphytic lichens settle on the base (butt) of the stem, while others climb up the trunk to a height of several meters, and others prefer habitats on the branches in the tree crown. Distribution of *Parmelia sulcata* thalli on the tree stems presented in Table IV.

TABLE IV
DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: HEIGHT

City district	Altitude, cm			Number of lichen thalli, %	
	mean	min.	max.	under 60 cm	above 60 cm
Parks in the center of the city	129.7	10	300	5.5	94.5
Zapkov'e	118.8	15	230	14.1	85.9
Zavelich'e-1	135.1	25	200	15.1	84.9
Zavelich'e-2	172.9	80	200	0	100.0
Near the railway station	175.0	150	200	0	100.0

In the Pskov green areas the vast majority of *Parmelia sulcata* thalli were found on stems above 60 cm in height. Up to 15% thalli may occupy the lower part of the stem (from the base to 60 cm). However, the annual treatment of the tree trunks with whitewash (protection from insect pests), leads to the disappearance of lichen thalli on the entire treated surface of the stem. In this case, mean height of thalli occurrence on the trunk increases (Table IV).

For different epiphytic lichen species physical properties of tree bark, in particular, parameters of the surface, are the determinants for settlement [1], [11]. Typically, for many tree species growth of stem leads the changes in the physical properties of the bark. It becomes more rough and cracked, the depth of cracks increases with age, creating more opportunities for lichens to settle and secure.

In the city of Pskov *Parmelia sulcata* grows on tree trunks with 3 different structural types of bark (in accordance with the V. Peciar [7]): 1. bark with deep cracks; 2. relatively thin bark with swallow cracks; 3. smooth bark, or in older trunks with shallow cracks (Table V).

TABLE V
DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: TYPE OF BARK (IN %)

City district	Type of bark		
	1	2	3
Center of the city	34.5	58.2	7.6
Zapskov'e	76	9	15
Zavelich'e-1	46	49	5
Zavelich'e-2	64	29	7
Near the railway station	93	7	0
Mean	62.6	30.4	7.0

In the environment of Pskov city, studied species prefers the first type of bark (with deep cracks). At the same time, in the parks of the central part of the city the majority of thalli was found on the bark of the second type (58.2%). Apparently, for the main park-forming species (linden, maple, ash) the types of bark correspond to the age stages of the phorophytes.

It is very widely believed that lichens prefer to settle on the northern side of the trunk, but A. V. Dombrovskaya [2] considered, that in most cases lichens settle either evenly (on any side of trunk), or on the leeward side. In our case the distribution of *Parmelia sulcata* thalli occurrence was not highly skewed (Table VI).

TABLE VI
DISTRIBUTION OF *PARMELIA SULCATA* BY PHOROPHYTES: EXPOSURE (IN %)

City districts	Exposure			
	North	East	South	West
Parks in the center of the city	41.4	25	18.8	14.8
Zapskov'e	44	25	7	24
Zavelich'e-1	31.7	27	21.3	20.3
Zavelich'e-2	35	20	23	22
Near the railway station	36.5	28	15.6	19.8
Mean	37.7	25	17	20.2

According to our data, *Parmelia sulcata* was found on all four exposures, preferring northern one.

Various factors of the urban environment effect on the physiological processes in lichen thallus, changing the speed of growth and morphological parameters. *Parmelia sulcata* thalli size in the studied green zones are shown in Table VII.

TABLE VII
PARMELIA SULCATA THALLI SIZE (IN CM²)

City district	Thalli size, cm ²		
	Mean	Min.	Max.
Center of the city	12.5	0.2	400
Zapskov'e	16.6	0.1	140
Zavelich'e-1	6.5	0.15	51
Zavelich'e-2	14.5	0.25	84

In general, reduction in the average size of lichen thalli is observed in different parts of the city. If we compare the data obtained with the average parameters specified in the literature (25-225 cm²) [3], it becomes evident, that these changes are significant.

Reducing the size of lichen thalli with increasing atmospheric pollution noted by many authors [1], [4]. A 4 times decrease in the size of lichens thalli in comparison with conventionally clear territory was shown by the investigations in Ekaterinburg [8].

The reproductive potential of the species is considered to be one more criterion of the environment impact assessment. In our study presence or absence of soredia on *Parmelia sulcata* thalli was recorded (Table VIII).

In the majority of the surveyed stands a high percentage of thalli with soredia (up 75.4%) was recorded. Some authors suggest that, for many lichen species increase in soredia production associates with protection from the harmful effects by sulfur dioxide on the thallus, as well as promotes the reproduction and expansion to new habitats in the urban environment [6]. Others [8], on the contrary, observed a decrease in the soredia generation for *Hypogymnia physodes* and *Parmelia sulcata* with increasing of anthropogenic pressure.

TABLE VIII
NUMBER OF *PARMELIA SULCATA* THALLI WITH SOREDIA

City district	Number of thalli recorded	Number of thalli with soredia	
		Count	Percentage
Center of the city	747	463	62.0%
Zapskov'e	234	-	-
Zavelich'e-1	243	147	60.5%
Zavelich'e-2	69	52	75.4%
Near the railway station	186	106	57.0%
Mean			63.7%

To determine the absolute age of lichens is difficult, but there is a direct correlation between development and age: the larger the thallus, the more his calendar age is. Therefore, in our study all *Parmelia sulcata* thalli were assigned to three groups:

- 1) up to 2.5 cm² – young samples;
- 2) from 2.5 to 25 cm² – middle-aged;
- 3) from 25 cm² – old.

The diagram (Fig. 2) shows the age structure of the investigated population.

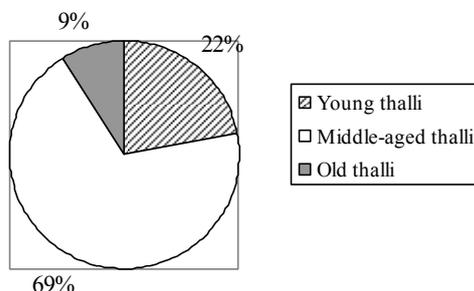


Fig. 2. Age structure of the *Parmelia sulcata* population

The population of *Parmelia sulcata* in the city of Pskov is mature, with the dominance of middle age generative thalli (69%).

Air pollution in the cities leads to a change in the color of the upper surface of the thalli and emergence of necro spots on them. In case of our study, the change of normally grey upper surface to rose and further brown color was recorded.

The quality of the thalli of different age groups is presented on the diagram on a Fig. 3.

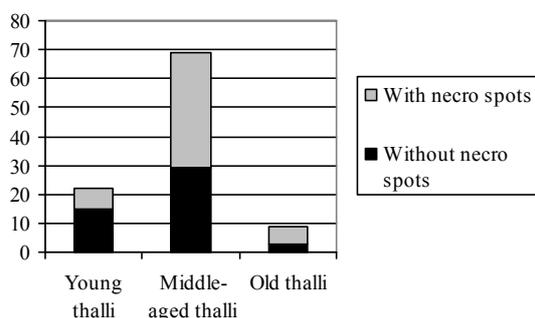


Fig. 3. Quality of different age groups thalli

In all surveyed areas in the city lichen thalli with necrosis were found in all age groups. Probably, changes in the color of thalli related to the degree of pollution, induced by traffic, the intensity of which increases in the city annually.

IV CONCLUSIONS

Tolerant lichen species *Parmelia sulcata* in the city of Pskov is in a state of depression. There is tendency

of lichen thalli size reducing, high soredia production and emergence of necro spots on *Parmelia sulcata* thalli, that appeared as a response to the city air pollution.

The data obtained can become the basis for the long-term monitoring of *Parmelia sulcata* population in the city of Pskov. Further study of species biology and its ability to adapt to the urban environment is planned.

V REFERENCES

- [1] L. G. Byazrov, *Lichens in environmental monitoring*. Moscow, 2002, 336 p.
- [2] A. V. Dombrovskaya, *Lichens of Hibiny*. Leningrad, 1970, 196 p.
- [3] *Handbook on the lichens of the USSR*. Vol. 1. Leningrad, 1971. 412 p. [in Russian]
- [4] I. D. Insarova, Effect of sulfur dioxide on lichens in *Problems of environmental monitoring and modeling of ecosystems*, Leningrad, 1982, vol. 5, pp. 33-48.
- [5] H. M. Lie, U. Arup, J.-A. Grytnes, M. Ohlson, The importance of the host tree age, size and growth rate as determinants of epiphytic lichen diversity in boreal spruce forests in *Biodiversity and Conservation*, 2009 [Online]. Available at: DOI 10.1007/s10531-009-9661-z. [Accessed: Mar. 15, 2010].
- [6] N. V. Malysheva, Lichens of Saint-Petersburg. The influence of the urban environment and lichenoidication of air pollution in *Bot. journ.*, 1998 vol. 83, no. 9, pp. 39-45.
- [7] A. G. Paukov, *Lichen flora of urboecosystems*. Thesis. Ekaterinburg, 2001.
- [8] A. G. Paukov, I. S. Gulika, Anatomical and morphological changes of lichens in anthropogenically disturbed habitats in *Development of the academician S. S. Schwartz' ideas in modern ecology*. Ekaterinburg, 1999, pp. 134-140.
- [9] V. Peciar, Epiphytische Moosgesellschaften der Slawakei in *Acte Fac Res. Nat. Univ. Botanica*, 1965, pp. 369-466.
- [10] Report on the environmental situation in the Pskov region in 2013 [Online]. Available at: <http://www.priroda.pskov.ru/ezhegodnyi-doklad-ob-ekologicheskoi-situatsii-pskovskoi-oblasti> [Accessed: Mar. 17, 2015].
- [11] E. Skye Lichens and air pollution. A study of cryptogamic epiphytes and environment in the Stockholm region in *Acta Phytogeographica Suecica*, vol. 52, Uppsala, 1968, pp. 1-123.
- [12] S. Stamenković, M. Cvijan, M. Arandjelović, Lichens as bioindicators of air quality in Dimitrograd (South-Eastern Serbia) in *Arch. Biol. Sci.*, Belgrade, 62 (3), 2010, pp. 643-648.
- [13] H. H. Trass, Classes of lichen poleotolerance and environmental monitoring in *Problems of environmental monitoring and modeling of ecosystems*. Leningrad, 1985, vol. 7, pp. 122-137.
- [14] I. Vicol, Preliminary Study On Epiphytic Lichens As An Indicator Of Environmental Quality In Forests From Around Bucharest Municipality (Romania) in *Analele Universității din Oradea – Fascicula Biologie*, vol. XVII/1, 2010, pp. 200-207.