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RESEARCH ARTICLE

# Diversity of lichens of the genus *Cladonia* P. Browne (Cladoniaceae, Ascomycota) in the Karegodsky Nature Reserve (Tomsk Oblast, Western Siberia)

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## Abstract

An inventory study of lichens of the genus *Cladonia* P. Browne was conducted in the Karegodsky Zoological Nature Reserve, located within the Ob–Chulym interfluve (Molchanovsky District, Tomsk Oblast, Western Siberia). Field investigations were carried out in August 2025 using route methods covering the main plant communities and substrate types. Pine forests, willow–poplar forests, birch–aspen forests, and anthropogenically disturbed areas were surveyed. More than 350 specimens were collected and identified. A total of 45 *Cladonia* species were recorded in the study area, which is comparable to the 44 species documented for the entire Ob–Chulym interfluve and indicates high representativeness of the reserve's lichen biota. Twelve species are reported for the first time for this physiographic region, substantially expanding knowledge of *Cladonia* distribution in Western Siberia. The highest species richness was observed in pine forests, characterized by high light availability and substrate diversity. Substrate preference analysis revealed predominance of epixylic and epigeic forms, as well as a high proportion of eurysubstrate species, reflecting the ecological plasticity of *Cladonia* in taiga ecosystems. The presence of pollution-sensitive species indicates favorable ecological conditions in the reserve. These data provide a foundation for future monitoring of lichen flora and assessment of natural complex dynamics in protected areas.

## Keywords

Lichen biota, biodiversity, taiga ecosystems, protected areas, substrate preference

## Introduction

Lichens of the genus *Cladonia* P. Browne represent one of the most widespread groups in the lichen biota of Western Siberia (Sedelnikova 2017) and are an important component of the ground cover in taiga ecosystems. They participate in moisture and nutrient accumulation (van Zuijlen et al. 2020), form substrate for other organisms, and serve as sensitive indicators of changes in abiotic conditions and anthropogenic impacts (Byazrov 2002). Despite their ecological significance, the lichen cover is often inadequately studied during vegetation inventories. This is particularly true for studies on protected areas, which preserve natural habitats and allow objective assessment of species diversity with minimal anthropogenic influence, making such research essential for subsequent monitoring and conservation of natural complexes.

The territory of Tomsk Oblast has been studied repeatedly regarding its lichen biota (Kuznetsov 1915; Sukhinina 1973; Rudenko 2000, 2001; Yefremov and Kovaleva 2001; Kovaleva 2001, 2004; Koneva 2007; Kazantseva et al. 2025a, 2025b). Among these investigations, one of the most comprehensive studies devoted to the lichens of the Ob–Chulym interfluve was conducted by Koneva (2004), who described 44 *Cladonia* species for the entire interfluve region with details on their distribution and ecological preferences. Subsequent publications (Koneva 2007, 2023) supplemented knowledge of the ecological role of these species in regional plant communities. However, the surveyed areas covered only parts of the interfluve, leaving significant portions insufficiently studied.

The present study addresses this gap by conducting an inventory of *Cladonia* species in the Karegodsky Nature Reserve, a protected area located within the Molchanovsky District of Tomsk Oblast in a previously unstudied section of the Ob–Chulym interfluve. Analysis of species distribution across different plant communities and substrates substantially expands understanding of the region's lichen biota and establishes a scientific foundation for future monitoring and conservation of the reserve's natural complexes.

### Study area

The Karegodsky Zoological Nature Reserve is located in Molchanovsky District of Tomsk Oblast within the Ob–Chulym interfluve (Fig. 1). The reserve covers 26,300 hectares within state forest land and is characterized by predominantly flat relief. The territory belongs to the southern taiga subzone and is characterized by a sharply continental climate with mean annual temperatures of –19.8 °C in January and +18.0 °C in July (Yevseyeva 2001).

The hydrological network includes a system of tributaries of the Ob and Chulym rivers, as well as numerous lakes of floodplain and terrace origin, oxbow lakes, and wetlands of various types. Vegetation is highly diverse and represented by a complex of forest and wetland communities. The taiga portion is characterized by dominance of pine forests with well-developed lichen and moss–herb cover. River valleys are characterized by floodplain meadows, birch–aspen groves, willow thickets, and flooded shrub–sedge communities. In relief depressions, birch lowland bogs are formed. Abandoned settlements are also present on the reserve territory.

The reserve has particular conservation value as a refuge preserving natural taiga ecosystems harboring fauna species included in the Red Books of the Russian Federation and Tomsk Oblast. The protected status ensures minimal anthropogenic impact and creates optimal conditions for inventorying natural biodiversity.

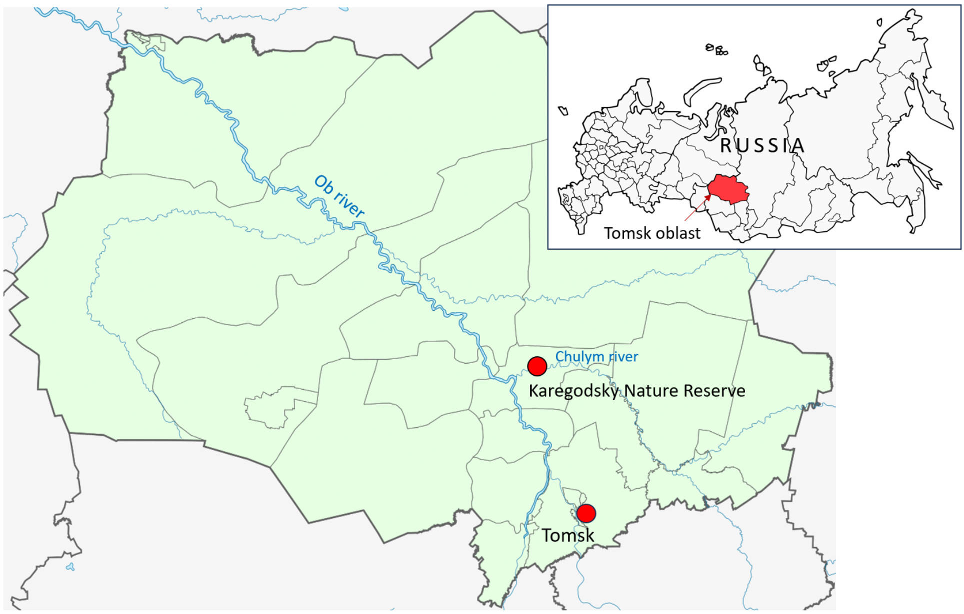



**Figure 1.** The physico-geographical location of the Karegodsky Nature Reserve in the Ob-Chulym interfluve (Tomsk Oblast).

## Materials and methods

Field investigations were conducted in August 2025. Lichen specimens of the genus *Cladonia* were collected using route methods covering the main plant community types and microhabitats. Forests on both banks of the Chulym River were surveyed across different vegetation types.

### Sampling locations

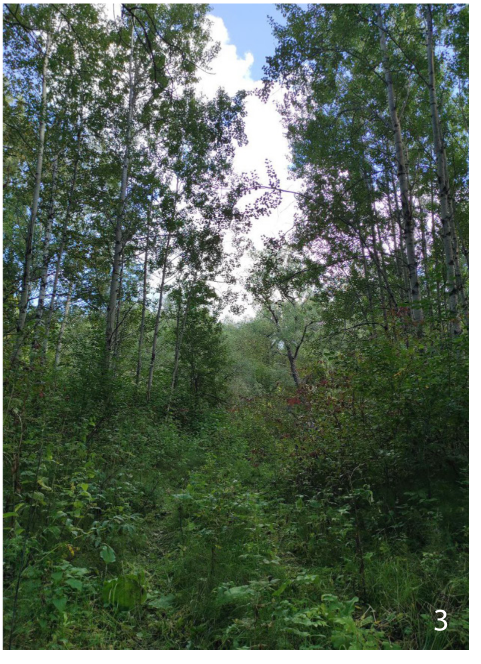
Pine forests (Fig. 2) – the predominant vegetation type of the reserve. Sites were surveyed with varying degrees of canopy closure, including open clearings. Lichen cover developed on soil, stumps, coarse woody debris in various states of decomposition, and on bark of living trees (pine, birch, larch, caragana).

Willow–poplar forests – floodplain forests in the Chulym River valley characterized by high moisture content, abundant fallen timber, and dead wood in various decomposition stages.

Birch–aspen forests – secondary forests on previously disturbed areas with well-developed herbaceous and moss cover.

Surroundings of the abandoned settlement Orlovka (Fig. 3) – anthropogenically disturbed sites with remnants of wooden structures, old fences, and wooden platforms.

Surroundings of the abandoned settlement Strezhnoe – abandoned territory with anthropogenic substrates.


**Figures 2–3.** Lichen collection sites in the Karegodsky Nature Reserve: **2** – Pine forest; **3** – Surroundings of the abandoned settlement Orlovka.

Specimens were collected from diverse substrates: forest litter, open ground, coarse woody debris, stumps, bark of living trees (pine, birch, larch, caragana), and anthropogenic substrates (remains of wooden structures). More than 350 specimens were collected in total.

Species identification was based on the following sources: Handbook of the Lichens of the USSR, Vol. 5 (Golubkova et al. 1978); Lichens of North America (Brodo et al. 2001); The Lichens of Great Britain and Ireland, 2nd ed. (Smith et al.

2009); and Handbook of Fruticose and Foliose Lichens of the USSR (Tomin 1937). Taxonomic nomenclature follows the Index Fungorum database (as of December 2025). Herbarium specimens are deposited at the Department of Botany, Tomsk State University.

## Results and discussion

Field investigations of the Karegodsky Nature Reserve revealed 45 lichen species of the genus *Cladonia*. An annotated list of species with information on habitats and substrates is presented below:

*Cladonia arbuscula* (Wallr.) Flot. – pine forest, on soil, on open ground.

*C. bacilliformis* (Nyl.) Sarnth. – pine forest, on stumps.

*C. botrytes* (K.G. Hagen) Willd. – pine forest, on stumps and coarse woody debris; birch–aspen forest, on coarse woody debris; willow–poplar forest, on coarse woody debris and soil; vicinity of Orlovka, on anthropogenic substrates.

*C. cariosa* (Lilj.) Spreng. – pine forest, on stumps; willow–poplar forest, on soil.

*C. carneola* (Fr.) Fr. – pine forest, on caragana bark; willow–poplar forest, on coarse woody debris.

*C. cenotea* (Ach.) Schaer. – pine forest, on open ground soil, on pine bark, on birch bark, on coarse woody debris; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on coarse woody debris and soil; vicinity of Orlovka, on coarse woody debris.

*C. cervicornis* (Ach.) Flot. – pine forest, on soil; willow–poplar forest, on soil and coarse woody debris.

*C. chlorophaea* (Flörke ex Sommerf.) Spreng. s. l. – pine forest, on stumps and soil; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on coarse woody debris.

*C. coccifera* (L.) Willd. – willow–poplar forest, on coarse woody debris.

*C. coniocraea* (Flörke) Spreng. – pine forest, on stumps, soil, coarse woody debris, and caragana bark; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on soil and coarse woody debris.

*C. cornuta* (L.) Baumg. – pine forest, on stumps and open ground soil; willow–poplar forest, on coarse woody debris and soil.

*C. crispata* (Ach.) Flot. – pine forest, on soil; willow–poplar forest, on coarse woody debris and soil.

*C. decorticata* (Flörke) Flot. – pine forest, on soil and open ground; birch–aspen forest, on birch bark; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on anthropogenic substrates.

*C. deformis* (L.) Hoffm. – pine forest, on stumps, pine bark, and soil; willow–poplar forest, on soil.

*C. digitata* (L.) Baumg. – pine forest, on stumps, coarse woody debris, soil, and birch bark; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on coarse woody debris.

*C. ecmocyna* Leight. – pine forest, on birch and pine bark; willow–poplar forest, on coarse woody debris.

*C. fimbriata* (L.) Fr. – pine forest, on soil, coarse woody debris, and caragana bark; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on soil and coarse woody debris; vicinity of Strezhnoe, on anthropogenic substrates.

*C. floerkeana* (Fr.) Flörke – willow–poplar forest, on coarse woody debris.

*C. foliacea* (Huds.) Willd. – pine forest, on pine bark; willow–poplar forest, on coarse woody debris.

*C. furcata* (Huds.) Baumg. – pine forest, on soil.

*C. glauca* Flörke – pine forest, on stumps and open ground soil; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on coarse woody debris.

*C. gracilis* (L.) Willd. – pine forest, on stumps, open ground soil, coarse woody debris, and soil; birch–aspen forest, on coarse woody debris; willow–poplar forest, on coarse woody debris and soil.

*C. grayi* G. Merr. ex Sandst. – pine forest, on open ground soil and pine bark.

*C. humilis* (With.) J.R. Laundon – pine forest, on soil; willow–poplar forest, on coarse woody debris.

*C. macilenta* Hoffm. – pine forest, on stumps and pine bark; birch–aspen forest, on birch bark and coarse woody debris; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on anthropogenic substrates.

*C. mitis* Sandst. – willow–poplar forest, on coarse woody debris and soil; vicinity of Orlovka, on anthropogenic substrates.

*C. ochrochlora* Flörke – pine forest, on stumps, coarse woody debris, larch bark, birch bark, and pine bark; birch–aspen forest, on birch bark; willow–poplar forest, on soil; vicinity of Strezhnoe, on anthropogenic substrates.

*C. parasitica* (Hoffm.) Hoffm. – willow–poplar forest, on coarse woody debris.

*C. peziziformis* (With.) J.R. Laundon – pine forest, on stumps and pine bark; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on coarse woody debris.

*C. phyllophora* Hoffm. – pine forest, on stumps, coarse woody debris, pine bark, soil, and birch bark; vicinity of Orlovka, on coarse woody debris.

*C. pleurota* (Flörke) Schaer. – pine forest, on birch and pine bark; willow–poplar forest, on coarse woody debris.

*C. polydactyla* (Flörke) Spreng. – pine forest, on larch and birch bark; willow–poplar forest, on soil.

*C. ramulosa* (With.) J.R. Laundon – pine forest, on birch bark; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on coarse woody debris.

*C. rangiferina* (L.) Weber – pine forest, on stumps, coarse woody debris, soil, and pine bark; willow–poplar forest, on coarse woody debris.

*C. rei* Schaer. – pine forest, on open ground soil and birch bark; willow–poplar forest, on soil.

*C. scabriuscula* (Delise) Nyl. – pine forest, on birch bark, soil, pine bark, and caragana bark; willow–poplar forest, on coarse woody debris; vicinity of Orlovka, on coarse woody debris.

*C. squamosa* Hoffm. – pine forest, on stumps, pine bark, soil, and birch bark; willow–poplar forest, on coarse woody debris.

*C. stellaris* (Opiz) Pouzar & Vězda – pine forest, on stumps and soil.

*C. stricta* (Nyl.) Nyl. – pine forest, on soil; willow–poplar forest, on soil and coarse woody debris.

*C. stygia* (Fr.) Ruoss – pine forest, on soil.

*C. subcervicornis* (Vain.) Kernst. – pine forest, on soil.

*C. subulata* (L.) F.H. Wigg. – pine forest, on stumps and birch bark; birch–aspen forest, on coarse woody debris; willow–poplar forest, on soil and coarse woody debris; vicinity of Orlovka, on anthropogenic substrates.

*C. sulphurina* (Michx.) Fr. – willow–poplar forest, on coarse woody debris.

*C. uncialis* (L.) F.H. Wigg. – pine forest, on soil; vicinity of Orlovka, on anthropogenic substrates.

## Comparative analysis

The inventory revealed 45 *Cladonia* species in the Karegodsky Nature Reserve, comparable to the 44 species documented by Koneva (2004) for the entire Ob–Chulym interfluve. Thirty species are shared between the two inventories, indicating the typicality of the reserve's lichen biota for the region.

Of particular interest are 12 species reported for the first time in the Ob–Chulym interfluve: *C. cervicornis*, *C. ecmocyna*, *C. foliacea*, *C. furcata*, *C. humilis*, *C. peziziformis*, *C. polydactyla*, *C. ramulosa*, *C. rei*, *C. scabriuscula*, *C. squamosa*, and *C. subcervicornis*.

Fourteen species from Koneva's (2004) list were not encountered in the reserve, which may be explained by local differences in habitat conditions or insufficient coverage of certain community types (e.g., ombrotrophic bogs).

## Substrate preferences

Analysis of substrate preferences for the 45 *Cladonia* species revealed wide diversity of ecological strategies and considerable variability in substrate utilization (Sedelnikova 2017). Most species are characterized by eurysubstrate ecology, reflecting the broad ecological plasticity of the genus in taiga landscapes.

Epixylic lichens predominated: 33 species (73.3%) were recorded on coarse woody debris (Fig. 4) and 19 species (42.2%) on stumps. The high proportion of epixylic species is typical for taiga ecosystems, where dead wood provides an important substrate ensuring stable moisture and nutrient conditions (Sedelnikova 2017). Coarse woody debris at various decomposition stages creates microhabitat diversity, facilitating colonization by species with varying ecological requirements.

**Figure 4.** Part of a log covered with *Cladonia* in willow–poplar forest.

Epigeic species ranked second in frequency: 33 species (73.3%), with 25 species found on forest litter and 8 on open ground. This pattern is consistent with reports of dominant epigeic and epixylic *Cladonia* forms in boreal forests (Sedelnikova 2017; Koneva 2007).

Epiphytic lichens inhabiting tree bark (including those among mosses) were represented by 23 species (51.1%), predominantly on birch bark (17 species) and pine bark (13 species). Four species occurred on caragana and 2 on larch.

Eight species (17.8%) were noted on anthropogenic substrates, indicating the presence of both disturbance-sensitive and disturbance-tolerant forms in the lichen flora (Byazrov, 2002). The ability of some *Cladonia* species to colonize processed wood and other anthropogenic materials indicates their potential for restoration on disturbed territories.

Regarding substrate specialization, both narrowly specialized monosubstrate species (9 species, 20%) and numerous eurysubstrate forms were identified. Twenty-one species (46.7%) occurred on three or more substrate types. The most ecologically plastic species was *C. ochrochlora*, recorded on seven substrate types, from forest litter and coarse woody debris to bark of various tree species and anthropogenic surfaces. This broad ecological amplitude allows successful colonization of diverse habitats and may serve as an indicator of resistance to environmental changes.

## Distribution among plant communities

Maximum species richness was observed in pine forests – 40 species (88.9%). This is associated with high light availability, acidic soil predominance, and diverse dead wood, creating optimal conditions for most *Cladonia* representatives (Sedelnikova 2017; Koneva 2004). Southern taiga pine forests are characterized by well-developed ground lichen cover, in which *Cladonia* species play a dominant role.

Thirty-six species (80%) were identified in willow–poplar communities. High species diversity in these communities is explained by elevated moisture levels in floodplain forests and abundant decaying wood providing diverse microhabitats. Periodic flooding and subsequent desiccation create moisture gradients allowing coexistence of species with different hydrological requirements.

Birch–aspen forests yielded 11 species (24.4%), likely reflecting weaker lichen cover development in these secondary communities and limited survey area. These forests are characterized by denser herb layer and reduced light availability in the ground layer, potentially limiting development of light-demanding *Cladonia* species.

## Ecological significance and monitoring prospects

The findings confirm that *Cladonia* lichen biota in the taiga zone is characterized by dominance of epixylic and epigeic forms and high proportion of eurysubstrate species. These features can be utilized in future monitoring studies, assessment of forest ecosystem condition, and analysis of lichen flora response to natural and anthropogenic changes.

The presence of sensitive species, including *C. stellaris* and *C. rangiferina*, indicates good preservation of the reserve's natural complexes and low atmospheric pollution levels. These species are known for their sensitivity to air pollution and can serve as environmental quality indicators (Byazrov 2002).

Conversely, detection of species on anthropogenic substrates in the vicinity of abandoned settlements indicates certain *Cladonia* representatives' ability to colonize secondary habitats. This is consistent with reports of gradual lichen community recovery on disturbed territories. Species *C. coniocraea*, *C. fimbriata*, and *C. ochrochlora* demonstrate greatest tolerance to anthropogenic changes and may be considered pioneer species in colonization of disturbed substrates.

The significant number of new species records (12 species) underscores the necessity of continuing inventory investigations at other protected areas. Future research should focus on lichen community dynamics across various vegetation types and assessment of climate change impacts on species distributions.

## Conclusion

Forty-five *Cladonia* species were identified in the Karegodsky Nature Reserve, substantially expanding knowledge of the Ob–Chulym interfluve's lichen biota. Twelve species are reported for the first time: *C. cervicornis*, *C. ecmocyna*, *C. foliacea*, *C. furcata*, *C. humilis*, *C. peziziformis*, *C. polydactyla*, *C. ramulosa*, *C. rei*, *C. scabriuscula*, *C. squamosa*, and *C. subcervicornis*.

Maximum species richness was documented in pine forests (40 species, 88.9%), associated with optimal light conditions and substrate diversity. Identified species are characterized by predominance of epixylic (33 species, 73.3%) and epigeic (33 species, 73.3%) forms, as well as high proportion of eurysubstrate species (21 species occurring on three or more substrate types, representing 46.7%).

The research confirms the ecological value of the Karegodsky Reserve as a refuge preserving natural southern taiga lichen communities. The presence of pollution-sensitive species (*C. stellaris*, *C. rangiferina*) indicates favorable environmental conditions in the reserve. These findings provide foundation for future monitoring of lichen flora under changing natural and anthropogenic conditions and can be utilized in developing measures for regional biodiversity conservation.

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