

Lycopodiella inundata (L.) Holub (Lycopodiaceae)
in the Komi Republic (Russian Federation)

© 2020. L. V. Teteryuk¹ ORCID: 0000-0002-9573-7923,
Yu. A. Bobrov² ORCID: 0000-0002-2709-7004, B. Yu. Teteryuk¹ ORCID: 0000-0002-7202-9956,
T. I. Marchenko-Vagapova³ ORCID: 0000-0003-4406-7939,
Yu. V. Golubeva³ ORCID: 0000-0001-6383-8749, V. A. Kanev¹ ORCID: 0000-0002-6284-0385,
S. N. Plyusnin² ORCID: 0000-0002-9342-152X

¹Institute of Biology of Komi Scientific Center of the Ural Branch
of the Russian Academy of Sciences,
28, Kommunisticheskaya St., Syktyvkar, Russia, 167982,

²Pitirim Sorokin Syktyvkar State University,
55, Oktyabrskiy Prospekt, Syktyvkar, Russia, 167001,

³Institute of Geology of Komi Scientific Center of the Ural Branch
of the Russian Academy of Sciences,
54, Pervomayskaya St., Syktyvkar, Russia, 167610,
e-mail: teteryuk@ib.komisc.ru

Lycopodiella inundata expands its areal on the European North-East of Russia. In the subzone of the middle taiga of the Komi Republic in 2017–2018, four local populations of this species were found, associated with anthropogenic ecotopes, poor and acidic sands, or peat, varying in moisture regime. Obligatory satellites of *L. inundata* in plant communities are *Drosera rotundifolia* L. and *Juncus filiformis* L., mosses of the genera *Sphagnum* L. and *Polytrichum* Hedw. Its local populations are small, beyond protection areas of the Komi Republic and so are endangered. The life-form of the *Lycopodiella inundata* sporophyte is a spore variance of perennial plant with annual shoot system. This species prefers vegetative multiplication through natural winter morphological disintegration. For determine the population in the beginning of shoots growth, ramets are recommended to be counted. The paleo-geographic analysis makes it possible to exclude the relic nature of the present locations of *L. inundata* in the European North and allows one to classify the species as an allochthonous element of the flora. In view of the fact that the species is rare and tends to decrease its habitats worldwide, we included *L. inundata* into new edition of the Red Data Book of the Komi Republic with protection status category 3 (Rare). All habitation places of the species are out of specially protected areas of the republic and so are threatened. Limiting factors for this stenotopic species in the Komi Republic are its narrow ecological amplitude, low competitiveness, instability to violations of the hydrological regime (bogging or draining) and overgrowth of biotopes due to natural succession processes.

Keywords: *Lycopodiella inundata*, North-East of the European part of Russia, the Komi Republic, flora, rare protected species.

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Lycopodiella inundata (L.) Holub (Lycopodiaceae)
в Республике Коми (Россия)

© 2020. Л. В. Тетерюк¹, к. б. н., с. н. с., Ю. А. Бобров², к. б. н., зав. кафедрой,
Б. Ю. Тетерюк¹, к. б. н., с. н. с., Т. И. Марченко-Вагапова³, к. г.-м. н., с. н. с.,
Ю. В. Голубева³, к. г.-м. н., н. с., В. А. Канев¹, к. б. н., н. с., С. Н. Плюсин², к. б. н., доцент,

¹Институт биологии Коми научного центра Уральского отделения Российской академии наук,
167982, Россия, г. Сыктывкар, ул. Коммунистическая, д. 28,

²Сыктывкарский государственный университет им. П. Сорокина,
167001, Россия, г. Сыктывкар, Октябрьский пр., д. 55,

³Институт геологии Коми научного центра Уральского отделения Российской академии наук,
167610, Россия, г. Сыктывкар, ул. Первомайская, д. 54,
e-mail: teteryuk@ib.komisc.ru

На Европейском Северо-Востоке России происходит расширение ареала *Lycopodiella inundata* (плаунок заливаемый). В подзоне средней тайги Республики Коми в 2017–2018 годах выявлены четыре местонахождения вида. Локальные популяции *L. inundata* приурочены к антропогенным экотопам, бедным и кислым песчаным или торфяным субстратам, условиям переменного увлажнения. Обязательными спутниками вида являются *Drosera rotundifolia* L. и *Juncus filiformis* L., мхи из родов *Sphagnum* L. и *Polytrichum* Hedw. Анализ палеогеографической истории вида позволил отнести его к аллохтонному элементу флоры региона. Из-за редкости *Lycopodiella inundata* в европейской части ареала, мы включили его в новое издание Красной книги Республики Коми с охранным статусом категории 3 (редкий). Спорофит *L. inundata* представляет собой споровый вариант многолетнего растения с однолетней побеговой системой. Размножается вид преимущественно вегетативным путём посредством естественной зимней морфологической дезинтеграции. Все местообитания вида расположены вне сети особо охраняемых природных территорий Республики Коми и находятся под угрозой разрушения. Лимитирующими факторами для вида также являются его узкая экологическая амплитуда, низкая конкурентоспособность, неустойчивость к нарушениям гидрологического режима.

Ключевые слова: *Lycopodiella inundata*, Европейский Северо-Восток России, Республика Коми, флора, редкие охраняемые виды растений.

For the last decades, flora of spore plants in the Komi Republic replenished new species. One of them is *Lycopodiella inundata* (L.) Holub (*Lycopodiaceae*). *L. inundata* areal covers Europe (except for its western and southern parts), North America. In the main part of the areal *L. inundata* is a plant of wet, bare, peaty or sandy margins of lakes, streams and marshes. It can rapidly colonize territories disturbed by peat mining, recreation loads, winter flooding [1]. However, it is rare in some parts of its range and is listed as a threatened species [2].

On the territory of Russia, *L. inundata* sporadically inhabits in the European part, the Urals Mountains, in West and East Siberia. In most territory *L. inundata* is a rare species. But, for the last decades there has been a tendency to range expansion [3–13]. *L. inundata* mostly inhabited disturbed places or secondary communities (moderately moist sandy pits, peat fields, mossy wastelands, wet sandy forest edges, sandy or poorly-silt river coasts). Sometimes it can be met along forest roads and electric energy transmission lines, at cutting areas. The species sharply decreases in number after moss cover recovery, intensive growth of trees, shrubs and dwarf shrubs, grassy plants. In spite of its anthropogenic preferences, more than 20 regions of Russia have acknowledged *L. inundata* as a protected plant, including the regions of the North and the Urals [3, 5, 14–20]. The limiting factors for the plant are its low competitive ability, narrow ecological amplitude, disturbed hydrological regime, natural succession processes of vegetation, and forest fires.

On the territory of the Komi Republic, *L. inundata* has been first identified in the Kortkeros District [21]. In the present work the aimed to specify the present distribution of *L. inundata* within the Komi Republic, to identify its ecological and habitat preferences, to

estimate the size of populations (taking into account biomorphological features of the species) and as well as conservations prospects.

Materials and methods

The study region is situated in the North-East of the European part of Russia, within the Vychegda-Mezen plain, in the middle taiga sub-zone of the Komi Republic. During the field surveys of 2017–2018, the authors discovered and investigated four local populations (LPs) of *L. inundata*. LP 1 (N 61.8498°, E 51.6153°) is an old re-vegetating sandy pit in pine forest situated along the Kortkeros-Madzha auto-road in the Kortkeros District. LP 2 (N 61.9590°, E 50.6061°) is a re-vegetating sandy pit in the outskirts of the Yazel settlements in the Syktyvdinsky District. LP 3 (N 62.6796°, E 51.2948°) is in the outskirts of the Trakt settlement in the Knyazhpogost District. LP 4 (N 60.5557°, E 50.9998°) is a roadside ditch on the skirts of lichen pine forest near the Sedtydor settlement on the left bank of the Sysola River in the Koigorodsky District (Fig.).

Geobotanical description of plant communities with participation of the study species have been made within their natural borders. The bio-morphological features of *L. inundata* are described using the comparative morphological method. Observations on the development of individuals were carried out. The *L. inundata* life-form is described by I.G. Serebryakov's system [22, 23]. For the identified local populations, the area was measured and the number of individuals was calculated. In LP 1 there was laid a transect with accounting area of 10 × 10 cm in size for calculation of density of individuals. Latin names for vascular plants were given according to "The Plant List" [24]. *L. inundata* herbarium samples are maintained in Herbarium of the Institute of

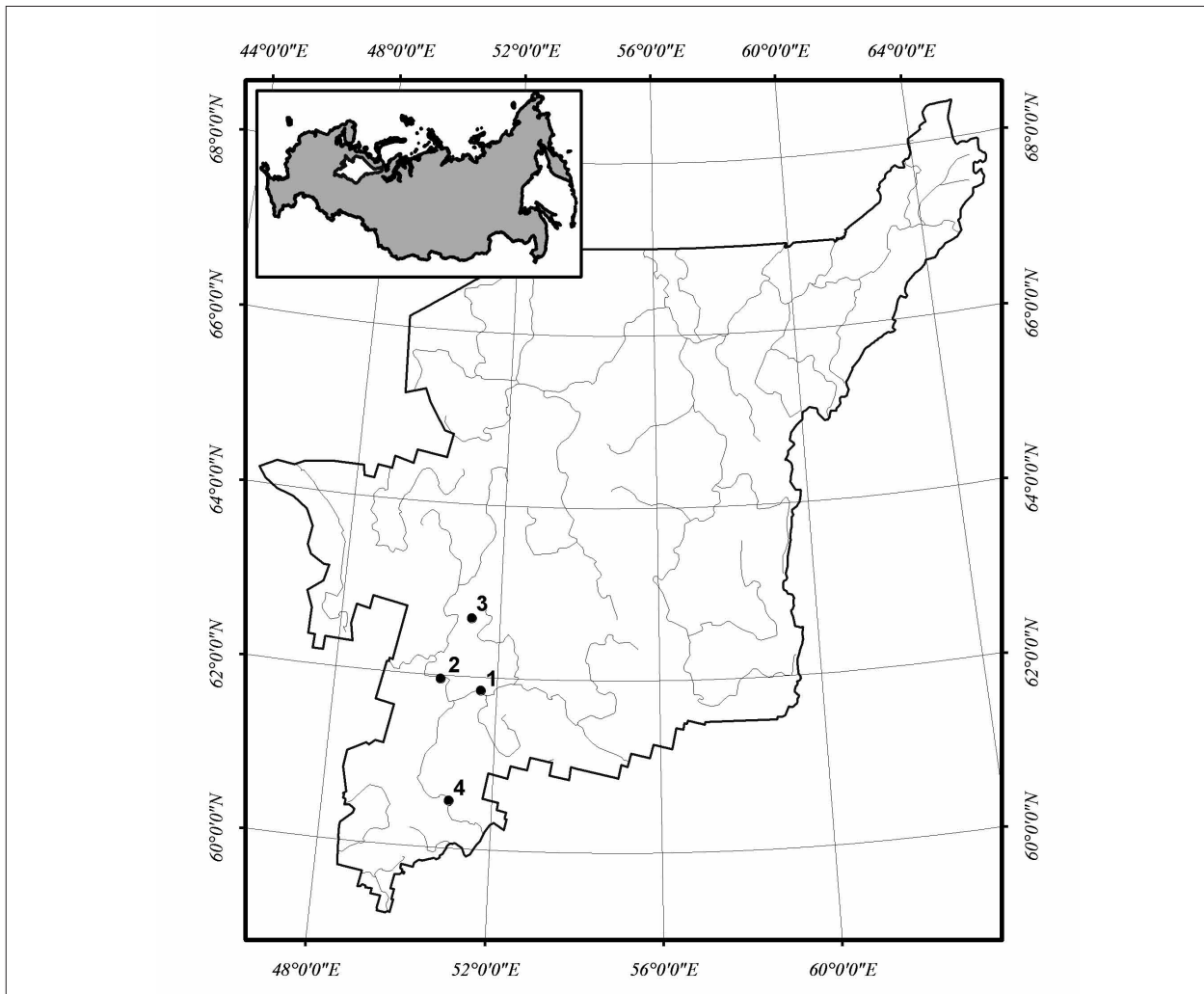


Fig. Location of the local populations (LP) of *Lycopodiella inundata* in the Komi Republic: 1 – LP1, 2 – LP2, 3 – LP3, 4 – LP4

Biology, Komi Science Centre UB RAS (SYKO) and that of the Pitirim Sorokin Syktyvkar State University (SYKT).

For analysis of the paleogeographic history of *L. inundata*, regional stratigraphic schemes of the Pleistocene of European Russia and some regions of Europe were used (according to [25], with some corrections (Table)). The age of the boundaries of the Holocene periods is indicated in radiocarbon years (¹⁴C years ago) according to the stratigraphic scheme of Khotinsky [26].

Results and discussion

The new habitation areas of *Lycopodiella inundata* located within the Vychegda-Mezen plain, in the south districts of the Komi Republic:

LP 1. Overgrown the sand quarry in pine forest. This local population of *L. inundata* is situated at the bottom of south-west-facing slope with an angle of 45°. The majority of population

inhabits the moist quarry slope bottom which gets overgrown with alone-standing *Alnus incana* (L.) Moench and *Populus tremula* L. representatives. The layer of grasses and dwarf shrubs counts 11 species which includes solitary (Sol. – solitariae) samples of *Trichophorum alpinum* (L.) Pers., *Dactylorhiza maculata* s.l., *Drosera rotundifolia* L., *Empetrum hermaphroditum* Hagerup, *Equisetum arvense* L., *Juncus filiformis* L., *Luzula pilosa* (L.) Willd., *Melampyrum pratense* L., *Oxycoccus microcarpus* Turcz. ex Rupr., and *Vaccinium uliginosum* L. *L. inundata* abundance is Sp. (sparsae). The layer of mosses and lichens is formed of green mosses as *Pleurozium schreberi* (Brid. ex Brid.) Mitt. (Sp.), *Polytrichum strictum* Menzies ex Brid. (Sp.), and *P. commune* Hedw. (Sp.). Population edges partly cover the dry quarry slope bottom, as well as cotton grass-sedge bog at the quarry bottom.

LP 2. Overgrown part of the sand quarry. *L. inundata* inhabits shores of small lakes at the

Table

Glaciations and interglacial periods for some glacial areas in Europe (according to S.M. Shik [26], revised)

| Division | Sub-division | Stage | After [27] | | European Russia | Belarus | Lithuania | Poland | North Europe | |
|----------------|---------------|-------|------------|-------|-----------------|----------------|----------------|--------------|-------------------|------------------|
| | | | Age (Ma) | MIS | | | | | | |
| Holocene | | | | 1 | | | | | | |
| Neopleistocene | Upper | 4-2 | 0.11 | 2-5d | Valday | Poozerie | Nemunas | Vustulan | Weichselian | |
| | | 1 | 0.127 | 5e | Mikulino | Murava | Merkine | Eemian | Eemian | |
| | Middle | 6 | 0.1860 | 6 | Moscow | Pripat | Medininkai | Wartanian | Wartanian | |
| | | 5 | 0.242 | 7 | Gorka | ? | Snaigupele? | Lubawa | Treene | |
| | | 4 | 0.301 | 8 | Vologda | | Zemaitija | Odranian | Drenthe | |
| | | 3 | 0.334 | 9 | Chekalin | | ? | Zboinian | Domnitz | |
| | | 2 | 0.364 | 10 | Kaluga | | ? | Liwecian | Fuhne | |
| | | 1 | 0.427 | 11 | Likhvin | Alexksandria | Butenei | Mazovian | Holsteinian | |
| | | Lower | 8 | 0.474 | 12 | Oka | Berezina | Dainava | Sanian2 | Elsterian |
| | 7 | | 0.528 | | Ikorets? | | ? | ? | Cromerian complex | Noorbergum |
| | | | | | ? | | | | | |
| | Muchkap | | Beloviezha | | Zhidin | Ferdynandovian | | | | |
| | 6 | | 0.568 | | Don | Yaelda | Dzykija | Sanian 1 | | Glacial C |
| | 5 | | 0.621 | | Late Ilyinka | Korchevo | Bine | Malopolonian | | Interglacial III |
| | 4 | | 0.659 | | Setun | Narev | Nalshya | Nidawian | | Glacial B |
| | 3 | | 0.712 | | Early Ilyinka | ? | Kamenai | Augostovian | | Interglacial II |
| | | | | | Pokrov | | Kalviai | | | |
| | 2 | | 0.760 | | ? | | ? | | | Glacial A |
| | 1 | 0.787 | ? | | ? | | Interglacial I | | | |
| | Eopleistocene | Upper | | 1.800 | Akulovo | Ruzhany | Dau-mantai | Narevian | Dorst | |
| Lower | | | 2.580 | | Varyazh | | | | | |

Note: a question mark (“?”) indicates that the time and name of the period are not defined. Empty cells in the first line indicate that the Holocene is (implied) everywhere.

pit bottom, water-line mineral ground areas. The plant prefers slopes with south-eastern, southern, and south-western expositions. *Populus tremula* and *Salix myrsinifolia* Salisb., sometimes *Salix acutifolia* Willd. are popular tree species. The layer of grasses and dwarf shrubs is poor with total projective cover of 10%. Most abundant (Cop. 1 – Cop. 2 – copiosae) are *Calluna vulgaris* (L.) Hull., *Carex acuta* L., *Drosera rotundifolia*, and *Empetrum hermaphroditum*. The abundance value of Sp. is given to *Antennaria dioica* (L.) Gaertn., *Equisetum fluviatile* L., *Festuca ovina* L., *Juncus filiformis*, and *Lycopodiella inundata*. *Agrostis tenuis* Sibth., *Arctostaphylos uva-ursi* (L.) Spreng., *Luzula pilosa*,

Vaccinium myrtillus L., *V. vitis-idaea* L., and *Hieracium sp.* have solitary representatives (Sol.). The well-developed mossy-lichen layer is dominated by *Polytrichum commune* (Cop. 2) and *Pohlia nutans* (Hedw.) Lindb. (Cop. 1). There are also *Aulacomnium palustre* (Hedw.) Schw gr. (Sp.), *Warnstorfia fluitans* (Hedw.) Loeske in Nitardy (Sp.) and *Cladonia chlorophaea* (Flrke ex Sommerf.) Spreng. s.str. (Sol.), *Cladonia coniocraea* (Flörke) Spreng. (Sol.).

LP 3. Exclusion zone of the linear structure between the gas pipeline strings. The tree layer includes alone-standing young trees of *Betula pubescens* Ehrh., *Populus tremula*, *Pinus sylvestris*, and *Salix phylicifolia* L. Total projec-

tive cover of the grassy-dwarf shrub layer is 30–35%. The layer is dominated by *L. inundata* (Cop. 2–Cop. 1) and *Juncus filiformis* (Cop. 1) and hosts solitary individuals of *Anthoxanthum odoratum* L., *Agrostis tenuis*, *Antennaria dioica*, *Drosera rotundifolia*, *Carex juncella* Th. Fries, *Chamaenerion angustifolium* (L.) Scop, *Dactylorhiza maculata* s.l., *Euphrasia* sp., *Filaginella uliginosa* (L.) Opiz, *Hieracium* sp., *Trifolium pratense* L. (Sol.). Mosses are *Polytrichum commune* (Cop. 3), *Polytrichum juniperinum* Hedw. (Sp.), *Polytrichum piliferum* Hedw. (Sp.), and *Sphagnum russowii* Warnst. (Cop. 1).

LP 4. Overgrown part wet of roadside belt at the edge of lichen pine forest. Plant community takes an area of 140 m². Spots of *Lycopodiella inundata* of 0.5–0.7 m² cover mineral ground parts. Tree species are *Pinus sylvestris*, *Betula pubescens*, *Salix phylicifolia*, *S. aurita* L., and *S. myrsinifolia*. Young growth reaches 2 m in height. The layer of grasses and dwarf shrubs counts 15 species with total projective cover of 20%. By abundance grades, *Calluna vulgaris*, *Juncus filiformis*, *Drosera rotundifolia* are Cop. 1, *Lycopodium clavatum* L., *Vaccinium myrtillus*, *V. vitis-idaea*, *V. uliginosum* L., *Carex paupercula* Michx., *C. nigra* (L.) Reichard – Sp., and *Chamaenerion angustifolium*, *Melampyrum pratense*, *Huperzia selago* (L.) Bernh. ex Schrank and C. Mart., *Oxycoccus palustris* Pers. – Sol. The mossy-lichen layer is well-developed (total projective cover of 80%) and consists of *Polytrichum commune* (Cop. 3) and *Sphagnum magellanicum* (Cop. 2).

Morphology, growth and allocation of counting units. *Lycopodiella inundata* is a creeping perennial poly-spore plant with annual shoot system. It develops two-type shoots. One type is vegetative shoots with an ascending tip and a lying base like plagiotropic shoots; they form rhizoids. These shoots are thickly covered with linear awl-shaped, smooth-margin sickle-curved leaves with a slightly rounded tip. The other type is spore-bearing orthotropic 2–10-cm high shoots with relatively seldom and protrude leaves. This type of shoots carries cylindrical sporiferous spikelets. Any shoots are annual and die towards the end of vegetation period from proximal end. The tip of vegetative shoot overwinters, starts formation of a new shoot system in summer of the next year, and soon dies. Vegetation proceeds in summer, starts relatively late in contrast with other club-mosses; the plant is summergreen. After several weeks of development, shoot systems of different individuals cover each other's and form a continuous carpet.

We think that *L. inundata* is a spore variance of a typical near-water seed perennial plant with annual shoot system which is sometimes called 'pseudoannual plant of vegetative origin'. The species is vegetative-moving, i. e. it is capable to vegetative multiplication through natural winter morphological disintegration. Countable unit in population studies changes during vegetation season. At the beginning of the growing season, the unit of account is an individual of vegetative origin (ramet). This approach was used when we researched LP 1 in the beginning of summer. Then, as shoot systems get branched, by our opinion, to be better to count vegetative shoot tips because every overwintered tip bears a new individual (ramet). Today, the majority of researchers evaluate the numerical strength of *L. inundata* cenopopulation via area it takes.

Area and numerical strength of local populations, conservation prospects. Local populations of *L. inundata* we identified take small areas: LP 1 – 6 m², LP 2 – 6–7 m² (including seven localities), LP 3 – 150 m², LP 4 – 6–7 m² (nine localities 0.5 m² each). Our data correspond with results obtained for Russia. By data regional red data books inform that populations of *L. inundata* normally take an area of 0.5–100 m². Only the Republic of Udmurtia marks through a high number of the species.

Number of *L. inundata* populations are often evaluated using relative attributes "low/high" and giving area they take [10, 28]. This situation exists because it is often difficult to decide upon the countable unit. Examination of LP 1 was performed at the time of regrowth of overwintered tops of last year's shoots. In this period, the use of young individuals of vegetative origin (ramet) as a unit of account was possible. Size of LP 1 was several thousand individuals with density of 850–4000 units/m². The remaining populations were examined later, in the second half of summer, but they were also counted individuals of vegetative origin (ramet). Size of LP 3 (several thousand ramets) is as large as LP 1. LP 2 and LP 4 are small populations (less than 1000 ramets).

In the Komi Republik habitation places of *L. inundata* are well-warmed temporally moistened southern or south-western slopes and poor sands which fully agree with ecological characteristics of species. In the study biotopes, *L. inundata* is accompanied by 35 spore and seed plants, 12 mosses and lichens. Its necessary companions in every community are *Drosera rotundifolia* and *Juncus filiformis*, mosses of the genera *Sphagnum* and *Polytrichum*. Numerous

companions of *L. inundata* in the Komi Republic remain its companions behind the territory of the republic [12–14, 28].

All habitats of *L. inundata* in the Komi Republic we identified as anthropogenic ones. In Russia, this species naturally grows only in several regions – on lake shores in the Arkhangelsk Region [4], in dark-coniferous forests in the Perm Krai [29], in wet peatland forests [30] and in interdunal valleys [12] in the Vologda Region, at pine forests edges in the Kirov Region [34], and in the Khanty-Mansi Autonomous District [18]. In all other cases, the sites of growth of the species are secondary community, which confirms the hypothesis of *L. inundata* resettlement at the present time along the anthropogenically disturbed sites [12–13].

The question of paleogeographic history of *L. inundata* is interesting. For adjacent areas, in particular for Western Siberia, it has been established that *L. inundata* is a relic of the Tertiary Period [13]. However, analysis of the palinological literature in the European North shows that in the most of the studied spores-and-pollen spectra, the *L. inundata* spores were not detected. Their single grains were first found in early Pleistocene sediments, 1800–800 thousand years ago (Eopleistocene), in the Middle Pechora below the Kipievo Village (N 65.6577°, E 54.5036°) [32]. To the north, in the Bolshezemelskaya Tundra (the Nalim-Yu River), a single *L. inundata* spore was found in the Chekalin Interstadial deposits (334–301 thousand years ago) [32]. To the south, in the Vologda and Arkhangelsk regions, *L. inundata* spores was encountered very rarely in the Mikulino Interglacial (127–71 thousand years ago) deposits in pollen zones from the Pas'va and Shenkursk sections sediments in the Vaga River valley (N 61.5843°, E 42.7158°; N 62.1056°, E 42.8996°) and also in zone of the Mikulino Interglacial (section in the Syuma and Pesa Rivers valley) [33]. Holocene sediments (11 thousand years ago – present) from the Chernaya Gorka palsa section located on the Bol'shaya Paypudyna River (N 67.0681°, E 65.3608°), in the Polar Urals, contain single grains of *L. inundata* spores [34]. Here the spores of *L. inundata* occur in deposits of the late Preboreal, Boreal and early Atlantic periods (9500–8000 ¹⁴C) and disappears in overlying sedge peat. However, this site is already located about 10 km east of the boundary between Europe and Asia. Thus, the analysis of the literature makes it possible to exclude the relic nature of the present locations of *L. inundata* in the European North and allows

one to classify the species as an allochthonous element of the flora.

Conclusion

Thus, our studies allowed specifying distribution of a new spore-bearing species in flora of the Komi Republic, *L. inundata* and identifying the species as an allochthonic flora element. Spores can be transported from neighboring territories due to road building or via migrant wetland or swimming birds. The identified habitats of *L. inundata* are located on poor and acid sands or peats with temporal moisture conditions. Necessary companions of the species in any communities are *Drosera rotundifolia* and *Juncus filiformis*, mosses of the genera *Sphagnum* and *Polytrichum*.

The life-form of the *Lycopodiella inundata* sporophyte is a spore variance of perennial plant with annual shoot system ('annual plant of vegetative origin'). This species prefers vegetative multiplication through natural winter morphological disintegration. For determine the population in the beginning of shoots growth, ramets are recommended to be counted. And with the full growth of shoot systems, the number of vegetative tops of shoots is calculated, which after overwintering give rise to new individuals.

In view of the fact that the species is rare and tends to decrease its habitats worldwide, we included *L. inundata* into new edition of the Red Data Book of the Komi Republic [35] with protection status category 3 (Rare). All habitation places of the species are out of specially protected areas of the republic and so are threatened. Limiting factors for this stenotopic species in the Komi Republic are its narrow ecological amplitude, low competitiveness, instability to violations of the hydrological regime (bogging or draining) and overgrowth of biotopes due to natural succession processes.

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