

Occurrence of the rare lichen *Nephromopsis laureri* (*Parmeliaceae*) at its northern limit in Europe, with the first record from Finland

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Abstract: Six new localities of *Nephromopsis laureri* were identified within the 61–63° N latitudinal range in Northern Europe, in middle boreal forests of North Karelia (Finland), as well as in the southern parts of the Republic of Karelia and the Arkhangelsk Region (Russia). We report the first record of *N. laureri* for Finland, which represents the westernmost point of the species' Northern European range. All specimens were found as single vegetative thalli (virginal stage, without ascomata, with soralia) in old-growth forests with high stand continuity (140–350 years). Repeated surveys in 2025 confirmed an extremely low population density, with no new individuals detected despite intensive searching. Phylogenetic analysis placed the Finnish specimen within the European *N. laureri* s. str. clade, clearly distinct from Asian lineages.

Keywords: Finland, Northern Europe, distribution, old-growth forests, conservation, molecular phylogeny

INTRODUCTION

Nephromopsis laureri (Kremp.) Kurok., 1991, J. Jap. Bot. 66: 156 (*Cetraria laureri* Kremp., 1851, Flora 34: 673; *Platysma laureri* (Kremp.) Nyl., 1855, Mém. Soc. Imp. Sci. Nat. Cherbourg 3: 172; *Platysma laureri* (Kremp.) A. Massal., 1856, Sched. Crit. Lich. Exsicc. (Veronae) 4: 79; *Tuckneraria laureri* (Kremp.) Randle & A. Thell in Randle et al., 1994, Acta Bot. Fenn. 150: 138; type: Germany, Bavaria (Bayern), Inzell, Appichl, A. von Krempelhuber; WU lectotype, Obermayer, 2004: 513) is a foliose lichen of the family *Parmeliaceae*. The thallus is up to 7 cm in diameter; lobes with ascending margins, 1.5–5 cm long and 0.5–1 cm wide, deeply divided, with rounded sinuses, dissected along the margins, crisped, bearing black marginal teeth formed by pycnidia. The upper surface is straw-coloured to greenish yellow, slightly glossy, smooth to minutely pitted, with yellowish-white soredia developing as a continuous or interrupted marginal rim along the lobe edges. The lower surface is pale to light brown, with sparse, relatively long rhizines and whitish pseudocyphellae (Randle & Saag, 2022). Isidia are absent. Pseudocyphellae on the lower surface appear as flat, rounded or irregular white spots, often surrounded by a light brown margin. Rhizines are scattered, sparse, relatively long, light brown to whitish. Apothecia are very rare, marginal, up to 8 mm in diameter, with a brown disc and a sorediate thalline margin. The cortex contains usnic acid; K–, C–,

P–, KC+ yellow, UV–; the medulla contains lichenic and protolichenic acids; K–, C–, KC–, P–, UV–. The species differs from the morphologically similar *Cetraria pinastri* Scop. by the paler thallus and marginal soredia, which are bright yellow in the that species. It is the only sorediate species in the genus *Nephromopsis*; it resembles another lichen with marginal soredia and a yellow foliose thallus, *Cetraria oakesiana* Tuck., but the latter has narrower, ribbon-like lobes and lacks pseudocyphellae on the lower surface (Randle & Saag, 2022).

The species is widely distributed but relatively rarely recorded and known from many regions, predominantly in mountainous areas. It occurs in Europe and Asia (Bhutan, China, Japan, Mongolia, Nepal, Russia), and outside Eurasia in South America (Colombia, Venezuela) (Golubkova, 1981; Randle & Saag, 2022). In Europe, the species is associated with montane forests and has been reported from several countries, including Austria, Germany, Italy, Poland, Romania, Slovakia, Switzerland, and Ukraine (Randle et al., 2001).

A large proportion of the Eurasian records of *Nephromopsis laureri* are from Russia, where the species occurs in both the European and Asian parts of the country. It has been recorded in northern and central European Russia, in the Ural Mountains and the Caucasus, and is widely distributed in Siberia (southern, central, and eastern Siberia, more rarely in western

Siberia), as well as in the southern part of the Russian Far East (Urbanavichene & Urbanavichus, 2010; Zhdanov, 2010; Skirina et al., 2016; Himelbrant et al., 2024).

In the northern part of European Russia (North-western Federal District), the species is known from the Republic of Karelia and Komi Republic, as well as Arkhangelsk and Leningrad regions. Specifically, one record is known from the Republic of Karelia (Fadeeva, 2007), three from the Arkhangelsk Region (Tarasova et al., 2020), 81 records from the Komi Republic (GBIF, 2026; Red Data Book, 2019), and 288 records from Leningrad Region (Stepanchikova et al., 2009; I. S. Stepanchikova, pers. comm). In adjacent regions of central European Russia, the species is known from scattered records in Novgorod (Stepanchikova et al., 2013), Kostroma (Kuznetsova & Skazina, 2010), and Kirov regions (Red Data Book, 2014).

The species inhabits trunks and branches of trees, mainly coniferous (*Abies*, *Juniperus*, *Picea*, *Pinus*), more rarely deciduous (*Betula*, *Quercus*, *Salix*, *Sorbus*); it is occasionally found on dead wood and rocks. It occurs in coniferous, deciduous, and mixed forests of the boreal forest zone, primarily within the middle and southern taiga subzones, as well as in mountainous regions within the forest belt (Randlane & Saag, 2022; Himelbrant et al., 2024). In the northern part of European Russia, the species grows on trunks and branches of *Betula* and *Picea*, more rarely on other tree species, mainly in old-growth mixed and swampy spruce forests, as well as along the margins of mires and in waterlogged pine forests. In the European part of its range, the species is particularly demanding in terms of habitat conditions and forest stand age: it is associated with little disturbed and undisturbed forests and prefers habitats with high air humidity and moderate shading (Himelbrant et al., 2024).

In European Russia and Western Siberia, the species is generally rare and is usually represented by single thalli or small compact groups within limited areas, with the notable exception of the Leningrad Region (Fadeeva, 2007; Kuznetsova & Skazina, 2010; Stepanchikova et al., 2013; Red Data Book., 2014, 2019, 2020a). A decline in population size has been recorded in some regions. For example, in the Republic of Tatarstan, the species has apparently dis-

appeared, with the last collections dating back to 1883 (Red Data Book., 2016). In the Republic of Mari El, about ten years ago, the population was estimated at approximately 30 individuals, but the species has not been recorded there in recent years (Red Data Book..., 2023).

Negative factors affecting the species include air pollution, logging, fires, and any economic activity in primary undisturbed forests that alter microclimatic conditions. A limiting factor is also the small area of suitable habitats, primarily old-growth humid spruce forests.

The species is included in the Red Data Book of the Russian Federation with category 3 (rare species). According to the International Union for Conservation of Nature (IUCN) criteria, it corresponds to the category Near Threatened (NT), close to Vulnerable (VU) (Himelbrant et al., 2024). It is also listed in the Red Data Books of 32 regions of the Russian Federation, including those in the northern part of European Russia – Arkhangelsk (2020a) and Leningrad regions (2018), the Republic of Karelia (2020b), and the Komi Republic (2019), as well as in adjacent regions: Kirov (2014), Kostroma (2019), and Novgorod regions (2015).

In northwestern Russia, the species is considered a specialized taxon primarily associated with old-growth, non-fragmented or weakly fragmented spruce and mixed forest landscapes of considerable extent (Andersson et al., 2009).

MATERIAL AND METHODS

Study area

Fieldwork was conducted periodically during lichen inventories from 1998 to 2025 across mesic, middle boreal forests in North Karelia (Finland), as well as the southern parts of the Republic of Karelia and the Arkhangelsk Region (Russia). The climate across the study area exhibits a pronounced longitudinal gradient, transitioning from sub-oceanic in the west to moderately continental in the east. This shift is reflected in the decrease of mean annual temperatures from approximately +3.5°C in Finland to +1.5°C in the southern Arkhangelsk Region. Winters are characteristically long and become increasingly severe eastward, with absolute minimum temperatures dropping to –45°C or lower in the Arkhangelsk Region, compared to more moder-

ate extremes in Finland. Mean annual precipitation varies from 700 mm in the west to 500 mm in the east (Fick & Hijmans, 2017). The topography is generally flat, with elevations not exceeding 250 m above sea level. The forest cover is dominated by pine (*Pinus sylvestris* L.) and spruce (*Picea* spp.), with the occasional presence of birch (*Betula* spp.), aspen (*Populus tremula* L.), and also in the Arkhangelsk Region, larch (*Larix sibirica* Ledeb.).

Field methods

Lichen species diversity and epiphytic cover characteristics were studied within sample plots ranging from 400 to 625 m² each. A detailed geobotanical description was performed for each plot, including stand parameters (height, age, basal area, and canopy density) and ground layer characteristics (shrub, herb, moss, and lichen layers). The time since last disturbance was determined using increment

cores or stem discs. In spruce forests with natural stand dynamics, the disturbance history was estimated based on the maximum age of the trees. The characteristics of the communities are presented in Table 1. For each specimen, the following parameters were recorded: the host tree species and its diameter at breast height (DBH), thallus size, ontogenetic stage, and associated lichen species. The collected material was identified under laboratory conditions using standard microscopic techniques and spot tests.

Mapping

Based on our own data and GBIF data, literature sources, and also personal communications from colleagues, a map was compiled showing all currently known localities of the species in Northern Europe. A total of 382 localities were mapped (Fig. 1).

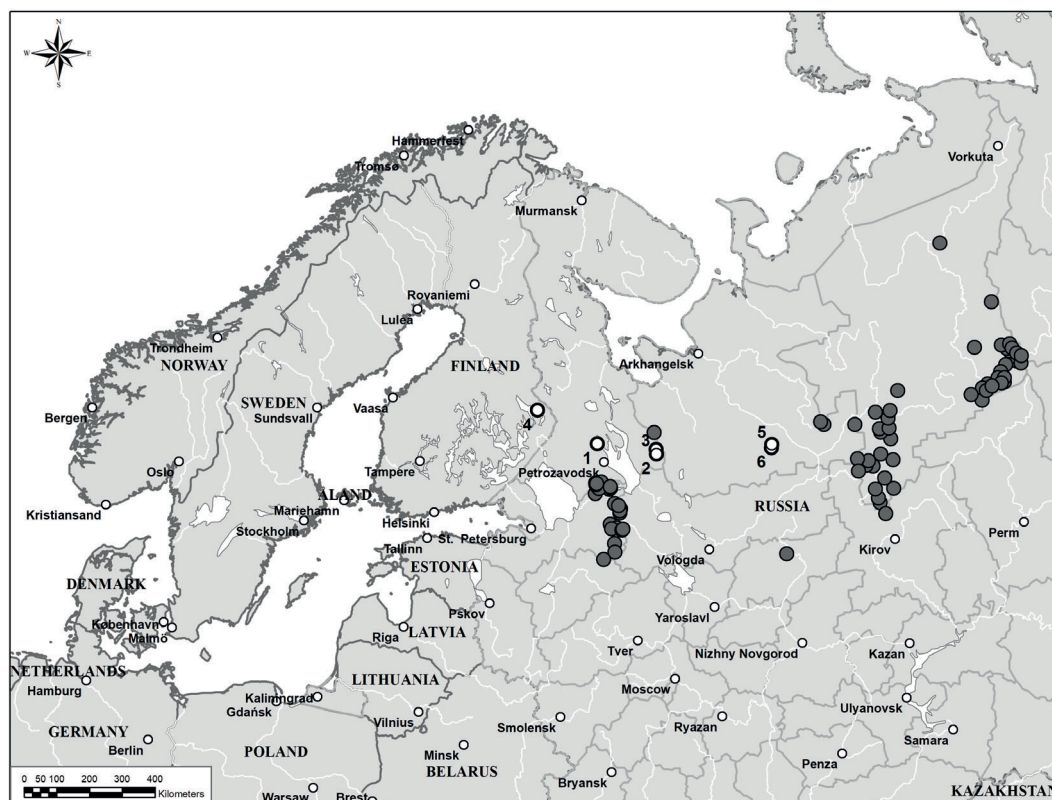


Fig. 1. The distribution of *Nephromopsis laureri* in Northern Europe. Open numbered circles indicate new localities reported in this study (see Table 1).

Table 1. The main characteristics of studied localities

Nº	Region and Country	GPS coordinate	Altitude, m a. s. l.	Type of forest	Age since disturbance, years	Density of crown, %	Basal area, m ² ha ⁻¹	Tree stand formula**	Time of description
1	Republic of Karelia, Russia	62°17'05"N 33°59'52"E	67	Paludified pine shrub-sphagnum forest	350	50	17.5	100P	21 June 1998
2	Republic of Karelia, Russia	61°59'18"N 37°26'26"E	66	Paludified herb-rich spruce forest	>350	35	21	71S 29B	06 August 2010
3	Republic of Karelia, Russia	61°59'18"N 37°26'26"E	97	Rock bilberry feathermoss mixed spruce and pine forest	250	55	28	73P 23S 4B	13 August 2010
4	Finland	63°11'19"N 30°29'58"E	230	Retention patch of cowberry feathermoss pine forest	140	40	23	61P 26B 13S	14 August 2021
5	Arkhangelsk Region, Russia	61°43'08"N 44°15'03"E	160	Paludified spruce wood sorrel-bilberry long-moss forest	>180	60	28.5	50S 40B 10P	03 August 2025
6	Arkhangelsk Region, Russia	61°41'57"N 44°13'13"E	151	Paludified pine sphagnum moss forest	n. d.	30	n. d.	95P 5S	04 August 2025

*numerous of sample plot (see Fig. 1); **tree species are marked by the following letters: P – *Pinus sylvestris*, B – *Betula* sp., S – *Picea* sp.; n.d. – no data.

Molecular methods

Total DNA was extracted from a small fragment of the Finnish specimen using the DNeasy Blood & Tissue Kit (Qiagen, Maryland, USA) as described in Myllys et al. (2011). The complete nuclear ribosomal internal transcribed spacer region (ITS) was amplified using PuReTaq Ready-To-Go PCR Beads (GE Healthcare, Chicago, Illinois, USA). Each 25 µl reaction volume contained 19–21 µl distilled water (dH2O), 1 µl of each primer (10 µM), and 2–4 µl extracted DNA. PCR was run under the following conditions: initial denaturation for 5 min at 95 °C followed by five cycles of 30 s at 95 °C (denaturation), 30 s at 58 °C (annealing) and 1 min at 72 °C (extension); in the remaining 35 cycles, the annealing temperature was decreased to 56 °C; the PCR schedule ended with a final extension for 7 min at 72 °C. PCR product was cleaned with ExoSAP (Affymetrix, Santa Clara, California, USA) and sequenced by the Institute for Molecular Medicine Finland FIMM Genomics unit supported by HiLIFE and Biocenter Finland FIMM Genomics. The resulting contig sequences were assembled using the program Sequencher (Gene Codes Corp., Ann Arbor, MI, USA). Primers ITS1-LM (Myllys et al., 1999) and ITS2-KL (Lohtander et al., 1998) were used both for PCR and sequencing.

Phylogenetic analysis

We sequenced the Finnish specimen that was preliminary identified as *Nephromopsis laureri* based on morphological inspection. 23 ITS sequences were additionally downloaded from GenBank (<http://www.ncbi.nlm.nih.gov>). These represented *N. laureri* or were members of the same strongly supported monophyletic group in the phylogenies of Thell et al. (2005), Nelsen et al. (2011), Divakar et al. (2017) and Chesnokov et al. (2023). *Flavocetraria cucullata* (= *Nephromopsis cucullata sensu* Divakar et al. (Change ‘2027’ to ‘2017’)) which appeared as a sister species to the ‘*Nephromopsis* s. str. clade’ was used as outgroup taxon.

A total of 24 ITS sequences were aligned (Table 2) with MUSCLE using the EMBL-EBI Job Dispatcher sequence analysis tools framework (<https://www.ebi.ac.uk/jdispatcher>; see Madeira et al., 2024). The aligned dataset was subjected to Maximum Likelihood analysis (ML). The analysis was performed using the

Table 2. List of specimens used in the phylogenetic analysis, including country and voucher information and GenBank accession numbers. New sequence is shown in bold. – = missing information.

Species	Country and Voucher	GenBank accession number (ITS)
<i>Cetrellopsis rhytidiocarpa</i>	Philippines, <i>Bawingan</i> CL0582	DQ980008
<i>Flavocetraria cucullata</i>	Russia, <i>Poryadina</i> s. n. (SASY)	MT229211
<i>Nephromopsis ahtii</i>	Bhutan, <i>Søchting</i> 8489 (LD)	AF404123
<i>Nephromopsis komarovii</i>	Russia, <i>Skirina</i> 10972 (LD), Russia	AF451779
<i>Nephromopsis laureri</i>	Finland, <i>Tarasova</i>, DNA FL101 (H)	PZ675876
<i>Nephromopsis laureri</i>	–, TH006	EF373573
<i>Nephromopsis laureri</i>	Czech Republic, ROK-Soun 1034	OQ717975
<i>Nephromopsis laureri</i>	Italy, <i>Feuerer & Thell</i> 64288 (HBG)	AF451786
<i>Nephromopsis laureri</i>	–	AF315461
<i>Nephromopsis laureri</i>	Taiwan, <i>S. Greenwood</i>	KU862982
<i>Nephromopsis laureri</i>	Bhutan, <i>Søchting</i> 8124 (LD)	AF404122
<i>Nephromopsis leucostigma</i>	Bhutan, <i>Søchting</i> 9151 (LD)	AF451777
<i>Nephromopsis melaloma</i>	Bhutan, <i>Søchting</i> 9151 (LD)	AF451778
<i>Nephromopsis morrisonicola</i>	China, <i>Obermayer</i> 8282 (GZU)	AF451781
<i>Nephromopsis morrisonicola</i>	China, <i>Obermayer</i> 8279 (GZU)	AF451780
<i>Nephromopsis nephromoides</i>	Philippines, <i>Ejem</i> s. n. (H)	DQ004574
<i>Nephromopsis ornata</i>	Russia, <i>Kudryavtseva</i> 10980 (LD)	AF451783
<i>Nephromopsis ornata</i>	–, <i>Hur</i> 041359	EU266109
<i>Nephromopsis pallescens</i>	Bhutan, <i>Søchting</i> 8206 (LD)	AF451784
<i>Nephromopsis pallescens</i>	–	AF315460
<i>Nephromopsis pallescens</i>	South Korea, KoLRI001283	KM250154
<i>Nephromopsis pseudocomplicata</i>	South Korea, <i>Hur</i> 040398	DQ394398
<i>Nephromopsis pseudocomplicata</i>	China, <i>Obermayer</i> 8276 (GZU)	AF404131
<i>Nephromopsis stracheyi</i>	Bhutan, <i>Søchting</i> 8095 (LD)	AF451785

IQ-TREE web server (Nguyen et al., 2015) with default settings and ultrafast bootstrap analysis (Hoang et al., 2018). The analysis was performed with three partitions of the ITS regions (Chernomor et al., 2016) and the bestfit models for the single trees were selected with the implemented model finder (Kalyaanamoorthy et al., 2017) of the program IQ-TREE: TNe+G4 for ITS1 region, K2P for the 5.8S region and TNe+G4 for the ITS2 region.

RESULTS

Phylogeny

The ITS alignment of 24 sequences consisted of 504 sites, of which 80 were parsimony informative. The ITS phylogeny (Fig. 2) shows that our new *Nephromopsis laureri* specimen collected from Finland groups with three other *N. laureri* specimens in a strongly supported clade. It is noteworthy that this clade includes only specimens collected from Europe (plus one specimen with an unknown locality) while two *N. laureri* specimens from Asia (one from Bhutan and one from Taiwan) fall outside this clade. The first one groups with *N. nephromoides*

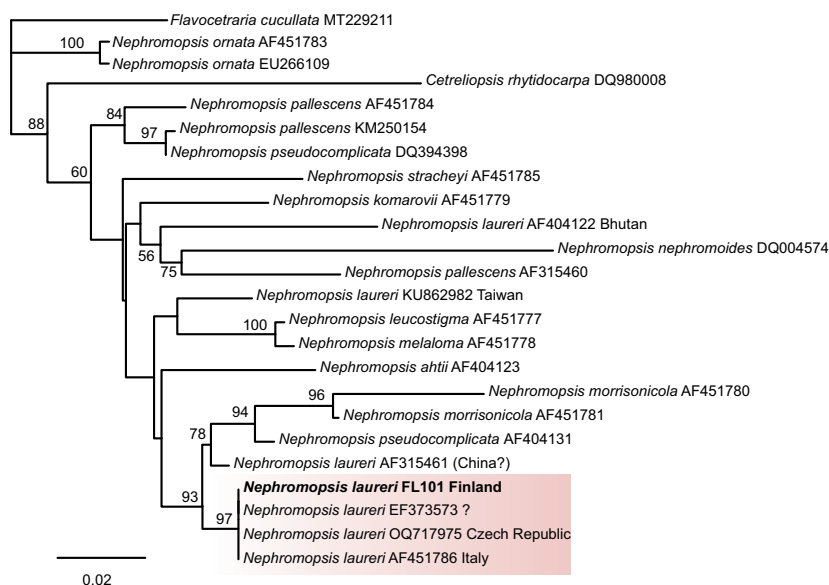


Fig. 2. Phylogenetic relationships of the studied *Nephromopsis* species, based on a Maximum Likelihood (ML) analysis of the ITS dataset. Maximum likelihood bootstrap values > 50% are shown at nodes. GenBank accession numbers for sequences downloaded from GenBank and DNA extraction numbers for the specimen sequenced for this study are shown after the taxon names. The European *Nephromopsis laureri* clade is indicated with a shadowed box. New sequence is shown in bold.

(DQ004574) and *N. pallescens* (AF315460) with poor support and the second with *N. leucostigma* (AF451777) and *N. melaloma* (AF451778) in an unsupported clade. One *N. laureri* specimen with an unknown locality (but may have been collected from China or nearby regions based on GenBank information) is close to the European *N. laureri* clade but groups with *N. morrisonicola* and *N. pseudocomplicata* (AF404131). The results suggest that *N. laureri* may include at least four separate species. Our Finnish specimen most probably represent *N. laureri* s. str. as the type of this species was collected from Germany.

Occurrence and ecology

Over more than 30 years of lichenological research by the first author in the studied regions, including the northern taiga (up to 65° N), at least 670 sample plots have been established. However, *Nephromopsis laureri* was recorded in only six of these plots.

Specimens examined (see also Table 1).

1. Russia, Republic of Karelia, Kondopozhsky District, Kivach State Nature Reserve, paludified pine shrub-sphagnum forest, on the trunk of an old *Pinus sylvestris* (DBH 37 cm) at a height of approximately 0.5 m; a single specimen, 2 cm in size, 21.06.1998, V. N. Tarasova (PZV, herbarium of Petrozavodsk State University). Notably, although the specimen was collected in 1998, it was identified only nine years later, in 2007, and this is the earliest herbarium record for the region, although it was not formally published at the time.

2. Russia, Republic of Karelia, Pudozhsky District, left bank of the Vodla River, near the confluence with the Pizhma River, paludified herb-rich spruce forest, on a branch of an old *Picea* sp. (DBH 22 cm) at a height of approximately 1.5 m; a single specimen, 2 cm (not collected), 6.08.2010, V. N. Tarasova (Fig. 3).

3. Same locality, right bank of the Vodla River, opposite the Vodla settlement, rock bilberry feathermoss mixed spruce-pine forest, on a branch of *Picea* sp. (DBH 19 cm) at a height of

approximately 1.3 m; a single specimen, 1.5 cm in size (not collected), 13.08.2010, V. N. Tarasova.

4. Finland, Pohjois-Karjala, Lieksa, Keljanvaara, a 10 × 25 m retention patch of middle-aged forest within a 20-year-old clear-cut, cowberry feathermoss pine forest, on a dead

dry branch of an old *Picea* sp. (DBH 33 cm) at a height of 1.3 m; a single specimen, 1 cm in size (H 9252371, DNA FL101 (H)), 14.08.2021, V. N. Tarasova (Fig. 4).

5. Russia, Arkhangelsk Region, Ustyansky District, Padoma River basin, paludified spruce wood sorrel-bilberry long-moss forest, on the

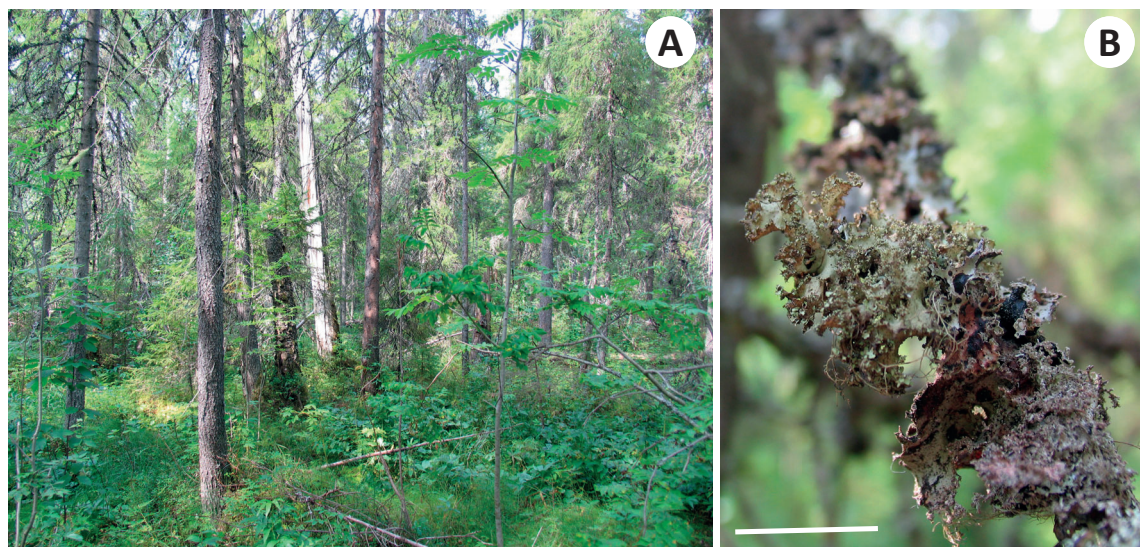


Fig. 3. *Nephromopsis laureri* in paludified herb-rich spruce forest (A) on the branch of old spruce (B), bank of the Vodla River, Republic of Karelia, Russia (locality 2) (scale = 1 cm).

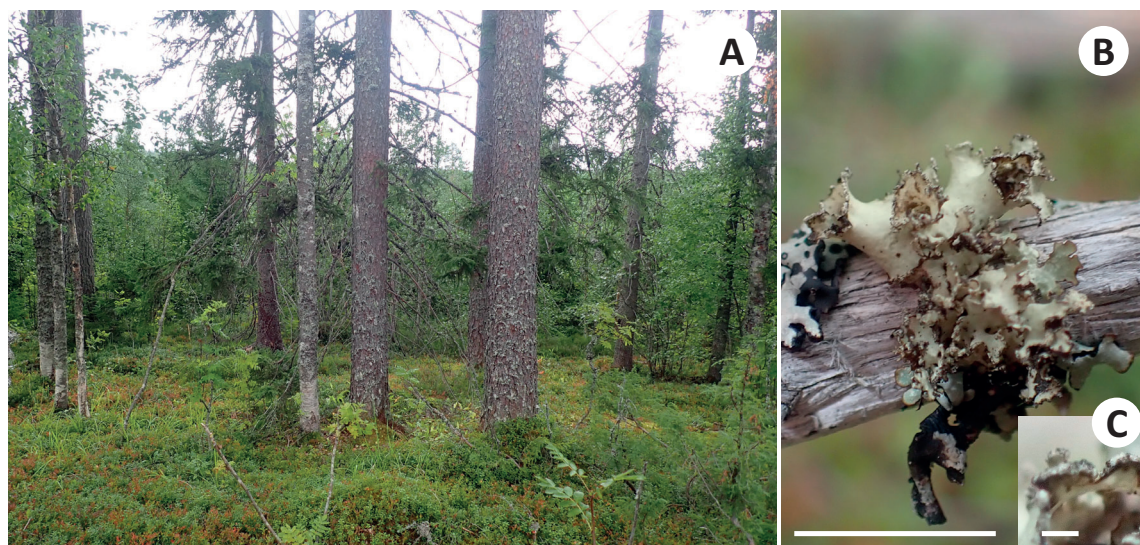


Fig. 4. *Nephromopsis laureri* in the retention patch of cowberry feathermoss pine forest (A) on dead branch of spruce (B) with marginal soralia on the thallus lobes (C), North Karelia, Finland (locality 4) (scale: B = 1 cm, C = 1 mm).

trunk of *Betula* sp.; a single specimen, 1.3 cm in size (not collected), 3.08.2025, V. N. Tarasova.

6. Same locality, Verkhnetoyemsky District, Padoma River basin, paludified pine sphagnum moss forest, on a branch of *Picea* sp.; a single specimen, 1.5 cm in size (not collected), 4.08.2025, V. N. Tarasova.

The six identified specimens are distributed within a narrow latitudinal range (61–63° N): three localities were recorded in the Republic of Karelia, two in the Arkhangelsk Region, and one in Finland (Fig. 1). In Karelia, these findings are consistent with a record from a paludified herb-rich spruce forest from the Chukozero Nature Reserve, situated approximately 60 km north of our study sites near the Vodla River (Fadeeva, 2007). At the northwestern limit of the species' European range, occurrences are sporadic, with isolated records occurring significantly further east (up to 66° N in the Komi Republic) and further south (61° N and below in the Leningrad Region).

The species showed a clear preference for waterlogged, paludified forests with a long history of stand continuity (180–350 years since the last major disturbance). *Picea* sp. was the main phorophyte (4 specimens), followed by *Pinus sylvestris* (1) and *Betula* sp. (1). All specimens belong to the pre-generative period, specifically the virginal stage (*v*). They lack ascomata but possess vegetative propagules in the form of soralia. Notably, each community hosted only a single individual. The extremely low population density was further confirmed during re-examination in 2025: no new thalli were detected at locations 2 and 3 near the Vodla River, despite a rigorous 3.5-hour survey of approximately 300 spruce trees.

The record from Finland represents the first documented occurrence of the species in Northern Europe outside Russia. Currently, this site is the westernmost point of the species' range in the region; it also represents the northernmost record, excluding several locations in the Komi Republic situated significantly further east. Notably, this specimen was found in an atypical habitat: rather than a waterlogged forest, it occurred in a relatively dry, well-lit fragment of pine forest left amidst a clear-cut area (Fig. 4). The time since the last disturbance (likely a fire) was only 140 years. The specimen was dis-

covered on the largest spruce tree among only ten individuals of the genus growing at the site. The nearest known location is situated approximately 200 km to the southeast, in the Kivach Nature Reserve (Republic of Karelia; Fig. 1).

The number of associated lichen species on the same phorophyte ranged from 9 to 23. Among the most frequent species recorded in at least 80% of the studied locations were *Bryoria fuscescens* (Gyeln.) Brodo et D. Hawksw., *Lecidea nylanderii* (Anzi) Th. Fr., and *Platismatia glauca* (L.) W. L. Culb. et C. F. Culb. Other common accompanying species included *Hypogymnia physodes* (L.) Nyl., *Mycoblastus sanguinarius* (L.) Norman, and *Parmeliopsis ambigua* (Wulfen) Nyl. In the more humid sites (e.g., localities 1, 2, 6), the communities were characterized by the presence of macrolichens such as *Alectoria sarmentosa* (Ach.) Ach. and species of *Usnea*, while the drier Finnish site (locality 4) hosted more photophilous taxa like *Pseudevernia furfuracea* (L.) Zopf. Single occurrences of certain taxa were noted at specific sites: *Chaenotheca phaeocephala* (Turner) Th. Fr., *C. stemonea* (Ach.) Müll. Arg., *Microcalicium disseminatum* (Ach.) Vain. at locality 2, and *Bryoria fremontii* (Tuck.) Brodo & D. Hawksw. at locality 6.

DISCUSSION

The taxonomic position of *Nephromopsis laureri* has undergone several revisions. The genus *Tuckneraria* Randlane & A. Thell was described to include a new species *Tuckneraria ahtii* Randlane & Saag, along with *T. laureri* (Kremp.) Randlane & A. Thell, *T. laxa* (Zahlbr.) Randlane & A. Thell and *T. pseudocomplicata* (Asahina) Randlane & Saag, which were earlier accommodated in *Nephromopsis* (Randlane et al., 1994). The new genus differed from *Nephromopsis* by the presence of cilia and subglobose ascospores. However, later study of Thell et al. (2005) showed, using ITS rDNA, β -tubulin and GAPDH sequence data, that the genus *Tuckneraria* should be included in *Nephromopsis*. Thell et al. (2005) included 19 species in the genus of which *Nephromopsis laureri* was the only sorediate taxon. Later Divakar et al. (2017), using temporal banding approach, reduced genera *Arctocetraria* Kärnefelt & A. Thell, *Flavocetraria* Kärnefelt & A. Thell, *Masonhalea* Kärnefelt and

Tuckermannopsis Gyelni to synonymy with *Nephromopsis*. However, this revised classification has not been accepted by all authors (see Chesnokov et al., 2023). The phylogeny presented here suggests that *Nephromopsis laureri* actually represents four distinct species, with our samples belonging to the European *N. laureri* s. str. clade.

At the northwestern edge of its range, *Nephromopsis laureri* exhibits extreme rarity and low population vitality. Despite more than 30 years of intensive lichenological research in the region and the species' conspicuous macrolichen growth form, it was recorded in less than 1% of the surveyed 670 plots. The population density is exceptionally low: our repeated surveys in 2025 at localities 2 and 3 failed to detect any additional thalli, and in Finland, only a single individual was found in 120 sample plots. This pattern stands in sharp contrast to the species' status in the core of its range. For instance, in Eastern Siberia (Buryatia), *N. laureri* is a frequent component of forest communities, occurring in one-third of the surveyed localities with high cover and regular production of apothecia (Urbanavichene & Urbanavichus, 2010). The high abundance in the continental climate in Siberia challenges the traditional view of *N. laureri* as a strictly nemoral relict. Our findings suggest that in Northern Europe, the species is a specialist confined to stable, old-growth forests.

The isolation of these northern localities, the extremely low abundance, and the strong association with undisturbed old-growth swamp forests (with the exception of the Finnish record) emphasize the high vulnerability of the species. Our results strongly support the continued inclusion of *Nephromopsis laureri* in regional Red Data Books and provide a solid basis for its inclusion in the Red Data Book of Finland. Targeted surveys in eastern Finland and adjacent Russian territories are essential to identify any remaining "stepping stones" of this fragmented population.

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REFERENCES

- Andersson, L., Alexeeva, N. & Kuznetsova, E. (eds). 2009. *Survey of biologically valuable forests in North-Western European Russia. Vol. 2. Identification manual of species to be used during survey at stand level* (in Russian). St. Petersburg: 258 pp.
- Chernomor, O., von Haeseler, A. & Minh, B. Q. 2016. Terrace aware data structure for phylogenomic inference from supermatrices. *Systematic Biology* 65: 997–1008. <https://doi.org/10.1093/sysbio/syw037>
- Chesnokov, S. V., Davydov, E. A., Konoreva, L. A., Prokopiev, I. A., Poryadina, L. N., Zheludeva, E. V. & Shavarda, A. L. 2023. The monotypic genus *Flavocetraria* and two new genera: *Cladocetraria* and *Foveolaria*, in the cetrarioid core. *Plant Systematics and Evolution* 309:24 <https://doi.org/10.1007/s00606-023-01862-2>
- Divakar, P. K., Crespo, A., Kraichak, E., Leavitt, S. D., Singh, G., Schmitt, I. & Lumbsch, H. T. 2017. Using a temporal phylogenetic method to harmonize family and genus-level classification in the largest clade of lichen-forming fungi. *Fungal Diversity* 84: 101–117. <https://doi.org/10.1007/s13225-017-0379-z>
- Fadeeva, M. A. 2007. Lichens. *Inventory of natural complexes and conservation assessment of the Chukozero area* (in Russian). Petrozavodsk. 59–68, 129–132.
- Fick, S. E., & Hijmans, R. J. 2017. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37(12): 4302–4315. <https://doi.org/10.1002/joc.5086>
- GBIF 2026. GBIF.org (09 March 2026). *Nephromopsis laureri* (Kremp.) Kurok. GBIF occurrences Download. <https://www.gbif.org/species/2603993>
- Golubkova, N. S. 1981. *Synopsis of the lichen flora of the Mongolian People's Republic* (in Russian). Leningrad. 200 pp.
- Himelbrant, D. E., Lishtva, A. V. & Stepanchikova, I. S. 2024. *Nephromopsis laureri*. *Red Data Book of the Russian Federation. Plants and Fungi* (in Russian). Moscow. 738 pp.
- Hoang, T. H., Chernomor, O., von Haeseler, A., Minh, B. Q. & Vinh, L. S. 2018. UFBoot2: improving the ultrafast bootstrap approximation. *Molecular Biology and Evolution* 35: 518–522. <https://doi.org/10.1093/molbev/msx281>

- Kalyaanamoorthy, S., Minh, B. Q., Wong, T. K. F., von Haeseler, A. & Jermini, L. S. 2017. ModelFinder: fast model selection for accurate phylogenetic estimates. *Nature Methods* 14: 587–589. <https://doi.org/10.1038/nmeth.4285>
- Kuznetsova, E. S. & Skazina, M. A. 2010. Contribution to the study of lichens of Kostroma Region. *Novosti sistematiki nizshikh rastenii* 44: 200–209 (in Russian).
- Lohtander, K., Myllys, L., Sundin, R., Källersjö, M. & Tehler, A. 1998. The species pair concept in the lichen *Dendrographa leucophaea* (Arthoniales): analyses based on ITS sequences. *Bryologist* 101: 404–411.
- Madeira, F., Madhusoodanan, N., Lee, J., Eusebi, A., Niewielska A., Tivey, A. R. N., Lopez, R. & Butcher, S. 2024. The EMBL-EBI Job Dispatcher sequence analysis tools framework in 2024. *Nucleic Acids Research* 52: W521–W525. <https://doi.org/10.1093/nar/gkae241>
- Myllys, L., Lohtander, K., Källersjö, M. & Tehler, A. 1999. Sequence insertions and ITS data provide congruent information on *Rocella canariensis* and *R. tuberculata* (Arthoniales, Euscomycetes) phylogeny. *Molecular Phylogenetics and Evolution* 12: 295–309.
- Myllys, L., Velmala, S., Holien, H., Halonen, P., Wang, L.S. & Goward, T. 2011. Phylogeny of the genus *Bryoria*. *Lichenologist* 45: 617–638. <https://doi.org/10.1017/S0024282911000132>
- Nelsen, M. P., Chavez, N., Sackett-Hermann, E., Thell, A., Randlane, T., Divakar, P. K., Rico, V. J. & Lumbsch, H. T. 2011. The cetrarioid core group revisited (*Lecanorales: Parmeliaceae*). *Lichenologist* 43: 537–551. <https://doi.org/10.1017/S0024282911000508>
- Nguyen, L.-T., Schmidt, H. A., von Haeseler, A. & Minh, B. Q. 2015. IQ-TREE: A fast and effective stochastic algorithm for estimating maximum likelihood phylogenies. *Molecular Biology and Evolution* 32: 268–274. <https://doi.org/10.1093/molbev/msu300>
- Randlane, T. & Saag, A. 2022. *Nephromopsis* Müll. Arg. *The lichen flora of Russia. Family Parmeliaceae* (in Russian). Moscow–St. Petersburg. 133–144.
- Randlane, T., Saag, A. & Obermayer, W. 2001. Cetrarioid lichens containing usnic acid from the Tibetan area. *Mycotaxon* 80: 389–425. <https://doi.org/p.418227>
- Randlane, T., Saag, A., Thell, A., & Kärnefelt, I. 1994. The lichen genus *Tuckneraria* Randlane & Thell – a new segregate in the *Parmeliaceae*. *Acta Botanica Fennica* 150: 143–151.
- Red Data Book of Arkhangelsk Region*. 2020a. Arkhangelsk. 482 pp. (In Russian).
- Red Data Book of the Kirov Region*. 2014. Kirov. 336 pp. (In Russian).
- Red Data Book of the Komi Republic*. 2019. Syktyvkar. 768 pp. (In Russian).
- Red Data Book of the Kostroma Region*. 2019. Kostroma. 432 pp. (In Russian).
- Red Data Book of the Novgorod Region*. 2015. Saint Petersburg. 480 pp. (In Russian).
- Red Data Book of the Leningrad Region: Objects of Plant World*. 2018. Saint Petersburg. 845 pp. (In Russian).
- Red Data Book of the Republic of Karelia*. 2020b. Belgorod. 448 pp. (In Russian).
- Red Data Book of the Republic of Mari El. Plants and Fungi*. 2023. Yoshkar-Ola. 352 pp. (In Russian).
- Red Data Book of the Republic of Tatarstan*. 2016. Kazan. 760 pp. (In Russian).
- Skirina, I. F., Salokhin, A. V., Tsarenko, N. A. & Skirin, F. V. 2016. New locations of rare and protected lichens on Sakhalin Island. *Turczaniowia* 19(2): 54–63. <https://doi.org/turczaniowia.19.2.6>
- Stepanchikova, I. S., Gagarina, L. V. & Kataeva, O. A. 2013. New and rare lichens and allied fungi from the Novgorod Region, Russia. *Folia Cryptogamica Estonica* 50: 49–55. <https://doi.org/10.12697/fce.2013.50.07>
- Stepanchikova, I. S., Kuznetsova, E. S. & Himelbrant, D. E. 2009. New records of lichens and allied fungi from the Eastern Leningrad Region. *Folia Cryptogamica Estonica* 46: 75–78. <https://ojs.utlib.ee/index.php/FCE/article/view/13665>
- Tarasova, V. N., Konoreva, L. A., Zhurbenko, M. P., Pystina, T. N., Chesnokov, S. V., Androsova, V. I., Sonina, A. V., Semenova, N. A. & Valekzhanin, A. A. 2020. New and rare species of lichens and allied fungi from Arkhangelsk Region, North-West Russia. *Folia Cryptogamica Estonica* 57: 85–100. <https://doi.org/10.12697/fce.2020.57.10>
- Thell, A., Randlane, T., Saag, A. & Kärnefelt, I. 2005. A new circumscription of the lichen genus *Nephromopsis* (Parmeliaceae, lichenized Ascomycetes). *Mycological Progress* 4(4): 303–316. <https://doi.org/10.1007/s11557-006-0135-3>
- Urbanavichene, I. N. & Urbanavichus, G. P. 2010. To the lichen flora of the Oka Plateau (East Sayan, Republic of Buryatia). *Novosti sistematiki nizshikh rastenii* 43: 229–245 (in Russian). <https://doi.org/10.31111/nsnr/2009.43.229>
- Zhdanov, I. S. 2010. The first data on the lichen flora of the Central Siberian Biosphere Reserve (Krasnoyarsk Region). *Novosti sistematiki nizshikh rastenii* 44: 153–170. <https://doi.org/10.31111/nsnr/2010.44.153>