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Psoroma urupukapukianum sp. nov. and squamulose *Pannaria* lichen species in Aotearoa / New Zealand

Arve Elvebakk, Allison Knight, Marley Ford

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Psoroma urupukapukianum sp. nov. and notes on squamulose *Pannaria* lichen species in Aotearoa / New Zealand

Arve Elvebakk[1]*, Allison Knight[2] and Marley Ford[3]

Affiliations:

1. **UiT The Arctic University of Norway, Arctic University Museum of Norway, PO Box 6050, Langnes, N-9037 Tromsø, Norway**
2. **Department of Botany, University of Otago, PO Box 56, Dunedin, New Zealand**
3. **School of Environment, University of Auckland, Auckland, New Zealand**

* **Corresponding author: arve.elvebakk@uit.no**

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Abstract

Psoroma urupukapukianum is described from Urupukapuka Island in the Bay of Islands, Te Tai Tokerau / Northland, Aotearoa / New Zealand based on two herbarium collections made in 1980. It has recently been sought at its type locality without success. The species is corticolous and squamulose, developing into a crust of gymnidia, where c. 3/4 represent the chloromorph and the remaining parts are conspicuous cephalodia with the same external morphology as the chloromorph. The species lacks lichen substances by thin layer chromatography (TLC) and the asci have apical IKI+ structures like other *Psoroma* species, but the ascospores differ in having long-apiculate perispores. The new species is hypothesised to represent a separate lineage in *Pannariaceae*, but fresh material for molecular phylogenetic analysis is needed. *Psoroma caliginosum* and *P. melanizum* are both newly treated here as synonyms of *Pannaria pholidotoides* described from the Otago / Ōtakou area. There is also still another unnamed species and an unresolved name from this area. The ascospores of *Pannaria pholidotoides* have a gibbose perispore, contrasting the long-apiculate perispores of the related species *P. implexa*. Knowledge of perispore morphology is decisive for identifying squamulose *Pannaria* species.

Keywords

Pannariaceae, taxonomy, new combinations, *Psoroma melanizum*, *Pannaria pholidotoides*, *Psoroma caliginosum*, lichen, Aotearoa / New Zealand

Introduction

Aotearoa / New Zealand has a very high biodiversity of lichens with 2026 taxa included by de Lange et al. (2018), where *Pannariaceae* was the fifth largest lichen family with 90 species. A large proportion of austral *Pannariaceae* species are tripartite, having both green algal and cyanobacterial photosynthetic partners. Previously, all these except *Psoromidium* were accommodated within *Psoroma*, which included 25 species in the flora of Galloway (1985). Elvebakk and Galloway (2003) transferred the tripartite and foliose members from New Zealand that had not previously been positioned in *Pannaria* to the latter genus as a preparation for the next flora edition (Galloway 2007), where *Psoroma* included 16 species. *Pannaria* was subsequently expanded with a number of New Zealand species – see review by Elvebakk and Elix (2017) and more recent supplements by Elvebakk (2022a; 2022b).

The genus *Pannaria* differs from *Psoroma* in the species lacking an amyloid ascus reaction and by containing a number of secondary metabolites, such as vicanicin, pannarin, leprolomin, numerous terpenoids and additional compounds (Ekman et al. 2014). These are present in abundance in the tripartite species, whereas bipartite species usually contain either pannarin or lack lichen substances by TLC. Species of the genus *Psoroma*, by contrast, have an amyloid structure in the asci, seen as blue cylinder-like structures under the compound microscope after staining with IKI and – except for the pannarin-containing *Psoroma aphthosum* Vain., a few cases featuring porphyrilic acid and a particular chemosyndrome in *Psoroma tenue* and related species (Henssen & Renner 1981; Jørgensen & Wedin 1999) – *Psoroma* species do not have TLC-detectable compounds (Ekman et al. 2014). Most species instead obtain UV-B protection by synthesis of brown or greyish melanins.

The differences between the genera *Psoroma* and *Pannaria* are also valid for the squamulose *Pannaria* species. Two squamulose *Psoroma* species were transferred to *Pannaria* by Passo et al. (2008) and Elvebakk (2022a), and two further common squamulose species, which contain usnic acid and are yellow when fresh, were segregated from *Psoroma* into the new genus *Xanthopsoroma* by Elvebakk et al. (2010).

The usually fertile species *Xanthopsoroma contextum* (Stirt.) Elvebakk has previously been misidentified as *Psoroma pholidotoides* (Nyl.) Trev. (Galloway 2007), with the result that the true *P. pholidotoides*, placed in *Pannaria* by Hue (1902), has not been correctly understood. This will be dealt with here, a treatment which also affects the interpretation of *Psoroma caliginosum* Stirt. and *P. melanizum* Zahlbr. This study reviews the squamulose *Pannaria* species in Aotearoa / New Zealand and changes will eventually be included in the new edition of the country's lichen checklist under preparation (D. J. Blanchon, personal communication, December 2024), which will probably include 32 accepted *Pannaria* species, although quite a number of both foliose and squamulose *Pannaria* species from Aotearoa / New Zealand still await description.

Concerning *Psoroma*, Elvebakk (2021) described a new species from Aotearoa / New Zealand and presented a list of the 11 *Psoroma* species accepted from the country. Whereas most species are terricolous and brownish from melanins, and with an alpine or polar distribution, there is also a fascinating group of corticolous species that includes *P. asperellum* Nyl., *P. coralloideum* (Nyl.) Nyl. and *P. geminatum* P.M.Jørg. (Galloway 2007) that lack brown melanins and clearly look different from the terricolous species.

Recent molecular phylogenies have shown that the terricolous species *Psoroma hypnorum* (Vahl) S.F.Gray and *P. tenue* Henssen characterise two separate evolutionary lineages (Ekman et al. 2014; Park et al. 2018; Elvebakk et al. 2020a). Elvebakk et al. (2020a) hypothesised that these two lineages evolved in or near Antarctica after its separation from previous parts of Gondwanaland at 34 Ma, with a subsequent almost-immediate cooling and formation of glaciers. Corticolous species such as *P. asperellum*, on the other hand, are members of one or several lineages that are possibly evolutionarily older and of late Gondwanaland origin. A phylogeny including these might, hypothetically, unite the two terricolous clades, and Elvebakk et al. (2020a) indeed warned against a redefinition of the genus *Psoroma* prior to a phylogeny that included these species. The corticolous species represent a key group to understanding the evolution of the genus *Psoroma*. However, knowledge of all three groups of *Psoroma* is currently insufficient, evidenced by both the incomplete phylogenies published so far and the presence of still undescribed species in all three lineages.

Below we describe one potentially extinct species of *Psoroma* as new to science, based on two herbarium collections from Urupukapuka Island in the Bay of Islands in Te Tai Tokerau / Northland, which are housed in the herbarium of the Auckland War Memorial Museum (AK). This species combines the characteristics of the genus *Psoroma* with the ascospore of a type found in squamulose *Pannaria* species, and chloromorph and cyanomorph being of almost equal importance in thallus development. The species has recently been searched for in vain on Urupukapuka Island, with the hope of rediscovery there or elsewhere for inclusion in future molecular phylogeny.

Material and Methods

The material under study originates from the herbaria AK, BM, CHR, E, OTA, TROM, W and WELT, with abbreviations following Index Herbariorum (Thiers 2016–onwards). Ascospore morphology was studied in water mounts and restricted to spores liberated from their asci. Detailed drawings of c. 200 ascospores from samples of the treated species were made, and copies of the sketches were included with the vouchers. Illustrated spore drawings are intended to show the variation within a given species. Unless stated otherwise, only samples that have been studied under the microscope are included in this study. Thin-layer chromatography (TLC) of acetone extracts followed standardised procedures and used solvents A and C (Orange et al. 2010). Nomenclature of ascospore structures follows Nordin (1997).

Taxonomy

***Pannaria implexa* (Stirt.) Passo, Stenroos & Calvelo**, *Mycological Research*, 112: 1471 (2008).

Mycobank accession number: 511990

Basionym: *Psoroma implexum* Stirt., Transact. New Zealand. Inst. 6: 236 (1874). Type: New Zealand, Wellington, Tinakori Hills, Dec 1871, *J. Buchanan 38* (WELT, lectotype!, designated by Galloway (1985: 476)); isolectotypes, GLAM; BM000764448!, designated by Galloway (2007: 1466); illustrated by Passo and Calvelo (2011: 760).

Mycobank accession number: 402778

Figures: 1D, 4B.

Notes: When Passo and Calvelo transferred this

Psoroma pholidotoides ISOLECTOTYPE E 00465262

Perispores gibbose like in its youngest synonym P. caliginosum

Nov. 2022
Arve Elvebakk

Psoroma pholidotoides Trevis

Lecanora
[Psoroma] sphinctrina Mont.
var. pholidotoides Nyl.
nov. var.
Saddlehill Bush
Otago N. Z.
Oct. 26, 1861.

Hb. Dr. L. LINDSAY

ROYAL BOTANIC GARDEN EDINBURGH
E00465262

127/79

ISOLECTOTYPE
Lecanora sphinctrina var. pholidotoides Nyl
Det. Conf.: A. Elvebakk Nov. -22
Spore sketch enclosed.
Psoroma caliginosum is a synonym

Figure 1. *Pannaria pholidotoides*: **A**. Part of isolectotype of *Psoroma caliginosum* at BM; **B**. Part of isolectotype of *Psoroma pholidotoides* at E; **C**. Label of isolectotype of *Psoroma pholidotoides* at E, with attached notes. *Pannaria implexa*: **D**. Part of the sample *Knight OTA 061731*. Scale bars = 5 mm.

species to *Pannaria*, they provided a description where the perispores were cited to be "thick, gelatinous and irregular (= halonated) with a long apiculus up to 7 µm at each apex" (2011, p.760). This morphology is illustrated here in more detail in Figure 4B. Laterally, the perispores have very large, but quite regular verrucae, c. 2 µm tall and 3–5 µm wide. Apical extensions are 5–7 µm broad basally, extending for 3–5 µm, until they narrow abruptly to an apiculate point. The apical extensions are 5–20 µm long and are rarely reduced to a nodulose extension at one end, but apiculi can sometimes be seen as broken. The perispore shape was found to be constant in mature spores as seen from numerous drawings, including both the lectotype and the isolectotype in BM. In addition to pannarin, the species was found to contain an unidentified anthraquinone by TLC.

Representative specimens: Aotearoa / New Zealand: *Te Ika-a-Māui / North Island: Te Tai Tokerau / Northland:* Puketi State Forest, kauri forest at end of Pirau Ridge Road, 35°13'N, 173°45'E, crown of a wind-thrown rimu tree, 19 July 1983, *A. E. Wright 5648* (AK 163745); Waima State Forest, Mt. Misery, 35°32'S, 173°31'E, 1900–2340 ft, Jan. 1984, *B. W. Hayward* (AK169311; TROM L-44827); Waima Forest, 35.516147°N, 173.549224°S, 581 m, corticolous on rimu, *M. Ford 1063* (TROM). *Tāmaki Makaurau / Auckland:* Little Barrier Island / Hauturu, 36°1'S, 175°0'E, 100 m, on *Pittosporum umbellatum* in kānuka forest, Aug. 1981, *B. W. Hayward* (AK 175463). *Te Matau-a-Māui / Hawke's Bay:* Ruahine Range, Sunrise Track, 39°47'51"S, 176°11'21"E, c. 700 m, bark of mature trunk, native forest – dry, eastern *Nothofagus*, contains pannarin, 19 Oct. 2009, *A. Knight* (TROM L-42457; OTA61731). *Te Whanganui-a-Tara / Wellington:* Wainuiomata Water Reserve, 41°15'36"S, 175°02'36"E, 360 m, large fallen branch, old-growth *Prumnopitys ferruginea*, mixed temperate rainforest, contains pannarin, 20 July 2011, *A. Knight* (TROM L-42458; OTA61720).

Recognition, ecology, distribution: As indicated by Galloway (2007) and Passo and Calvelo (2011), this species has a very coarse, black, fibrous prothallus and conspicuously thick squamules. Apothecia are robust and concave, soon becoming crowded, developing in concentric rings and often with thalline granules on the discs. Old herbarium specimens gradually take on a yellowish-brown colour. This morphology is quite distinct, but spores should be checked when verifying herbarium material. Passo and Calvelo (2011) treated the names *Pannaria campbelliana* Hue and *Psoroma sphinctrinum* var. *crispellum* Nyl. as synonyms of *Pannaria implexa*, but, when treating these species in *Pannaria*, Elvebakk (2022a) showed that their spores are morphologically different and represent distinct species.

Passo et al. (2008) included the species from South America in a phylogram, which was reanalysed by Ekman et al. (2014) and Magain and Sérisiaux (2014). However, Passo and Calvelo (2011) revised the South American collections to the endemic species *Pannaria byssoidea* Passo & Calvelo. Passo and Calvelo (2011) and Passo et al. (2020) concluded that *P. implexa* should not be accepted for South America, but regarded as endemic to Aotearoa / New Zealand, including the subantarctic Auckland and Campbell Islands.

Galloway (2007) described the species as corticolous and widely distributed throughout Aotearoa / New Zealand, whereas Passo and Calvelo (2011), in addition to some old samples 'from New Zealand', included one sample from Greymouth in Te Waipounamu / South Island and several samples from the Auckland and Campbell Islands. Its distinct morphology described by Galloway (2007) from numerous localities has been confirmed by herbarium specimens seen by us and we believe it is a very widespread species. However, microscopic examinations of more samples than presented here are necessary to document its distribution.

***Pannaria pholidotoides* (Nyl.) Hue**, *Bull. Soc. Bot. France* 48: LVII (1902)

Mycobank accession number: 396970

Basionym: *Lecanora sphinctrina* var. *pholidotoides* Nyl. *J. Linn. Soc. Bot.* 9: 250 (1866).

Type: New Zealand, Otago: Saddlehill ['Saddle Hill'] Bush, 26 Oct. 1861, *W. L. Lindsay* (H-NYL 30773–lectotype!, lectotypified by Galloway (1985), p. 480; E00465262–isolectotype!.

Illustration: JSTOR Global Plants (2024).

≡ *Psoroma pholidotoides* (Nyl.) Trev., Lich. Ven. 98 (1869).

Mycobank accession number: 402792

= *Psoroma caliginosum* Stirt., *Proc. Roy. Philos. Soc. Glasgow* 10: 295 (1877), syn. nov.

Type: New Zealand, pr. Wellington, *J. Buchanan 247* (*'45'*) lectotype GLAM, lectotypified by Galloway 1985: 471; isolectotype BM000764453!, typified as isotype in hb. BM by J. Murray in 1960.

Mycobank accession number: 402739

= *Psoroma melanizum* Zahlbr. *Denkschr. Akad. Wiss. Wien Math.-naturwiss. Kl.* 104: 277 (1941), syn. nov.

Type: New Zealand, Otago, Boyd's Bush, North Taieri, near Dunedin, South Island, xii 1932, *J. S. Thomson* [ZA 74], (W 2010-00391–holotype!), typified by Galloway (1985), p. 478.

Figures: 1A, 1B, 1C, 2, 4A.

Mycobank accession number: 369757
For a description, see Galloway (1985; 2007) as *Psoroma caliginosum*.

Notes: Elvebakk et al. (2010) concluded that the lectotype of *Psoroma pholidotoides* in H-NYL was very small, and as no attempt had been made to section apothecia, it was difficult to interpret, apart from representing a still-unresolved squamulose *Pannaria* taxon with pannarin. Fortunately, the isolectotype in E is much better developed – see Figure 1A. Illustrations of both types are now available online at JSTOR Global Plants. The first author visited E in 2022, with the hypothesis that this taxon is an older synonym of *Psoroma melanizum*, which is also saxicolous and described as being from the same area. However, as shown in Figure 1C, the ascospores of *P. pholidotoides* have perispores corresponding to those of *P. caliginosum*, which is now identified as a new synonym of this species.

The isolectotype of *Psoroma caliginosum* in BM consists of three specimens of *J. Buchanan 247* marked as 'a' mounted together with one specimen of *J. Buchanan 157*, marked as 'b' and arranged and determined at BM by J. Murray in 1960. The 'a' specimens have sessile apothecia with narrow margins and black filmy prothalli, which correspond to the morphology of *P. pholidotoides*. The single 'b' specimen was determined as *Psoroma implexum* by J. Murray in 1960 and has now been redetermined as *Xanthopsoroma contextum* here. The ascospores of the latter correspond with those illustrated by Elvebakk et al. (2010), but the yellow usnic acid colour has faded, as in other usnic acid species after storage in herbaria. As shown in Figures 1C and 4A, the perispores of the ascospores of *Pannaria pholidotoides*, including the type collections of *Psoroma caliginosum* and *P. melanizum*, are very distinctive, with irregular, large and obtuse swellings, corresponding to the terminology 'gibbose' used by Elvebakk et al. (2016) for the tropical genus *Gibbosporina*, and without apiculate apical extensions.

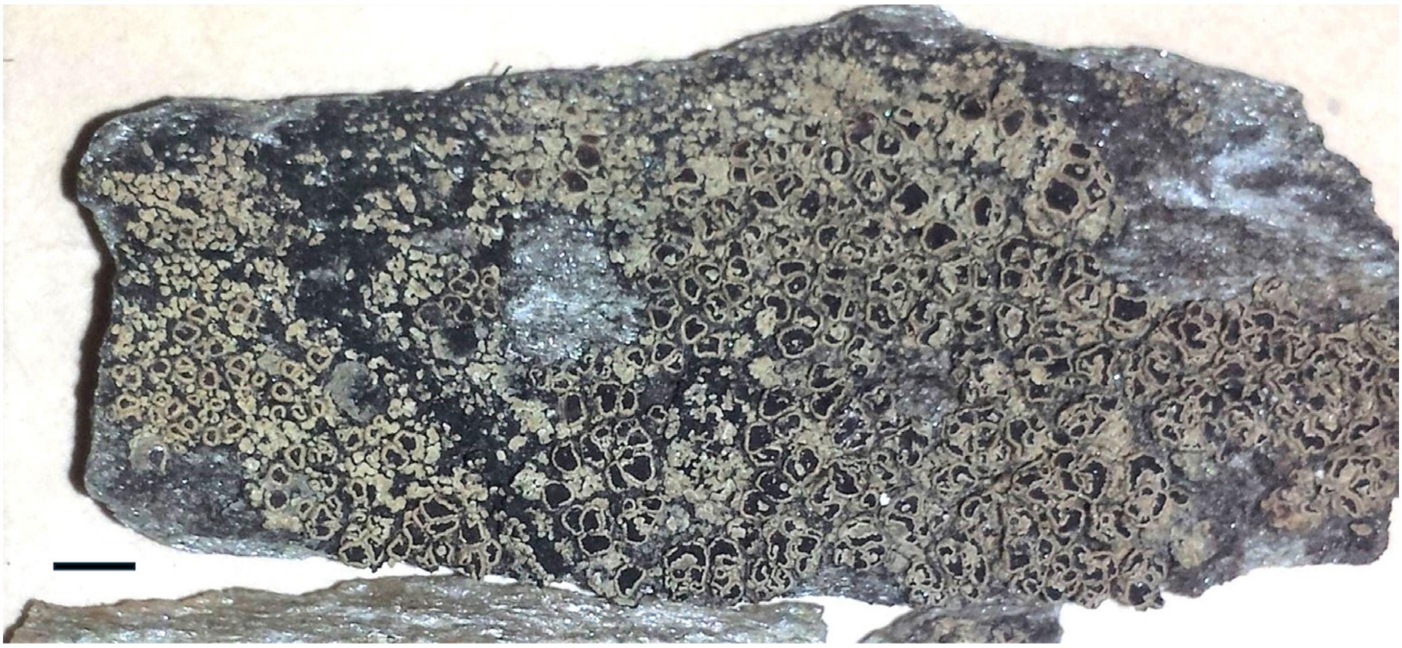

Figure 2. *Pannaria pholidotoides*, holotype of the synonymous *Psoroma melanizum* at W. Scale bar = 5 mm.

The holotype of *Psoroma melanizum* has now been studied and shown to represent a synonym of *Pannaria pholidotoides*. Galloway (2007) also listed isotypes of *Psoroma melanizum* deposited at CHR and OTA. These are not accepted as isotypes here because they are *Thompson T497*, collected on 7 July 1933, as opposed to the holotype *Thompson ZA74*, collected in Dec. 1932 on a previous visit to the same area, thus representing the concept of topotypes. Both these samples have been studied microscopically and also represent synonyms of *Pannaria pholidotoides*.

In addition to pannarin, the species contains two distinct unidentified terpenoids in minor quantities. These were found in all the analysed samples, and were absent from those of *P. implexa* and the unnamed species dealt with here.

Representative specimens: Aotearoa / New Zealand: *Te Ika-a-Māui / North Island: Te Whanganui-a-Tara / Wellington*: Wainuiomata Water Reserve, 41°15'30"S, 175°02'45"E, 730 m, on branch of fallen *Nothofagus menziesii*, temperate rainforest, 20 July 2011, *A. Knight* (TROM L-42456; OTA 061717); NW of Taihape, Mataroa, Pangaroa Scenic Reserve, river track, on *Myrsine divaricata* in *Dacrycarpus dacryioides* forest, 39°38'S, 175°43'E, (imm. apothecia), 520 m, *B. Polly* (WELT L005632); East Harbour, Butterfly Creek, 41°19'S, 174°53'E, on *Brachyglottis repanda*, south-facing, 40 m, 2 May 1992, *C. J. West* (WELT L3949). *Te Waipounamu / South Island: Whakatū / Nelson*: Kahurangi National Park, Lodestone Track, on *Fuscospora cliffortioides*, 12 March 2022, *J. Mosimann JM003* (CHR; TROM L-44751). *Ōtākou / Otago:* Boyd's Bush, North Taieri, near Ōtepoti / Dunedin, on *Griselinia littoralis*, date?, *J. S. Thomson T.475* (CHR 160607); Boyd's Bush, on schistose rock, 7 July 1933, *J. S. Thomson T497* (OTA 29818 a, b; CHR 163000, as '*Psoroma melanizum* isotype'); Boyd's Bush, on schistose rocks, 7 July 1933, *J. S. Thompson* (OTA 29818 a, b); Maclennan [River] Scenic Reserve, Papatowhai Highway, Catlins, silver beech–kāmahi forest, 41°32'07"S, 168°28'43"E, 12 m, 20 Feb. 2022, *A. Knight AKC15* (OTA 073178; TROM L-44776); Mihiwaka, Blueskin Road, *Melicytus ramiflorus* trunk, base of climbing rock, partial shade, 45°47'30"S, 170°38'05"E, 511 m, 20 Feb. 2022, *A. Knight AKM4* (OTA 073173; TROM L-44778). *Murihiku / Southland:* near McLean Bridge, c. 13 km along the road northwards from Papatowhai, 46°35.52'S, 169°21.46'E, 140 m, on *Weinmannia*, 10 Dec. 2002, *Elvebakk 02:643* (TROM). *Rakiura / Stewart Island*, Rakiura Ecological Region, Port Pegasus, Islet Cove, 47°12'S, 167°38'E, 10 m, in coastal forest, 3 Feb. 1989, *B. W. Hayward* (AK206790); Mt. Anglem, 46.741468°S, 167.960066°E, 299 m, corticolous, in forest, *M. Ford 1063, M. Hutchison & Y. Heled* (TROM). *Rēkohu / Chatham Islands*, Chatham Ecological Region and District, Rangihaute (Rangiauria) / Pitt Island, Tupangi Stream, near Lake Tupangi, 44°14'0"S, 176°12'0"E, 1 m, in swamp forest bordering creek, on exposed shell *Olearia telmatica* trunk, 15 Sept. 2007, *P. J. de Lange CH2331 & P. B. Heenan* (AK 313048).

Recognition, ecology, distribution: The species is easily distinguished from the other species by its characteristic perispores, and from *P. implexa* by its filmier prothallus and less robust squamules and excipuli. The examined samples listed above reflect a wide distribution range from Te Ika-a-Māui / North Island to Rakiura / Stewart Island and including Rēkohu / Chatham Islands. The species has been reported from southern South America by Lücking et al. (2003); however, their illustrated specimen represents a taxon in the *Pannaria minutiphylla* Elvebakk aggregate, and the specimen from Argentina analysed phylogenetically by Passo and Calvelo (2011) represents *Xanthopsoroma contextum*. It has also been reported from Australia as *Psoroma caliginosum* (McCarthy 2016), but this has not yet been studied by us.

Pannaria sp. aff. *pholidotoides*

Despite the synonymisation of *Psoroma caliginosum* and *P. melanizum* with *Pannaria pholidotoides*, another unnamed squamulose *Pannaria* species remains, particularly in the Dunedin area. It morphologically overlaps with *P. pholidotoides* (Figure 3), and contains pannarin, but the spores are different. Proper ascospores are simple, hyaline, globose, subglobose to weakly short-ellipsoid, 13–18 × 7–9 µm, perispores 17–21 × 9–11 µm, regularly verrucose with large verrucae, 2–3 × 0.5–1 µm, and with apical pulvinate to nodulose extensions, c. 2 × 3 µm in size (Figure 4C). The regular lateral verrucae and pulvinate or nodulose apical extensions contrast the irregularly gibbose perispores of *P. pholidotoides*. The proper spores of *Pannaria* sp. are also more long-ellipsoid than those of *P. pholidotoides*. In general, only a single mature spore is required to determine which species is being studied.

A number of samples from the Ōtepoti / Dunedin area previously determined under several names have

Figure 3. *Pannaria* sp., specimen *Ford 1066 et al.* Photographed in the field on Rakiura / Stewart Island. Scale bar = 5 mm.

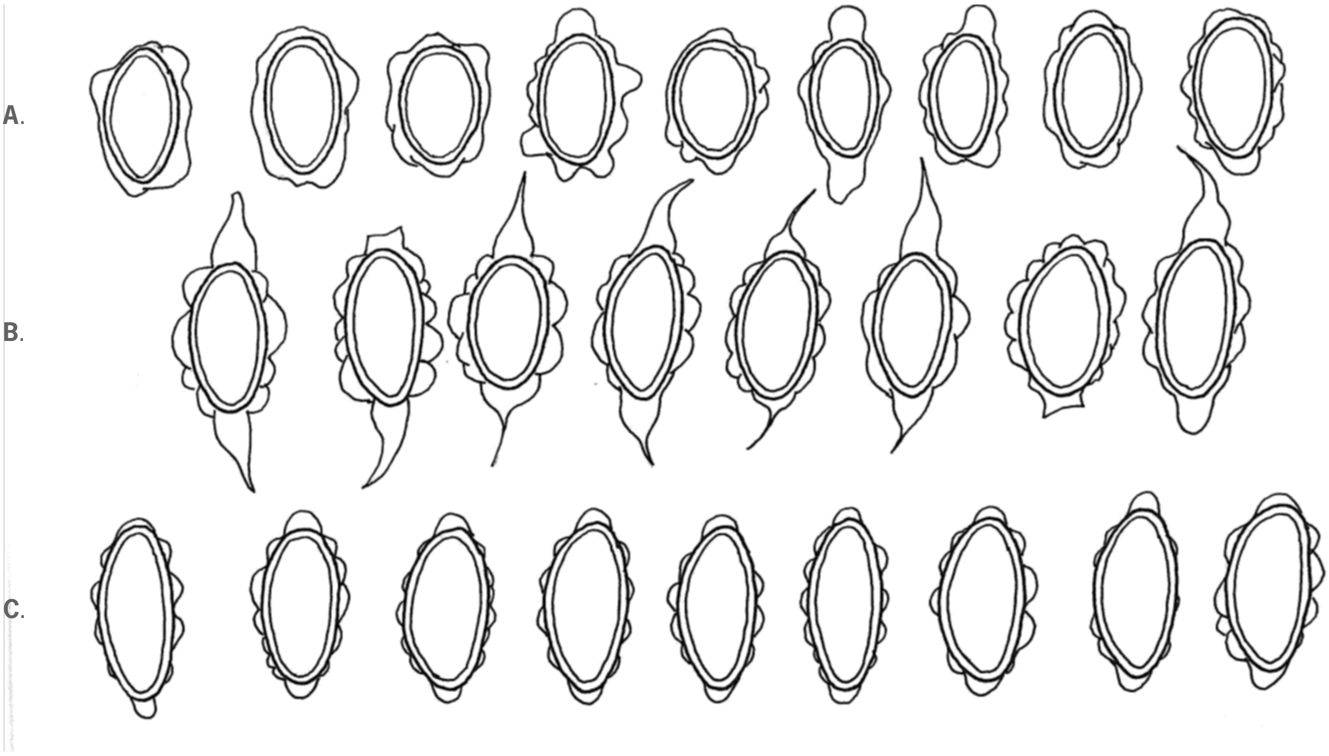

Figure 4. *Pannaria* ascospores: **A**. *Pannaria pholidotoides*; **B**. *P. implexa*; **C**. *P.* sp. Scale bar = 10 μm.

now been redetermined as *P. pholidotoides*, which is apparently common in the area, where it co-occurs with *P.* sp. known from four localities. It should be added that a third species has been described from the Ōtepoti / Dunedin area: *Psoroma spectabile* Zahlbr. (Mycobank accession number 369758) from Flagstaff Hill, with the holotype also housed at W. Unfortunately, this specimen is on loan and currently unavailable. The species has been considered a synonym of *Pannaria implexa* by Galloway (1985; 2007) and Passo and Calvelo (2011). Still, we believe a renewed study of *Psoroma spectabile* should be undertaken before deciding to describe *Pannaria* sp. as a new species from the same area. The latter species is also known from elsewhere, and Figure 3 illustrates a specimen from Rakiura / Stewart Island.

Representative specimens: Aotearoa / New Zealand:

Te Ika-a-Māui / North Island: Te Whanganui-a-Tara / Wellington: East Harbour, Butterfly Creek, 41°19.'S, 174°53'E, on *Brachyglottis repanda*, south-facing. 40 m, 2 May 1992, *C. West* (WELT L-39049). *Te Waipounamu / South Island: Te Tauihu-o-te-waka / Marlborough:* Banks Peninsula, Crater Rim Walkway above Rāpaki, NZTM: 1572768 5172790, 428 m, open basalt bluff in *Cytisus scoparius / Dactylis glomerata* shrubland on south-facing slope of ridge, 24 Feb. 2022, *D. Glenny 15205* (CHR 674512; TROM L-44752). *Ōtākou / Otago:* Orokonui Ecosanctuary, 10–15 km NE of Dunedin, 45°46'37"S, 170°35'59" E, 276 m, on rock under regenerating *Kunzea robusta* (as *K. ericoides*) coastal forest, 12 June 2010, *A. Knight* (OTA 061732; TROM); East Taieri Bush, on rock, 5 Nov. 1861, *W. L. Lindsay* (E00465260); Tuapeka West, Knight's Bush, off Remarkable Road, rock below hut on track to river, under mixed broadleaf–tōtara forest in medium light, 45°54'48"S, 169°29'35"E, 83 m, 9 Jan. 2022, *A. Knight* (OTA 073166; TROM L-44781); Mihiwaka, Blueskin Road, volcanic phonolite, base of climbing rock, partial shade, 45°47'30"S, 170°36'05"E, 511 m, 20 Feb. 2022, *A. Knight AKM6* (OTA 073174; TROM L-44782). *Rakiura / Stewart Island*, Buggery Hut, 46.781642°S, 167.995104°E, 9 m, corticolous on mānuka (*Leptospermum scoparium*), 22 March 2022, *M. Ford 1066, M. Hutchison & Y. Heled* (TROM).

Psoroma urupukapukianum **Elvebakk & M. Ford, sp. nov.**

Mycobank accession number: 859783

Holotype: Aotearoa / New Zealand, Te Ika-a-Māui / North Island, Te Tai Tokerau / Northland: Eastern Northland Ecological Region, Eastern Northland and Islands Ecological District, Bay of Islands, Urupukapuka Island. 35°1'S, 174°1'E, on tea tree bark, Jan. 1980, *B.W. & G.C. Hayward* (AK 155087).

Paratype: New Zealand, North Island, Northland: Eastern Northland Ecological Region, Eastern Northland and Islands Ecological District, Bay of Islands, Urupukapuka Island. 35°1'S, 174°1'E, on tea tree bark, 1 Jan. 1980, *B. W. & G. C. Hayward* (AK 155086). This specimen is selected as a paratype and not an isotype, as a precaution, because the condition of the apothecia, notably its pigmentation, suggests that, despite being collected in the same month and probably day (we cannot be certain), it was most likely collected from a different location or aspect than the holotype.

Figures: 5, 6, 7.

Diagnosis: Differs from *Psoroma asperellum* by the small, peripheral, appressed squamules soon developing into a crust of gymnidia intermixed with subdominant cephalodia with the same morphology, and ascospore perispores with scattered lateral verrucae and conspicuous, long, filiform, apical extensions.

Etymology: Named after its only known locality, Urupukapuka Island, Pēwhairangi / Bay of Islands, Te Tai Tokerau / Northland, Te Ika-a-Māui / North Island, Aotearoa / New Zealand.

Description: *Thallus*, corticolous, squamulose, forming a coralloid crust, c. 5 cm diam. *Primary thalline squamules*, whitish grey, initially pulvinate and tiny (0.03–0.15 mm) and united by an indistinct whitish prothallus, later forming adpressed squamules, c. 1 mm wide, 100–200 µm thick, inconspicuous and hidden by gymnidia. *Gymnidia*, formed from the primary thallus, including both the chloromorph squamules and the cephalodia, with the composed crust divided by cracks into c. 1 mm-wide areolae. *Chloromorph gymnidia*, constituting c. 60–70 % of the crust, whitish grey, arising from the thalline squamules, densely branched with terminal parts forming densely set, globose granules, slightly compressed horizontally, 0.1–0.2 mm wide, distinctly tomentose, densely packed medullary hyphae without cortical structures also present, broken up into 0.5–1 mm-wide areolae. *Chlorobiont Trebouxia*, cells tiny, 2–4 µm diam., chloroplasts angular. *Cyanobiont Nostoc*, cells blue, 4–6 × 2.5–3.5 µm, arranged in chains, forming 0.1 mm-wide globose cephalodia in peripheral parts, soon developing into coralloid, gymnidia-like structures similar to those of the chloromorph. *Prothallus*, whitish, indistinct, protruding 0.2–0.3 mm beyond thallus margins. *Apothecia*, common, 1–2 mm diam., disc pale brown to reddish brown, flat, occasionally with thallus grains centrally, excipulum thalline, indistinctly crenulate, c. 1 mm wide; *epithecium*, 15–20 µm deep; *paraphyses*, adglutinated and pigmented distally, 2–3 µm wide, septate; *hymenium*, 100–130 µm deep; *asci*, c. 100 × 20 µm, with amyloid, IKI+ blue tube structures apically, ascospores 8/ascus, non-septate; *proper spores*, ellipsoid, 13–16 × 8–10 µm; *perispores*, ellipsoid, 20–34 × 8–12 µm, including large, scattered verrucae 1–2 µm tall, 2–3 µm wide, and apical extensions

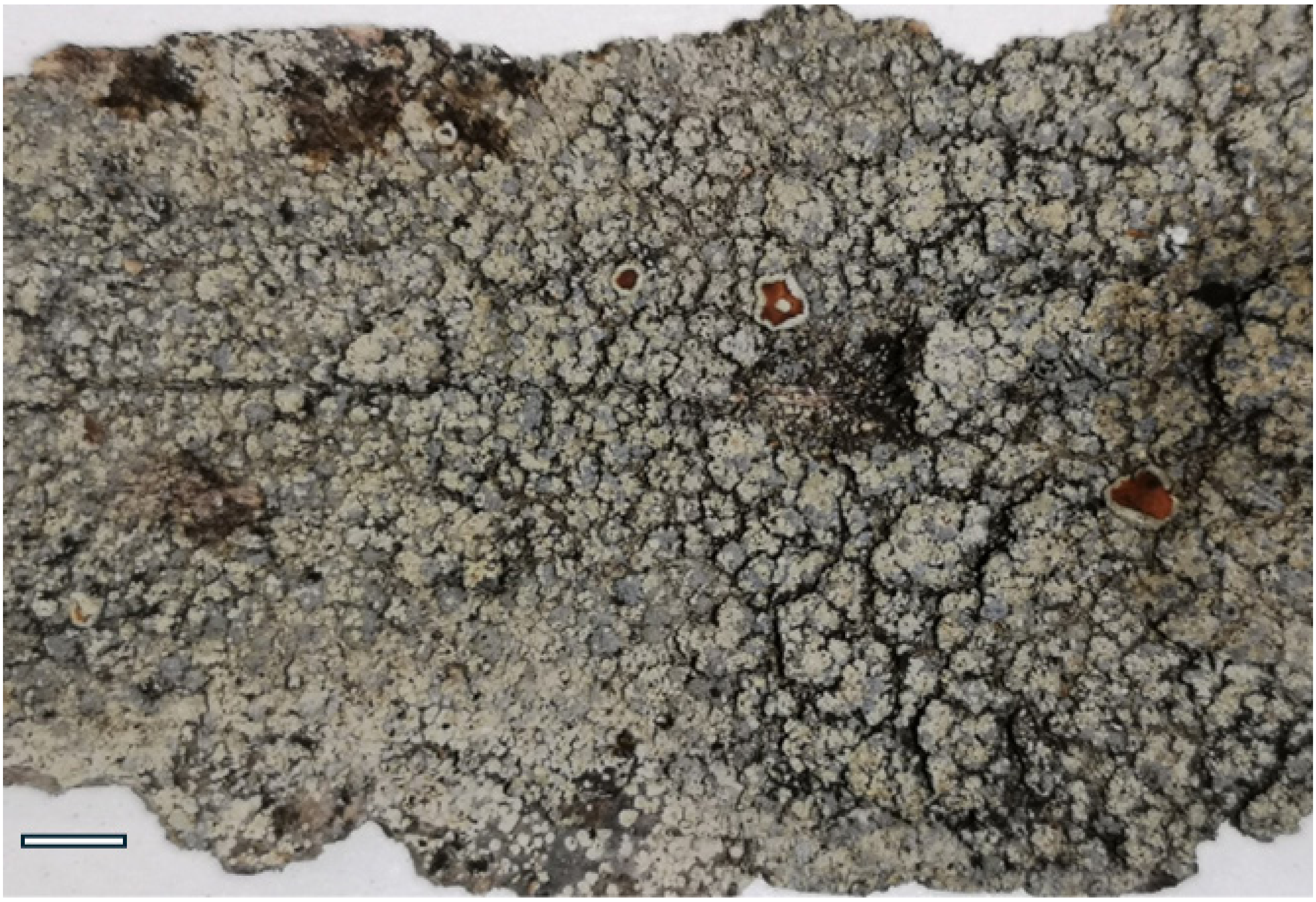

Figure 5. *Psoroma urupukapukianum*, the holotype. Scale bar = 5 mm.

Figure 6. *Psoroma urupukapukianum*, part of the paratype moistened. Scale bar = 1 mm.

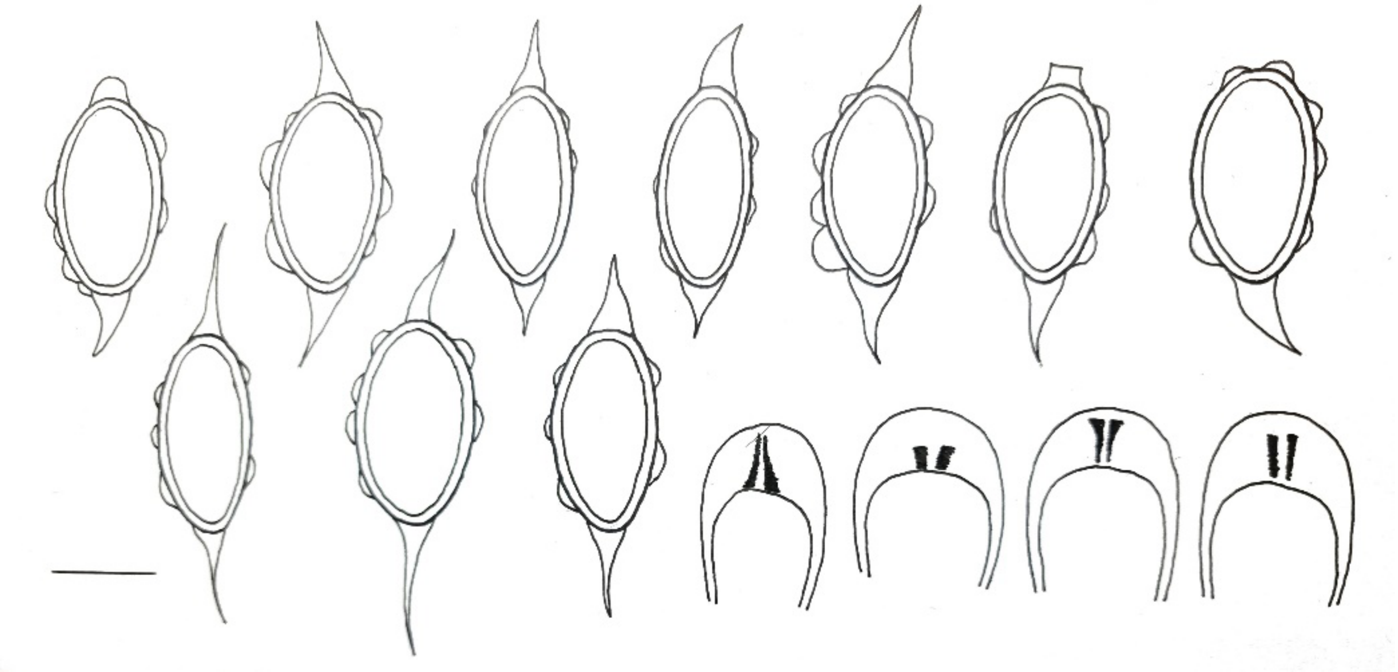

Figure 7. Ascospores and IKI+ amyloid tubes in asci of *Psoroma urupukapukianum*. Scale bar = 10 µ.

tapering from a broad base into 5–14 µm-long apiculi, occasionally absent or broken; *hypothecium*, c. 80 µm deep. *Chemistry:* No substances detected by TLC.

Recognition, ecology, distribution: *Psoroma urupukapukianum* has a very thin, whitish prothallus as in other *Psoroma* species, whereas the prothallus is mostly blackish in squamulose *Pannaria* species. The tiny, appressed, peripheral, chlorobiont squamules increase in size towards the centre, but gradually become almost invisible as they are hidden by the dominating isidia-like crust, which, on closer examination, was shown to lack cortical structures. By definition, these structures are, therefore, gymnidia, a term introduced by Jørgensen and Kashiwadani (2001), who used it for coarse, cobwebby, ecorticate, isidia-like structures in the *Pannariaceae* that characterise bipartite species such as *Pannaria conoplea* (Ach.) Bory, *P. globigera* Hue and *Kroswia gemmascens* (Nyl.) P.M.Jørg. However, in the case of *Psoroma urupukapukianum*, the gymnidiate morphology also includes the cyanobiont.

The species must be beautiful when fresh and moist in the field, with the green chloromorph and the blue cyanomorph both being coralloid, the cephalodia very prominent and covering about one third of the thallus, and the brown apothecia turning reddish brown when moist, although the cited paratype has orange–brown apothecia (Figures 5, 6).

The cyanobiont initially forms normal, small, globose cephalodia, c. 0.1 mm wide, but these soon become coralloid and contribute to 30–40% of the massive gymnidiate crust. A coralloid, gymnidiate crust composed almost equally by the chloromorph and the cyanomorph has not to our knowledge been previously described in *Pannariaceae* or any other lichenised family. Several *Pannariaceae* species have cephalodia that have developed into finely branched and brittle structures functioning as vegetative dispersal units (Jørgensen & Wedin 1999; Elvebakk et al. 2016) such as occur in *Psoroma urupukapukianum*, but there is no case where a parallel adaptation has also taken place with the chloromorph.

Due to its whitish grey primary thalline squamules, it was initially thought that *P. urupukapukianum* might represent a squamulose species of *Pannaria*, and the long-tailed peripores appeared to support such an affiliation. However, the species has very distinct IKI+ blue internal tube-like, apical ascus structures (Figure 7), corresponding to those illustrated for *Psoroma hypnorum* (Vahl) S.F. Gray by Elvebakk et al. (2010).

The TLC negative chemistry is also in agreement with a position within *Psoroma*, because the Aotearoa / New Zealand squamulose *Pannaria* species dealt with have pannarin or the related argopsin as a primary secondary compound. *Psoroma urupukapukianum* is morphologically distinct from all three major groups currently identified within *Psoroma*. However, its corticolous habit and occurrence in lowland forests in the northern parts of Aotearoa / New Zealand indicates an affinity with the *Psoroma asperellum* group, in which melanins are absent or much reduced, and where TLC-detectable compounds are also absent, except for porphyrilic acid in *P. asperellum*. This group also has a subdominant cyanobiont as shown by the prominent cephalodia.

However, *P. urupukapukianum* is distinguished from these species by the strikingly different long-apiculate perispores of its ascospores that are not known from any species of *Psoroma*. We hypothesise that it represents a distinct lineage related to the *P. asperellum* group, although the possibility of a position outside of *Psoroma* cannot be excluded. Its distinct morphology indicates that the species has not been overlooked among the *Psoroma* collections in the many herbaria studied by the first author. However, the *Pannariaceae* biota of northern parts of Aotearoa / New Zealand is understudied, as witnessed by another isolated taxon with affinity to *Psoroma* collected from northern parts and currently under study. This species was found on Aotea / Great Barrier Island during several days of field work, where *P. urupukapukianum* was not seen. The latter species was searched for in vain on Urupukapuka Island by co-author Marley Ford in 2020. A rediscovery somewhere would be most welcome, given the need to understand its phylogenetic relationships.

Discussion

With the two species treated by Elvebakk (2021), the squamulose, tripartite members of *Pannaria* in Aotearoa / New Zealand now include four named species. In addition, *Pannaria byssoidea* occurs in southernmost South America (Passo et al. 2011). These all develop a distinct dark prothallus, where repeated lichenisations of the chlorobiont and the cyanobiont are seen as scattered small thallus islands. The chemistry of these species is mostly pannarin, with a few unidentified terpenoids and anthraquinones as minor constituents. In the case of *P. pholidotoides*, two terpenoids have been detected in several samples, a topic that should have been extended to a study of a larger material. Exceptions to this pattern are *Pannaria crispella*, which contains the related compound argopsin (Elvebakk 2022a), and *P. byssoidea*, which contains leprolomin (Passo et al. 2011).

Spore morphology

The proper ascospores of all these species are ellipsoid, whereas the diverse shapes of the perispores are new observations presented here. In *Pannaria campbelliana* the perispores are finely verruculose without apical extensions, and in *Pannaria* sp. the verrucae are larger and more scattered and the apical extensions large and pulvinate to nodulose. *Pannaria pholidotoides* has gibbose perispores, whereas *P. crispella* has smooth perispores with very long-apiculate apical extensions. In *Pannaria implexa* they are also apiculate but have very large lateral verrucae. Because perispore morphology is important in characterising taxa in *Pannariaceae*, this diversity is expected to reflect a long evolution among the tripartite squamulose *Pannaria* species and a molecular phylogenetic study has been initiated. When compared to the ascospores of other *Pannaria* species, those of *P. campbelliana* are similar to most foliose *Pannaria* species. Those of *Pannaria crispella* and *P. implexa* resemble the perispores of the *P. athroophylla* group, where species with a prothallus also recruit chlorobiont and cyanobiont granules (Elvebakk 2022b) like small islands. The perispores of *P. pholidotoides* are unique within *Pannaria*, whereas those of *P. byssoidea* and *P.* sp. are intermediate between *P. implexa* and foliose *Pannaria* species. This perispore diversity makes it easy to identify these species, even without knowledge of their secondary metabolite chemistry. Perispore morphology can also easily separate these species from the two species of *Xanthopsoroma* when the usnic-acid colour of the latter is indistinct due to low-light habitats or due to degradation after storage (Elvebakk et al. 2010). Samples with significantly different perispore structures might represent one of the several undescribed species from Aotearoa / New Zealand on which we are accumulating data.

The sequence of *Pannaria byssoidea* analysed by Passo and Calvelo (2011), and another sample of the same species added by Elvebakk et al. (2020b), are the only samples of squamulose species of *Pannaria* for which molecular data is currently available. The diversity and phylogeny of squamulose *Pannaria* species of Aotearoa / New Zealand and other austral areas is a topic of an initiated study.

The new species

Psoroma urupukapukianum is entirely different from the terricolous and mostly polar-alpine *Psoroma* species, but also clearly different from evolutionarily older and primarily corticolous species in Aotearoa / New Zealand. Among these species, *Psoroma asperellum* is the only one that is common, whereas the two remaining species, *P. coralloideum* and *P. geminatum*, are not as well understood. However, all these species have cyanobionts that produce very conspicuous cephalodia (Jørgensen & Wedin 1999), a characteristic shared with *P. urupukapukianum*.

The rarity of the new species *Psoroma urupukapukianum* is difficult to explain given its adaptations to vegetative dispersal by its cover of gymnidia. Local vegetative dispersal is difficult to exclude. Urupukapuka Island has undergone extensive clearing in recent years, with most remnant vegetation reduced to small fragments around the coast. The only known host mānuka (*Leptospermum hoipolloi* L.M.H. Schmid & de Lange) is an early successional tree. If this common habitat represents its primary ecology, this fails to explain why this species is so rare. Alternatively, it is possible that *Psoroma urupukapukianum* was more common before European arrival, when the island was dominated by old-growth coastal forest, and its recent confinement to mānuka communities is a suboptimal and unstable occurrence. Finding more specimens of this new species would establish a clearer idea of its ecology.

Both photobionts of *P. urupukapukianum* appear distinct from other lichen photobionts. The *Trebouxia* strain forms tiny cells, smaller than in any other *Pannariaceae* species studied by the first author. Northern Aotearoa / New Zealand *Pannaria* species are known to have smaller *Trebouxia* strains than elsewhere (Elvebakk *in prep.*), but no studied *Psoroma* species has such small chlorobiont cells. The cyanobiont is also morphologically distinct in being blue, rather large-celled and forming distinct chains, characteristics unknown in any other studied *Psoroma* species, and rare in *Pannariaceae* outside of tropical areas.

Because lichenisation of this species requires two photobionts, both apparently morphologically unique, it is possible that this is a bottleneck restricting the distribution of *P. urupukapukianum*. Photobiont choice is apparently a crucial element in the evolution of *Pannariaceae* lichens (Magain & Sérusiaux 2014). However, *P. urupukapukianum* is less dependent on such new lichenisation events as both photomorphs disperse vegetatively. Its adaptation to vegetative dispersal is one reason why searching should be primarily concentrated on its known distribution area in the Bay of Islands, although the species may potentially occur in other parts of northern Aotearoa / New Zealand.

Another possibility is that *P. urupukapukianum* occurs primarily elsewhere and that its occurrence at Urupukapuka Island is of secondary character. If this is the case, the ideal place to search for it would be New Caledonia, given the richness of *Pannariaceae* species that recent publications (Elvebakk 2007; Elvebakk et al. 2016; Jørgensen & Gjerde 2012) have far from fully explored.

Being currently known from only a single location and with recent searches being unsuccessful, *Psoroma urupukapukianum* is estimated as a candidate for being in the category 'Threatened / Nationally Critically Endangered', qualified 'DPR' [Data Poor Recognition], using the New Zealand Threat Classification System (NZTCS) (see Rolfe et al. 2022). However, as it also fits 'Data Deficient' as defined by the NZTCS, more searches are clearly needed. The species is probably an exclusive and evolutionarily isolated representative in the biota of Aotearoa / New Zealand.

Data Accessibility Statement

No additional database.

Author Contributions

Arve Elvebakk: Conceptualisation (lead); data curation (lead); validation (lead); visualisation (lead); writing – original draft (lead); writing – review and editing (lead).
Allison Knight: Specimen collection.
Marley Ford: Field work, provision of Figure 3 and specimen collection.

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