Five new records of *Pyrenula* (Pyrenulaceae) for New Zealand

Andrew J. Marshall, Dan J. Blanchon, André Aptroot & Peter J. de Lange

To cite this article: Andrew J. Marshall, Dan J. Blanchon, André Aptroot & Peter J. de Lange (2019): Five new records of *Pyrenula* (Pyrenulaceae) for New Zealand, New Zealand Journal of Botany

To link to this article: <https://doi.org/10.1080/0028825X.2019.1662816>

Published online: 16 Sep 2019.

Submit your article to this journal [↗](#)

View related articles [↗](#)

View Crossmark data [↗](#)

RESEARCH ARTICLE

Five new records of *Pyrenula* (Pyrenulaceae) for New Zealand

Andrew J. Marshall^a, Dan J. Blanchon^a, André Aptroot^b and Peter J. de Lange ^a

^aSchool of Environmental & Animal Sciences, Unitec Institute of Technology, Auckland, New Zealand;

^bLaboratório de Botânica / Liquenologia, Instituto de Biociências, Bairro Universitário, Mato Grosso do Sul, Brazil

ABSTRACT

Pyrenula (Pyrenulaceae) is a poorly studied genus of lichenized mycobiota in New Zealand. Following the sampling of lichens from over 50 vegetation plots established within the Auckland Region by the Auckland Council, we have recognised a further five species of *Pyrenula*: *P. leucostoma* (Zahlbr.) R. C. Harris, *P. microcarpa* Müll. Arg., *P. pyrenuloides* (Mont.) R. C. Harris, *P. subumblicata* (C. Knight) Aptroot and *P. subvariolosa* (C. Knight) Aptroot from the New Zealand Botanical Region. These discoveries increase the number of *Pyrenula* accepted for New Zealand from 10 to 15, and extend the range of two species previously regarded as endemic to Australia. The discoveries also highlight the importance of undertaking more comprehensive lichen sampling within New Zealand's ecosystems. We recommend that, for those regions where permanent vegetation plots have been established for long-term monitoring, an assessment of lichen diversity should also be included in their initial sampling phase and monitoring protocols. With these additions, as well as changes in the taxonomy of New Zealand *Pyrenula*, a revised key to the known species of *Pyrenula* in New Zealand is presented.

ARTICLE HISTORY

Received 5 August 2019

Accepted 29 August 2019

HANDLING EDITOR

Matt Renner

KEYWORDS

Pyrenulaceae; *Pyrenula*;
P. leucostoma; *P. microcarpa*;
P. pyrenuloides;
P. subumblicata;
P. subvariolosa; Auckland
Region; additions New
Zealand mycobiota

Introduction

Internationally, lichens are used as bioindicators of forest health (Rose 1974, 1976, 1992; Selva 1994, 1996; Zedda 2002), although in New Zealand their use is in its infancy (Ranft et al. 2018). The first step in using lichens as bioindicators is to understand the lichen diversity and composition within different vegetation associations. While the New Zealand lichenized mycobiota is reasonably well-known (Galloway 1985, 2007; de Lange et al. 2012, 2018), systematic studies of different habitat or substrate types are uncommon (e.g. Reynolds et al. 2017), and, despite their ecological importance (Scott et al. 1997; Ryan 2002; Porada et al. 2013), lichens are either not included in surveys or for monitoring purposes (de Lange et al. 2012) or their documentation is limited. For example, the New Zealand Department of Conservation maintains an extensive series of permanent vegetation monitoring plots throughout the country, and for these records of some of the lichens present are made, though notably not the crustose taxa (DOC 2017; S. Rowland pers. comm., January 2019). By contrast permanent vegetation

plots placed across the Auckland Region (Figure 1) by the Auckland Council do not record lichens at all (Khin 2013). In response to this, a project was initiated by Unitec Institute of Technology and Auckland Council (Unitec Institute of Technology Project RE15008) to do a complete inventory of the lichens present within a subsample of 50 of the 257 Auckland Council permanent vegetation monitoring plots (400m²). The 50 plots sampled encompass the full diversity of forest vegetation associations of the Auckland region. From those plots we have collected nearly 3000 lichen specimens, the ongoing analysis of which has uncovered unexpectedly high diversity, including a number of lichens that

Figure 1. The Auckland Region showing locations where the *Pyrenula* species discussed in this paper have been collected.

Table 1. A concordance of names used for New Zealand Pyrenulaceae by Galloway (2007).

Galloway (2007)	This paper
<i>P. crassescens</i> (Stirt.) Müll.Arg.	<i>P. quassiaecola</i> (Fée) Fée
<i>P. cyrtospora</i> (Stirt.) Müll.Arg.	<i>P. sexlocularis</i> (Nyl.) Müll.Arg.
<i>P. dealbata</i> (C.Knight) Müll.Arg.	<i>P. nitidula</i> (Bres.) R. C. Harris
<i>P. deliquescent</i> (C.Knight) Müll.Arg.	<i>P. deliquescent</i> (C.Knight) Müll.Arg.
<i>P. deprimens</i> (C.Knight) D. J. Galloway	<i>P. chlorospila</i> (Nyl.) Arnold
<i>P. homalisma</i> (C.Knight) D. J. Galloway	<i>P. quassiaecola</i> (Fée) Fée
<i>P. knightiana</i> Müll.Arg.	<i>P. chlorospila</i> (Nyl.) Arnold
<i>P. moniliformis</i> (C.Knight) Müll.Arg.	<i>P. moniliformis</i> (C.Knight) Müll.Arg.
<i>P. occulta</i> (C.Knight) Müll.Arg.	<i>P. dermatodes</i> (Borrer) Schaer.
<i>P. prostrata</i> (Stirt.) D. J. Galloway	<i>P. ravenelii</i> (Tuck.) R. C. Harris
<i>P. pseudonitidella</i> (C.Knight) D. J. Galloway	<i>P. dermatodes</i> (Borrer) Schaer.
<i>P. pyrenastroides</i> (C.Knight) D. J. Galloway	<i>P. ravenelii</i> (Tuck.) R. C. Harris
<i>Anthracotheicum cellulolum</i> (C.Knight) Müll.Arg.	<i>P. thelomorpha</i> Tuck.

are either apparently new and require a formal description or are additions to the New Zealand lichenized mycobiota e.g. *Pertusaria endoxantha* Vain (Marshall and Blanchon 2017). As part of our analysis for a major paper detailing our findings, we intend to publish on these new discoveries. In this paper we formally add and provide descriptions for five species of *Pyrenula* discovered in our sampling that have previously not been recorded from the New Zealand lichenized mycobiota (Galloway 2007; de Lange et al. 2018).

As a genus, *Pyrenula* is not well-known in New Zealand (Galloway 2007) as was last studied comprehensively by Charles Knight in 1860 (Knight 1860). A number of species were named in the nineteenth century from New Zealand material (mainly by Knight 1860; Galloway 1985), only to be later placed into synonymy with other more widespread species (Aptroot 2012; de Lange et al. 2018). Galloway (1985; 1992) reported ten species for New Zealand but cautioned that this was just a list of names available in the literature based on type specimens. Galloway (2007) later recorded 12 species and de Lange et al. (2012) recognised 14 species. The publication of a worldwide revision and key by Aptroot (2012) resulted in the recognition of 10 species for New Zealand by de Lange et al. (2018) (see Table 1 for a comparison of the taxonomic changes between Galloway (2007) and de Lange et al. (2018)) as a result of more recently recognised synonymies. This paper reports the presence of an additional five species new to New Zealand, all collected from the Auckland Region.

As these additions and taxonomic changes render the key in Galloway (2007) out of date, we here provide an updated key to the New Zealand species here.

Materials and methods

Specimens were examined with standard microscopic techniques. The chemical constituents were studied using thin-layer chromatography (Culberson 1972; White and James 1985) using solvent C. Voucher specimens were deposited in the herbarium at Unitec Institute of Technology (UNITEC).

Conservation status assessments are proposed using the New Zealand Threat Classification System manual (Townsend et al. 2008). The suggested conservation statuses remain provisional until they have been formally ratified by the New Zealand Lichen Threat Listing panel (see de Lange et al. 2018).

Descriptions and notes of five new records of *Pyrenula* for New Zealand

Pyrenula leucostoma Ach., Syn. Meth. Lich. 124. 1814.

Lectotype (*vide* Lendemer and Harris 2016): “Habitat in India Occidentalis super corticem Crotonis Cascarillae.” H, Ach. 837 (*n.v.*)

≡ *Verrucaria leucostoma* (Ach.) Mont., Ann. Sci. Nat., Bot., sér. 2 19: 60. 1843.

≡ *Anthracothecium leucostomum* (Ach.) Malme, Ark. Bot. 22A(11): 32. 1929.

Description **Figure 2A–C**: Corticolous. Thallus grey-brown, brown to olive green, corticate, pseudocyphellate or not, UV-. Ascomata black, initially immersed, subglobose, 0.5–1.5 mm diameter, ostioles apical, crystals abundant in wall, hymenium not interspersed with oil droplets, hymenial gel IKI + pale orange. Ascospores eight per ascus, mostly biseri-ate, colourless to pale brown (darker brown if over-mature), muriform with 5–8 rows of up to c.3 locules; locules large, often angular, $27.5\text{--}52.5 \times 12.5\text{--}15.0\ \mu\text{m}$.

Chemistry: No substances detected

Specimens seen: NEW ZEALAND, NORTH ISLAND. AUCKLAND: Omaha Bay, Takatu Peninsula, Tawharanui Regional Park, A. J. Marshall 43B5, P. J. de Lange & D. J. Blanchon, 20 Apr 2018 (UNITEC 10882); Cowan Bay Road, McElroy Scenic Reserve, A. J. Marshall 45X & S. Graham, 30 May 2018 (UNITEC 10851); Cowan Bay Road, McElroy Scenic Reserve, A. J. Marshall 45BE & S. Graham, 30 May 2018 (UNITEC 10851); Waitakere Ranges, Cascades, A. J. Marshall 14CB. & N. Leddy, 23 Jul 2015 (UNITEC 10587).

Distribution and Ecology: *Pyrenula leucostoma*, a pantropical species (Aptroot 2012) is so far known from two locations in New Zealand (**Figure 1**); a secondary forest in the Waitakere Ranges on kahikatea (*Dacrycarpus dacrydioides*), and from McElroy Scenic

Figure 2. *Pyrenula leucostoma*. **A**, *P. leucostoma* thallus of the pseudocyphellate race, showing numerous minute ‘fleck-like’ pseudocyphellae and semi-immersed perithecia. Scale bar = 2 mm; **B**, *P. leucostoma* thallus of the non-pseudocyphellate race. Scale bar = 2 mm; **C**, Ascospores. Scale bar = 25 μm .

Reserve on kauri (*Agathis australis*) and rewarewa (*Knightia excelsa*). The specimen growing on kahikatea was pseudocyphellate, whereas the other two were not.

Recognition: *Pyrenula leucostoma* differs from the other muriform spored taxa recorded from New Zealand that have similar sized ascospores by having fewer and, larger locules (Figure 2C). Non pseudocyphellate (Figure 2B) and smaller spored specimens of *Pyrenula leucostoma* could be confused with *P. thelomorpha*. These specimens can be distinguished from *P. thelomorpha* by the lumina of the ascospores which are large, angular and up to six in number between two primary septae (Figure 2C), whereas those of *P. thelomorpha* are mostly round with more than six between two primary septae.

Conservation Status: As this species is only known from three specimens collected from two locations in New Zealand, and there is no available information on population size and trends, we provisionally assess *Pyrenula leucostoma* as ‘Data Deficient’ *sensu* Townsend et al. (2008).

Pyrenula microcarpa Müll.Arg. Bot. Jahrb. Syst. 6: 412 (1885)

Holotype (fide Aptroot 2009): Cuba, C. Wright, *Lich. Cub.* 80; G (n.v.)

= *Pyrenula melaleuca* Müll.Arg., Nuovo Giorn. Bot. Ital. 23: 403 (1891).

Holotype (fide Aptroot 2009): Brisbane, Queensland, F. M. Bailey 519 (n.v.), *isotypes* G, BRI (n.v.)

= *Pyrenula microcarpoides* Müll.Arg., Rep. Australas. Assoc. Advancem. Sci. 1895: 457 (1895). *Holotype* (fide Aptroot 2009): Mount Perry, Qld, J. Shirley 1872G (n.v.); *isotype* BRI.

= *Pyrenula conspurcata* Müll.Arg., Bull. Herb. Boissier 3: 326 (1895). *Holotype* (fide Aptroot 2009): N.S.W., C. Knight 16 p.p.; G.

= *Pyrenula cinerea* Zahlbr., Ann. Cryptog. Exot. 5: 202 (1932). *Holotype* (fide Aptroot 2009): Knysna, Cape Province, South Africa, Jan. 1932, P. A. van der Byl 867; *isotype* LD,

Figure 3. *Pyrenula microcarpa*. **A**, *P. microcarpa* thallus showing the distinctive semi-immersed perithecia. Scale bar = 1 mm; **B**, *P. microcarpa* 3-septate ascospore. Scale bar = 20 µm. Plate 3.

Description (Figure 3A–B): Corticolous. Thallus white to greyish, lacking pseudocyphellae, not corticate, rough. UV-. Ascomata black, usually solitary, subglobose, erumpent from the substratum, the sides often partly covered by the thallus, c. 0.3–0.4 mm in diameter. Ascomatal wall lacking crystals, to 100 µm thick; ostiole apical, pale or black. Hamathecium not inspersed with oil droplets, IKI-. Ascospores eight per ascus, irregularly biseriate, 3-septate, fusiform, with pointed ends, initially hyaline, greyish brown at maturity, $17.5\text{--}25.0 \times 7.0\text{--}10.0$ µm; lumina angular; terminal lumina separated from the exospore by an endospore layer.

Chemistry: No substances detected.

Specimens seen: NEW ZEALAND, NORTH ISLAND. AUCKLAND: Cowan Bay Road, McElroy Scenic Reserve, A. J. Marshall 45BS, D. Blanchon & P. J. de Lange, 15 Jun 2018 (UNITEC 10590); Waitakere Ranges, Lower Nihotupu Dam Rd, A. J. Marshall 13AD & M. Cook, 22 Jul 2015 (UNITEC 10591); Waitakere Ranges, Cascades, A. J. Marshall 14BG & N. Leddy, 23 Jul 2015 (UNITEC 10588).

Distribution and Ecology: A mainly pantropical species of open, coastal areas, but also in lowland to montane forest (Aptroot 2009). Outside New Zealand *Pyrenula microcarpa* is widespread in Australia where it has been reported from eastern Queensland and New South Wales, and in the South Pacific from Lord Howe and Norfolk Islands (Aptroot 2009).

Within the Auckland Region widespread, occurring at 20 of the 50 plots we studied between Tawharanui (-36.3721665 , 174.8502029) and the Hunua Ranges (-37.0759847 , 175.1898585). This species was noted from a range of vegetation associations including old growth coastal rainforest and urban bush fragments on 14 different phorophytes; for example, *Freycinetia banksii*, *Myrsine salicina*, *Prumnopitys ferruginea* and *Quintinia serrata*.

Recognition: *Pyrenula microcarpa* is recognised by its very pale, usually bright white thallus and small perithecia (usually less than 0.4 mm diameter) with apical ostioles (Figure 3A). Perithecia are usually partially immersed in the white thallus (occasionally not immersed at all) (Figure 3A). Ascospores (Figure 3B) are eight per ascus, uni or biseriate, 3-septate, $17.5\text{--}22.5 \times 10.0$ µm. Its 3-septate fusiform ascospores are very similar to other species of *Pyrenula* present in New Zealand, but it is easily differentiated by its thallus morphology (see above). New Zealand material may have previously been misidentified as *Pyrenula pseudonitidella* by (Galloway 2007).

Conservation status: *Pyrenula microcarpa* has been collected from multiple sites across the Auckland region and, based on these occurrences and the wide range of phorophyte preferences, it is likely to be widespread throughout northern New Zealand. While there is no available information on population trends, within the Auckland Region the species seems to be secure and so we provisionally assess it as ‘Not Threatened’ *sensu* Townsend et al. (2008).

Pyrenula pyrenuloides (Mont.) R. C. Harris, Memoirs of the New York Botanical Garden 49: 99 (1989). *Holotype* (*vide* Aptroot 2009) French Guiana, J. P. F. C. Montagne. PC.

Figure 4. *Pyrenula pyrenuloides*. **A**, *P. pyrenuloides* thallus showing numerous minute 'fleck-like' pseudocyphellae, note the ascomata which are partially covered by the thallus. Scale bar = 2 mm; **B**, muriform ascospore of *Pyrenula pyrenuloides*. Scale bar = 25 μ m.

Description (Figure 4A–B): Corticolous. Thallus brownish to pale olive-green, with pseudocyphellae, corticate. UV-. Ascomata solitary, black, subglobose, erumpent from the substratum, the sides often partly covered by the thallus, c. 0.5–1.3 mm in diameter. Ascomatal wall with crystals, to 200 μ m thick; ostiole apical, pale. Hamathecium not interspersed with oil droplets, IKI+ orange. Ascospores 8 per ascus, uniseriate to irregularly biseriate, muriform, with c. 8–10 rows of c. 3–8 locules, fusiform, with rounded ends, grey to brown, 37.5–65.0 $\times$ 15.0–25.0 μ m; lumina rounded to somewhat angular.

Chemistry: No substances detected.

Specimens seen: NEW ZEALAND, NORTH ISLAND. AUCKLAND: Waitakere Ranges, Scenic Drive, Pukematekeo, A. J. Marshall 12BK & S. Graham, 13 Jul 2015 (UNITEC 10582); St Heliers, Dingle Dell Reserve, A. J. Marshall 32AD & J. Anderson, 13 Sep 2016 (UNITEC 10586).

Distribution and Ecology: In Australia, this species is widespread in eastern Queensland and New South Wales, and in the South Pacific reported from Norfolk Island (Aptroot 2009). Aptroot (2009) considered this species to be pantropical and subtropical, and to inhabit open, coastal vegetation. This is not the case for the New Zealand localities. Within the Auckland Region, this species has been found growing at two sites at Dingle Dell (39 m a.s.l.) in regenerating/replanted mixed indigenous forest and at Pukematekeo (334 m a.s.l.), Waitakere Ranges within regenerating Podocarp forest. At these locations the phorophytes are *Pseudopanax crassifolius* and the hybrid *P. crassifolius* $\times$ *P. lessonii*. The history of Dingle Dell is interesting. This location had been historically cleared of indigenous vegetation and then revegetated towards the end of the nineteenth century (Wilcox et al. 2013). Despite this, the lichen mycobiota at Dingle Dell is particularly diverse (Wilcox et al. 2013; A. J. Marshall & D. J. Blanchon unpubl. data) which is unusual for

an area of forest that was once cleared, suggesting that perhaps small fragments of indigenous vegetation had persisted through the clearance.

Recognition: The species has a distinctly corticate, pseudocyphellate thallus with ascomata that are erumpent from, and often partly covered by the thallus (Figure 4A). *Pyrenula pyrenuloides* differs from *P. leucostoma* by having a greater number of locules in the central rows, and these locules are generally somewhat less angular (Figure 4B). Galloway (2007) only recognised two muriform-spored species of *Pyrenula* in the New Zealand flora (*P. pyrenastroides* and *P. prostrata*), both of which have now been synonymised with *P. ravenelii* (Aptroot 2012). *P. pyrenuloides* differs from *P. ravenelii* in that it has solitary ascomata (the ascomata of *P. ravenelii* are usually in groups of 2–4 with fused ostioles). *P. pyrenuloides* has pseudocyphellae, and *P. ravenelii* does not, or it may have minute ones (Aptroot 2009).

Conservation status: As this species is known from only two sites in New Zealand, and there is no available information on population size and trends, we provisionally assess it as ‘Data Deficient’ *sensu* Townsend et al. (2008).

Pyrenula subumbilicata (C. Knight) Aptroot, Australasian Lichenology 60: 39 (2007). *Holotype* (*fide* Aptroot 2007): Toowoomba, Queensland, Australia. C. H. Hartmann, G; isotype BRI.

Description (Figure 5A–B): Corticolous. Thallus yellowish to olive-green, lacking pseudocyphellae, corticate. UV–. Ascomata black, occasionally solitary, but usually in groups of 2–6 with fused ostioles, flask-shaped, immersed to erumpent from the substratum, usually partly covered by the thallus, c. 0.4–1.2 mm in diameter. Ascomatal wall without crystals, to 200 µm thick; ostiole lateral, pale. Hamathecium not interspersed with oil droplets, IKI–. Ascospores eight per ascus, uniseriate to irregularly biseriate, submuriform, with c. 5–6 transverse septa, the end locules simple, only a few medial locules

Figure 5. *Pyrenula subumbilicata*. **A**, *P. subumbilicata* thallus, in this species the pyrenocarps are sometimes fused and have lateral ostioles. Scale bar = 2 mm; **B**, submuriform ascospore of *Pyrenula subumbilicata*. Scale bar = 20 µm.

longitudinally septate, fusiform, with pointed ends, grey to brown, $27.5\text{--}32.5 \times 10.0\text{--}12.5 \mu\text{m}$; lumina angular.

Chemistry: No substances detected.

Specimens seen: NEW ZEALAND, NORTH ISLAND. AUCKLAND: North Shore, Okura Bush, A. J. Marshall 42BA, D. Blanchon, T. J. P. de Lange & P. J. de Lange, 16 Apr 2018 (UNITEC 10579); North Shore, Okura Bush, A. J. Marshall 42BS, D. Blanchon, T. J. P. de Lange & P. J. de Lange, 16 Apr 2018 (UNITEC 10578); Waitakere Ranges, Lower Huia Reservoir, A. J. Marshall 5Q & H. Le Gros, 13 Jul 2014 (UNITEC 10577).

Distribution and Ecology: *Pyrenula subumbilicata* has been found at two of our study sites and on three different phorophytes, *Knightia excelsa*, *Myrsine australis* and *Pseudopanax crassifolius*. Both locations, near Lower Huia Reservoir, Waitakere Ranges and Okura Bush are regenerating coastal forest.

Prior to these discoveries, this species had been treated as endemic to lowland rainforest in eastern Queensland, Australia (Aptroot 2009).

Recognition: *Pyrenula subumbilicata* differs from the other submuriform-spored taxon found in New Zealand, *P. subvariolosa*, by having ascomata that are often fused in groups and have lateral ostioles (Figure 5A), and ascospores (Figure 5B) that are of smaller size ($27.5\text{--}32.5 \mu\text{m} \times 10.0\text{--}12.5 \mu\text{m}$ versus $32.5\text{--}47.5 \mu\text{m} \times 15.0\text{--}19.0 \mu\text{m}$).

Conservation status: As this species is known from only two sites in New Zealand, and there is no available information on population size and trends, we provisionally assess it as 'Data Deficient' *sensu* Townsend et al. (2008).

Pyrenula subvariolosa (C. Knight) Aptroot, Australasian Lichenology 60: 40 (2007)

Holotype (fide Aptroot 2009) Queensland, J. Shirley s.n.; WELT; isotype: BRI.

Figure 6. *Pyrenula subvariolosa*. **A**, *P. subvariolosa* thallus, in this species the ascomata are partially covered by the thallus. Scale bar = 2 mm; **B**, submuriform ascospores of *P. subvariolosa*. Scale = 40 μm .

Description (Figure 6A–B): Corticolous. Thallus yellowish to olive-green, lacking pseudocyphellae, corticate. UV-. Ascomata solitary, black, subglobose, immersed to erumpent from the substratum, usually partly covered by the thallus, c. 0.4–1.4 mm in diameter. Ascomatal wall without crystals, to 200 µm thick; ostiole apical, pale. Hamathecium not interspersed with oil droplets, IKI-. Ascospores eight per ascus, irregularly biseriate, submuriform, with c. 5–7 transverse septa, the end locules simple, with only a few medial locules longitudinally septate, fusiform, with pointed ends, grey to brown, $32.5\text{--}47.5 \times 15.0\text{--}1.09$ µm; lumina angular.

Chemistry: No substances detected.

Specimens seen: NEW ZEALAND, NORTH ISLAND. AUCKLAND: North Shore, Smith's Bush, A. J. Marshall 30CB & J. Anderson, 1 Sep 2016 (UNITEC 10584); Dingle Dell Reserve, A. J. Marshall 32CO & J. Anderson, 13 Sep 2016 (UNITEC 10585); Waitakere Ranges, Anawhata Road, A. J. Marshall 18L & J. Taylor, 17 Oct 2015 (UNITEC10583); Waitakere Ranges, Scenic Drive, Pukematekeo, A. J. Marshall s.n. & S. Graham, 13 Aug 2015 (UNITEC 10581).

Distribution and Ecology: Found at four locations in the Auckland region, including Dingle Dell, two plots in the Waitakere Ranges and Smith's Bush, a mature native forest fragment on Auckland's North Shore. *Pyrenula subvariolosa* was found on two substrates, *Myrsine australis*, and *Pseudopanax crassifolius*, alongside other lichen species such as *Graphis anfractuosa*, *Thelotrema lepadinum* and *Chiodecton colensoi*. *Pseudopanax crassifolius* and *Myrsine australis* are two of the most common hosts of *Pyrenula* in the region along with *Rhopalostylis sapida*, and in the light of this study should probably be more closely examined in future. Aptroot (2009) recorded this species as endemic and locally abundant in Australian rainforests in eastern Queensland, New South Wales and Tasmania.

Recognition: *Pyrenula subvariolosa* differs from other species of *Pyrenula* in New Zealand by the possession of solitary ascomata (Figure 6A), submuriform ascospores (Figure 6B), usually with 5–7 transverse septae and 1 longitudinal septum, $32.5\text{--}45.0 \times 10.0\text{--}16.5$ µm in size.

Conservation status: *Pyrenula subvariolosa* is known from only four sites in the study area. As there is no available information on population size and trends, we provisionally assess it as 'Data Deficient' *sensu* Townsend et al. (2008).

Discussion

Knowledge of the New Zealand lichen mycobiota has grown significantly in the last 60 years, with 700 more species recognised since 1960 (Sipman and Aptroot 2001; de Lange et al. 2018), but until relatively recently, most taxonomic treatments have focused on macrolichens (Sipman and Aptroot 2001; Galloway 2007). Sipman and Aptroot (2001) predicted that further gains in lichen diversity from the Southern

Hemisphere would be most likely made from studies of crustose lichens. Indeed, where systematic sampling has occurred in New Zealand, novel diversity is usually found in more cryptic crustose lichen genera (e.g. Er et al. 2015; Marshall and Blanchon 2017). In this context, the discovery of five new records of *Pyrenula* species in Auckland forested sites is unsurprising. As already noted, *Pyrenula* is not well-known in New Zealand (Galloway 2007), the genus is under-collected, and specimens in New Zealand herbaria are often incorrectly named or simply labelled with the generic name. Our sampling of the lichens from 50 permanent vegetation plots demonstrates this point because, as part of our sampling protocol we collected all lichens, in the process recording, including the five new records reported in this paper, 11 *Pyrenula* species.

Necessarily this paper has only looked at *Pyrenula* specimens collected from the Auckland region (Figure 1). Although this is only a small subset of the total area of New Zealand (1.86% of the total land area of New Zealand (StatsNZ 2019)) we found with the exclusion of the additional five *Pyrenula* species reported here, six species previously accepted for the New Zealand lichenized mycobiota (de Lange et al. 2018). This is still 60% of the total number of *Pyrenula* species reported from New Zealand (de Lange et al. 2018) prior to the discoveries documented here. It would be interesting therefore to study the genus more comprehensively in a national context. Considering both the diversity of *Pyrenula* worldwide (c. 745 taxa (Aptroot 2012)) and the scope of our study being restricted to just the Auckland region, we believe that further new records of *Pyrenula* from New Zealand are inevitable.

Key to *Pyrenula* spp. in New Zealand

- 1 Spores transversely septate 2.
Spores muriform 10.
- 2 Spores filiform c.50 × 5 µm *P. filiformis*
Spores fusiform 3.
- 3 Spores 7-septate *P. moniliformis*
Spores 3–5 septate 4.
- 4 Thallus with pseudocyphellae 5.
Thallus lacking pseudocyphellae 8.
- 5 Spores 5-septate *P. sexlocularis*
Spores 3-septate 6.
- 6 Spores mostly < 25 µm, 17–20(–24) × 7–10 µm *P. deliquescens*
Spores mostly > 25 µm 20–38 × 8–15 µm 7.
- 7 Locules diamond shaped..... *P. chlorospila*
Locules rounded or quadrangular..... *P. quassiaecola*
- 8 Thallus UV+ yellow..... *P. dermatodes*
Thallus UV- 9.
- 9 Thallus white, ascomata solitary c 0.3–0.4mm..... *P. microcarpa*
Thallus brownish to olive green, ascomata c.0.3–0.5mm..... *P. nitidula*
- 10 Ostioles mainly lateral..... 11.
Ostioles mainly apical..... 12.
- 11 Spores muriform, c. 8–10 rows of 3–8 locules, 45–70 × 18–28 µm..... *P. ravenelii*

- Spores submuriform, c. 5 transverse septae, spores $24\text{--}32 \times 10\text{--}13 \mu\text{m}$
 P. subumbilicata
- 12 Thallus with pseudocyphellae 13.
 Thallus without pseudocyphellae 14.
- 13 Lumina large and angular, up to 6 between two primary septae, $27.5\text{--}52.5 \times 12.5\text{--}16.0 \mu\text{m}$ *P. leucostoma*
 Lumina mostly round, more than 6 between two primary septae, $37.5\text{--}65.0 \times 15.0\text{--}25.0 \mu\text{m}$ *P. pyrenuloides*
- 14 Ascomata small (0.05–0.7mm), spores with small rounded locules...*P. thelomorpha*
 Ascomata large (0.4–1.5mm), spores with large angular locules..... 15.
- 15 Spores muriform, up to 6 locules between two primary septae, $27.5\text{--}52.5 \times 12.5\text{--}16.0 \mu\text{m}$*P. leucostoma*
 Spores submuriform, 5 - 7 transverse septae, $34\text{--}72 \times 15\text{--}33 \mu\text{m}$ *P. subvariolosa*

Acknowledgements

We thank all the volunteers who gave their time to assisting in the field and lab work for this project, including Christy Reynolds, Craig Perkins, Daniel Bennett, James Anderson, Jim Taylor, Matthew Cook, Michael Watson, Nadine Leddy, Nic Fletcher, Orhan Er, Sharen Graham, Theo de Lange, Tom Greer, and not least the senior author's partner Heloise Le Gros who not only assisted with fieldwork in the earlier stages of the project, but also tolerated her living room being regularly occupied with drying lichen specimens. We are extremely grateful to Te Kawerau a Maki and Auckland Council for permits. We thank Chris Lusk, Jack Elix and Jeremy Rolfe for their comments on a draft of this paper, and Allison Knight for her thoughtful review of the submitted version.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

We are extremely grateful to the Australia and Pacific Science Foundation (APSF) for funding Unitec (Project APSF15/6).

ORCID

Peter J. de Lange <http://orcid.org/0000-0001-6699-7083>

References

- Aptroot A. 2007. New species, combinations, lectotypifications and synonyms in Australia Pyrenulaceae. *Australasian Lichenology*. 60:34–41.
- Aptroot A. 2009. Pyrenulaceae. *Flora of Australia*. 57:449–480.
- Aptroot A. 2012. A world key to the species of *Anthracothecium* and *Pyrenula*. *The Lichenologist*. 44:5–53.
- Culberson CF. 1972. Improved conditions and new data for identification of lichen products by standardized thin-layer chromatographic method. *Journal of Chromatography A*. 72:113–125.

- de Lange P, Blanchon D, Knight A, Elix J, Lücking R, Frogley K, Harris A, Cooper J, Rolfe J. 2018. Conservation status of New Zealand indigenous lichens and lichenicolous fungi, 2018. New Zealand Threat Classification Series 27. Department of Conservation, Wellington. p. 64.
- de Lange PJ, Galloway DJ, Blanchon DJ, Knight A, Rolfe JR, Crowcroft GM, Hitchmough R. 2012. Conservation status of New Zealand lichens. New Zealand Journal of Botany. 50:303–363. Department of Conservation. 2017. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots, Version 11. Department of Conservation, Wellington
- Er OAH, Reynolds CL, Blanchon DJ. 2015. Additional lichen records from New Zealand 49. *Pertusaria puffinia* AW.Archer et Elix. Australasian Lichenology. 77:28–31.
- Galloway DJ. 1985. Flora of New Zealand lichens. Wellington: Government Printer. p. 662.
- Galloway DJ. 1992. Checklist of New Zealand lichens. DSIR Land Resources scientific report, no. 26. p. 1–58.
- Galloway DJ. 2007. Flora of New Zealand lichens. Revised 2nd ed. Lincoln: Manaaki Whenua Press. p. 1006.
- Khin J. 2013. Environmental monitoring methodology for regional status and trends – terrestrial biodiversity program – forest – version 4. Auckland: Auckland Council. p. 110.
- Knight C. 1860. On some New Zealand Verrucariae. Transactions of the Linnean Society of London. 23:99–100.
- Lendemer J, Harris R. 2016. Studies in lichens and lichenicolous fungi – no. 20: further notes on species from the eastern North America. Opuscula Philolichenum. 15:105–131.
- Marshall AJ, Blanchon DJ. 2017. Additional lichen records from New Zealand 50. Australasian Lichenology. 80:58–61.
- Porada P, Weber B, Elbert W, Pöschl U, Kleidon A. 2013. Estimating global carbon uptake by lichens and bryophytes with a process-based model. Biogeosciences. 10:6989–7033.
- Ranft H, Moncada B, de Lange PJ, Lumbsch HT, Lücking R. 2018. The *Sticta filix* morphodeme (Ascomycota: Lobariaceae) in New Zealand with the newly recognized species *S. dendroides* and *S. menziesii*: indicators of forest health in a threatened island biota? The Lichenologist. 50:185–210.
- Reynolds CL, Er OAH, Winder L, Blanchon DJ. 2017. Distribution and community composition of lichens on mature mangroves (*Avicennia marina* subsp. *australasica* (Walp.) J.Everett) in New Zealand. PLoS ONE. 12:e0180525.
- Rose F. 1974. The epiphytes of oak. In: Morris MG, Perring FH, editors. The British Oak: Its History and Natural history. Oxfordshire: Clarendon; p. 250–273.
- Rose F. 1976. Lichenological indicators of age and ecological continuity in Woodlands. In: Brown DH, Hawksworth DL, Bailey RH, editors. Lichenology: progress and problems. London: Academic Press; p. 279–307.
- Rose F. 1992. Temperate forest management: its effects on bryophyte and lichen floras and habitats. In: Bates JW, Farmer AM, editors. Bryophytes and lichens in a changing environment. Oxford: Oxford Scientific; p. 211–233.
- Ryan P. 2002. Overview of non-vascular plants, lichens, fungi and algae in the Goulburn broken catchment: their status, threats and management. Ecolines Environmental Services, Canberra; [accessed 2019 July 17]. www.gbcma.vic.gov.au/downloads/BISforGBC/3_Non-vascularPlants.pdf.
- Scott GAM, Entwistle TJ, May TW, Stevens GN. 1997. A conservation overview of Australian non-marine lichens, bryophytes, algae and fungi. Canberra: Environment Australia. p. 121.
- Selva SB. 1994. Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western New Brunswick. The Bryologist. 97:424–429.
- Selva SB. 1996. Using lichens to assess ecological continuity in northeastern forests. In: Byrd M. editor. Eastern old-growth forests: prospects for rediscovery and recovery Island Press, Washington, DC; p. 35–48.
- Sipman H, Aptroot A. 2001. Where are the missing lichens? Mycological Research. 105:1433–1439.
- Statistics New Zealand. 2019. Regional Council 2019 (generalised). [accessed 2019 Jul 22]. <https://datafinder.stats.govt.nz/>.

- Townsend A, de Lange P, Duffy C, Miskelly C, Molloy J, Norton D. [2008](#). New Zealand threat classification system manual. Wellington. 35 p.
- White FJ, James PW. [1985](#). A new guide to microchemical techniques for the identification of lichen substances. British Lichen Society Bulletin. 57(suppl.):1–40.
- Wilcox M, Cameron E, Braggins J, Beever J, Blanchon D, Kooperberg R, Shirley C. [2013](#). Flora of Dingle Dell, St Heliers. Auckland Botanical Society Journal. 68:118–132.
- Zedda L. [2002](#). The epiphytic lichens on *Quercus* in Sardinia (Italy) and their value as ecological indicators. Englera. 24:1–468.