

A new corticolous species of Rinodina (Physciaceae) and two interesting range extensions for species collected from Katmai National Park, Alaska

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1 **A new corticolous species of *Rinodina* (Physciaceae) and two interesting range extensions**
2 **for species collected from Katmai National Park, Alaska.**

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10

11 **ABSTRACT.** *Rinodina pallidescens* is described as a new species, endemic to southern Alaska.
12 *Rinodina buckii* and *R. oregana* are discussed in terms of their range extensions and possible
13 phytogeographic histories.

14

15 **KEYWORDS.** Lichen systematics, species dispersal, phytogeography, Tertiary, glacial refugia

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19 The genus *Rinodina* (Ach.) Gray is relatively well known amongst the crustaceous lichens.
20 Mayrhofer & Poelt (1979), Mayrhofer (1984) and Kaschik (2006) provide monographic accounts
21 of saxicolous species for Europe, the world and the Southern Hemisphere, respectively. Giralt
22 (2001), Mayrhofer & Moberg (2002) and Sheard (2010) provide other regional studies which
23 include corticolous species for the Iberian Peninsula, Scandinavia and North America. New
24 species and new records of *Rinodina* continue to be added to the North American flora (Sheard
25 2011, Sheard et al. 2011, Lendemer et al. 2012, Sheard et al. 2012). Another new species to
26 science is added here. The total number of *Rinodina* species now known from North America is
27 106.

28 This new *Rinodina* species, and two other species with remarkable range extensions,
29 came to our attention from collections made in Katmai National Park in southwestern Alaska.
30 This park is located at the eastern end of the Aleutian Range, in the base of the Alaska Peninsula.
31 The area lies near the edge of the forested zone, approaching the southwestern Alaskan treeline
32 as the climate transitions to summers too cool to support coniferous trees. Proceeding farther
33 west on the Alaska Peninsula trees disappear altogether. The species in Katmai National Park
34 have ranges with arctic, boreal, and oceanic affinities. This paper provides the first results from a
35 new lichenological study of the Park, begun in 2013.

36

37 **METHODS**

38 Surface observations of specimens were made using a Wild M5 stereomicroscope. Thallus
39 measurements were taken at 25× magnification and rounded to the nearest 0.05 mm. Internal
40 ascomatal measurements were made on vertical sections (ca. 25 µm thick), cut with a Leitz

41 freezing microtome, at 50× magnification to an accuracy of 5 µm using a Wild M20 compound
42 microscope. Ascospores from the freshly collected material were cleared of internal oil globules
43 to reveal lumina structure by gently heating slide preparations over a methylated spirits burner.
44 Ascospore measurements were taken at 500× magnification using a Wild vernier micrometer
45 (scale of 0.1 µm) to an accuracy of 0.5 µm. They are quoted as the range between the 25th and
46 75th percentiles with the outlying 5th and 95th percentiles indicated in brackets. Other procedures
47 were according to Sheard (2011). Thin-layer chromatography was carried out according to the
48 methods of Culberson & Kristinsson (1970) and Culberson (1972) with later modifications.

49

50 TAXONOMY

51 *Rinodina buckii* Sheard

52 *Rinodina buckii* was recently described from eastern North America, Japan, Korea and
53 the Russian Far East (Sheard et al. 2012). Its discovery in Katmai National Park and Preserve
54 (KATM) is therefore of considerable phytogeographic interest. It is a sorediate species with
55 soralia arising from verrucae forming centrally on its areoles. *Rinodina buckii* is superficially
56 similar to *R. willeyi* Sheard and Giralt but is distinguished by ascospore type when fertile and by
57 the position of its soralia which first form on the areole margins in the latter species. Of the
58 specimens cited below one, *TT42695*, was fertile.

59 **Specimens examined.** U.S.A. Alaska. Lake and Peninsula Borough, Katmai National
60 Park, at Naknek Lake, Brooks Camp, 58°33.43'N 155°46.69'W, alt. 10–12 m, corticolous on
61 *Alnus crispa* bordering lakeshore, 25 July 2013, *T. Tønsberg* 42571 (BG, ALA); 58°33.50'N
62 155°46.69'W, alt. 10–20 m, corticolous on *Salix*, 26 July 2013, *T. Tønsberg* 42695 (BG).

63

64 ***Rinodina oregana* H. Magn.****Figure 1**

65 This species is characterized, above all, by its very large *Dirinaria*-type spores which
 66 possess the most obvious Type B spore development encountered in any species possessing this
 67 spore type (Sheard 2010). The species is previously known from Oregon to California and inland
 68 to Idaho and Montana (Sheard 2010), and the Kenai Peninsula, Alaska (McCune & Rosentreter
 69 2014). The Katmai location extends the known range westward to near the southwestern treeline
 70 of Alaska (Figure 1). Both known Alaskan populations are in typical habitat for this species,
 71 consisting of *Populus* – conifer riparian forest at low elevations. In both cases, the species
 72 cohabits *Populus* trunks with cyanolichens such as *Lobaria pulmonaria*, *Leptogium saturninum*,
 73 and *Collema furfuraceum*.

74 **Specimens examined.** U.S.A. Alaska. Lake and Peninsula Co., Katmai National Park, near
 75 shore of Naknek Lake, north of Brooks Camp, 58°33.75'N 155°46.51'W *Populus* with
 76 occasional *Salix*, on *Populus balsamifera*, 26 July 2013, B. McCune 32889 (OSC). Kenai
 77 Peninsula Co., Primrose Creek near its mouth at Kenai Lake, Aug. 2010, B. McCune 30714
 78 (OSC).

79

80 ***Rinodina pallidescens* Sheard & Tønsberg species nova****Figures 1, 2**

81 MYCOBANK MB xxxxxxxx

82 *Similar to Rinodina septentrionalis but ascospores frequently asynchronous in development and*
 83 *often only four in mature asci. The Physcia-type ascospores are also slightly larger and*
 84 *consistently more broadly ellipsoid and with more inflated, less angular lumina.*

85 TYPE. U.S.A. Alaska. Lake and Peninsula Co., Katmai National Park, near shore of Naknek
86 Lake, north of Brooks Camp, 58.55748°N 155.77822°W, *Betula-Picea* forest, on
87 *Populus* bark, 26 July, 2013, B. McCune 32760A (holotype – ALA, isotype OSC).

88 **Description.** *Thallus* typically very thin, pallid grey, rarely brownish; areoles scattered,
89 convex and isolated at first, becoming contiguous, mature areoles to 0.20–0.30 mm wide; surface
90 plane, rarely slightly convex, often with necrotic areas, then somewhat scabrid, matt; margin
91 indeterminate; vegetative propagules lacking; prothallus not seen. *Apothecia* broadly attached at
92 first, becoming more narrowly attached, to 0.40–0.70 mm in diam.; discs brown to dark brown
93 or black, plane becoming slightly convex in oldest apothecia; thalline margin concolourous with
94 thallus, 0.05–0.10 mm wide, entire, rarely crenulate, sometimes becoming partly excluded;
95 excipular ring present, confluent or absent. *Apothecial anatomy.* Thalline exciple ca. 50–70 µm
96 wide laterally; cortex ca. 10 µm wide; epinecral layer ca. 5 µm wide when present; crystals
97 absent in cortex and medulla; cortical cells to 4.0–5.5 µm wide, not pigmented; algal cells
98 typically to 10.0–14.5 µm long when not dividing; thalline exciple 50–80 µm wide below; cortex
99 often expanded to ca. 20 µm deep, cellular; proper exciple relatively undifferentiated from
100 hymenium, 5–15 µm wide, expanded to 15–30 µm wide at periphery; hypothecium hyaline,
101 40–45 µm deep; hymenium 70–90 µm high, not inspersed; paraphyses 2.0–2.5 µm wide, apices
102 to 4.0–5.0 µm wide, capitate, immersed in dispersed pigment forming an orange- to red-brown
103 epihymenium; asci ca. 55 × 16–18 µm. *Ascospores* 4 to 8/ascus (Figure 2 A-C, E-G), Type A
104 development, *Physcia*-type, (15.0–)17.0–19.5(–22.0) × (7.5–)8.0–9.0(–10.0) µm (n=150); l/w
105 ratio (1.8–)1.9–2.2(–2.4), often asynchronous in development (Figure 2 E, F), immature spores
106 often with narrow lumina canals; sometimes irregularly ellipsoid and/or slightly inflated at

107 septum, sometimes becoming slightly waisted; torus present becoming prominent; walls darkly
108 pigmented at maturity, sometimes lightly ornamented. *Pycnidia* not observed.

109 **Chemistry.** All spot tests negative; TLC based on two specimens (*Tønsberg 42572* and
110 *42919*) yielded ‘gracilenta unknown 1’ (of Tønsberg 1992) in one (*42572*) and no substances in
111 the other.

112 **Distribution and ecology.** As yet known only from southern Alaska, KATM and Glacier
113 Bay National Park (Figure 1). The vertical distribution in KATM ranged from 5–10 to 112 m.
114 The species has been found on trunks of *Alnus*, including *A. crispa*, *Populus balsamifera*,
115 branches of *Salix* shrubs, and once on a twig of *Picea glauca*. It occurred on lakeshores and in
116 forests and woodlands.

117 **Notes.** The distinguishing features of *Rinodina pallidescens* are the pale, very thin thallus
118 and the *Physcia*-type ascospores with a well developed and ultimately prominent torus. The
119 spores are often variable in size due to their frequent asynchronous development. When
120 asynchronous, typically four spores are mature and are measured, the remaining spores are
121 immature, smaller and left unmeasured. Asci with synchronous development have eight spores of
122 a similar but relatively smaller size. Therefore, spores of two sizes classes are often present
123 accounting for the size variation. *Fryday 10242*, a relatively luxuriant specimen with large
124 apothecia and areoles, had only 8-spored asci with spores of average size, possibly because of a
125 higher nutrient status due to an epiphytic cyanobacterium. The pallid thallus colour of *R.*
126 *pallidescens* is sometimes enhanced by the death of algal cells leaving those parts of the thallus
127 with an almost colorless and scabrid appearance.

128 The darkest and most mature spores with prominent tori immediately bring to mind
129 *Rinodina freyi* H. Magn., which now includes *R. glauca* Ropin (Sheard 2010), and *R.*

130 *septentrionalis* Malme. The spores of both these species, while overlapping in size, are smaller
131 on average than for *R. pallidescens*. The differences in spore size between *R. pallidescens* and *R.*
132 *septentrionalis* are confirmed by the type collection (*McCune 32760*) in which both species are
133 present (Table 1). The differences are small but mostly consistent, in favor of the larger size of *R.*
134 *pallidescens* and more narrowly ellipsoid shape of *R. septentrionalis*. The spores of *R.*
135 *pallidescens* often develop asynchronously in the ascus and only four may develop to maturity
136 (Figure 2E, F). Asynchrony has never been observed in *R. septentrionalis* and there are always
137 eight spores per ascus (Figure 2D). There are also subtle differences in spore structure, the spores
138 of *R. pallidescens* being somewhat irregularly shaped and the lumina more rounded than in *R.*
139 *septentrionalis* (Figure 2B and D, respectively).

140 Young (small) apothecia of *Rinodina pallidescens* and *R. septentrionalis* are also very
141 similar in being relatively narrowly attached, with plane discs and entire thalline margins.
142 However, they differ increasingly with age, the discs and margins of *R. pallidescens* eventually
143 becoming convex and sometimes coronate, respectively, while those of *R. septentrionalis* remain
144 plane and entire. Another possible difference between the two species, based on the limited
145 collections examined, is that *R. pallidescens* has smaller algal cells (10.0–14.5 μm) compared to
146 *R. septentrionalis* (15.0–18.0 μm). However, it must be noted that Sheard (2010) reported algal
147 cells as small as 10.0 μm for *R. septentrionalis*.

148 *Rinodina freyi* and *R. septentrionalis* usually have darker thalli than *R. pallidescens*, the
149 thalli of *R. freyi* varying from dark grey to copper brown, depending on exposure to sunlight, and
150 are typically thicker with contiguous areoles and apothecia. The thalli of *R. septentrionalis* are
151 usually a shade of brown, again often copper brown, typically comprised of small isolated
152 areoles which are convex, and frequent but scattered apothecia. Mayrhofer & Moberg (2002)

153 noted that thalli may be grey, as in the present collections, in contrast to the brown thalli quoted
 154 by Sheard (2010) from the northern continental interior of North America. This grey morph
 155 closely corresponds to *R. subfusca* H. Magn. (= *R. septentrionalis* Mayrhofer & Moberg 2002)
 156 which was incorrectly placed into synonymy with *R. laevigata* (Ach.) Malme by Sheard (2010).

157 Three other species with *Physcia*-type spores might possibly be confused with *Rinodina*
 158 *pallidescens*. *Rinodina laevigata* has similar sized spores with less prominent tori but is best
 159 characterized by the very large size of the lower apothecial cortex with intricate hyphae
 160 (Mayrhofer & Moberg 2002), although this character may not always be so well developed in
 161 North America (Sheard 2010). The fact that the occasional spore of *R. pallidescens* is swollen at
 162 the septum immediately brings to mind *R. ventricosa* Hinteregger & Giralt for which this is
 163 characteristic (Hinteregger 1994). This central European species is found on *Rhododendron* in
 164 the Alps. Its spores are also similar in size but they have a narrow torus and persistently very
 165 angular lumina. Finally, there is *R. plana* H. Magn. to be considered. This is a Mediterranean
 166 species with similar sized spores and a well developed torus. It differs from *R. pallidescens*, and
 167 all the above species, in its yellow-brown epihymenium, yellowish hypothecium, and spores
 168 constricted at the septum. The species is not well understood and may comprise an aggregate of
 169 related species (Giralt & Mayrhofer 1995).

170 *Rinodina pallidescens* will key out in Sheard (2010) to couplet 106. This couplet should
 171 be replaced as follows:

172 106 (104) Asci frequently only 4-spored, or 8-spored often with asynchronous development,
 173 spore lumina less angular than typical for the *Physcia*-type, mostly 17.0–19.5 × 8.0–9.0
 174 µm *R. pallidescens*

175 106 Asci always 8-spored, with synchronous development, spore lumina sharply angular at
 176 least during development, typical of the *Physcia*-type, spores smaller or larger than above
 177 106a

178 106a(106) Spores averaging $>18.0 \times 8.5 \mu\text{m}$ 107

179 106a Spores averaging $<18.0 \times 8.5 \mu\text{m}$ 112

180 then following on as before in Sheard (2010).

181 **Specimens examined.** Paratypes. U.S.A. Alaska. Lake and Peninsula Borough, Katmai
 182 National Park, Brooks Camp, at Naknek Lake, alt. 10–15 m, corticolous on trunk of dead *Alnus*
 183 in mixed *Picea/Betula nealaskana* forest near lakeshore, 25 July 2013, *T. Tønsberg* 42573 with
 184 *R. degeliana* (BG); corticolous on *Alnus crispa* bordering lakeshore, *T. Tønsberg* 42572 (BG);
 185 *Populus* with occasional *Salix*, on *Salix*, 26 July 2013, *B. McCune* 34119 (ALA). S of W end of
 186 Tony Malone Lake, 98 m, on dead *Salix* shrub, 31 July 2013, *T. Tønsberg* 42919 (BG); E bank
 187 of Headwaters Creek, alt. 112 m, on trunk of *Populus balsamifera*, *T. Tønsberg* 43008 (BG); at
 188 NE corner of Tony Malone Lake, alt. 83 m, on *Salix* sp. (shrub), 1 August 2013, *T. Tønsberg*
 189 43034 (ALA); 85 m, on twig of *Picea glauca*, 1 August 2013, *T. Tønsberg* 43052 (BG); Hoonah-
 190 Angoon District, Muir Point, Glacier Bay National Park, on alder, 5–10 m elevation, *A.M.*
 191 *Fryday* 10242 (MSC).

192

193 **DISCUSSION**

194 *Rinodina pallidescens* has a distribution, as far as yet known, limited to coastal central
 195 and southern Alaska (Figure 1). The two other *Rinodina* species included here, *R. buckii* and *R.*
 196 *oregana*, represent interesting outliers of species with wider distributions and their discovery in
 197 Alaska is of phytogeographic interest.

198 There has been a long history of interest in the disjunctive distribution of flowering
199 plants, at the genus level, between eastern Asia and eastern North America (Gray 1846, Wood
200 1969, Boufford & Spongberg 1983) which is now well documented (Wen 1999, Xiang *et al.*
201 2000, Qian 2002). A similar relationship has also been noted for bryophyte (Schofield 1965) and
202 lichen species (Yoshimura 1968, Culberson 1972, Sheard *et al.* 2008, Lendemer *et al.* 2012,
203 Sheard *et al.* 2012). East Asian - western North American disjunctions are less common (Xiang
204 *et al.* 1998, Kurokawa 2006) probably due to the late Tertiary and Quaternary orogenies in
205 western North America (Wen 1999). KATM is volcanically active and fits this general profile.

206 Disjunctions between eastern and western North American phanerogams at the genus
207 level are very common, except for Alaska (Wood 1969). Also lichen species with similar broad
208 distributions in eastern and western North America are frequent (Day 1976, Sheard 2010).
209 Lendemer *et al.* (2013) briefly discuss the distribution of oceanic lichen species common to the
210 Appalachians, north eastern and north western North America.

211 Sheard (1995) studied the distributions of seven vegetatively reproducing *Rinodina*
212 species between western and eastern North America and Europe, considering the disjunctions to
213 be refugia for species associated with a broad-leaved forest surrounding the Arctic Ocean in Late
214 Paleocene-Early Eocene times (LePage & Basinger 1991). To this list can now be added *R.*
215 *flavosoralifera* Tønsberg which occurs in the Alaskan panhandle, the British Isles, Norway,
216 France, and the Canary Islands (van den Boom *et al.* 1995, Mayrhofer and Moberg 2002, Giralt
217 *et al.* 2010, Sheard 2010). In addition, *R. griseosoralifera* Coppins is now known to extend north
218 into south central Alaska (Sheard 2010) and south into central Europe and northwestern Africa
219 (Mayrhofer & Moberg 2002, Tønsberg 2002). The presence of *R. buckii* on the south central
220 coast of Alaska fits well with the distribution of this group of species.

221 As previously mentioned, *Rinodina oregana* is a western North American endemic
222 species occurring in the Coastal Ranges, the Cascades and Sierra Nevada, with an outlying
223 population in the Washington, Idaho and Montana boundaries region (Sheard 2010).
224 Floristically, this last region has been referred to as the “maritime extension” of the Pacific
225 Ocean rainforest by McCune (1984). *Rinodina oregana* does not produce vegetative propagules
226 and with its very large spores (to 38.0 μm long), the species must be considered a poor candidate
227 for long-distance dispersal. Its spores are about twice as long as the common and widespread
228 southern and northern boreal species, *R. freyi* and *R. septentrionalis*, respectively. The discovery
229 of *R. oregana* in KATM, and also in the relatively close Kenai Peninsula (McCune &
230 Rosentreter 2014), was unexpected and requires explanation.

231 The northern limit of the main range of *Rinodina oregana* is close to the southern border
232 of Canada, approximating the southern edge of the ice sheet during the last glacial maximum
233 (LGM) in western North America. The limits of the ice sheets at the LGM have been mapped by
234 Dyke et al. (2002) and given in greater detail for western North America south of the
235 international border by Brunsfeld et al. (2007). The ice limit extended ca. 90 km south of the
236 border into Idaho. Molecular studies provide evidence for the existence of a refugium for
237 phanerogams ca. 180 km south of the ice limit in the ‘Greater Clearwater Refugium’ (Brunsfeld
238 and Sullivan 2005, Brunsfeld et al. 2007). Even if *R. oregana* survived the glaciation further
239 south than this refugium it is evident that it has not been as successful at dispersing northwards
240 into previously glaciated terrain across the international border as phanerogam species
241 (Brunsfeld et al. 2007, Godbout et al. 2008) and that the species has a poor dispersal ability. This
242 hypothesis is supported by the scarcity of records in the glaciated region of Idaho, despite the
243 abundance of apparently suitable habitat (cyanolichen-rich riparian forests). The presence of *R.*

244 *oregana* in southern Alaska may therefore reflect a Tertiary history in the region, and if so, that it
245 also survived the LGM there in a refugium.

246 Brubaker et al. (2005) have presented evidence for the survival of boreal trees and shrubs
247 in Beringia during the LGM and therefore the host trees of the corticolous species under
248 consideration. Beatty & Provan (2010) provide a map of putative refugia around the LGM ice
249 sheets and provide references for each including the coastal Pacific Northwest (Alexander
250 Archipelago and Haida Gwaii). The presence of unglaciated coastal terrain further north in south
251 central Alaska (Dyke et al. 2002), now mostly submerged, present other opportunities for
252 refugia, although the western Kodiak Island refugium (in the north of the island) allowed the
253 survival of only continental species (Karlstrom & Ball 1969). These authors also provide maps
254 of plant species reaching the south coast of Kodiak Island which are mostly endemic to southern
255 Alaska and provide evidence of a refugium somewhere in this region.

256 It is our opinion that the presence of *Rinodina buckii*, *R. oregana* and the endemic *R.*
257 *pallidescens* all provide further evidence of a southern Alaskan glacial refugium (or refugia) for
258 lichens. It is notable that Printzen et al. (2003) provide molecular evidence of refugia for
259 *Hypogymnia hultenii* (Degel.) Krog in both southern and south central Alaska.

260

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266

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383

384 FIGURE HEADINGS

385 Figure 1. Distribution of *Rinodina pallidescens*, solid dots (•), and *R. oregana*, crosses (+), in
386 southern Alaska.

387

388 Figure 2. Ascospores of *Rinodina pallidescens* A–C, E–G, and *R. septentrionalis* D. A–C

389 *McCune 32760A*, *R. pallidescens*. A. 4-spored ascus with immature spores. B. 8-spored ascus
390 with mature spores. C. 4-spored ascus with mature spores. D. *McCune 32760B*, *R.*

391 *septentrionalis*, mature ascus from same collection for comparison. E. *Rinodina pallidescens*,

392 *McCune 34119* asynchronous spore development, upper ascus with 5 immature spores, one large
393 spore and four smaller spores from first division, two smaller and two relatively larger spores

394 derived from second and third divisions; lower ascus relatively mature with seven spores, the

395 division sequence not possible to determine. F, G *Walton 185462*, *Rinodina pallidescens*, F. 8-

396 spored ascus with asynchronous spore development, division sequence indicated by size and

397 pigmentation of spores. G. 8-spored ascus with mature, darkly pigmented walls and prominent

398 tori. All scales = 10 microns.

399