Phytotaxa 712 (3): 207–229
https://www.mapress.com/pt/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

https://doi.org/10.11646/phytotaxa.712.3.1

The Thin Horizon of a Plan is Almost Clear: Towards a Lichen Biodiversity Inventory of the Southern Rocky Mountains, USA

ERIN A. MANZITTO-TRIPP[1,2,3*] & JACOB L. WATTS[1,4]
[1]*Department of Ecology & Evolutionary Biology, University of Colorado, Boulder, Colorado 80309, USA*
[2]*Museum of Natural History, Botany Department (COLO Herbarium), University of Colorado, Boulder, Colorado 80309, USA*
[3] *erin.manzittotripp@colorado.edu; https://orcid.org/0000-0001-9340-8723*
[4] *Jacob.Watts-1@colorado.edu; https://orcid.org/0000-0002-1138-8587*
**Author for Correspondence*

Abstract

Among the grand challenges of the 21st Century is the documentation and description of the Earth's biodiversity. This is especially the case for groups of organisms that historically have received far less attention than others, which is likely related to a lack of formal education/training in many to most K–12 systems. Lichens remain among the least studied groups of macro-organisms anywhere in the world. New research to understand their biodiversity is met with heightened urgency considering unprecedent rates of habitat destruction and that 21st Century ecosystems are now sculpted by human activities as much as they are by natural phenomena. The present contribution builds on early evidence of an exceptionally rich but as yet poorly documented lichen biota of the southern Rocky Mountains of Colorado. Here, we describe three species new to science and conduct molecular phylogenetic analyses that help place this diversity within the context of related species: *Lecanora indigoana, Lepraria saliersiae,* and *Pertusaria rayana*. We provide the new combination *Lecanora gigantea* for *Myriolecis gigantea*, and the new name *Lecanora planata* for *Myriolecis complanata*, which cannot be transferred under its original epithet due to homonymy in *Lecanora*. Additionally, we provide three new dichotomous keys that aid in the identification of these species in comparison to close relatives that occur throughout the region. Finally, we conduct IUCN conservation assessments for all three species to assist in future preservation strategies. Through discovery and description of the Colorado lichen biota, we aim to engage a broad audience of stakeholders and interest groups in these remarkable symbiotic organisms.

Key words: biodiversity, conservation, description, dichotomous key, floristics, *Lecanora*, *Lepraria*, lichen, lichenized fungi, *Pertusaria*, phylogeny, species discovery, taxonomy

Introduction

Among the grand challenges for 21st century biology is reconciling vast gaps in knowledge of Earth's biodiversity. This challenge is met with tremendous urgency considering unparalleled rates of habitat destruction and resultant irreversible biodiversity losses on a global scale. Addressing this grand challenge requires that we invest new time and resources into documenting poorly understood groups of organisms. Despite their striking morphological diversity and ecological importance, lichens remain among the least studied groups of macroscopic organisms worldwide. Lichens are obligate symbiotic organisms composed of at least one primary fungal and one primary algal partner (the "mycobiont" and "photobiont"), but a given thallus (individual) typically contains numerous additional fungi, algae, and bacteria as well as hosts myriad specialist invertebrates (Sanders & Masumoto 2021; Rolshausen *et al.* 2022; Schwob *et al.* 2024; Tagirdzhanova *et al.* 2024; Loeffelholz *et al.* 2025). As such, lichens function as hubs of trophic interactions (Honeggar 1991) and have been called "super organisms" (Schulz *et al.* 2022). In addition to their numerous ecological contributions (Asplund & Wardle 2017), lichens are impressively stress-tolerant. They are often the only macroscopic organisms capable of living on bare rock in arid environments, such as in the western United States, owing to a suite of adaptive traits including pigmentation and diverse secondary chemistries (Gaya *et al.* 2015), reproductive modes (Tripp & Lendemer 2018), and a plethora of morphological innovations (Tretiach & Brown, 1995). As such, lichens are essential for primary succession and soil formation in mountainous and surrounding environments, in addition to many other ecological functions.

Accepted by Klara Scharnagl: 9 Jul. 2025; published: 1 Aug. 2025

Despite their ecological importance and conspicuous diversity in North America (NA) (~6,000 species; Esslinger 2021), we still lack a comprehensive inventory of North American lichens. This gap is particularly profound in the southern Rocky Mountains of western North America. Whereas regional lichen "floras" exist for a limited number of locations in the United States including the Greater Sonoran Desert (Nash 2002–2004), the Pacific Northwest (McCune 2017), and southern Appalachian Mountains (Tripp & Lendemer 2019a, b), knowledge of lichen biodiversity throughout the southern Rocky Mountains remains woefully understudied. To date, only localized treatments or early checklists have been produced (e.g., Weber and Shushan 1955; Anderson 1962, 1964; Shushan and Anderson 1969; Anderson and Carmer 1974; Carmer 1975; Flock 1978; Shrestha and St. Clair 2009; Tripp 2015, 2017; Tripp *et al.* 2019).

The southern Rocky Mountain ecoregion (SoRo) is a biological mosaic of environments that includes high elevation tundra and talus slopes, vast subalpine areas, riparian woodlands, montane conifer forests, semi-arid piñon-juniper mesas, extensive short-grass prairies and sagebrush communities, treeless high desert steppe, and dunes. Colorado (CO) alone, with nearly ~43% of its land in the public domain, contains 54 peaks that exceed 14,000 feet in elevation and 637 peaks that exceed 13,000 feet. Lichen biodiversity of the southern Rocky Mountains (SoRo) shares important evolutionary and geological history with the adjacent high plains and together, these two ecosystems are among the most endangered landscapes in North America (Dodds *et al.* 2004; CNHP 2011). The SoRo and high plains of CO are known to harbor ~3,000 species of vascular plants; however, before our lichen inventory began, only ~700–800 lichen species were known from the state. Our early estimates (see below) suggest that this is a drastic underestimate during a time when human demands on both the high peaks and high plains are escalating, with risk factors such as fire, development, resource extraction, and climate change predicted to grow (Golubiewski 2006). Documenting the biodiversity of poorly understood groups of organisms such as lichens in this region is therefore both timely and met with a high sense of urgency.

Three summers ago, we launched the initial stages of a first comprehensive inventory of lichen biodiversity of Colorado and the adjacent SoRo. The early phases of our research have provided preliminary evidence of an exceptional biota that is undiscovered to a degree well-beyond our initial expectations (Tripp 2015, 2017; Tripp *et al.* 2018, Tripp *et al.* 2019; Raynor *et al.* 2023, 2024, 2025; Diaz & Manzitto-Tripp 2023; Manzitto-Tripp *et al.* 2025; Manzitto-Tripp & Watts 2025; Watts *et al.* 2024, 2025; Raynor & Manzitto-Tripp in revision). "The thin horizon of a plan is almost clear" (Saliers & Ray 1994, *Swamp Ophelia*, "The Wood Song"): towards advancing a comprehensive inventory of the lichens of the southern Rocky Mountains, we here describe three species new to science: *Lecanora indigoana, Lepraria saliersiae,* and *Pertusaria rayana*. These species were collected by us during fieldwork in the summers of 2024 and 2025 (ongoing) that traversed the state of Colorado, sampling lichens from all biomes. Below, we provide morphological and molecular evidence to support their status as new species, dichotomous keys to help aid in their identification, and formal IUCN-based conservation assessments to guide preservation efforts. Additionally, we provide a distribution map for the three new species. This contribution is made in honor of *Indigo Girls*—Emily Saliers and Amy Ray (among the only songwriters in history to reference lichens in a song (Ray & Saliers 2005, *Rarities*, "Point Hope")—for their decades of advocacy for environmental justice (and numerous other topics, namely human rights). Their hard work, poignant contributions, and words of hope have inspired millions of listeners, including us, who have heard their calls to action and found ways to try to give back, even if only a little. The present contribution represents one such attempt.

Materials & Methods

Field Work. Specimens included in this study were obtained through our ongoing project to comprehensively document lichen biodiversity in the southern Rocky Mountains, from 2022 to the present. As part of this work, we are sampling all major habitat types (alpine, subalpine, and lower montane forests, grasslands, riparian areas, and rock outcrops), lichen growth forms (foliose, fruticose, crustose, squamulose, leprose), and substrates suitable for lichen growth (rock, bark, lignum, soil, bryophytes, sap, other lichens). We are placing special emphasis on difficult to reach, off-trail terrain unlikely to have been sampled for lichens in earlier times, as well as on mesic canyons and corridors that we predict could harbor unusual diversity. High resolution field photographs were made using either a Nikon D7100 digital SLR or a Nikon D3200 digital SLR, both equipped with a 105 mm 1:1 macrolens and ring flash. Geographical coordinates and habitat characteristics were recorded. Collections were pre-processed (i.e., stabilized, gluing where necessary) and placed in temporary packets to prepare for final identifications (see below). Subsamples were removed for DNA sequencing then stored under refrigeration until returned to freezers in Manzitto-Tripp's molecular laboratory at The University of Colorado—Boulder. Field photographs were labeled and archived for future use.

Herbarium Study. We made final identifications of our lichen field collections at the University of Colorado, Museum of Natural History, COLO Herbarium (Thiers, continuously updated) using an Olympus SZX16 and Olympus BX51 coupled to an Olympus EP50 camera. Samples were hand-sectioned then examined in water mounts along with other media (e.g., in K or stains). Spot tests using standard reagents (K, C, KC, P, N) along with UV illumination were conducted at COLO. Additionally, Thin Layer Chromatography and/or DNA sequencing was conducted by the authors at COLO (in Manzitto-Tripp's molecular lab) on a subset of specimens to help confirm identifications where necessary. Thin Layer Chromatography (TLC) utilized Solvent A (for dibenzofurans) and Solvent C and silica plates following Culberson & Kristinsson (1970) and Culberson (1972). In addition to studying our own newly collected materials, we examined material housed at COLO using the same methods as above, providing updated identification annotations where necessary. All collections cited below were verified by the authors but nonetheless we include a "!" (to indicate material was seen and verified by us) following studied specimen cited below, unless in reference to a type specimen housed elsewhere and only photographs were seen (in which case "photo!" was utilized). We referenced the identification of our collections using published literature, protologues, floras, field guides, existing herbarium materials as well as the Consortium of Lichen Herbaria (CLH, Lichen Portal; www.lichenportal.org). Our taxonomy followed Esslinger (2021) for the most part. Data and specimens reported in this study were deposited at COLO and data were uploaded to COLO's database, which is hosted on Lichen Portal .

Molecular Analyses. To place the new species in a molecular genetic context, we generated sequence data for each of the three species for the nuclear ribosomal internal transcribed spacer (nrITS) "barcoding" locus. Genomic DNA was extracted using a modified CTAB protocol (Doyle and Doyle 1987). We amplified the nrITS region (including *5.8s*) using ITS4 and ITS5 primers (White *et al.* 1990). Resultant successful PCR products were sent to Quintara Biosciences (Cambridge, MA) for product cleanup and bidirectional Sanger Sequencing. We generated DNA alignments using our newly generated sequences together with pre-existing nrITS data retrieved from GenBank. Matrix assembly was guided by referencing relevant literature including phylogenetic results presented therein, including outgroup selection (Howard 1970; Laundon 1989; Brodo 1991; Tønsberg 1992; Gilbert and Coppins 1992; Lumbsch *et al.* 1997; Printzen 2001; Schmitt and Lumbsch 2004; Śliwa 2007; Saag and Randlane 2009; Flakus *et al.* 2011; Kukwa 2011; Śliwa *et al.* 2012; Lendemer 2013; Zhao *et al.* 2016; Guzow-Kremińsak *et al.* 2019; Payzulla and Mamut 2025). Final matrices consisted of 55 (*Lecanora*), 50 (*Lepraria*), and 96 (*Pertusaria*) terminals, which contained multiple accessions of each of the three new species (i.e., two of *Lecanora indigoana*, five of *Lepraria saliersiae*, and two of *Pertusaria rayana*).

Phylogenetic relationships were constructed from each of the three matrices using maximum likelihood methods implemented in raxml 2.0 (Edler *et al.* 2020) and an ML + transfer bootstrap + consensus algorithm, with a GTR + FO + I + GA model of sequence evolution and 100 bootstrap replicates. We generated a 50% majority rule consensus tree from each matrix then visualized results using FigTree v1.4.4 (Rambaut 2010). We interpreted bootstrap values indicative of support for a given phylogenetic relationship as follows: ≥ 90% = strong support, ≥ 80–89% = moderate support, ≥ 70–79% = weak support, and <70% = unsupported. Taxon identification, GenBank number, and collection locations for each specimen included in our phylogenies were displayed at branch tips in resultant phylogenies (see results).

Conservation Assessments. The conservation statuses of the new species described herein are assessed following the International Union for Conservation of Nature (IUCN). Given a lack of useful historical data on population sizes and trends through time, which are necessary for criteria A, B, C, and E, we opted to utilize criterion D of the IUCN guidelines version 16 (IUCN Standards and Petitions Committee, 2024). Under IUCN criterion D, species are classified as Critically Endangered (CR) or Endangered (E) if the total estimated population size is less than 50 individuals or between 51 and 250, respectively. We consider one mature individual as any one m^2 surface of rock containing an individual of the focal species, following practices recommended by a recent review about conducting conservation assessments of lichens (Yahr *et al.* 2024).

Results & Discussion

Our overarching objective of the present contribution was to generate and disseminate new knowledge of southern Rocky Mountain lichens towards building new capacity and engagement in lichen biodiversity by diverse parties throughout western North America. This goal presented us with the unique opportunity to honor Emily Saliers &

Amy Ray of the Indigo Girls, and below we describe three lichen species new to science (Figure 1–6; *Lecanora indigoana*; *Lepraria saliersiae*; *Pertusaria rayana*), with descriptions accompanied by a map of their geographical distributions (Figure 7) and results of molecular phylogenetic analyses (Part 1). We then provide dichotomous keys to aid in their identification (Part 2), followed by additional nomenclatural innovations (Part 3). Although our launching of the first comprehensive inventory of Colorado's lichens began only two summers ago, already the number of new biogeographical records and new species has far surpassed our early expectations (Tripp 2015; Tripp *et al.* 2018, Tripp *et al.* 2019; Raynor *et al.* 2023, 2024, 2025; Manzitto-Tripp *et al.* 2025; Manzitto-Tripp & Watts 2025; Watts *et al.* 2024, 2025; Raynor & Manzitto-Tripp in revision). These reports highlight only the earliest stages of extensive more discovery to come: "the thin horizon of a plan is almost clear."

Part 1: TAXONOMY

Lecanora indigoana E. Tripp & J. Watts, *sp. nov.*

TYPE. USA, Colorado. Delta County. Gunnison National Forest, CR265, lower montane stand of *Populus tremuloides* and *Picea pungens*, corticolous on *P. pungens*, 8710 ft. elev., 39.124568, -107.54828, 13 May 2024, *E. Manzitto-Tripp & J. Watts 10446* (Holotype: COLO!). Figures 1–2 & 7.

Mycobank #. 860001

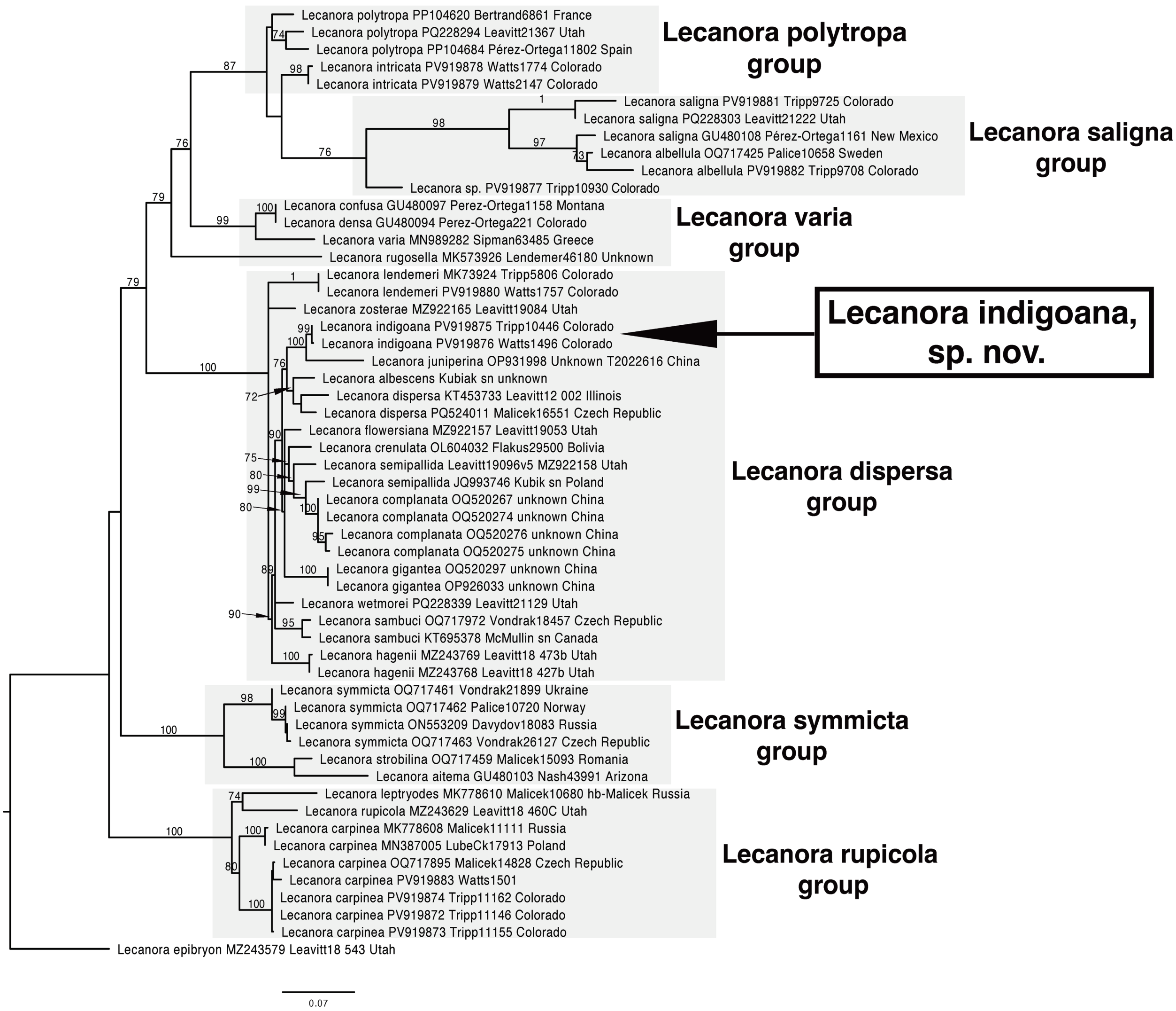

FIGURE 1. Phylogenetic analysis of *Lecanora indigoana* using Maximum Likelihood methods to resolve evolutionary relationship of new species to close relatives. Labels of terminals include taxon name, collector (lead collector only) and collection number, GenBank reference number, and geographical origin of sample (where known).

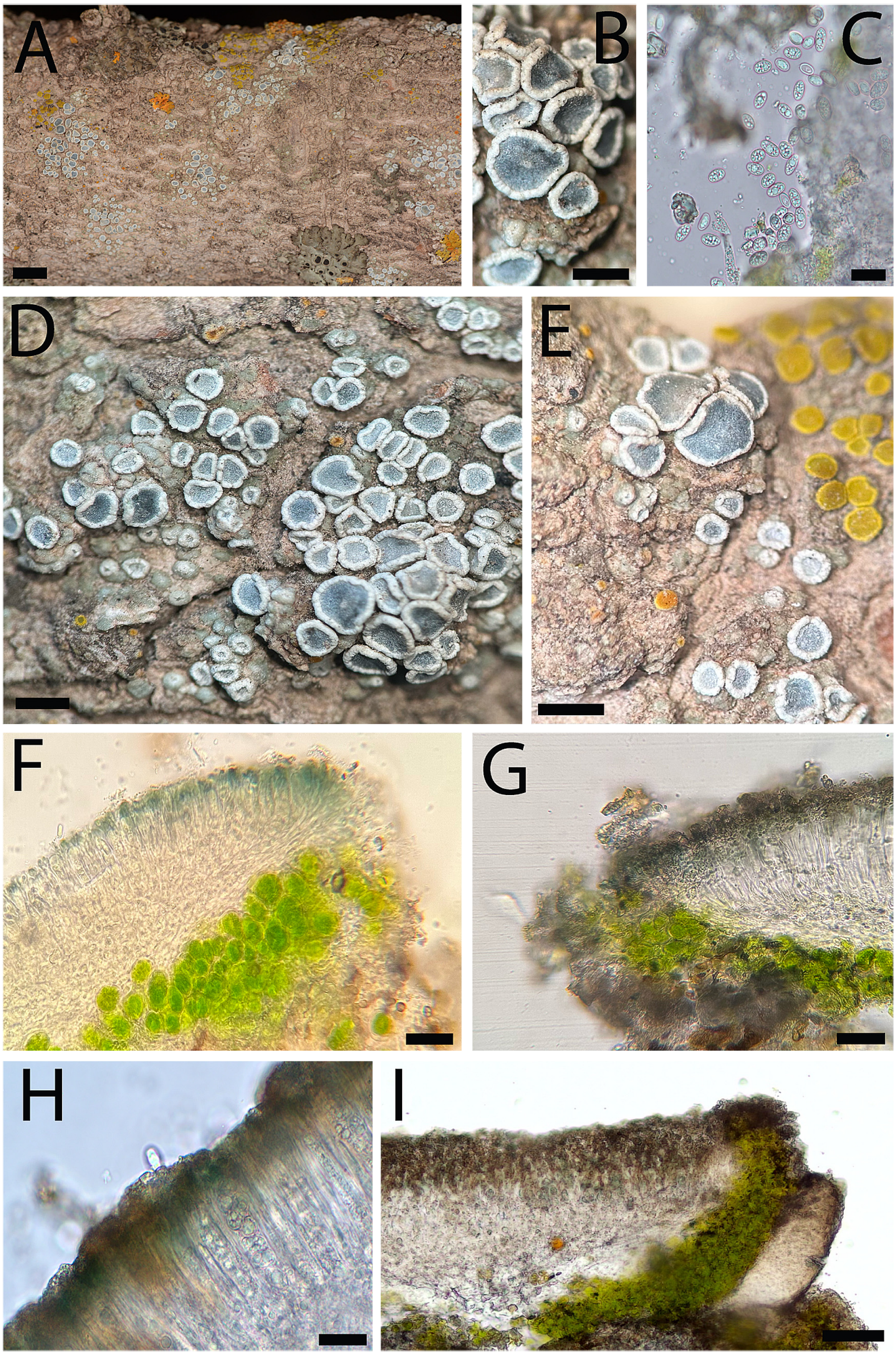

FIGURE 2. A. Macromorphology of *Lecanora indigoana*. A: Holotype showing vibrant indigo discs occuring in irregular clusters, on branch of *Picea pungens*. B, D, & E: Pale greenish-gray, irregularly areolate to bullate thallus and characteristic apothecia with distinctly indigo-blue discs, these densely pruinose, slightly concave, with white, entire to cracked margins strongly raised above discs. C: Simple, hyaline subspherical to broadly ellipsoidal spores sometimes surrounded by hyaline ring. F, G, & H: Cross sections of apothecium showing brownish gray epihymenium and indigo pigment interspersed among paraphyses tips, this remarkable pigment persistent in K (Figure 2F). I: Ampithecium with conspicuously well-developed lower cortex. Scale Bars: A=5mm, B=1mm, C=20µm, D=1mm, E=1mm, F=20µm, G=20µm, H=20µm, I=60µm. Photos taken from *E. Manzitto-Tripp & J. Watts 10,436, E. Manzitto-Tripp & J. Watts 10,446,* and *J. Watts & E. Manzitto-Tripp 1496.*

Description. Thallus light gray to pale greenish gray, not continuous, irregularly areolate to bullate, the areoles sometimes producing small lobules, epruinose. **Apothecia** sessile and constricted at the base, prominent, 0.5–1.2 mm in diameter, occurring in irregular clusters, less commonly solitary. **Discs** distinctly indigo blue, invariably densely pruinose, slightly concave to plane. **Margins** white, mostly entire to occasionally incised/cracked, corticate, much lighter in color compared to the thallus, strongly raised above disk. **Parathecium** hyaline, inconspicuous. **Amphithecium** 74–112 µm thick, apical portions of cortex (26–)29–37(–47) µm thick, lower portions of cortex extremely well-developed and prominent, (40–)53–75(–90) µm thick, the upper and lower cortices as well as algal layer containing fine POL+ crystals, not dissolving in K, dissolving in N. **Epihymenium** brownish gray, containing fine POL+ crystals, not dissolving in K, C, or N, also with a conspicuous indigo-colored pigment interspersed among paraphyses tips, indigo pigment not dissolving in K but dissolving in C, reacting pale red in N, (10–)13–30(–37) µm tall, with fine POL+ crystals, not dissolving in K or N**. Hymenium** hyaline, densely inspersed with oil droplets, (43–)69–88(–100) µm tall. **Hypothecium** hyaline, (30–)55–65 µm tall. **Asci** with 8 spores per ascus, 32–38(–42) × cylindrical, frequently branched toward the apex, 1.5–2.5 µm wide apically, 1.0–1.5 µm basally. **Ascospores** simple, hyaline, subspherical to broadly ellipsoidal, (8–)9–11.5 × (5–)6–7, 1.4 to 1.7(–2.1) times longer than wide, sometimes surrounded by a thin, hyaline ring ca. 0.2–0.3 µm thick. **Pycnidia** not seen. **Photobiont** chlorococcoid, spherical 7–15(–18) µm in diameter.

Etymology. The new species is named in honor of *Indigo Girls*, a now five-decade musical duo and legend that has inspired millions of listeners with their lyrical contributions, commitment to environmental protection, and social activism. Emily Saliers and Amy Ray of *Indigo Girls* have been major proponents of climate justice and, for years, led grassroots-style campaigns to increase awareness and promote change in social atmospheres. Songs by *Indigo Girls* have universally conveyed an interconnectedness between environmental health and social rights, which reminds us of lichen biodiversity and our parallel need to continue advancing initiatives that promote education and awareness of these remarkable symbiotic organisms. The new species further reminds us of *Indigo Girls* because it is both lustrous and assertive, introspective yet audacious, and reflective of voices that have not yet been heard, until now.

Chemistry. Spot Tests: K,- C-, KC-, P- UV- (thallus and apothecia). **Thin Layer Chromatography:** No substances detected.

Distribution. Current data document the presence of *Lecanora indigoana* only from Delta and Pitkin Counties, Gunnison National Forest, in central-western Colorado. We expect that additional collection efforts throughout Colorado and the southern Rocky Mountains, as well as further study of existing herbarium materials, will in time reveal a broader geographical distribution of this remarkable species.

Substrate & Habitat. *Lecanora indigoana* has been found in lower montane forests occurring on two of Colorado's most iconic tree species: Quaking Aspen (*Populus tremuloides*) and Blue Spruce (*Picea pungens*). Future lichenological fieldwork throughout the southern Rocky Mountains in similar habitats is likely to expand the known range of this species into comparable habitats, and potentially on additional substrates.

Notes. The most immediately recognizable and distinguishing features of *Lecanora indigoana* (Figure 2) are its densely pruinose apothecial discs that are unwaveringly deep indigo in color. Because of these two traits, in North America *Lecanora indigoana* is likely only confusable for four other taxa that sometimes bear heavily pruinose discs appearing bluish to slate-colored: *L. juniperina* Śliwa, *L. wetmorei* Śliwa, *L. invadens* H. Magn., and *L. perpruinosa* Fröberg. Of these, only *L. juniperina* and *L. wetmorei* are similarly corticolous like the new species (note: the latter two are also lignicolous). Phylogenetic analyses resolved our two accessions of *L. indigoana* as reciprocally monophyletic with strong support (99% bootstrap [BS]) and sister to *L. juniperina*, also with strong support (100% BS). *Lecanora indigoana* can be differentiated from *L. juniperina* by the former's conspicuous areoles that sometimes produce small lobules, its prominent indigo pigment interspersed among paraphyses tips, its inspersed hymenium that is taller than that of *L. juniperina*, its brownish gray (vs. yellow granular) epihymenium, its spores that are slightly shorter and wider, and its complete lack of secondary metabolites (vs. unknown xanthones in *L. juniperina*). Furthermore, whereas *L. juniperina* is currently known most predominantly from low elevations, primarily pinyon-juniper habitats of the Colorado Plateau, so far as understood, *L. indigoana* occurs in middle montane forests east of the Colorado Plateau at higher elevations such as those dominated by aspen and blue spruce. With *L. wetmorei* the new species shares relatively large apothecia, a strongly expanded basal portion of the amphithecial cortex, and a primarily western North American montane distribution. However, *L. wetmorei* cannot be mistaken for *Lecanora indigoana* because of the former's complete lack of a thallus (Śliwa 2007; examination of the holotype, *C. Wetmore 16568,* MIN! [MIN722988]). Additionally, *L. wetmorei* has entire (never occasionally incised) disc margins, and for the most part, a taller amphithecium.

Like *Lecanora indigoana*, both *L. perpruinosa* and *L. invadens* have clearly visible thalli. However, the new species can nonetheless be readily differentiated from both. *Lecanora perpruinosa* differs by having a primarily thin, continuous thallus with indefinite edges, black to very dark brownish black discs, discs that are for the most part smaller in diameter (~0.3–0.8 mm; Śliwa 2007), an indistinctly delimited lower cortex of the amphithecium, and occurrence on calcareous rocks. *Lecanora perpruinosa* moreover is known primarily from Europe with only a limited number of occurrences in North America. *Lecanora invadens* differs from the new species by having an indistinct thallus, for the most part smaller apothecia (0.4–1.0 mm; Śliwa 2007), primarily yellow to brown or black discs, a much taller amphithecium (~160–170 µm), its chemistry (typical presence of lichen substances), and occurrence on non-calcareous or calcareous rocks as well as occasionally parasitic on other lichens. Finally, it is possible that some could confuse the new species for *L. hagenii* (Ach.) Ach., which is also corticolous and similarly sometimes has slightly incised apothecial margins, however *L. hagenii* differs by lacking a thallus, having evenly distributed apothecia, orangish brown discs, and an indistinctly delimited lower cortex of the amphithecium. The latter species also has smaller apothecia with typically thinner discs (Śliwa 2007; examination of the conserved type, *F. Arnold, Exs. Sic. No. 31*, M! [M-00345420]).

Elsewhere (outside North America), *Lecanora indigoana* bears resemblance to two species recently described from China (Payzulla & Mamut 2025) although both are phylogenetically less closely related to the new species (Figure 1): *Lecanora gigantea* (R. Mamut & T. Payzula) E. Tripp & J. Watts and *Lecanora planata* E. Tripp & J. Watts (both treated under *Myriolecis* in Payzulla & Mamut 2025, new combinations provided in Part 3, below). *Lecanora gigantea* differs in numerous features including its very conspicuous thallus and presence of vinetorin; that species also occurs on calcareous rocks and is so far known only from China. *Lecanora planata* differs from by having a thallus that is primarily within the substrate (or at most, occurring only underneath the apothecia), by its apothecia with margins that are level and even with the discs, and its slightly narrower spores; that species also occurs on calcareous rocks and is so far known only from China.

As in Tripp *et al.* (2019), we here opt to place the new species within a broadly defined concept of the genus *Lecanora* vs. the alternative, more narrowed circumscription of the lineage, i.e., *Myriolecis* Clements (Zhao *et al.* 2016), which has been used recently to refer to members of the *Lecanora dispersa* (Pers.) Röhl. group to which the new species belongs. We refrain from treatment of *L. indigoana* in other genera until a more stable classification (i.e., one in which the recognition of multiple segregate genera no longer renders *Lecanora* massively non-monophyletic) can be put forward.

Conservation Assessment. Based on current knowledge, *Lecanora indigoana* is here assessed as Critically Endangered (CR) under criterion D of the IUCN Red List (IUCN 2024), which was invoked as a result of only two known populations consisting of a total of two mature individuals each.

Additional Specimens Examined. USA, Colorado, **Delta County**. Gunnison National Forest, CR265, lower montane stand of *Populus tremuloides* and *Picea pungens*, corticolous on *P. pungens*, 8710 ft., 39.124568 -107.54828, 13 May 2024, *J. Watts & E. Manzitto-Tripp 1496* (COLO!). **Pitkin County.** White River National Forest, Placita Trailhead, semi-arid, west-facing slope dominated by *Quercus gambellii* Liebm. and *Populus tremuloides*, corticolous on *P. tremuloides*, 7586 ft., 39.13545 -107.26985, 13 May 2024 (*E. Manzitto-Tripp & J. Watts 10436* (COLO!).

Lepraria saliersiae E. Tripp & J. Watts, *sp. nov.*

TYPE. USA. Colorado. Saguache County, BLM land east of Cochetopa Pass, Sheep Creek Road (BLM 5252N), high elevation sage steppe dissected by mesic, boulder-rich ravines with *Artemesia* spp., *Abies lasiocarpa, Populus tremuloides, Rosa woodsii,* and *Pinus aristata*, saxicolous on rocks in ravine, 9086 ft. elev., 38.19928, -106.49064, 17 July 2024, *E. Manzitto-Tripp & J. Watts 10,998* (Holotype: COLO!; Isotype: KANU!). Figures 3–4 & 7.

Mycobank #. 860002

Description. Thallus crustose, leprose, placodioid, with (usually) crisped margins forming a conspicuously raised lip that ascends upward, prominently above primary plane of thallus, very rarely with only somewhat raised margins that are not conspicuously crisped and raised, the lips and margins conspicuously yellow in color, central portions of thallus irregularly pigmented, ranging from yellowish gray to whitish gray. **Lobes** indistinct to distinct, when distinct, raised, yellowed, and 1–2 mm wide. **Granules** irregular to less commonly subglobose, mostly ecorticate (ecorticate portions extremely yellow), typically with short projecting hyphae, to sometimes pseudocorticate (these portions whitish gray), 50–110 µm in diameter. Hypothallus consisting of thick, white, protruding hyphae, these ca. 80 µm long, segmented and branching, 2.5–3.5 µm thick. **Hypothallus** bearing scattered, reddish-brown, morphologically highly differentiated shiny, prominent rhizohyphae, 3.0–3.5 µm thick, branched. **Photobiont** chlorococcoid, cells 7–12 µm in diameter.

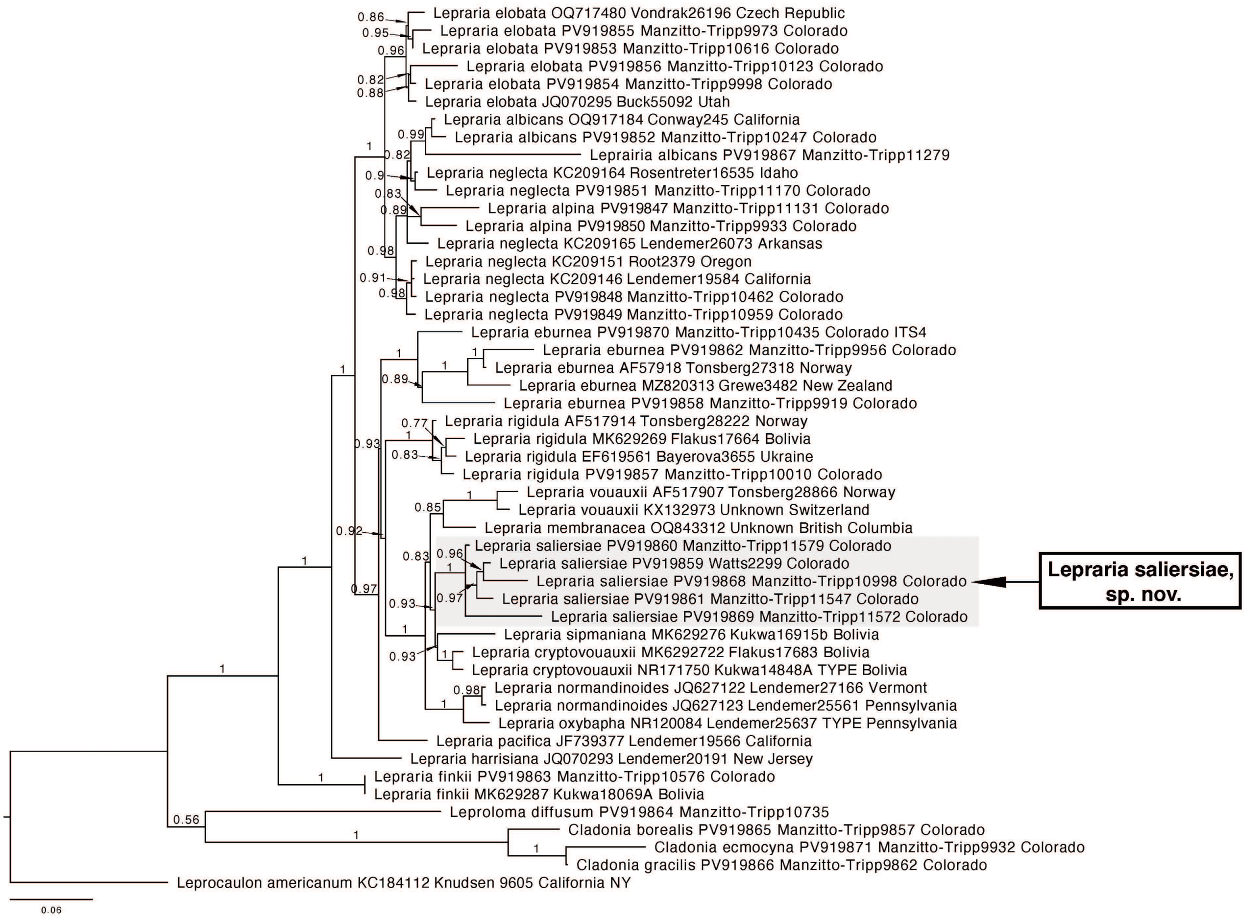

FIGURE 3. Phylogenetic analysis of *Lepraria saliersiae* using Maximum Likelihood methods to resolve evolutionary relationship of new species to close relatives. Labels of terminals include taxon name, collector (lead collector, only) and collection number, GenBank reference number, and geographical origin of sample (where known).

Etymology. This new lichen species is named in honor of Emily Saliers of the long-time musical duo, *Indigo Girls*. Together with Amy Ray, Emily has worked tirelessly to advocate for environmental rights and to end destructive, industrial practices that are catastrophic to both biodiversity and human livelihood. She has been a vocal opponent of (and has helped to fundraise against) the Dakota Access, Keystone, and Enbridge Pipelines, which devastate river water quality, violate treaty rights of Native Nations, and pose major threats to riparian ecosystems and the peoples that depend on them. Emily's music is rooted in intellectual curiosity, understanding, awareness, compassion, and reflection. Her songs have been a powerful catalyst to inspire social change, which is intimately linked and crucial to the preservation of our native ecosystems and their resident species. Emily's music has kept us company over many years of fieldwork (and microscopy!) spent documenting and conserving the biodiversity that surrounds us. This new species reminds us of Emily because its striking yellow thallus is bright, lively, and conveys a warmness.

Chemistry. Spot Tests. K+ yellow, C-, KC-, P+ orange to red, UV-. **Thin Layer Chromatography:** atranorin (major to trace or rarely absent), roccellic/angardianic (major to absent), pannaric acid 6-methyl ester (major), pannaric acid (major), unknown dibenzofuran A, and +/- pannaric acid 2-methyl ester (only 2 specimens).

Distribution. *Lepraria saliersiae* is known currently from 20 specimens deriving from 12 different counties, nine in Colorado (Boulder, Gunnison, Huerfano, Jefferson, Mineral, Otero, Park, Pitkin, Saguache, San Miguel) and three in New Mexico (Hidalgo, San Juan, Sandoval).

Substrate & Habitat. The 20 collections of *Lepraria saliersiae* reported here were made primarily on rocks (or rarely overgrowing mosses in crevices) in sheltered habitats such as in micro-watersheds (i.e., less than 100 m wide) and rock crevices. The new species seems to have an affinity in particular for soft rocks such as sandstone. *Lepraria saliersiae* has been found growing in a variety of low to mid elevation habitats of the SoRo ranging from mixed-grass prairie ecosystems to high elevation sage-steppe and upper montane forests ranging between ~4,400–10,500 ft. elev. We expect that continued surveys of the southern Rocky Mountain lichen biota (coupled with new herbarium studies of existing materials) will continue to expand the known range of this remarkable species.

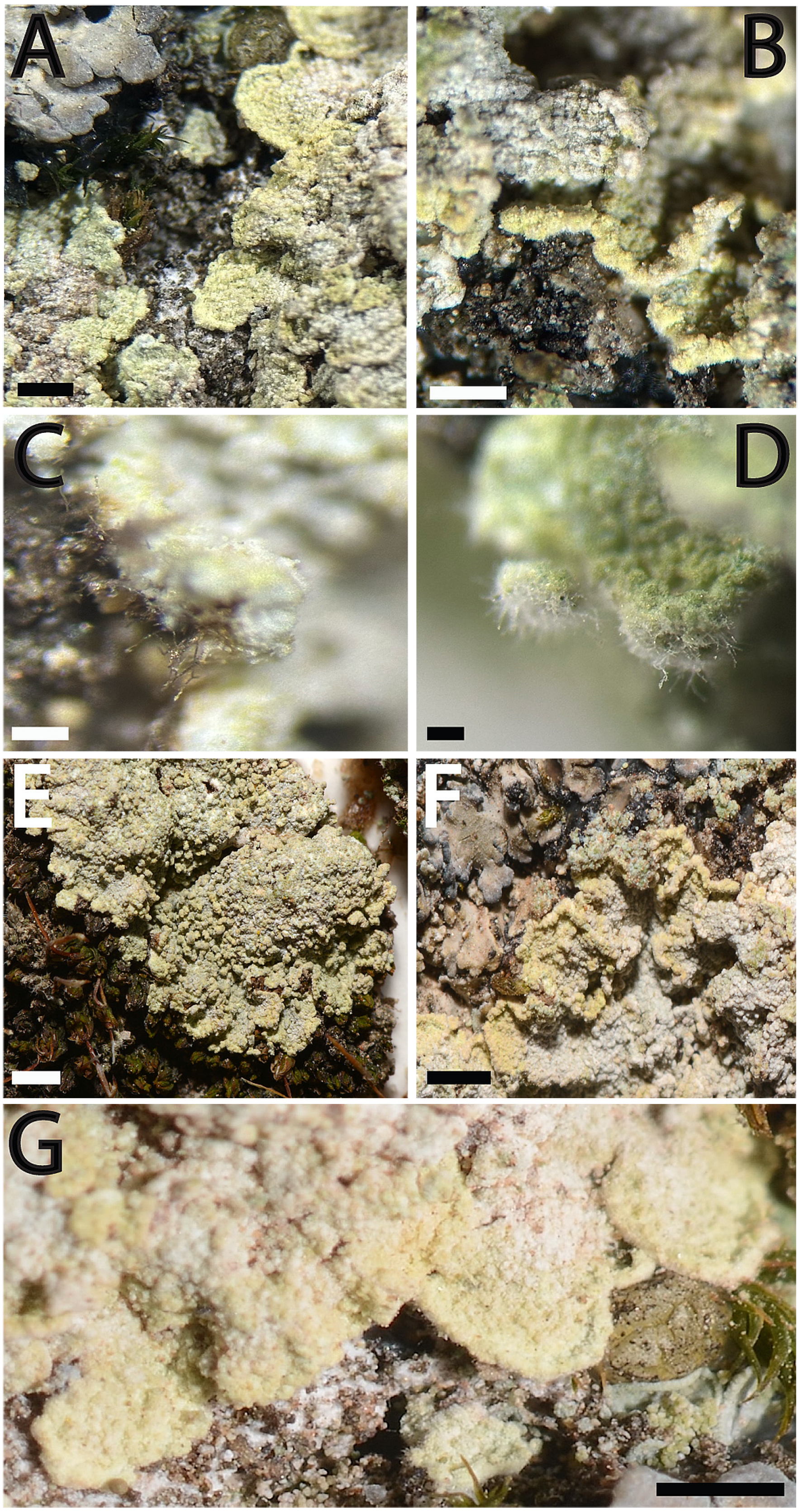

FIGURE 4. Macromorphology of *Lepraria saliersiae*. A, B, E, F, & G: Crisped, raised lip and conspicuous yellow pigmentation of thallus C: Reddish-brown, shiny, differentiated rhizohyphae. D: Hypothallus of thick, white, protruding hyphae, these segmented and branching. Scale Bars: A=2mm, B=2mm, C=100µm, D=100µm, E=3mm, F=2mm, G=2mm. Photos taken from *E. Manzitto-Tripp & J. Watts 10998*, *J. Watts & S. Raynor 2299*, and *J. Watts 3450.*

Notes. In North America, *Lepraria saliersiae* (Figure 4) is a charismatic component of the leprose crust lichen community of the southern Rocky Mountains, distinctive by its placodioid thallus with crisped margins that form conspicuously raised lips that ascend clearly above primary plane of the thallus (i.e. *normandinoides*-type sensu Lendemer [2013]), its remarkable yellow pigmentation that accentuates various portions of the thallus but especially the margins, its irregularly shaped granules that vary from predominantly ecorticate with short projecting hyphae to occasionally pseudocorticate, its hypothallus that bears reddish-brown rhizohyphae that are long, branched, shiny, and reddish-brown in color, and its nearly consistent production of atranorin (in addition to other compounds). In the southern Rocky Mountains, *Lepraria saliersiae* has historically likely been to be confused for *L. vouauxii* (Hue) R.C. Harris, but that species lacks defined margins (i.e., has an aggregate-type thallus), has non-pigmented rhizohypae (where present), is chemically variable but most frequently lacks atranorin, oftentimes occurs on bark (both of which are the case for the type, *L. Vouaux* s.n. in Claudel, Claudel & Harmand, *Lich. Gall. Praec. Exs. No. 300*, H-9504035, isolectotype [photo!]; TLC=methyl pannaric acid complex only), and is phylogenetically more distantly related to *Lepraria saliersiae* (Figure 3; Laundon 1989; Lendemer 2013). Lendemer (2013) employs a broad species concept for *L. vouauxii* in North America to include many saxicolous specimens from western North America that we here treat as *L. saliersiae*. Consistent with the type specimen (cited above), the current contribution adopts a narrower concept of *L. vouauxii* to only include those specimens that occur primarily on bark or mosses and detritus over bark, lack atranorin, and have aggregate-type thalli. Based on current knowledge, we do not consider it yet known from Colorado and therefore exclude it from the key. The new species may also be confused *L. membranacea* (Dicks.) Vain., which has been variously treated as present either only in eastern North America (Lendemer 2013) or more widely recognized throughout much of North America (https://lichenportal.org/portal/). In concordance with Lendemer (2013), it is likely that *L. membranacea* is largely or wholly restricted to eastern North America and absent from arid regions of western North America; we therefore do not currently recognize the species as occurring in Colorado and exclude it from the key. *Lepraria saliersiae* can, however, be differentiated from *L. membranacea* (*J. Dickson* s.n., BM, holotype [photo!]) because the latter, while placodioid, lacks crisped, raised margins (i.e. *finkii*-type sensu Lendemer [2013]), has unpigmented rhizohypae (where present), rarely produces atranorin, lacks metabolites in the methyl pannaric acid complex, and is phylogenetically more distantly related to *Lepraria saliersiae* (Figure 3; Laundon 1989; Lendemer 2013). We suspect that many specimens currently annotated as *L. vouauxii* or *L. membranacea* in arid, western North America likely belong to the new species: *L. saliersiae*. *Lepraria diffusa* (J.R. Laundon) Kukwa is another yellow, dibenzofuran-containing species reported from western North America (mostly from the Pacific Northwest and northern Rocky Mountains, but also from Colorado [e.g., *E. Manzitto-Tripp, J. Watts, & S. Raynor 11818, E. Manzitto-Tripp & W. Manzitto-Tripp 10735, and J. Watts, E. Manzitto-Tripp, & S. Raynor 4214*]) but it is easily differentiated from *L. saliersiae* by its aggregate-type thallus. Finally, the new species may be confused with *Lepraria xerophila* Tønsberg, but that is a strongly western maritime, terricolous species with exceptionally thick thalli that are uniformly whitish yellow (vs. bright yellow at the margins as in *L. saliersiae*) and often squamulose so to appear similar to a *Cladonia*. Additionally, *L. xerophila* is distinct chemically from *L. saliersiae* as it lacks pannaric acid as a major metabolite and produces porphyrilic acid (and related compounds) and rangiformic acid and/or roccellic/angardianic as fatty acids rather than only roccellic/angardianic as in *L. saliersiae*. In instances where thalli of species of *Lepraria* are poorly developed and/or immature, TLC is highly recommended to help aid in their identification and to differentiate the new species from congeners.

In Colorado, other species of *Leparia* with placodioid thalli include *L. eburnea* J.R. Laundon, *L. finkii* (B. de Lesd.) R.C. Harris, and *L. normandinoides* Lendemer & R.C. Harris. *Lepraria eburnea* is similarly shades of yellow to green but lacks a crisped margin and produces alectorialic, barbatolic, and sometimes protocetraric acid. *Lepraria finkii* can sometimes bear yellowish green granules but lacks a crisped margin and produces zeorin, stictic acid aggregate, and sometimes roccellic/angardianic acids. *Lepraria normandinoides* cannot be confused with *Lepraria saliersiae* as it is bluish white to gray in color and produces roccellic/angardianic acid, and sometimes protocetraric acid.

Based on observations during recent field efforts, thallus morphology of *Lepraria saliersiae* appears to vary considerably with microclimatic conditions. In more sheltered situations over harder rocks and/or overgrowing cushion mosses, *L. saliersiae* tends to exhibit less conspicuously raised margins, smaller granules with less well-developed pseudocortices, and more uniformly greenish yellow thalli, thereby approaching the morphology of *L. membranacea*. In exposed microsites, *L. saliersiae* appears to be restricted to vertical to overhung faces of soft sandstones or the soil-rock interfaces where it develops strongly crisped margins, irregular granules with pseudocortices, and distinctly bicolored thalli with bright yellow margins and irregularly/patchily whitish gray centers, in some ways approaching the morphology of *L. xerophila* but never as thick, white, and squamulose as the latter. We have sequenced a range of these moprhologies and all were resolved as reciprocally monophyletic, with strong support (100% BS; Figure 3).

The chemistry of *Lepraria saliersiae* is notable because it invariably produces a presumably undescribed dibenzofuran (unknown dibenzofuran A in TLC section) as a major metabolite. Unknown dibenzofuran A is characterized by an Rf value of ~15 in solvent A, its lack of charring after sulfuric acid and application of heat, and its longwave UV (greenish yellow) fluorescence before charring (UV- after charring). Unknown dibenzofuran A may be related to the dibenzofuran methyl porphyrilate, as this chemical species also does not char, but the latter compound has an Rf value of 23 and fluoresces purple under longwave UV.

Our phylogenetic analyses placed our five accessions of *Lepraria saliersiae* as reciprocally monophyletic with strong support (100% BS; Figure 3). *Lepraria saliersiae* was resolved, also with strong support (93%), as sister to a clade (93% BS) containing collections of *L. sipmaniana* (Kümmerl. & Leuckert) Kukwa and *L. cryptovouauxii* Kukwa from Bolivia (Figure 3). Indeed, *L. sipmaniana* and *L. cryptovouauxii* are similarly placodioid, yellow in color, and produce dibenzofurans, like *Lepraria saliersiae* (Laundon 1989; Flakus *et al.* 2011; Guzow-Krzemińska *et al.* 2019). However, *Lepraria saliersiae* can be readily differentiated from *L. cryptovouauxii* in having conspicuous, crisped lip-like margins, in producing pannaric acid 2-methyl ester, by its branching rhizohyphae, in never producing anthraquinones, and by the single nucleotide polymorphisms present in the nrITS DNA alignment. *Lepraria saliersiae* can be readily differentiated from *L. sipmaniana* in its granules with hyphal projections, its production of atranorin and pannaric acid 2-methyl ester (trace) (and spot tests, i.e., C-), and its typically smaller granules. So far as known, *L. cryptovouauxii* and *L. sipmaniana* have not yet been reported from North America.

Conservation Assessment. Based on our current knowledge and field exploration throughout the southern Rocky Mountains, *Lepraria saliersiae* is currently assessed as Endangered (EN) under criterion D of the IUCN Red List (IUCN 2024), which was invoked as a result of the total known population size of the species being less than 250 individuals. *Lepraria saliersiae* appears to be relatively widespread in Colorado based on the authors' collections. In addition to new fieldwork throughout western North America, further study of herbarium materials currently ascribed to "*Lepraria vouauxii*" and "*Lepraria membranacea*" should be examined to determine whether these specimens may represent additional material of the new species, which may alter this preliminary IUCN assessment.

Additional Specimens Examined. USA. Colorado**. Boulder County.** City of Boulder Open Space & Mountain Parks, outcropping between S. Cherryvale Rd. and Marshall Drive, mixed-grass prairie and *Cercocarpus montanus*, *Pinus ponderosa*, *Prunus virginiana*, *Ribes cereum*, saxicolous at base of vertical outcropping of soft Laramie Sandstone, 39.962026, -105.21188, 5650 ft. elev., 14 April 2025, *J. Watts 3450* (COLO!). **Gunnison County.** Gunnison National Forest, outcropping just south of McClure Pass, north-facing slope of Douglas Fir, Spruce, Fir, and Aspen, geology of coarse-grained sandstone, saxicolous, 39.126761, -107.288151, 8864 ft. elev., 11 June 2025, *E. Manzitto-Tripp & J. Watts 11649* (COLO!). Gunnison National Forest, Raggeds Wilderness, Dark Canyon Trail along Anthracite Creek north of Prospect Point, south-facing outcropping of Rollins Sandstone of the Mesaverde Formation amongst *Juniperus scopularum* and *Quercus gambelii*, saxicolous in cracks, 38.960708, -107.256943, 6940 ft. elev., 10 June 2025, *J. Watts & E. Manzitto-Tripp 3902* (COLO!). **Huerfano County.** Southern extent of San Isabel National Forest just west of CR 630, pinyon-juniper woodland with the occasional Ponderosa Pine over soft sandstone, saxicolous in cracks, 37.89597, -105.15325, 8406 ft. elev., 24 May 2025, *E. Manzitto-Tripp & J. Watts 11547* (COLO!); *J. Watts & E. Manzitto-Tripp 3749* (COLO!). San Isabel National Forest, Spanish Peaks Wilderness, Wahatoya Creek, mature, open canopy, humid, riparian middle montane forest with a lush herbaceous layer, *Abies concolor*, *Pseudostuga menziesii*, and *Populus tremuloides* dominant, *Picea engelmannii* and *Populus angustifolia* occasional, geology of intermixed Cuchara sandstone outcroppings and hard intrusive igneous outwashed boulders, saxicolous, 37.40199, -104.95368, 9058 ft. elev., 24 May 2025, *E. Manzitto-Tripp & J. Watts 11572* (COLO!); *J. Watts & E. Manzitto-Tripp 3780* (COLO!). **Jefferson County.** South Valley Park, inclined *Pinus ponderosa* savanna on Front Range cuesta, saxicolous on vertical soft Lyons sandstone near ephemeral stream, 39.558099, -105.139437, 6,037 ft. elev., 4 January 2025, *J. Watts & R. Wilkens 3095* (COLO!). **La Plata County.** San Juan National Forest, Weminuche Wilderness, Vallecito Creek Trail (529) between the first bridge and the trailhead along the west banks of Vallecito Creek, a montane forest of *Pseudostuga menziesii*, *Pinus ponderosa*, and the occassional *Picea engelmannii*, *Pinus flexilis*, and *Abies concolor*, understory lush with *Rubus* spp., *Lonicera involucrata*, *Prunus americana*, and *Quercus gambelii*, abundant granitic cliffs and outcroppings, saxicolous, 37.510638, -107.53618, 8353 ft. elev., 19 June 2025, *E. Manzitto-Tripp & J. Watts 11782* (COLO!). **Mineral County.** Rio Grande National Forest, La Garita Wilderness, northwest facing slopes between Wheeler NM Trail and East Bellows Creek, a spruce bark-beetle damaged forest with *Dasiphora fruticosa* as the dominant shrub, large north-facing outcrops south of river, geology of intrusive igneous rocks, saxicolous, 37.831773, -106.732012, 10483 ft. elev., 17 June 2025, *E. Manzitto-Tripp & J. Watts 11699* (COLO!). San Juan National Forest, vicinity of Treasure Falls, west-facing gulch of mixed montane forest of *Abies concolor*, *Picea engelmannii*, *Pseudostuga menziesii*, and *Populus tremuloides*, understory of *Amelchier alnifolia*, *Quercus gambelii*, and *Cornus sericea*, muscicolous over rock in crevice, 37.442226, -106.875829, 8182 ft. elev., 18 June 2025, *J. Watts & E. Manzitto-Tripp 4022* (COLO!). **Otero County.** Comanche National Grassland, open wash dominated by *Juniperus* and sheltered outcrops, saxicolous at base of rocks, 37.652519, -103.570902, 4,384 ft. elev., 27 March 2025, *S. Raynor & J. Watts 6100* (COLO!). **Park County.** Eagle Rock Ranch, rocky hillside with large and *Artemesia dracunculus, Mertensia lanceolata, Ribes cereum,* and *Muhlenbergia montana*, saxicolous and on moss under rock, 39.243711, -105.644322, 9,000 ft. elev., 14 July 2023, *T. Cook. s.n.* (COLO!). **Pitkin County.** White River National Forest, South Fork Fryingpan River, ~4 aerial miles southeast of Norrie Colony, lower subalpine forest of Spruce and Fir with the occasional Douglas Fir, *Lycopodium annotinum* in understory with abundant large granitic boulders densely covered in mosses and lichens, saxicolous, 39.27927, -106.61148, 9328 ft. elev., 12 June 2025, *E. Manzitto-Tripp & J. Watts 11681* (COLO!); *J. Watts & E. Manzitto-Tripp 3978* (COLO!). **San Miguel County.** West-facing slope east of Fall Creek from Fall Creek Recreation Site, montane forest with *Pseudotsuga menziesii* and *Picea englemannii* and steep canyon wall of crumbling Dolores Formation sandstone, saxicolous in rock crevice, 37.978955, -108.0298, 7,697 ft. elev., 24 July 2024, *J. Watts & S. Raynor 2299* (COLO!). New Mexico. **Hidalgo County.** Granite Pass, saxicolous in crack in boulder, 26 April 1992, 5,000 ft., *R. Worthington 20667* (COLO!). **San Juan County.** S side of Chaco Wash across from Casa Chiquita ruins, on soil and among mosses, 6,200 ft., 7 August 1979, *L. Sigal & T. Nash III 16,303* (COLO!). **Sandoval Country.** Bandelier National Monument, travel from Saint Peters Dome to breaks of Capulin Canyon, steep, moist, north-facing slopes with *Pseudotsuga menziesii*, *Pinus ponderosa*, and *Pinus strobiformis,* 6,894 ft., 11 June 1980, *W. Weber & T. Kelso s.n.* (COLO!).

Pertusaria rayana E. Tripp & J. Watts, *sp. nov.*

TYPE: USA. Colorado. Eagle County. White River National Forest, Holy Cross Wilderness. Northwest-facing slopes just above the middle fork of Homeskate Creek amongst a dense lower subalpine forest of *Picea engelmanii* and *Pinus contorta*. Saxicolous and muscicolous on large, shaded vertical rock faces, locally abundant, 9492 ft. elevation, 39.387005, -106.451006, 16 July 2024, *J. Watts & E. Manzitto-Tripp 2235* (Holotype: COLO!; Isotypes: ASU!, BYU!, KANU!, NY!). Figures 5–7.

Mycobank #: 860003

Description. Thallus crustose, continuous, thin, smooth, shiny where corticate, becoming ecorticate near regions of isidia development, whitish gray. **Prothallus** absent. **Upper cortex** thin, 18–48 µm thick, prosoplectenchymatous. **Algal layer** interrupted and irregular, up to 25–50 µm thick. **Medulla** prominent, 74–126 µm. **Lower surface** consisting of single layer of parallel-oriented hyphae, shiny, whitish gray, lacking attachment structures. **Isidia** pale yellow to grayish white and slightly lighter in color than surrounding thallus, coralloid, solid, unbranched or branched primarily once towards apex giving a forked appearance, occasionally with additional branching, oftentimes very dense and covering majority of surface of thallus on older thalli, but occurring isolated and dispersed on younger thalli, 125–187 µm thick and up to 750 µm long. **Apothecia** and associated sexual reproductive structures unknown. **Photobiont** chlorococcoid, cells 9–16 µm in diameter.

Etymology. This new lichen species is named in honor of Amy Ray of the long-time musical duo, *Indigo Girls*. Together with Emily Saliers, Amy has been an indefatigable advocate for environmental protection and social justice. She (along with Emily and Winona LaDuke) co-founded the non-profit organization Honor the Earth, which works to promote education and raise awareness of environmental issues impacting indigenous communities. For numerous years, Amy has campaigned to help end nuclear waste dumping on Native American reservations and, together with Emily, has long integrated activism into her tours. Amy's music is rooted in empathy, justice, wit, and equality, especially equal pay for women and other social rights that are inextricably linked to ecological health. Her songs have kept us company over many years spent understanding and describing lichen biodiversity; they have furthermore inspired much of our own scientific activism to help end repressive behaviors by governments and industries that do not serve the interests of our ecosystems nor human livelihood. This new species reminds us of Amy because its yellow isidia are radiant and full of life. It's UV+ orange reaction further reminds us that it is rather dynamic on the inside, too.

Chemistry. Spot Tests: K+ pale yellow to K-, C+ orange to C-, KC+ orange, P-, UV+ orange (thallus and isidia). **Thin Layer Chromatography:** thiopaninic acid (major), atranorin (minor), unknown lichexanthone.

Distribution. So far as currently understood, *Pertusaria rayana* is restricted to the Sawatch and San Juan Mountain ranges of Colorado where it is known only from two locations in two watersheds: Homeskate Creek immediately below Homeskate Reservoir and Vallecito Creek above Vallecito Reservoir. It is likely to be discovered elsewhere in comparable habitats, as future fieldwork to inventory the lichens of the southern Rocky Mountains continues.

Substrate & Habitat. *Pertusaria rayana* grows directly over rocks or on mosses over rocks. It is thus far known to be restricted to vertical or slightly overhung rock faces in lower subalpine/upper montane forests proximal to creeks, between ~8,700–10,000 ft. elev. It has been collected associated with other sterile crustose lichens that occur in rich, riparian communities including trees draped abundantly with species of *Bryoria* Brodo & D. Hawksw. and *Usnea* Dill. ex Adans. Thus, the new species has an affinity to high humidity environments wherein valley fog likely commonly accumulates. The abundant, long isidia of the species likely represent a dual adaptation for asexual reproduction and fog capture as in the "Cloud Lichens" *Niebla* Rundel & Bowler, and other fruticose genera associated with foggy habitats (Stanton & Horn 2013).

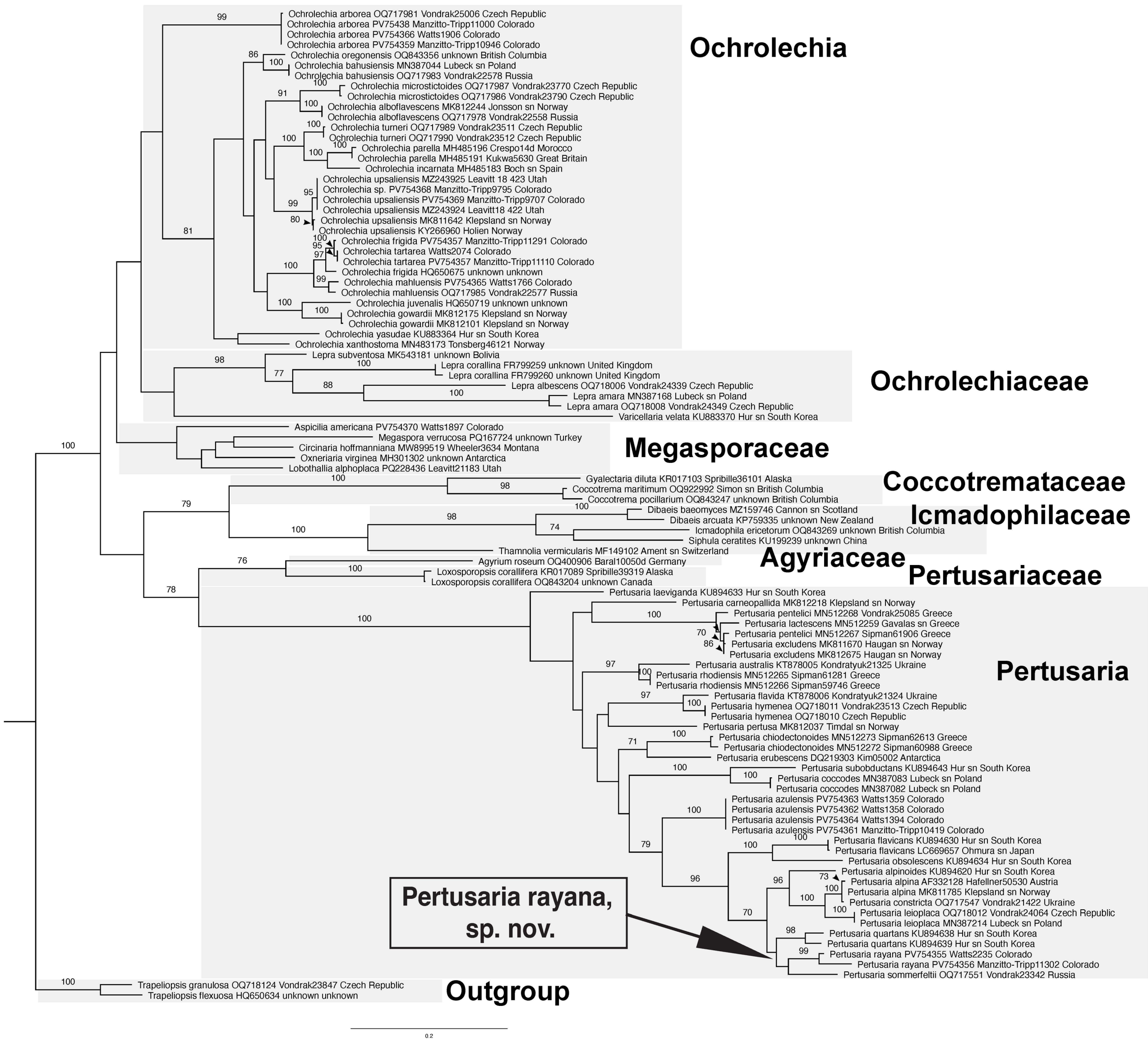

FIGURE 5. Phylogenetic analysis of *Pertusaria rayana* using Maximum Likelihood methods to resolve evolutionary relationship of new species to close relatives. Labels of terminals include taxon name, collector (lead collector, only) and collection number, GenBank reference number, and geographical origin of sample (where known).

Notes. *Pertusaria rayana* (Figure 6) is a charismatic and easily recognizable species in Colorado by its pale yellow, dense, long, and coralloid isidia. The isidia of *Pertusaria rayana* are more yellow than the underlying thallus as a function of uneven pigment distribution, a phenomenon also characteristic for *Lepraria saliersiae* wherein the margins are far more pigmented than central portions of the thallus. Of isidiate *Pertusaria* in North America, *Pertusaria rayana* is readily differentiable by its substrate and chemistry, making it difficult to confuse for any congeneric species. Chemically, the most similar species is *P. flavocorallina* Coppins & Muhr, however that species lacks atranorin and has a K+ violet pigment at the apices of its isidia (Gilbert & Coppins 1992). Furthermore, *P. flavocaroallina* is known from maritime rather than continental habitats. Additional features that help differentiate *Pertusaria rayana* from other isidiate species in western North America can be found in the key below (Part 2). It is possible the new species could be confused for a few other isidiate crustose lichens in other genera. Namely, some could confuse *Pertusaria rayana* for *Loxosporopsis corallifera* Brodo, Henssen & Imshaug, which differs by its UV+ white reaction owing to the presence of divaricatic acid in the thallus, its heavily contorted isidia, and its corticolous habit (Brodo & Henssen 1995). *Lepra corallina* (L.) Hafellner, a primarily European species, is similarly saxicolous on vertical rock faces like *Pertusaria rayana*, but the former produces thamnolic acid and is therefore P+ yellow-orange and UV- (Tønsberg 1992).

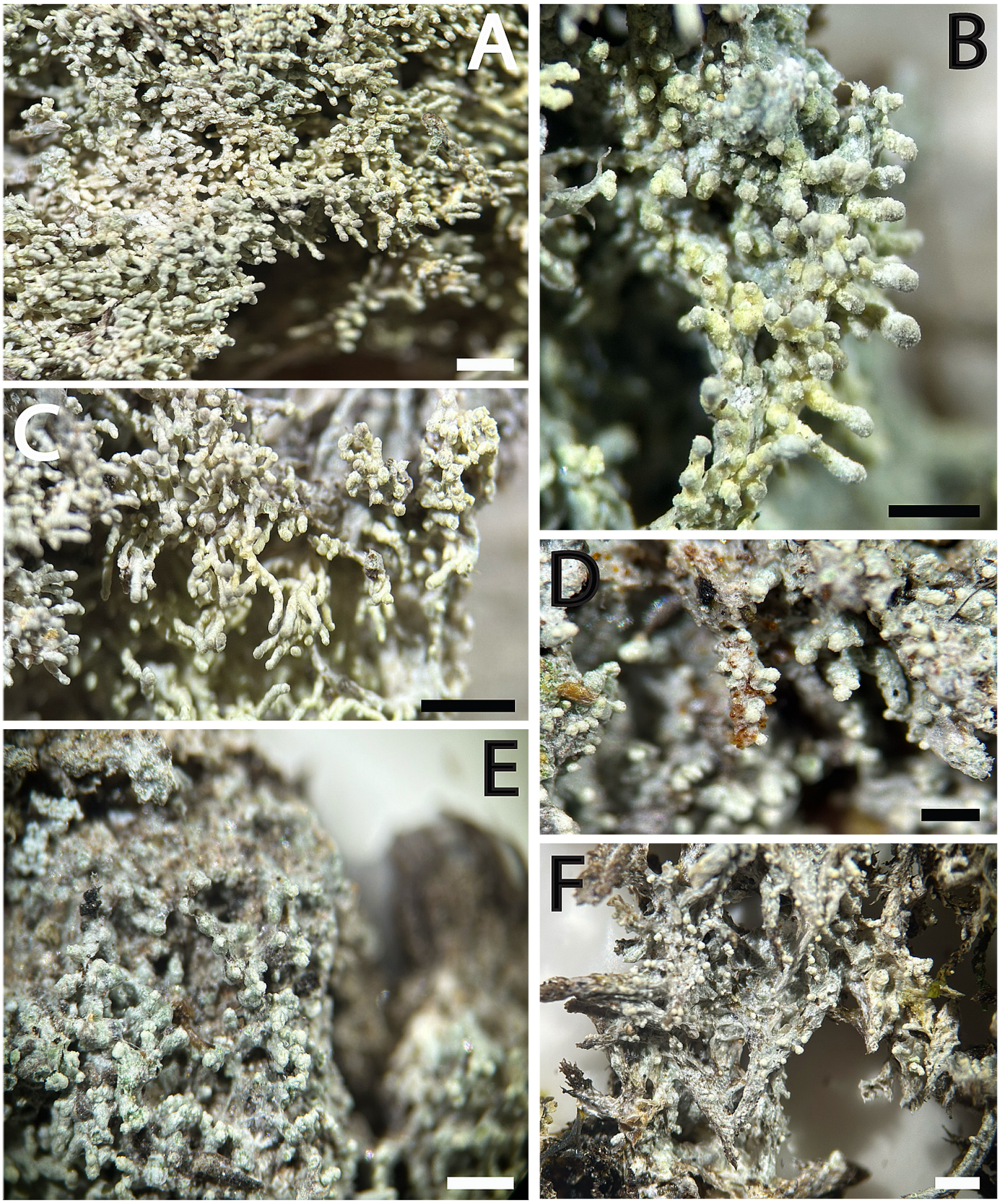

FIGURE 6. Macromorphology of *Pertusaria rayana*. A, B, & C: Slender, coralloid, primarily unbranced (to once-branced) isidia, which are typically dense on mature specimens and cover th majority of the thallus surface, the isidia characteristically pale yellow on mature specimens to grayish-white on less mature specimens. D, E, & F: Thin, continuous, smooth and shiny whitish-gray thallus bearing immature isidia. Scale Bars: A=1mm, B=1mm, C=1mm, D=0.5mm, E=0.5mm, F=0.5mm. Photos taken from *J. Watts & E. Manzitto-Tripp 2235, E. Manzitto-Tripp 11300,* and *E. Manzitto-Tripp 11302.*

Our phylogenetic analyses strongly support the reciprocal monophyly of our two accessions of *Pertusaria rayana* (99% BS). The clade containing both accessions of the new species was resolved as sister to *P. sommerfeltii* (Flörke ex Sommerf.) Fr., which is a widespread, sexually reproducing species, but without support.

Conservation Assessment. *Pertusaria rayana* is here assessed as Critically Endangered (CR) under IUCN criterion D because of its highly restricted occurrence in humid, riparian upper montane/lower subalpine forests where only ~10 mature individuals have been observed, making the estimated total population size fewer than 50 individuals. Although future fieldwork will surely result in the discovery of additional populations of this remarkable new species, it nonetheless is likely to be rare to very rare, as the authors have searched numerous other watersheds (with seemingly suitable habitat) for individuals, but without success.

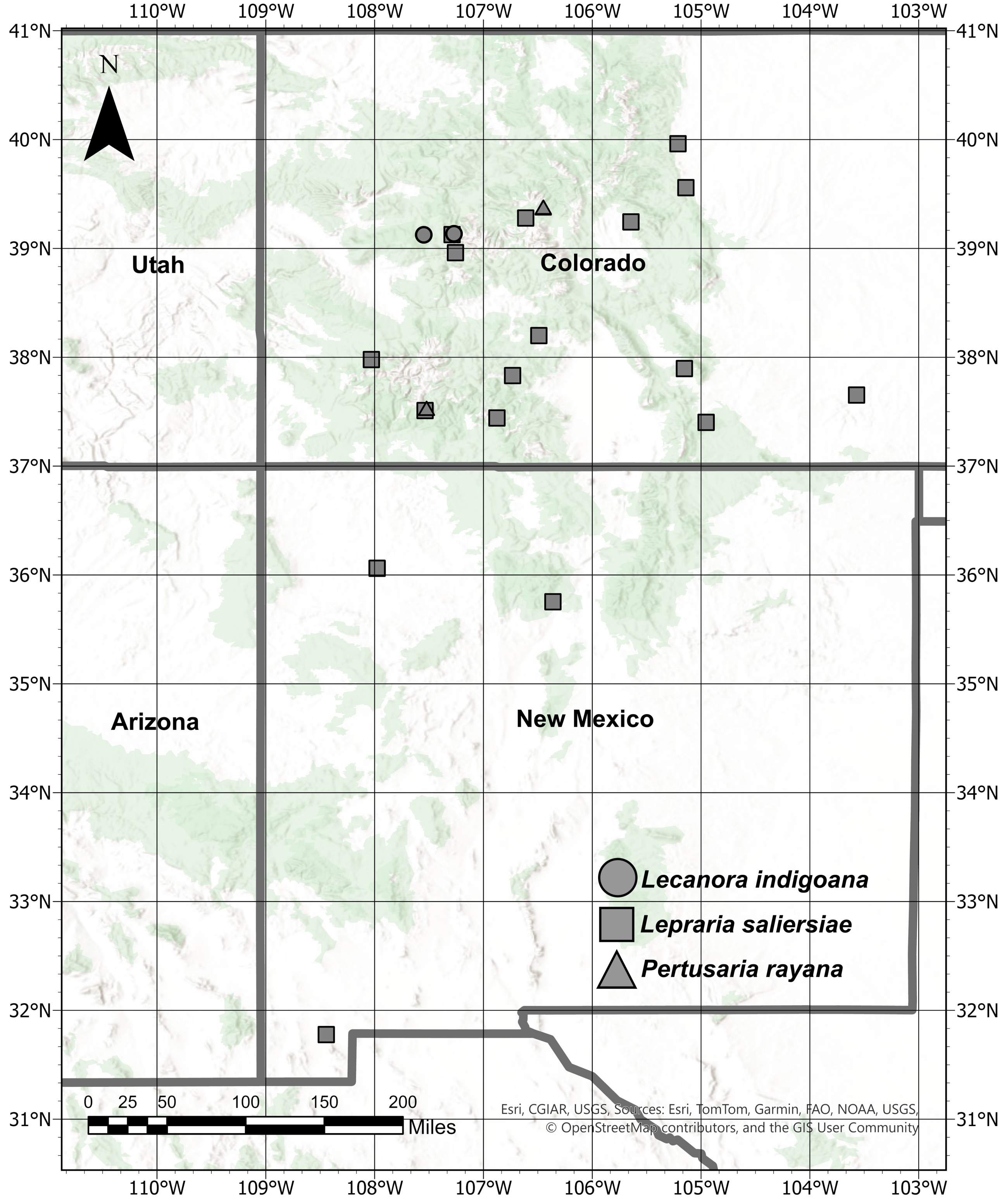

FIGURE 7. Distribution map of collections of *Lecanora indigoana* (solid circles), *Lepraria saliersiae* (solid squares), and *Pertusaria rayana* (solid triangles), so far known from Colorado and New Mexico, North America. We expect continued fieldwork / inventory efforts of the lichens of the southern Rocky Mountains, combined with revision of existing herbarium materials, will yield broader distributions for all three species.

Additional Specimens Examined. USA. Colorado. **Eagle County.** White River National Forest, Holy Cross Wilderness, middle fork of Homeskate Creek, rich, north-facing slopes amongst subalpine forest dominated by *Abies lasiocarpa* and *Populus tremuloides*, saxicolous on shaded rocks, 9796 ft. elev., 39.38102 -106.45019, *E. Manzitto-Tripp 11,300* (COLO!). White River National Forest, Holy Cross Wilderness, middle fork of Homeskate Creek, rich, north-facing slopes amongst subalpine forest dominated by *Abies lasiocarpa* and *Populus tremuloides*, 39.38801 -106.44980, 9,441 ft. elev. *E. Manzitto-Tripp 11,302* (COLO!). **La Plata County.** San Juan National Forest, Weminuche Wilderness, Vallecito Creek Trail (529) between the second and first bridges along east banks of Vallecito Creek, spruce bark beetle-damaged montane forest in a large valley with abundant granitic cliffs, canopy of mostly dead *Picea engelmannii*, *Pseudostuga menziesii*, and the occasional *Abies concolor*, understory lush with *Rubus* spp., *Lonicera involucrata*, *Prunus americana*, and *Quercus gambelii*, muscicolous over nearly vertical rock ~10 m above creek, 37.540005, -107.523342, 8705 ft. elev., *J. Watts & E. Manzitto-Tripp 4103* (COLO!).

PART 2: Dichotomous Keys to Aid in the Identification of *Lecanora indigoana*, *Lepraria saliersiae*, and *Pertusaria rayana*

KEY 1: Key to corticolous and lignicolous *Lecanora* s.l. lacking atranorin and having distinctly pruinose apothecial disks in the western United States

1a. Thallus and/or apothecial margin yellowish green, containing usnic or isousnic acid, epihymenium granular, usually ochre (rarely with blackish green pigment), of POL+ granules, these soluble in K (varia, saligna, symmicta groups) 2
1b. Thallus and apothecial margin color various, not distinctly yellowish green, epihymenium usually granular and variously pigmented, solubility various (dispersa group) 15
2a. Thallus and/or apothecial margins P+Y or P+O 3
2b. Thallus and/or apothecial margins P- 5
3a. Thallus P+O, fumarprotocetraric acid present.. ***L. austrocalifornica*** Lendemer & K. Knudsen
3b. Thallus and/or apothecial margins P+Y 4
4a. Apothecia large (~0.5–0.8 mm in diameter), amphithecial cortex lacking above, ~100µm below, spores ellipsoid (10–12 × ~5 µm), usually on wood.. ***L. varia*** (Hoffm.) Ach.
4b. Apothecia small (rarely large than 0.6 mm in diameter), amphithecial cortex distinct above, ~25–65µm below, spores broadly ellipsoid (6.0–9.0 × 6.0–7.5 µm), usually on conifer twigs.. ***L.densa*** (Śliva & Wetm.) Printzen
5a. Thallus C+O, containing xanthones, amphithecium ecorticate, distribution maritime..6
5b. Thallus C-, lacking xanthones, amphithecium usually corticate, distribution various..8
6a. Most spores shorter than 10 µm .... ***L. substrobilina*** Printzen
6b. Most spores longer than 10 µm 7
7a. Most spores wider than 4 µm, 2 to 3 times longer than wide, maritime California .... ***L. confusa*** Almb.
7b. Most spores narrower than 4 µm, 3 to 5 times longer than wide, mostly Baja Pennisula, rare in southern California .... ***L. perconfusa*** Printzen
8a. Amphithecium ecorticate.. ***L. perconfusa*** Printzen (xanthone deficient chemotypes)
8b. Amphithecium corticate 9
9a. Most spores narrow (2.8–3.7 µm wide)..10
9b. Most spores wide (3.5–6.5 µm wide), apothecial margins not excluded 11
10a. Apothecial margin becoming excluded or excluded from young.. ***L. latens*** Printzen
10b. Apothecial margin prominent when young, becoming level with base .... ***L. subintricata*** (Nyl.) Th. Fr.
11a. Most spores shorter than 9.5 µm, mature apothecia large (0.5–0.9 mm), becoming conspicuously constricted at the base and disks convex with age .... ***L. laxa*** (Śliva & Wetm.) Printzen
11b. Most spores longer than 9.5 µm, mature apothecia smaller, not conspicuously constricted at the base and disks plane 11
12a. Amphithecial cortex distinctly thickened at base (20–40–(60) µm) 13
12b. Amphithecial cortex uniformly thickened (10–20 µm)..14
13a. Spores narrowly ellipsoid, more than two times longer than wide, most spores longer than 12 µm, epihymenium often with a blackish green pigment.. ***L. mughicola*** Nyl.
13b. Spores broadly ellipsoid, less than two times longer than wide, most spores shorter than 12 µm, epihymenium granular, lacking blackish green pigment.. ***L. coniferarum*** Printzen
14a. Most spores longer than 12 µm, epihymenium often with a blackish green pigment.. ***L. mughicola*** Nyl.
14b. Most spores shorter than 12 µm, epihymenium granular, lacking blackish green pigment .... ***L. albellula*** Nyl.
15a. Thallus distinct, areolate, usually subsquamulose/lobate..16
15b. Thallus indistinct, lacking, or of irregularly bullate areoles..17
16a. Usually on calcareous rocks, rarely on bark or wood, thallus yellowish or cream colored, pruinose, epihymenium yellow or brown, granular, disks orange.. ***L. albescens*** (Hoffm.) Flörke
16b. Only known from bark, thallus light blue, epruinose, epihymenium brownish gray, granular, containing a blue pigment, disks grayish blue .... ***L. indigoana*** E. Tripp & J. Watts *sp. nov.*
17a. Thallus of irregularly bullate areoles..18
17b. Thallus indistinct or lacking..19
18a. Epihymenium with a blue pigment, hymenium tall (>60 µm), inspersed with oil droplets..

....***L. indigoana*** E. Tripp & J. Watts, *sp. nov.*
18b. Epihymenium lacking blue pigment, hymenium short (<60 µm), not inspised with oil droplets.................................***L. juniperina***
19a. Amphithecial cortex expanded basally to 60–100 µm thick, apothecial disk heavily pruinose.....................................***L. wetmorei***
19b. Amphithecial cortex <60 µm at base, apothecial disk lightly to heavily pruinose..***L. hagenii***

KEY 2: Key to *Lepraria* in Colorado (excluding fruticose forms):

1a. Thallus aggregate...2
1b. Thallus placodioid 6
2a. Thallus shades of white-blue-gray...3
2b. Thallus shades of yellow-green 5
3a. Thallus with long, persistent, projecting hyphae persistent at maturity, primarily on mosses and soil, K+ yellow, C-, KC-, P-, UV- (atranorin, nephrosteranic acid)... ***L. rigidula*** (B. de Lesd.) Diederich
3b. Thallus lacking long, projecting hyphae persistent at maturity, chemistry various 4
4a. Thallus primarily mound forming, often consisting of (at least in part) large, pseudocorticate granules that exceed 1 mm in diameter, almost invariably on alpine soil where it sometimes forms monodominant stands, K- or K+ yellow, C-, KC-, P- or P+ yellow, UV- (atranorin, roccellic/angardianic acid, porphyrilic acid, fatty acids).............................. ***L. alpina*** (B. de Lesd.) Tretiach & Baruffo
4b. Thallus never mound-forming, lacking large, pseudocorticate granules that exceed 1 mm in diameter, primarily in lower montane to subalpine habitats (rarely in the alpine), on mosses, soil, and non-calcareous rocks, K+ yellow or K-, C-, KC- or KC+ red, P+ yellow or orange, UV- (chemistry various, but always P+) ....***L. neglecta*** (Nyl.) Erichsen
5a. Thallus with distinct yellowish hue, uncommon on bark, soil, mosses, and rocks, K- or K+ red, C-, KC-, P+ orange, UV- (dibenzofurans, oxypannaric acid-2-methylester) ....***L. diffusa*** (J.R. Laundon) Kukwa
5b. Thallus with greenish hue, widespread on on non-calcareous rocks, soil, mosses, lignum, and tree bases, K+ yellow or K+ yellow to red, C-, KC-, P+ yellow or P+ orange (atranorin, zeorin, +/- stictic acid aggregate, roccellic/angardianic acid, salazinic acid) ... . ***L. elobata*** Tønsberg
6a. Thallus KC+ pink or red, on soils, mosses, and trees, sometimes forming large stands especially under rock overhangs, K-, C-, P+ yellow or orange, UV- (alectorialic acid, +/- barbatolic acid, +/- protocetraric acid) ....***L. eburnea*** J.R. Laundon (*take care to carefullyy find placodioid portions of the thallus under magnification, which can sometimes superficially appear as aggregate and therefore could be mistaken for Lepraria elobata)
6b. Thallus KC- 7
7a. Thallus (entirely) shades of white-blue-gray, never with yellow to green portions, with highly distinctive rounded margins and raised lip, on non-calcareous rocks, conifers, and hardwoods, K+ yellow, C-, KC-, P+ orange, P+ red, or P-, UV- (atranorin, roccellic/angardianic acid, +/- protocetraric acid).. ***L. normandinoides*** Lendemer & R.C. Harris
7b. Thallus shades of yellow to green, at least in part (thallus often gray to white in center but always yellow to green elsewhere, particularly along the margins)...8
8a. Thallus often rosette forming, with highly distinctive rounded, crisped margins that have raised lips ascending well above the primary plane of the thallus (aff. L. normandinoides), these margins distinctively a sunny yellow in color, occuring over a wide variety of substrates but preferentially on soft substrates (e.g., soft rocks such as sandstones and over mosses), in exposed, arid microhabitats but also in more sheltered environments, K+ yellow, C-, KC-, P+ orange to red, UV- (atranorin, roccellic/angardianic acid, pannaric acid 6-methyl ester, pannaric acid, unknown dibenzofuran A, and occasionally pannaric acid 2-methyl ester.......... ....***L. saliersiae*** E. Tripp & J. Watts, *sp. nov.*
8b. Thallus rarely rosette forming, lacking raised lips, thallus and margins only inconspicuously faint yellow at most, more commonly with a greenish to bluish hue, growing on wide variety of substrates in moist to drier habitats and from forested to urban ecosystems, K+ yellow-brown, C-, KC-, P+ orange, UV-, (atranorin, zeorin, stictic acid aggregate, +/- roccellic/angardianic acid)................... ....***L. finkii*** (B. de Lesd.) R.C. Harris

KEY 3: Key to isidiate *Pertusaria* in the western United States

1a. True isidia absent, thallus usually fertile; isidia-like papillae present; on mosses in arctic tundra... ....***P. bryontha*** (Ach.) Nyl.
1b. True isidia present, thallus often sterile; substrate various, distribution various 2
2a. All spot tests negative; distribution mostly eastern on moss and bark...***P. globularis*** (Ach.) Tuck.
2b. At least one spot test positive; distribution various...3
3a. Thallus K+ yellow to red, producing norstictic acid 4
3b. Thallus K test otherwise, lacking norstictic acid...5
4a. Isidia constricted at the base, subglobose to cylindrical, with enlarged, browned tips; usually on rock; containing connorstictic and subnorstictic acids as minor components ....***P. pseudocorallina*** (Lilj.) Arnold
4b. Isidia not constricted at the base, globose to rarely cylindrical, with browned tips; usually on bark; lacking accessory metabolites ....***P. coccodes*** (Ach.) Nyl.
5a. Thallus P+ yellow to red-orange, C-, UV+ white, containing fumarprotocetraric acid; on soil or plant detritus............................... ....***P. oculata*** (Dickson) Th. Fr.
5b. Thallus P- or P+ faint yellow, C+ orange, UV+ orange, containing thiophaninic acid; substrate various 6
6a. Thallus K-, lacking atranorin, isidia apices often darkened and therefore K+ violet; distribution maritime on bark......................... .... ***P. flavocorallina*** Coppins & Muhr
6b. Thallus K+ faint yellow, containing atranorin, isidia apices not darkened and therefore not K+ violet; distribution interior on mosses and rock.. ***P. rayana*** J. Watts & E. Tripp, *sp. nov.*

Part 3: NOMENCLATURAL INNOVATIONS

Lecanora gigantea (R. Mamut & T. Payzula) E. Tripp & J. Watts, ***comb. nov.***

Basionym: *Myriolecis gigantea* R. Mamut & T. Payzula, Payzulla & Mamut, *The Bryologist* 128: 22–24.
Mycobank #. 860123

Lecanora planata E. Tripp & J. Watts, ***comb. et nom. nov.***

Basionym: *Myriolecis complanata* R. Mamut & T. Payzula, Payzulla & Mamut, *The Bryologist* 128: 20–22. [The epithet "complanata" is already occupied in *Lecanora* (*L. companata* Körb.) and as such, a new epithet is needed; we here propose the "planta" in attempt to retain the intentions of the original etymology, which was in reference to its apothecia margins that are plane with the discs].
Mycobank #. 860124

Conclusions & Future Prospects

The paucity of lichenology (and lichenologists) in North America and indeed in many places worldwide is the direct result of a lack of formal education in the subject in classrooms. Very few institutions anywhere in the Western Hemisphere offer a single course on lichens, whether it be at the grade school, high school, or university level. The outlook is slightly better in portions Europe where lichens have been a part of formal education for centuries (Zedda 2023), such as with "herbaria generalis" wherein taxonomists would commonly collect lichen (and bryophyte) materials, identify their specimens, then sell these at affordable prices to local schools to help augment scientific education particularly amongst younger schoolchildren. This global deficiency in lichen education translates directly to a 21st Century wherein lichens are among the least understood macro-organisms from a biodiversity perspective and, concurrently, from a conservation planning and action standpoint (Allen *et al.* 2019; Wrobleski *et al.* 2023). Yet, natural history collections and the intellectual resources they house remain crucial tools to understanding the biological processes that shape our modern world (Boldgiv *et al.* 2024).

As a result, both (1) lichen biodiversity discovery and (2) continued investment in capacity building, i.e., training a younger generation of lichenologists, are critically time sensitive, especially in an era of mass destruction of native habitats. Landscapes worldwide and especially those in western North America (WNA) are in the midst of a massive and unprecedented reworking of native niches, much of this human-mediated (Knapp *et al.* 2002; Leu *et al.* 2008; Haddad *et al.* 2015). Never-before have such marked ecological transformations been recorded over such short time spans as in the last century (Dirzo *et al.*, 2014). Taxa with already narrow niches such as those in the southern Rocky Mountains face exacerbating threats including climate change, extensive forest mortality from disease outbreaks and unnatural fire cycles, increasing demands on resources such as water and petroleum extraction, non-native species invasions, and habitat loss associated with agriculture and development (Schoennagel *et al.* 2004; Loarie *et al.* 2009; Jiang 2013; Rondeau *et al.* 2013; Diaz *et al.* 2014; Handwerk *et al.* 2014; Funk *et al.* 2014; Munson *et al.* 2015; Calder *et al.* 2015). The impacts on populations are severe and include drastic population size reductions to complete population or species extirpations (Lesica *et al.* 2004; Tripp 2004; Locklear 2013). In the absence of a capable and invested next generation of lichenologists and conservation biologists, these trends are only predicted to intensify. New and/or renewed efforts to introduce the wonderful (downright magnificent) world of lichenology into our classrooms, early and often, is a first step towards broader understanding of and appreciation for these remarkable organisms.

Acknowledgements. The authors acknowledge that much of Colorado and the surrounding southern Rocky Mountains are the traditional and ancestral homelands of the Hinono'ei (Arapaho), Tsistsistas (Cyenne), Nuuchu (Ute) Nations, among other peoples. We recognize the Indigenous peoples as original stewards of this land and are honored to research the incredible biodiversity that lies therein. We are indebted to Emily Saliers and Amy Ray of *Indigo Girls* for tireless decades of environmental activism (and lyrical contributions), which have so inspired millions of listeners. We acknowledge Klara Scharnagl, a wonderful editor and colleague, and are grateful for her help on this manuscript in particular. We are grateful to the following individuals for kindly scanning and sharing images of type specimens with us, which facilitated this research: Tim Whitfeld (MIN), Gothamie Weerakoon (BM), and Andreas Beck (M). We thank our Colorado lichen colleague Seth Raynor for his extensive communication and input on these new species and many others within the southern Rocky Mountain lichen biota. We are grateful to the following Collections Managers and staff at the University of Colorado Herbarium (COLO) for their assistance with specimen curation and support of this project: Dina Clark, James Ryan, Amber Horning, and the late Tim Hogan. We thank staff members at the United States National Forest Service (Region 2), Bureau of Land Management (in particular, Carol Dawson), and City of Boulder's Open Space and Mountain Parks (in particular, Ann Lezberg and Lynn Riedell) for their unwavering support of our inventory of Colorado lichens, including their granting of fieldwork permits. Finally, we are grateful to several organizations who have supported our fieldwork and subsequent discoveries, financially: Indianapolis Zoo, Indian Peaks Wilderness Alliance, Boulder County Nature Association, Colorado Native Plant Society, Botanical Society of America, American Society of Plant Taxonomists, the International Association for Plant Taxonomy, and University of Colorado's Museum of Natural History along with Department of Ecology and Evolutionary Biology.

Author Contributions. EMT conceived the project. EMT and JLW conducted new fieldwork to advanced discoveries. EMT and JLW generated and analyzed morphological, chemical, anatomical, and molecular data presented here. EMT and JLW wrote and revised the manuscript.

Data Availability. Genetic data are available publicly at https://www.ncbi.nlm.nih.gov/. Genbank accession numbers are provided in the figures.

Literature Cited

Allen, J.A., McMullin, R.T., Tripp, E.A. & Lendemer, J.C. (2019) Lichen conservation in North America: a review of current practices and research in Canada and the United States. *Biodiversity and Conservation* 28: 3103–3138.
https://doi.org/10.1007/s10531-019-01827-3

Anderson, R.A. (1962) The lichen flora of the Dakota Sandstone in north-central Colorado. *The Bryologist* 65: 242–261.
https://doi.org/10.1639/0007-2745(1962)65[242:TLFOTD]2.0.CO;2

Anderson, R.A. (1964) *The genus Lecidea in Rocky Mountain National Park.* Unpublished Ph.D. Thesis, University of Colorado-Boulder.

Anderson, R.A. & Carmer, M.B. (1974) Additions to the lichen flora of Colorado. *The Bryologist* 77: 216–223.
https://doi.org/10.2307/3241559

Asplund, J. & Wardle, D.A. (2017) How lichens impact on a terrestrial community and ecosystem properties. *Biological Reviews* 92: 1720–1738.
https://doi.org/10.1111/brv.12305

Boldgiv, B. *et al.* (2024) Global natural history infrastructure requires international solidarity, support, and investment in local capacity. *Proceedings of the National Academy of Sciences of the United States of America* 122: e2411232122.
https://doi.org/10.1073/pnas.2411232122

Brodo, I.M. (1991) Studies in the lichen genus *Ochrolechia*. 2. Corticolous species of North America. *Canadian Journal of Botany* 69: 733–772.
https://doi.org/10.1139/b91-098

Brodo, I.M. & Henssen, A. (1995) A new isidiate crustose lichen in northwestern North America. *Bibliotheca Lichenologica* 58: 27–41.

Brodo, I.M. & Lendemer, J.C. (2012) On the perplexing variability of reproductive modes in the genus *Ochrolechia*: notes on *O. africana* and *O. arborea* in eastern North America. *Opuscula Philolichenum* 11: 120–134.
https://doi.org/10.5962/p.382089

Calder, J.W., Parker, D., Stopka, C.J., Jiménez-Moreno, G. & Shuman, B.N. (2015) Medieval warming initiated exceptionally large wildfire outbreaks in the Rocky Mountains. *Proceedings of the National Academy of Sciences of the United States of America* 112: 13261–13266.
https://doi.org/10.1073/pnas.1500796112

Carmer, M.B. (1975) Corticolous lichens of riparian deciduous trees in the central Front Range of Colorado. *The Bryologist* 78: 44–56.
https://doi.org/10.2307/3242106

Colorado Natural Heritage Program (CNHP) (2011) *The State of Colorado's Biodiversity*. Colorado State University, Fort Collins, Colorado, 209 pp.

Culberson, C.F. (1972) Improved conditions and new data for identification of lichyen products by standardized thin-layer chromatographic method. *Journal of Chromatography A* 72: 113–125.
https://doi.org/10.1016/0021-9673(72)80013-X

Culberson, C.F. & Kristinsson, H.-D. (1970) A standardized method for the identification of lichen products. *Journal of Chromatography A* 46: 85–93.

https://doi.org/10.1016/S0021-9673(00)83967-9
Díaz, H.F., Bradley, R.S. & Ning, L. (2014) Climatic changes in mountain regions of the American Cordillera and the tropics: historical changes and future outlook. *Arctic and Alpine Research* 46: 1–9.
https://doi.org/10.1657/1938-4246-46.4.735
Díaz, V. & Manzitto-Tripp, E.A. (2023) A synopsis of the yellow-green, usnic-acid producing *Xanthoparmelia* in Colorado. *Opuscula Philolichenum* 22: 1–40.
https://doi.org/10.5962/p.388458
Dirzo, R., Young, H.S., Galetti, M., Ceballos, G., Isaac, N.J.B. & Collen, B. (2014) Defaunation in the Anthropocene. *Science* 345: 401–406.
https://doi.org/10.1126/science.1251817
Dodds, W.K., Gido, K., Whiles, M.R., Fritz, K.M. & Matthews, W.J. (2004) Life on the edge: the ecology of Great Plains prairie streams. *BioScience* 54: 205–216.
https://doi.org/10.1641/0006-3568(2004)054[0205:LOTETE]2.0.CO;2
Doyle, J.J. & Doyle, J.L. (1987) A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochemical Bulletin* 10: 11–15.
Edler, D., Klein, J., Antonelli, A. & Silvestro, D. (2020) raxmlGUI 2.0: a graphical interface and toolkit for phylogenetic analysis using RAxML. *Methods in Ecology and Evolution* 12: 373–377.
https://doi.org/10.1111/2041-210X.13512
Esslinger, T.L. (2021) North American lichen checklist, Version #24. *Opuscula Philolichenum* 20: 100–394.
https://doi.org/10.5962/p.388279
Flakus, A., Elix, J.A., Rodriguez, P. & Kukwa, M. (2011) New species and records of *Lepraria* (Stereocaulaceae, lichenized Ascomycota) from South America. *The Lichenologist* 43: 57–66.
https://doi.org/10.1017/S0024282910000502
Flock, J.W. (1978) Lichen-bryophyte distribution along a snow-covered-soil-moisture gradient at Niwot Ridge, Colorado. *Arctic and Alpine Research* 10: 31–47.
https://doi.org/10.1080/00040851.1978.12003942
Funk, J., Saunders, S., Sanford, T., Easley, T. & Markham, A. (2014) *Rocky Mountain Forests at Risk: Confronting Climate-Driven Impacts from Insects, Wildfires, Heat, and Drought*. Union of Concerned Scientists and the Rocky Mountain Climate Organization, Cambridge, Massachusetts.
Gaya, E., Fernández-Brime, S., Vargas, R., Lachlan, R.F., Gueidan, C., Ramírez-Mejía, M. & Lutzoni, F. (2015) The adaptive radiation of lichen-forming *Teloschistaceae* is associated with sunscreening pigments and a bark-to-rock substrate shift. *Proceedings of the National Academy of Sciences of the United States of America* 112: 11600–11605.
https://doi.org/10.1073/pnas.1507072112
Gilbert, O.L. & Coppins, B.J. (1992) The lichens of Caenlochan, Angus. *The Lichenologist* 24: 143–163.
https://doi.org/10.1017/S0024282900500061
Golubiewski, N.E. (2006) Urbanization increases grassland carbon pools: effects of landscaping in Colorado's Front Range. *Ecological Applications* 16: 555–571.
https://doi.org/10.1890/1051-0761(2006)016[0555:UIGCPE]2.0.CO;2
Guzow-Krzemińska, B., Sérusiaux, E., van den Boom, P.P.G., Brand, A.M., Launis, A., Łubek, A. & Kukwa, M. (2019) Understanding the evolution of phenotypical characters in the *Micarea prasina* group (Pilocarpaceae) and descriptions of six new species within the group. *MycoKeys* 57: 1–30.
https://doi.org/10.3897/mycokeys.57.33267
Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A., Holt, R.D., Lovejoy, T.E., Sexton, J.O., Austin, M.P., Collins, C.D., Cook, W.M., Damschen, E.I., Ewers, R.M., Foster, B.L., Jenkins, C.N., King, A.J., Laurance, W.F., Levey, D.J., Margules, C.R., Melbourne, B.A., Nicholls, A.O., Orrock, J.L., Song, D.X. & Townshend, J.R. (2015) Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* 1: e1500052.
https://doi.org/10.1126/sciadv.1500052
Handwerk, J., Kuhn, B., Rondeau, R. & Grunau, L. (2014) *Climate Change Vulnerability Assessment for Rare Plants of the San Juan Region of Colorado*. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado, 156 pp.
Honegger, R. (1991) Functional aspects of the lichen symbiosis. *Annual Review of Plant Physiology and Plant Molecular Biology* 42: 553–578.
https://doi.org/10.1146/annurev.pp.42.060191.003005
Howard, G.E. (1970) The lichen genus *Ochrolechia* in North America north of Mexico. *The Bryologist* 73: 93–130.
https://doi.org/10.2307/3241590

IUCN Standards and Petitions Committee (2024) *Guidelines for Using the IUCN Red List Categories and Criteria*. Version 16. Prepared by the Standards and Petitions Committee. [https://www.iucnredlist.org/documents/RedListGuidelines.pdf]

Jiang, X., Rauscher, S.A., Ringler, T.D., Lawrence, D.M., Williams, A.P., Allen, C.D., Steiner, A.L., Cai, D.M. & McDowell, N.G. (2013) Projected future changes in vegetation in western North America in the twenty-first century. *Journal of Climate* 26: 3671–3687. https://doi.org/10.1175/JCLI-D-12-00430.1

Knapp, A.K., Fay, P.A., Blair, J.M., Collins, S.L., Smith, M.D., Carlisle, J.D., Harper, C.W., Danner, B.T., Lett, M.S. & McCarron, J.K. (2002) Rainfall variability, carbon cycling, and plant species diversity in a mesic grassland. *Science* 298: 2202–2205. https://doi.org/10.1126/science.1076347

Kukwa, M. (2011) *The Lichen Genus Ochrolechia in Europe*. Fundacja Rozwoju Uniwersytetu Gdańskiego, Gdańsk, 309 pp.

Laundon, J.R. (1989) The species of *Leproloma*—the name for the *Lepraria membranacea* group. *The Lichenologist* 21: 1–22. https://doi.org/10.1017/S0024282989000034

Lendemer, J.C. (2013) A monograph of the crustose members of the genus *Lepraria* Ach. s.str. (Stereocaulaceae, lichenized Ascomycetes) in North America north of Mexico. *Opuscula Philolichenum* 12: 27–141. https://doi.org/10.5962/p.382102

Lesica, P. & McCune, B. (2004) Decline of arctic-alpine plants at the southern margin of their range following a decade of climatic warming. *Journal of Vegetation Science* 15: 679–690. https://doi.org/10.1111/j.1654-1103.2004.tb02310.x

Leu, M., Hanser, S.E. & Knick, S.T. (2008) The human footprint in the West: a large scale analysis of anthropogenic impacts. *Ecological Applications* 18: 1119–1139. https://doi.org/10.1890/07-0480.1

Loarie, S.R., Duffy, P.B., Hamilton, H., Asner, G.P., Field, C.B. & Ackerly, D.D. (2009) The velocity of climate change. *Nature* 462: 1052–1055. https://doi.org/10.1038/nature08649

Locklear, J.H. (2013) Taxonomic identity and historical accounts of *Dalea cylindriceps* (Fabaceae), a species of conservation concern in the Great Plains (U.S.A.). *Journal of the Botanical Research Institute of Texas* 7: 879–890.

Loeffelhoz, J.D., Raynor, S.J., Sánchez-Moreno, S., Momeni, S. & Manzitto-Tripp, E. (2025) *Tardigrada* and *Nematoda* associations with lichen and bryophyte habitats from southwest Wisconsin state parks, universities, and private land. *Biogeographia* 40: a045. https://doi.org/10.21426/B6.40056

Lumbsch, H.T., Plümper, M., Guderly, R. & Feige, G.B. (1997) The corticolous species of *Lecanora* sensu stricto with pruinose apothecial discs. *Symbolae Botanicae Upsaliensis* 32: 131–161.

Manzitto-Tripp, E.A., Agabani, R. & McMullin, R.T. (2018) New and noteworthy reports of Colorado lichens and lichen allies, 1. *Opuscula Philolichenum* 17: 362–367. https://doi.org/10.5962/p.386182

Manzitto-Tripp, E.A., Watts, J.L. & Raynor, S.J. (2025 [in press]) New and noteworthy reports of lichens and allied fungi to Colorado, including descriptions of two species new to science. *Journal of the Botanical Research Institute of Texas*.

Manzitto-Tripp, E.A. & Watts, J.L. (2025) *Ochrolechia raynori*, a New Lichen Species from the Southern Rocky Mountains (Colorado, USA) and Key to Asexually Reproducing *Ochrolechia* in Western North America. *Wild* 2 (3): 28. https://doi.org/10.3390/wild2030028

McCune, B. (2017) *Microlichens of the Pacific Northwest*, Vols. 1–2. Blueberry Media, Corvallis, OR, USA.

Munson, S.M. & Sher, A.A. (2015) Long-term shifts in the phenology of rare and endemic Rocky Mountain plants. *American Journal of Botany* 102: 1268–1276. https://doi.org/10.3732/ajb.1500079

Nash, T.H., Ryan, B., Gries, C. & Bungartz, F. (2002) *Lichen Flora of the Greater Sonoran Desert*, Vol. 1. Lichens Unlimited, Arizona State University, Tempe, AZ.

Nash, T.H., Ryan, B., Gries, C. & Bungartz, F. (2004) *Lichen Flora of the Greater Sonoran Desert*, Vol. 2. Lichens Unlimited, Arizona State University, Tempe, AZ.

Nash, T.H., Ryan, B., Gries, C. & Bungartz, F. (2007) *Lichen Flora of the Greater Sonoran Desert*, Vol. 3. Lichens Unlimited, Arizona State University, Tempe, AZ.

Payzulla, T. & Mamut, R. (2025) New species and new records of the genus *Lecanora* (Lecanoraceae, lichenized Ascomycota) from China. *The Bryologist* 128: 16–29. https://doi.org/10.1639/0007-2745-128-1.016

Printzen, C. (2001) Corticolous and lignicolous species of *Lecanora* (Lecanoraceae, Lecanorales) with usnic or isousnic acid in the Sonoran Desert region. *The Bryologist* 103: 382–409. https://doi.org/10.1639/0007-2745(2001)104[0382:CALSOL]2.0.CO;2

Rambaut, A. (2010) *FigTree v1.4.4*. Institute of Evolutionary Biology, University of Edinburgh, U.K. [http://tree.bio.ed.ac.uk/software/figtree]

Ray, A. & Saliers, E. (2005) *Rarities, "Point Hope"*. Producer: Various.

Raynor, S.J., Kesler, J., Allen, J.R. & Manzitto-Tripp, E.A. (2023) New and noteworthy reports on Colorado lichens and lichen allies, 2: *Biatoropsis hirtae* and *B. minuta*. *Western North American Naturalist* 83: 454–461. https://doi.org/10.3398/064.083.0403

Raynor, S.J., Watts, J.L. & Manzitto-Tripp, E.A. (2024) *Sarea cirrhendocarpa*, a fungus species new to science from the southern Rocky Mountains. *Phytotaxa* 671: 87–97. https://doi.org/10.11646/phytotaxa.671.1.5

Raynor, S.J., Watts, J.L. & Manzitto-Tripp, E.A. (2025 [in press]) *Polycauliona pancakeana,* a new species to science from the southern Rocky Mountains. *The Bryologist*. https://doi.org/10.11646/phytotaxa.671.1.5

Raynor, S.J. & Manzitto-Tripp, E.A. (In revision) Lichen inventory of the Indian Peaks Wilderness, Roosevelt National Forest, Colorado. *Systematic Botany.*

Rolshausen, G., Dal Grande, F., Otte, J. & Schmitt, I. (2022) Lichen holobionts show compositional structure along elevation. *Molecular Ecology* 32: 6619–6630. https://doi.org/10.1111/mec.16471

Rondeau, R.J., Pearson, K.T. & Kelso, S. (2013) Vegetation response in a Colorado grassland-shrub community to extreme drought: 1999–2010. *American Midland Naturalist* 170: 14–25. https://doi.org/10.1674/0003-0031-170.1.14

Saag, L., Saag, A. & Randlane, T. (2009) World survey of the genus *Lepraria* (Stereocaulaceae, lichenized Ascomycota). *The Lichenologist* 41: 25–60. https://doi.org/10.1017/S0024282909007993

Saliers, E. & Ray, I. (1994) *Swamp Ophelia, "The Wood Song".* Producer: Peter Collins, with Indigo Girls, Nashville, TN.

Sanders, W.B. & Masumoto, H. (2021) Lichen algae: the photosynthetic partners in lichen symbioses. *The Lichenologist* 53: 347–393. https://doi.org/10.1017/S0024282921000335

Schmitt, I. & Lumbsch, H.T. (2004) Molecular phylogeny of the Pertusariaceae supports secondary chemistry as an important systematic character set in lichen-forming ascomycetes. *Molecular Phylogenetics and Evolution* 33: 43–55. https://doi.org/10.1016/j.ympev.2004.04.014

Schoennagel, T., Veblen, T.T. & Romme, W.H. (2004) The interaction of fire, fuels, and climate across Rocky Mountain forests. *BioScience* 54: 661–676. https://doi.org/10.1641/0006-3568(2004)054[0661:TIOFFA]2.0.CO;2

Schulz, M., Schmitt, I., Weber, D. & Dal Grande, F. (2022) Fungal host affects photosynthesis in a lichen holobiont. *Journal of Fungi* 8: 1267. https://doi.org/10.3390/jof8121267

Schwob, G., Almendras, K., Veas-Mattheos, K., Pezoa, M. & Orlando, J. (2024) Host specialization and spatial divergence of bacteria associated with *Peltigera* lichens promote landscape gamma diversity. *Environmental Microbiome* 19: 57. https://doi.org/10.1186/s40793-024-00598-x

Shrestha, G. & St. Clair, L.L. (2009) The lichen flora of southwest Colorado. *Evansia* 26: 102–123. https://doi.org/10.1639/0747-9859-26.3.102

Śliwa, L. (2007) A revision of the *Lecanora dispersa* complex in North America. *Polish Botanical Journal* 52: 1–70.

Śliwa, L., Miadlikowska, J., Redelings, B.D., Molnar, K. & Lutzoni, F. (2012) Are widespread morphospecies from the *Lecanora dispersa* group (lichen-forming Ascomycota) monophyletic? *The Bryologist* 115: 265–277. https://doi.org/10.1639/0007-2745-115.2.265

Stanton, D.E. & Horn, H.S. (2013) Epiphytes as "filter-drinkers": life-form changes across a fog gradient. *The Bryologist* 116: 34–42. https://doi.org/10.1639/0007-2745-116.1.034

Tagirdzhanova, G., Saary, P., Cameron, E.S., Allen, C.C.G., Garber, A.I., Díaz Escandón, D., Cook, A.T., Goyette, S., Nogerius, V.T., Passo, A., Mayrhofer, H., Holien, H., Tønsberg, T., Stein, L.Y., Finn, R.D. & Spribille, T. (2024) Microbial occurrence and symbiont detection in a global sample of lichen metagenomes. *PLOS Biology* 22: e3002862. https://doi.org/10.1371/journal.pbio.3002862

Thiers, B. (2025 [continuously updated]) Index Herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium.

Tønsberg, T. (1992) The sorediate and isidiate, corticolous, crustose lichens in Norway. *Sommerfeltia* 14: 1–336. https://doi.org/10.2478/som-1992-0002

Tretiach, M. & Brown, D.H. (1995) Morphological and physiological differences between epilithic and epiphytic populations of the lichen *Parmelia pastillifera*. *Annals of Botany* 75: 627–632.
https://doi.org/10.1006/anbo.1995.1072

Tripp, E.A. (2015) Lichen inventory of White Rocks Open Space (City of Boulder, Colorado). *Western North American Naturalist* 75: 301–310.
https://doi.org/10.3398/064.075.0307

Tripp, E.A. (2017) *Field Guide to the Lichens of White Rocks (Boulder, Colorado)*. University Press of Colorado.

Tripp, E.A. & Lendemer, J.C. (2018) Twenty-seven modes of reproduction in the obligate lichen symbiosis. *Brittonia* 70: 1–14.
https://doi.org/10.1007/s12228-017-9500-6

Tripp, E.A., Morse, C.A., Keepers, K.G., Stewart, C.A., Pogoda, C.S., White, K.H., Hoffman, J.R., Kane, N.C. & McCain, C.M. (2019) Evidence of substrate endemism of lichens on Fox Hills Sandstone: discovery and description of *Lecanora lendemeri* as new to science. *The Bryologist* 122: 246–259.
https://doi.org/10.1639/0007-2745-122.2.246

Tripp, E.A. & Lendemer, J.C. (2019a) *Field Guide to the Lichens of Great Smoky Mountains National Park*. University of Tennessee Press.

Tripp, E.A. & Lendemer, J.C. (2019b) Highlights from 10+ years of lichenological research in Great Smoky Mountains National Park: Celebrating the United States National Park Service Centennial. *Systematic Botany* 44: 943–980.
https://doi.org/10.1600/036364419X15710776741332

Watts, J.L., Raynor, S.J., Li, Y., Meier, R., Cook, C., Casini, G. & Chadwick, E. & Manzitto-Tripp, E.A. (2024) *Lecanora exspersa*: A new lichen record for North America and a key to sorediate *Lecanora* (Lecanoraceae) in western North America. *The Bryologist* 127: 427–440.
https://doi.org/10.1639/0007-2745-127.4.427

Watts, J.L., Raynor, S.J. & Manzitto-Tripp, E.A. (2025) Character evolution in Heterodermia s.l. (Physciaceae; Caliciales) and two new species from the southern Rocky Mountains, USA. *Phytotaxa* 698 (2): 61–81.
https://doi.org/10.11646/phytotaxa.698.2.1

Weber, W.A. & Shushan, S. (1955) *The Lichen Flora of Colorado: Cetraria cornicularia, Dactylina, and Thamnolia*. University Press of Colorado, Boulder, CO.

White, T.J., Bruns, T., Lee, S. & Taylor, J. (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. *In*: Innis, M.A., Gelfand, D.H., Sninsky, J.J. & White, T.J. (Eds.) *PCR Protocols: A Guide to Methods and Applications*. Academic Press, New York, pp. 315–322.
https://doi.org/10.1016/B978-0-12-372180-8.50042-1

Wrobleski, A., Ernst, S., Weber, T. & Delach, A. (2023) The impact of climate change on endangered plants and lichen. *PLOS Climate* 2: e0000225.
https://doi.org/10.1371/journal.pclm.0000225

Yahr, R., Vilgalys, R. & DePriest, P.T. (2006) Geographic variation in algal partners of *Cladonia subtenuis* (Cladoniaceae) highlights the dynamic nature of a lichen symbiosis. *New Phytologist* 171: 847–860.
https://doi.org/10.1111/j.1469-8137.2006.01788.x

Yahr, R., Allen, J.L., Atienza, V., Bungartz, F., Chrismas, N., Dal Forno, M., Degtjarenko, P., Ohmura, Y., Pérez-Ortega, S., Randlane, T., Næsborg, R.R., Simijaca-Salcedo, D., von Hirschheydt, G., Anderson, F., Aptroot, A., Balderas, E., Borukhiyah, N., Chandler, A.M., Chesa Marro, M., Divakar, P.K., García, R.A., Herrera-Campos, M.d.l.Á., Howe, N., Joseph, S., Larsen, E.M., Lendemer, J.C., McMullin, R.T., Michlig, A., Moncada, B., Paulsen, J., Roa-García, F., Rosentreter, R., Scheidegger, C. & Sparrius, L.B. (2024) Red Listing lichenized fungi: Best practices and future prospects. *The Lichenologist* 56: 345–362.
https://doi.org/10.1017/S0024282924000355

Zhao, X., Leavitt, S.D., Zhao, Z.T., Zhang, L.L., Arup, U., Grube, M., Pérez-Ortega, S., Printzen, C., Śliwa, L., Kraichak, E., Divakar, P.K., Crespo, A. & Lumbsch, H.L. (2016) Towards a revised generic classification of lecanoroid lichens (Lecanoraceae, Ascomycota) based on molecular, morphological and chemical evidence. *Fungal Diversity* 78: 293–304.
https://doi.org/10.1007/s13225-015-0354-5

Zedda, L. (2023) The importance of a transformative biodiversity education for perceiving, appreciating and supporting lichen diversity in German urban environments. *The Lichenologist* 55: 161–168.
https://doi.org/10.1017/S0024282923000312