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Current Status of Lichen Diversity in Iowa

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Compilation of available herbarium records, as well as additional collections, lead to an estimate of 6,108 identified lichen specimens collected in Iowa that are included in the Iowa Lichens Database. Approximately 35% of the Iowa lichen accessions were collected prior to 1960, while ~65% were collected after 1960. These accessions correspond to 448 species reported for Iowa. Of these 448 species, 42 species of macrolichens appear to be rare or extirpated, based on the criterion of no collection records after 1960. Searches for one of these potentially rare or extirpated lichens, *Lobaria pulmonaria*, have, thus far, been unsuccessful, and the available evidence supports the conclusion that this lichen species is extirpated from Iowa.

INDEX DESCRIPTORS: Iowa lichens, *Lobaria pulmonaria*, extirpation, local extinction, habitat loss, land use change, climate change, biodiversity, rare species.

The lichen diversity of the State of Iowa has been under investigation for over 130 years and yet our understanding of the diversity and distribution of lichens in Iowa is still quite limited. The first lichen recorded for Iowa, *Collema conglomeratum* Hoffm., was collected by Bruce Fink in 1880. Bessey (1884) reported the occurrence of 24 species of lichens in the central portion of the state. Fink (1895, 1897) reported a total of 226 lichen species found in the state based on extensive collections, largely in northeast Iowa. Further additions to Iowa's known lichen diversity were made prior to 1940 (Wolden, 1935). Compilation of previous reports and nomenclatural updates, as well as additional collecting efforts, resulted in an estimate of 263 lichen species recorded for Iowa (Malone and Tiffany, 1978). Herbarium studies and additional collection allowed Dunlap and Tiffany (1980) to provide a checklist of 91 species of foliose lichens known for Iowa, as well as to indicate which of these species might be rare or extirpated. Schutte (1983) added to the understanding of the diversity and distribution of foliose and fruticose lichens in eastern Iowa.

These historic baseline data are of great value, but it is clear that much remains to be learned about the diversity, as well as the distribution, of lichens in Iowa. In the words of Fink (1897, page 184), "this number [of lichen species] could be increased largely by thorough work in several widely separated regions within Iowa." Fink's 1897 assertion is likely to still be true, and minor additions to Iowa's lichen diversity have recently been made (Colbert, 2011). Historical records, however, may not accurately reflect the current lichen diversity of Iowa. Dramatic land use changes and habitat loss in Iowa, beginning prior to 1880 and continuing to the present day, may have caused the extirpation of some lichen species from the state. As early as 1915 Bohumil Shimek reported that the abundance of lichens on trees had diminished in northwest Iowa, though no particular species were mentioned (Shimek, 1915). On-going climate change (Takle, 2010) may impact the diversity of lichen species present in the State of Iowa going forward into the future.

The work reported here is an effort to further our understanding of both the past and present lichen diversity of

Iowa, as well as to help provide direction for future study of lichens in the state. In addition, this study provides an opportunity to identify species that may be rare in, or extirpated from, the state. Inventories of the lichen biodiversity of natural landscapes, for example the "Ozark Ecoregion" (Harris and Ladd, 2007) or the "Great Plains of North America" (Lichen Flora of the Great Plains, 2011), may make more sense from a biological perspective than do biodiversity inventories of geopolitical entities, but decisions about land use and protection of rare species are made in the context of geopolitical entities such as the State of Iowa. Therefore, an improved understanding of what species of lichens may be rare in Iowa is of potential value. Tiffany and Knappus (1998) emphasized the need for additional information to provide a basis for identifying species that may be rare in, or extirpated from, Iowa. Although the State of Iowa does not currently list any lichens on its Threatened and Endangered Species list, the work reported here may help identify potential candidates for such listing.

METHODS

Specimens of Iowa lichens that had been identified to species from 23 herbaria (Table 1) were compiled into a database with 6,108 records (Iowa Lichen Database (ILD), available at the Iowa State University Ada Hayden Herbarium (ISC) web page: <http://www.public.iastate.edu/%7Eherbarium/IowaLichen/index.html>). Species nomenclature followed Esslinger (2011). With the exceptions noted below (Tables 2 and 3) accessions at herbaria other than ISC were not verified as being correctly identified. Synonymous species names for accessions in the various herbaria were updated to currently valid names for inclusion in the ILD. Valid names corresponding to lichen species not thought to be present in North America (Esslinger, 2011) were excluded from the ILD. In addition, six other herbaria (Table 1) reported having no Iowa lichen accessions. Of the 6,108 accessions included in the ILD 6,016 had a collection date. Lichens not reported from the state since prior to 1960 (i.e., over 50 years) were considered to be candidates for rare or extirpated lichen species.

Table 1. Collections searched for Iowa lichens.

Herbarium	Accessions ^a	Source
Minnesota (MIN)	2,332	Site visit, Consortium of North American Lichen Herbaria ^b
Iowa State (ISC)	2,313	Site visit
University of Kansas (KANU)	678	http://collections.nhm.ku.edu/LichenWeb/ (July 2010)
Michigan State (MSC)	337	Consortium of North American Lichen Herbaria ^b
University of Michigan (MICH)	75	Consortium of North American Lichen Herbaria ^b
National Museum – Smithsonian (US)	73	Site visit and http://botany.si.edu/lichens/
Brigham Young (BRY)	67	Consortium of North American Lichen Herbaria ^b
Nebraska-Omaha (OMA)	56	Consortium of North American Lichen Herbaria ^b
Arizona State (ASU)	45	Consortium of North American Lichen Herbaria ^b
Wisconsin (WIS)	38 ^c	Site visit and Consortium of North American Lichen Herbaria ^b
Duke (DUKE)	22	http://www.biology.duke.edu/herbarium/lichen.html (July 2010)
New York Botanical Garden (NY)	22	Consortium of North American Lichen Herbaria ^b
Santa Barbara Botanic Garden (SBBG)	18	Consortium of North American Lichen Herbaria ^b
Canadian Museum of Nature (CANL)	6	Consortium of North American Lichen Herbaria ^b
Oregon State (OSC)	6	Consortium of North American Lichen Herbaria ^b
Illinois Natural History Survey (ILLS)	4	Consortium of North American Lichen Herbaria ^b
Uppsala (UPS)	4	Consortium of North American Lichen Herbaria ^b
Tennessee (TENN)	3	Consortium of North American Lichen Herbaria ^b
Boise State (SRP)	2	Consortium of North American Lichen Herbaria ^b
Field Museum (F)	2	Consortium of North American Lichen Herbaria ^b
Drake University	2	Site visit
Putnam Museum (BDI)	2	Site visit
University of California-Riverside (UCR)	1	Consortium of North American Lichen Herbaria ^b
Grinnell (GRI)	0	Personal communication: Vince Eckhart
Intermountain Herbarium (UTC)	0	Consortium of North American Lichen Herbaria ^b
Iowa Lakeside Lab (ILH)	0	Personal communication: Peter van der Linden
North Carolina (NCU)	0	Consortium of North American Lichen Herbaria ^b
Northern Iowa (ISTC)	0	Personal communication: Steve O'Kane
Washington (WTU)	0	Consortium of North American Lichen Herbaria ^b
Total	6,108	

^aOnly including specimens identified to species

^b<http://symbiota.org/nalichens/> 3 June 2012

^cA partial list with respect to Iowa lichens (J. Bennett, personal communication)

The ILD includes 511 accessions collected and identified by the author between 2002 and 2012. These specimens correspond to 114 species and were collected from 17 counties in Iowa. Identification was carried out with standard morphological observations and chemical tests, using the keys in Brodo et al. (2001) and Thompson (2003). The specimens were deposited in the Iowa State University Ada Hayden Herbarium (ISC) and currently correspond to 22% of the lichen accessions in the Ada Hayden Herbarium. The author has also served as the curator of the ISC lichen collection by updating nomenclature and, in numerous instances, verifying or modifying previous identifications.

Eleven sites in five counties of northeast Iowa were searched for the presence of *Lobaria pulmonaria* (L.) Hoffm. In 2008, 2009, 2010, and 2012. As an indication of search effort, distance traveled while searching (mostly off-trail) was measured using a Garmin eTrex Legend handheld GPS unit. Special attention was given to the bark of mature sugar maples (*Acer saccharum* Marshall), which were present at all 11 sites, and are a favored substrate of *L. pulmonaria*.

RESULTS AND DISCUSSION

The 6,108 accessions in the ILD (Table 1) correspond to 448 species of lichens reported for Iowa. The median number of

records in the ILD corresponding to each species is 4.5. Species represented by only one or two accessions constitute 34% of the estimated total, while species bracketing the median (three to six accessions) make up 28% of the estimated total. Species whose presence in Iowa is supported by more than six accessions correspond to 38% of the total. The most commonly collected lichen species in Iowa is *Physcia stellaris* (L.) Nyl. with 225 records in the ILD. While there is clearly excellent evidence for the presence of *Physcia stellaris* in Iowa, it does not necessarily follow that the presence in Iowa of a lichen species represented by only a single accession is poorly supported. For example, *Solorina saccata* (L.) Ach. (collection date: 1956) and *Ramalina sinensis* Jatta (collection date: 1899) are each represented in the ILD by only a single accession. The *Solorina saccata* specimen is in the ISC collection and was confidently identified by the author after the unidentified specimen was donated to ISC by Steve O'Kane (University of Northern Iowa). The author visited the University of Minnesota Herbarium (MIN) and viewed the *Ramalina sinensis* specimen, which appeared to be correctly identified. Still, those species for which only a few accessions document their presence in the state should be further investigated to determine whether they were correctly identified.

In addition to the herbaria listed in Table 1, three other herbaria are known by the author to have Iowa lichens in their

Table 2. Foliose lichens likely to be rare or extirpated in Iowa.

Taxon	Accessions	Herbaria ^a	Most Recent	Habitat
<i>Collema coccophorum</i> ^f Tuck.	1	MSC	1957	rock
<i>Collema conglomeratum</i> ^{c,f} Hoffm.	9	ISC, MIN, MSC, OMA	1897	bark, dead trees
<i>Collema nigrescens</i> ^f (Hudson) DC.	3	MIN, US ^d	1897	trees
<i>Collema polycarpon</i> ^f Hoffm.	1	MSC	1957	-
<i>Collema pulcellum</i> ^{c,f} Ach.	1	ISC	1895	trees
<i>Collema pustulatum</i> ^{c,f} Ach.	5	ISC, MIN, MICH	1896	calcareous rock
<i>Heppia despreauxii</i> ^f (Mont.) Tuck.	2	ASU, ISC	1894	calcareous earth
<i>Heterodermia echinata</i> ^c (Taylor) W. L. Culb.	3	ISC, MIN	1895	juniper branches
<i>Heterodermia galactophylla</i> (Tuck.) W. L. Culb.	1	ISC	1894	juniper
<i>Leptogium burnetiae</i> ^{c,f} C. W. Dodge	3	ISC, MIN	1895	trees
<i>Leptogium corticola</i> ^{c,f} (Taylor) Tuck.	15	ISC, MIN, MSC, US ^d		dead trees, wood
<i>Leptogium milligrana</i> ^{b,c,f} Sierk	-	-	-	-
<i>Leptogium saturninum</i> ^{c,f} (Dickson) Nyl.	1	MIN	1893	-
<i>Lobaria pulmonaria</i> ^{c,f} (L.) Hoffm.	7	ISC, MIN ^d , MU, WIS ^d , US ^d	1901	bark
<i>Pannaria conoplea</i> ^{c,f} (Ach.) Bory	6	DUKE, ISC, MSC,	1894	moss and limestone
<i>Parmelia squarrosa</i> Taylor	2	MIN	1913	bark
<i>Parmotrema cetratum</i> ^c (Ach.) Hale	4	MIN	1898	trees
<i>Parmotrema eurysacum</i> ^c (Hue) Hale	3	US ^g	1895	-
<i>Peltigera horizontalis</i> ^f (Hudson) Baumg.	2	MIN, MICH	1957	-
<i>Peltigera malacea</i> ^f (Ach.) Funck	3	MIN	1925	-
<i>Placidium arboretum</i> (Schwein. ex E. Michener) Lendemer	6	MIN, OMA	1898	cedar bark
<i>Psora russellii</i> (Tuck.) A. Schneider	6	ISC, MIN, MSC	1957	calcareous rocks
<i>Solorina saccata</i> (L.) Ach.	1	ISC	1956	decayed rock
<i>Tuckermannopsis americana</i> ^c (Sprengel) Hale	9	ISC, MIN, US ^d	1949	trees, wood
<i>Tuckermannopsis ciliaris</i> ^c (Ach.) Gyelnik	3	MIN, US ^d	1893	wood
<i>Tuckermannopsis orbata</i> (Nyl.) M. J. Lai	1	MIN	1895	wood
<i>Xanthoparmelia stenophylla</i> (Ach.) Ahti & D. Hawksw.	1	MIN	1896	Sioux quartzite

^aAll ISC accessions verified, to the best of the author's ability, as correctly identified

^bAccording to Dunlap and Tiffany (1980)

^cPreviously identified as potentially extirpated by Dunlap and Tiffany (1980)

^dIdentification verified during site visit by author

^eISC accessions in very poor condition

^fLichens including a cyanobacterial component

^gOn loan during site visit by author

collections, but these collections are not currently available in database form. The number of Iowa lichens in the collections at Coe College (Paula Sanchini, personal communication), the University of Colorado (COLO; site visit) and Miami University (MU; Michael Vincent, personal communication) is currently unknown, but clearly the ILD does not include all of the lichens collected in Iowa. Still, in its present form, the ILD is the best available resource for directing future research on Iowa lichen diversity and distribution.

The estimate of 448 lichen species recorded for Iowa represents a substantial increase over the estimate of 263 species reported by Malone and Tiffany (1978). This increase is not surprising because Malone and Tiffany (1978) relied on the lichen collections available at the University of Iowa and at Iowa State University (the University of Iowa collection was subsequently merged into the Iowa State University Ada Hayden Herbarium collection), as well as their own additional collections. Subsequent work (Dunlap and Tiffany, 1980) also included specimens from the University of Minnesota (MIN), University of Michigan (MICH), University of Wisconsin (WIS) and the Smithsonian Institution (US) collections. But, Dunlap and Tiffany (1980)

restricted their focus to foliose lichens, and the extent to which these additional collections were searched for Iowa lichens is unclear.

A lichen diversity of 448 species is similar to the diversity of lichens reported for three states bordering Iowa: Minnesota (780 species; Bennett and Wetmore, 2004), Nebraska (411 species; Egan et al., 1995, Egan et al., 2002), and Wisconsin (726 species; Bennett, 2006). It is likely that additional collection of lichens within the State of Iowa would lead to further additions to the list of lichen species known to occur in the state (e.g., Colbert, 2011), and it is even possible that lichen species new to science could be discovered (e.g., Esslinger, 2004; Wetmore, 2009).

The ILD reveals two additional features of interest with respect to efforts to understand lichen diversity and distribution in Iowa. First, there has been a reasonably consistent collecting effort over time. Comparing 20-year intervals, beginning in 1880, the least active time of collection was 1920–1939 (172 accessions) and the most active time of collection was 1960–1979 (2,014 accessions). The current time interval (2000–2019) already includes 1,341 accessions, with some current collections remaining to be identified and more collections likely to occur. Thanks largely

Table 3. Fruticose lichens likely to be rare or extirpated in Iowa.

Taxon	Accessions	Herbaria	Most Recent	Habitat
<i>Bryoria furcellata</i> (Fr.) Brodo & D. Hawksw.	2	MIN ^b , WIS ^b	1895	-
<i>Cladonia gracilis</i> (L.) Willd.	5	ISC, MIN	1928	earth, tree stump
<i>Cladonia innominata</i> Lendemer	2	NY	1923	-
<i>Cladonia ramulosa</i> (With.) J. R. Laundon	2	MSC	1957	-
<i>Cladonia scabriuscula</i> (Delise) Nyl.	1	MIN	1894	-
<i>Cladonia stellaris</i> (Opiz) Pouzar & Vězda	1	MIN	1894	-
<i>Cladonia uncialis</i> (L.) F. H. Wigg.	3	MIN, MSC	1957	-
<i>Evernia mesomorpha</i> Nyl.	3	MIN ^b , WIS ^b	1895	-
<i>Ramalina calicaris</i> (L.) Fr.	11	ISC	1903	sandstone, limestone
<i>Ramalina farinacea</i> (L.) Ach.	1	ISC	1894	limestone
<i>Ramalina sinensis</i> Jatta	1	MIN ^b	1899	-
<i>Ramalina unifolia</i> J. W. Thomson	4	MIN	1909	oak tree
<i>Usnea angulata</i> Ach.	7	ISC, MIN, WIS	1895	trees
<i>Usnea strigosa</i> (Ach.) Eaton	3	MIN ^b , WIS ^b	1894	-
<i>Usnea trichodea</i> Ach.	1	ISC	1894	bark

^aAll ISC accessions verified, to the best of the author's ability, as correctly identified

^bIdentification verified during site visit by author

to the pioneering work of Bruce Fink and Bohumil Shimek we have numerous historically invaluable accessions from the 1880–1899 interval (1,101 accessions), and the 1900–1919 interval (545 accessions). Overall, 35% of the records in the current ILD correspond to collections made before 1960, while 65% of the records correspond to collections made after 1960. Second, the geographic distribution of collecting effort has not been consistent across the state. Comparison of the four counties in the northeast (Allamakee, Clayton, Fayette, and Winneshiek), northwest (Lyon, O'Brien, Osceola, and Sioux), southwest (Fremont, Mills, Montgomery, and Page), and southeast (Des Moines, Lee, Henry, and Van Buren) corners of the state reveals dramatic disparity. The four counties in the northeast corner of the state are represented by 2,136 accessions in the ILD, while the four counties in the southeast corner of the state are represented by only 98 accessions in the ILD. The southwest and northwest corners of the state are represented by 238 and 365 accessions, respectively. Clearly, we know very little about the diversity and distribution of lichens in southeast Iowa. Schutte (1983), who collected in eastern Iowa, did not collect in the four southeast-most counties of the state. This region of the state, with its proximity to the Mississippi River corridor, might be expected to have lichen species more typically found further south.

Identification of potentially rare or extirpated Iowa lichens

Of the 448 lichen species present in the current ILD, 111 (~25%) have not been reported in Iowa since prior to 1960. Sixty of these lichen species are crustose ("microlichens") and, assuming they were correctly identified in the first place, could easily have been overlooked since 1960 even though they might be relatively common in the state. Fifty-one of the species are relatively large and prominent foliose and fruticose lichen species ("macrolichens") that might have been expected to be collected since 1960, especially given that about 2/3 of the total lichen collecting effort has occurred since 1960. Dunlap and Tiffany (1980) identified 33 species of foliose lichens that might be "rare" or "extirpated" in the state. Of the 13 species categorized as being potentially extirpated, 12 have no records in the ILD

since prior to 1960. The most recent record in the ILD for any of these species is 1903. One of these 12 species (*Leptogium milligranum* Sierk) is not included in the ISC collection (i.e., not collected by Dunlap) or the ILD. Presumably, Dunlap and Tiffany (1980) observed specimens of this species in the other herbaria they investigated. The list of Iowa lichens in the ILD from WIS, for example, is known to be incomplete (Table 1). The other species listed as potentially extirpated by Dunlap and Tiffany (1980), *Collema crispum* (Hudson) F.H. Wigg, was actually collected by Dunlap in 1978 (two accessions from Clayton County) and should, therefore, likely be categorized as rare rather than potentially extirpated. An additional species, *Collema pustulatum* Ach., was categorized by Dunlap and Tiffany (1980) as being "not common", but the most recent record in the ILD is 1896, suggesting that it might be potentially extirpated. Once again, it is possible that Dunlap and Tiffany (1980) were aware of more recently collected specimens not currently included in the ILD. Finally, one of the species identified by Dunlap and Tiffany (1980) as potentially extirpated may correspond to two species included in the ILD. "*Cetraria ciliaris* Ach." may include both *Tuckermannopsis americana* (Sprengel) Hale (= *Cetraria ciliaris* var. *halei*) and *Tuckermannopsis ciliaris* (Ach.) Gyelnik (= *Cetraria ciliaris*).

Dunlap and Tiffany (1980) categorized an additional 19 species of foliose lichens as being "rare". Of these 19 species, one species (*Parmelia squarrosa* Hale) has no record in the ILD since 1913 and should, perhaps, be considered as potentially extirpated. An additional 11 of these "rare" species were collected and recorded between 1960 and 1980, some by Dunlap. Six of the species that Dunlap and Tiffany (1980) listed as rare have been recorded since the time of their publication. One of the species listed as rare by Dunlap and Tiffany (1980), *Umbilicaria vellea* (L.) Ach., is not included in the ISC collection (i.e., not collected by Dunlap) or in the ILD, though specimens may be present in the other herbaria investigated by Dunlap and Tiffany (1980).

The criterion of no records in the ILD since prior to 1960 includes as potentially rare or extirpated all of the species (with the modifications noted above) categorized by Dunlap and

Tiffany (1980) as potentially extirpated, as well as one species (*Parmelia squarrosa*) categorized as rare. This means that the addition of records from herbaria not investigated by Dunlap and Tiffany (1980), as well as the addition of 1,898 identified accessions of Iowa lichens since their work was published, has led to no further records for these species. It seems likely that these species are, in fact, extirpated from the state, assuming the initial collections were correctly identified. In addition, the current analysis adds 38 species of "macrolichens" to the list of potentially rare or extirpated species, based on the lack of records since prior to 1960. These species include an additional 18 species of foliose lichens (including some species often categorized as "squamulose"), as well as 20 species of fruticose lichens.

Based on current understanding of lichen species distribution in North America, some of these records of potentially rare or extirpated species are geographically close to currently known populations. For example, relatively recent collections of *Peltigera horizontalis* (Hudson) Baumg. are known from southwest Wisconsin and portions of Minnesota, while *Cladonia stellaris* (Opiz) Pouzar & Vezda is common in northeast Minnesota. It is reasonable to imagine relict populations of these species in the driftless area of northeast Iowa where these two species were last collected in 1957 and 1894, respectively. The current, or past, presence of five species of these potentially rare or extirpated foliose lichens in Iowa, however, seems quite unlikely. *Leptogium plicatile* (Ach.) Leighton and *Melanobalea exasperata* (De Not.) O. Blanco are known only from sites west of the Rocky Mountains (Consortium of North American Lichen Herbaria website: <http://symbiota.org/nalichens/index.php>). Similarly, *Parmelina coleae* Argüello & A. Crespo is known only from California and *Physcia tribacia* (Ach.) Nyl. is known only as far east as western Nebraska (Consortium of North American Lichen Herbaria website). In addition, *Punctelia punctilla* (Hale) Krog, which is represented in the ILD by one accession (MSC) collected on white pine bark and identified by Henry Imshaug in 1957, as presently conceived, appears to be restricted to rocky substrates along the California coast (Aproot, 2003; Lendemer and Hodkinson, 2010). Although disjunct populations separated by large distances are known for various lichen species (see, for example, the known distribution of *Ramalina sinensis* in North America), it seems likely that these five records may be the result of misidentification. Consequently, they are not included in the subsequent analysis.

Of the 20 potentially rare or extirpated fruticose lichens two species, *Cladonia cylindrica* (A. Evans) A. Evans and *Usnea birta* (L.) F. H. Wigg., were reported for Iowa after 1960 by Schutte (1983), although the author has not yet had access to these records due to on-going renovation at the Coe College herbarium. According to the Consortium of North American Lichen Herbaria website, *Usnea evansii* Motyka is known only from sites along the Atlantic coast of the southern United States, while *Usnea florida* (L.) F. H. Wigg. is known from three widely disparate sites in California, Maine, and Mexico. It seems unlikely that these two species were ever present in Iowa suggesting that the records in the ILD are probably the result of misidentification. An additional potentially rare or extirpated fruticose lichen in the ILD, *Cladonia coccifera* (L.) Willd., is represented by only a single accession in the ISC collection. This specimen is very small and in poor condition, consequently it was excluded from further analysis.

Deleting these unlikely records results in an estimate of 13 foliose lichen species, in addition to those noted by Dunlap and Tiffany (1980), (Table 2) and 15 fruticose lichen species (Table 3) that may be rare or extirpated. Of the 42 species of potentially rare or extirpated macrolichens identified in Tables 2 and 3, only 4 species (*Cladonia arbuscula*, *Collema polycarpon*,



Fig. 1. *Lobaria pulmonaria* (damp) growing on *Acer saccharum* bark in Maine. Bar approximately 1 cm.

Ramalina unifolia, and *Usnea angulata*) are shared in common with the list of 47 potentially rare or extirpated Wisconsin macrolichens reported by Bennett and Wetmore (2004).

As predicted by Tiffany and Knaphus (1998), additional information has provided a clearer picture of the species of lichens that may be rare in, or extirpated from, the State of Iowa. The 42 macrolichen species listed here as potentially rare or extirpated should be considered for inclusion in the Iowa Threatened and Endangered Species list. It is, of course, possible that some of the 42 species included in Tables 2 and 3 are incorrectly identified. All of the accessions of potentially rare or extirpated lichens present in ISC were, to the extent possible, verified by the author as being correctly identified. Some of the accessions located at MIN, WIS, and US were also verified by the author (as noted in Tables 2 and 3). Other accessions have been recently verified by experts, e.g., the two *Cladonia innominata* Lendemer accessions at NY verified by J.C. Lendemer. Iowa is reasonably close to the known ranges for all of the species listed in Tables 2 and 3 (Consortium of North American Lichen Herbaria website). Still, some of the species listed in Tables 2 and 3 are represented by only a few accessions that may not have been correctly identified. Further exploration of whether these species were, or are, present in Iowa should be preceded by verification of the identification of the existing specimens.

Looking for *Lobaria*

Lack of records for a species in a particular geographic area over an extended period of time suggests the hypothesis that the species may be extirpated from that area. Given that lichens receive little attention in Iowa, however, it is difficult to know whether lack of recent reports of prominent lichen species reflects rarity, extirpation, or insufficient search effort. Of the 42 potentially rare or extirpated macrolichen species listed in Table 2 and Table 3, *Lobaria pulmonaria* (L.) Hoffm. was selected to test the hypothesis that lack of recent collection implies extirpation. *Lobaria pulmonaria* is a relatively large lichen with an upper cortex that is bright green in color when wet (Fig. 1). This species was chosen for further study for several reasons. First, this foliose lichen can achieve lengths in excess of 5 cm, making it easy to detect in the field compared to many lichen species. Second, *L. pulmonaria* grows in an easily observed habitat, typically the bark of deciduous trees – commonly at eye level. Third, unlike 15 of the 42 potentially rare or extirpated lichen



Fig. 2. A portion of the *Lobaria pulmonaria* specimen collected by Bruce Fink in Clayton County, Iowa (1894). ISC accession number = 25303. Note the characteristic pattern of ridges bearing soralia (light colored spots) on the upper cortex.

species listed in Tables 2 and 3, *L. pulmonaria* has been collected in Iowa on more than one occasion. *Lobaria pulmonaria* was collected once in 1894 (Fink, 1897) and twice in 1901. Fourth, even in 1897 *L. pulmonaria* was recognized as an unusual lichen for Iowa about which much remained to be learned: "Only known thus far in Iowa along the Mississippi River in Clayton County. How far this northern lichen [*Lobaria pulmonaria*] extends south along the river, or possibly in other parts of Iowa, is of special interest" (Fink 1897, page 186). Finally, *L. pulmonaria*, by comparison to many lichens, is easy to identify with confidence.

Seven accessions of *L. pulmonaria* from Iowa are known to be present in herbarium collections. Accessions from the 1894 collection (Bruce Fink, Clayton County, Iowa) are located in the Iowa State University Herbarium (ISC), the Miami University Herbarium (MU), the University of Minnesota Herbarium (MIN), the University of Wisconsin-Madison Herbarium (WIS), and the Smithsonian Herbarium (US). The specimen in the US collection was originally submitted to the Missouri Botanical Garden collection (Accession # 36744) and was subsequently transferred to the US collection. Accessions from the two 1901 collections (Bohumil Shimek, Millville Township in Clayton County, Iowa, and White Pine Hollow State Preserve (Herzberg and Pearson, 2001) in Dubuque County, Iowa) are located in the University of Minnesota Herbarium (MIN). Dunlap and Tiffany (1980) appear not to have been aware of Shimek's 1901 collections, even though they made use of the MIN lichen collection, as they report the last collection of *L. pulmonaria* in Iowa to be 1894. The identity of each of these specimens has been verified by the author (e.g., Fig. 2), with the exception of the specimen present at Miami University. Iowa accessions of *L. pulmonaria* are not present in the collection at the University of Colorado.

During 2008, 2009, 2010, and 2012 efforts were made to search for *L. pulmonaria* in the two counties in northeast Iowa from which the previous collections were made, as well as three adjacent counties. Approximately 42 miles of travel on foot were logged searching for *L. pulmonaria* at eleven sites (Table 4). Most of the search effort was carried out during March with smaller portions carried out during July and October. No populations of *L. pulmonaria* were discovered. Recently, the aid of the public was enlisted by publishing a "wanted poster" for *L. pulmonaria*

Table 4. Search Effort for *Lobaria pulmonaria*

Location	Search
Backbone State Forest, Delaware Co.	3.3 miles
Bixby State Preserve, Clayton Co.	1.7 miles
Bluffton State Preserve, Winneshiek Co.	4.9 miles
Heritage Valley, Allamakee Co.	5.0 miles
Malanaphy Springs, Winneshiek Co.	2.1 miles
Merritt Forest State Preserve, Clayton Co.	0.9 miles
Mossy Glen State Preserve, Clayton Co.	7.0 miles
Private Land west of Clayton, Clayton Co.	0.5 miles
Roggman State Preserve, Clayton Co.	4.5 miles
Turkey River Mounds, Clayton Co.	1.0 miles
White Pine Hollow State Preserve, Dubuque Co.	11.2 miles
Total	42.1 miles

(Colbert and Pearson, 2012). To date no reports of *L. pulmonaria* populations have been received.

These data do not unequivocally demonstrate that *L. pulmonaria* is extirpated from Iowa. It is possible that additional searching in northeast Iowa (or other forested regions of the state) would reveal the presence of extant *L. pulmonaria* populations. Our current understanding of the distribution of *L. pulmonaria* in North America (primarily boreal and Appalachian/Great Lakes, with populations more distant from Iowa in the Pacific Northwest to Alaska; Jordan, 1973; Brodo et al., 2001), taken together with the paucity of historic collections of this prominent lichen species, suggests that Iowa may have been on the edge of suitable *L. pulmonaria* habitat prior to European settlement of Iowa. Populations of *L. pulmonaria* have been reported to be in decline in other locations, and *L. pulmonaria* is considered to be an endangered species throughout much of Europe and Scandinavia (Zoller et al., 1999).

If *L. pulmonaria* was extirpated from Iowa sometime after 1901, what might have been the cause of this loss of biodiversity from the state? *Lobaria pulmonaria* has been reported to be a species most commonly found in old growth forests (Zoller, 1999; Brodo et al., 2001). Available records indicate that very little of the ~ 6.7 million acres of old growth deciduous forest present in Iowa prior to European settlement escaped clearing for lumber and/or agricultural purposes (Iowa-Portrait of the Land, 2000). One the sites unsuccessfully searched for *L. pulmonaria* (Merritt Forest State Preserve) is thought to be a small (~20 acres) old growth forest remnant (Herzberg and Pearson, 2001). This potential old growth forest remnant is currently surrounded by row crop fields, and is exposed to environmental conditions much different than it would be within an extensive forest. The lack of substantial remnant old growth forest in Iowa is likely to have contributed to the apparent extirpation of *L. pulmonaria* from the state. Another possible contributing factor, though one that would not have been significant until well after 1901, is the use of agricultural herbicides (Jensen et al., 1999) and fungicides (Bartok, 1999). *Lobaria pulmonaria* has been shown to be as sensitive to the commonly used herbicide atrazine as are flowering plants (Jensen et al., 1999). Impaired air quality could also contribute to population declines of *L. pulmonaria*. Air pollution issues in Iowa can include sulfur dioxide, nitrogen oxides and acid rain (Iowa Air Pollution, 1998), as well as emissions from confined animal feeding operations such as hydrogen sulfide and ammonia (Iowa Concentrated Animal Feeding Operations Air Quality Study, 2002). Cyanolichens, including *L. pulmonaria*, have been shown (Brodo et al., 2001;

Richardson and Cameron, 2004) to be especially sensitive to impaired air quality. It is also possible that on-going climate change in Iowa may have played a role in the apparent extirpation of *L. pulmonaria*. Iowa has recently been experiencing climate change that can be characterized as including drier autumns, warmer winters, warmer nighttime lows, and increases in extreme precipitation events, especially in the spring (Takle, 2010). Each of these potential contributing factors would need to be taken into consideration should an effort be made to reintroduce this native species, as has been done with some other extirpated native Iowa species, e.g., wild turkeys and otters. It may be worth noting that of the 42 potentially rare or extirpated species listed here, 15 species are cyanolichens (Table 2). Given that globally about 10% of lichens are cyanolichens (Richardson and Cameron, 2004), the observation that ~36% of Iowa's potentially rare or extirpated macrolichens are cyanolichens seems higher than expected. It is possible that cyanolichens are especially susceptible to the habitat changes that have occurred in Iowa since 1880.

The available data lead to the conclusion that *L. pulmonaria* was historically rare in Iowa and is now an extirpated species. This large and lovely lichen species should then, most likely, be added to the list of species lost from the state as a result of human activities. This list currently includes charismatic megafauna (e.g., bison, elk, black bears, timber wolves, etc.), as well as less prominent animal species such as freshwater mussels (Poole and Downing, 2004). Flowering plant species such as Grass Pink (*Calopogon tuberosus* (L.) Britton, Sterns & Poggenb.), last collected in 1951, or Green Adder's Mouth Orchid (*Malaxis unifolia* Michx.), last collected in 1923, (John Pearson, personal communication) also appear to have been extirpated from the state. The loss from Iowa of thundering herds of bison or bugling elk would be expected to be widely noted, and available records indicate that wild bison and elk were extirpated from Iowa by about 1870 (Dinsmore, 1994). But, the loss of smaller, more unobtrusive, species could easily pass unnoticed. Without the pioneering work of Fink and Shimek we would never know that *L. pulmonaria* was part of Iowa's complement of native biodiversity. The small amount of evidence (just three separate collections) supporting the presence of *L. pulmonaria* in Iowa's recent past begs the question of how many other small and unobtrusive species were extirpated from the state as a result of human activities without their presence ever being recorded. The idea that trees in Story County (central Iowa) would be draped with spectacular pendent fruticose lichens seems highly unlikely today, but that is what Louis Pammel observed in 1884 when he collected a specimen of *Usnea trichodea*. At this point it is unknown whether any of the other 41 macrolichen species identified in Tables 2 and 3 are extirpated from the state. Similar, though more challenging to answer, questions could be asked regarding the 60 species of microlichens in the ILLD that appear not to have been collected since prior to 1960. Further investigation is needed, especially in portions of the state (e.g., southeast Iowa) that have received little attention, to more accurately understand both the current and past diversity of lichens in Iowa.

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