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Getting to know our biomonitor neighbours: urban lichens and allied fungi of Edmonton, Alberta, Canada

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ABSTRACT. – Here we provide one of the first detailed studies of lichen and allied fungi diversity in a continental North American city (Edmonton, Alberta, Canada), including an annotated checklist, images of all species, dichotomous keys, and local distribution maps. Edmonton is the northernmost city in North America with a population of over one million, and an industrial and transportation gateway for much of northern Canada. Lichen-based biomonitoring could be a tool to track airborne pollutants resulting from Edmonton's growing populace and industrial activity. The first step towards such a program is documenting the diversity and distribution of lichens in the city. To accomplish this, we conducted a city-wide, systematic survey of 191 sites focused on epiphytes growing on deciduous boulevard trees. We augmented that survey with surveys of rare trees, opportunistic collections from river valley and ravine habitats, herbarium collections, phylogenetic analyses of a subset of collections, and observations submitted to online nature-reporting applications. We present ITS sequence barcode data for 33 species, phylogenetic analyses for Candelariaceae, *Endocarpon*, *Flavopunctelia*, the *Lecanora dispersa* group, *Lecidella*, *Peltigera*, *Physconia*, and *Punctelia*, and detailed descriptions of 114 species in 47 genera and 23 families. Two species are hypothesized to be new to North America (*Endocarpon* aff. *unifoliatum*, *Lecidella albida*), twelve more are new to Alberta (*Amandinea dakotensis*, *Bacidia circumspecta*, *Candelaria pacifica*, *Candelariella antennaria*, *Heterodermia japonica*, *Lecania naegelii*, *Lecanora sambuci*, *Lecanora stanislai*, *Lecidea erythrophaea*, *Peltigera islandica*, *Phaeocalicium* aff. *tremulicola*, and the introduced *Xanthoria parietina*), and five are putative new species to science (*Physcia* aff. *dimidiata*, *Physcia* aff. *stellaris*, *Phaeocalicium* sp., *Phaeocalicium* aff. *tremulicola*, Lichenaceae sp.). Illustrations are provided for all species to aid in verification and public outreach. Species richness was highest in foliose lichens (48), followed by crustose and calicioid lichens and allied fungi (41), with the lowest richness in fruticose lichens (25). We did a preliminary assessment of the suitability of species for citizen-science biomonitoring by assessing their distribution across the city, perceptibility to the public, identification accuracy, and, for a subset, how consistently species were surveyed by trained novices. Compared to other urban areas where lichen diversity has been studied, Edmonton is relatively species-rich in calicioids and *Peltigera*. Promising bioindicators may be limited to chlorolichens, including *Caloplaca* spp., *Evernia mesomorpha*, *Flavopunctelia* spp., *Phaeophyscia orbicularis*, *Physcia adscendens*, *Physcia aipolia* group, *Physcia* aff. *stellaris*, *Usnea* spp., and *Xanthomendoza fallax*. Other genera that may be responsive to pollutants such as *Cladonia* and *Peltigera* were almost exclusively restricted to river valley and ravine ecosystems, limiting their application as bioindicators. Some species commonly used as biomonitors elsewhere were too rare, small, poorly developed, or obscured by more common species locally (e.g., *Candelaria concolor s.l.*, *Xanthomendoza hasseana*). The low overlap with lists of biomonitoring species from other regions of North America illustrates the necessity of grounding monitoring in knowledge of local diversity. Future augmentation of this list should focus on enhanced sampling of downed wood-, conifer-, and rock-dwelling lichens, particularly crustose species. The next step in developing a biomonitoring program will require modelling species' responses to known air quality and climatic gradients.

KEYWORDS. – Air quality, lichenized Ascomycetes, biomonitoring, calicioids, Candelariaceae, cyanolichens, continental climate, detection error, *Endocarpon*, *Flavopunctelia*, floristics, *Lecanora dispersa* group, *Lecidella*, molecular phylogenetics, *Peltigera*, *Punctelia*, survey repeatability, urban biodiversity.

INTRODUCTION

Lichens are widespread, spanning the globe from the Arctic to Antarctica (Sancho et al. 2019), grow on many different substrates, are long-lived, and can be studied in any season (Nimis et al. 2002). Individual species' responses to atmospheric conditions including anthropogenic pollutants determine overall species diversity patterns (e.g., Matos et al. 2019). These traits and others have led to a long history of using lichens in urban environments as biological monitors (biomonitors) of air quality (Grindon 1859, Llop et al. 2012, Nimis et al. 2002, Nylander 1866, Pungin & Dedkov 2017). While physicochemical air quality monitoring stations can provide highly accurate contaminant data, they are costly and do not provide the high spatial resolution of multiple lichen sampling sites. Air quality stations can monitor levels of specific air quality parameters like SO_2 and NO_2 from point sources, but differences in lichen communities can indicate relative deposition and the cumulative biological effect of complex atmospheric conditions across an entire city (McCarthy et al. 2009).

In Canada, lichens have been used as biomonitors for a variety of pollutants (reviewed by MacDonald & Coxson 2013, Thormann 2006), but lichen surveys have failed to gain widespread traction in biomonitoring. In 1994, the federal government created the Ecological Monitoring and Assessment Network (EMAN) and commissioned the creation of standardized protocols for community-based ecological and biodiversity monitoring. EMAN included a lichen-based, rapid-assessment air quality protocol, using lichens that could be identified in the field, based largely on work in the milder climes of the Mixedwood Plains ecozone (Marshall et al. 1999, ecozones.ca) of southeastern Canada. The EMAN protocol was trialed in Hamilton, Ontario (McCarthy et al. 2009), but shortly thereafter EMAN was defunded. Similar studies in continental climates are limited. In Stringer and Stringer (1974), lichen diversity was mapped and interpreted based on putative air quality gradients in Winnipeg, Manitoba. Locally, Case (1980) examined the response of epiphytic lichens on conifers to proximity to a sour gas (H_2S) plant approximately 200 km northwest of Edmonton, Alberta. Lee & Vitt (1974) and Elsinger et al. (2007) examined the response of epiphytic lichens on *Populus* trees in proximity to a zone of industrial activity on the outskirts of Edmonton. The province of Alberta has a long history of industrial activity, including oil and gas extraction and refinement, pulp and paper mills, and coal mining. These industries have been associated with air pollution including H_2S, NO_X, fine particulate matter, polycyclic aromatic hydrocarbons, and trace element deposition (Alberta Capital Air Shed 2017, Government of Canada 2016, Kindierski & Bari 2015, Makar et al. 2018). Given the prevalence of these industries and their proximity to major population centers, there is a need to better understand how air pollution may impact local species, such as lichens, as well as human health (e.g., Rodriquez-Villamizar et al. 2017).

Alberta has benefited from the attention of resident and visiting lichenologists (e.g., Bird 1970, 1973, Björk 2013, Haughland et al. 2018, McCune & Goward 1995, Spribille 2002, Thomson & Ahti 1994), and a province-wide biodiversity monitoring program that includes lichens (the Alberta Biodiversity Monitoring Institute, hereafter referred to as the ABMI [2020], www.abmi.ca). However, as in many regions, little is published on lichens in urban environments. Alberta's capital city Edmonton is an interesting test case for biomonitoring with lichens because it has a cold, dry, temperate climate that is not associated with many of the lichens found to be effective biomonitors elsewhere; it is bisected by a ribbon of river valley parks, potentially elevating urban lichen diversity; and, as in many Canadian cities, there is a long history of planting deciduous boulevard trees that could be used as a standard substrate for lichen biomonitoring. Lichens are colorful components of many urban landscapes, adorning boulevard trees lining sidewalks and streets. With investment in public outreach and identification training, lichens can become more perceptible to the public, who could be mobilized to document local lichens as potential air quality and/or climate change biomonitors.

Here we aim to address Edmonton's deficit of lichen knowledge by publishing the first annotated lichen list for the city. We sought to document patterns of lichen diversity across the Edmonton area to 1) inform future studies on lichens as citizen science biomonitors, and 2) disseminate documentation on lichen diversity and identification to help non-specialists learn the broad groups of lichens and appreciate lichen diversity. We conducted systematic surveys of boulevard trees across the city, rare tree surveys, opportunistic surveys in river valley and ravine parklands, herbarium searches, online database searches, and searches of lichen records in two public, online nature-reporting applications, iNaturalist (2020) and NatureLynx (2020). We conducted molecular phylogenetic analyses to aid in the identification of a subset of collections. We used these composite data to determine if species had some of the attributes of an effective biomonitor. Lichens were deemed potential biomonitors if they were relatively abundant, widely distributed, present in different habitats, perceptible to the public, and amenable to consistent, accurate identification. We used online observations as a metric of perceptibility, i.e., which species and genera the public noticed. We assessed accuracy through examination of vouchers, herbarium specimens, visual verifications of online reports, as well as field audits of a portion of the systematic boulevard tree surveys. This work assesses the potential for using lichens as citizen science biomonitors in Edmonton, as well as a filter to guide future work modeling the responsiveness of promising lichen species to urban climate and air quality gradients.

MATERIALS AND METHODS

Study Area. – Edmonton (53°34′24″N, 113°25′06″W, 620–720 m elevation, municipal area of 783 km^2, Fig. 1), is the northernmost North American municipality with a population over one million, and is an industrial and transportation gateway to Alberta's northeastern oil and gas region. Industry in Edmonton is concentrated in three main areas: along the eastern border, within the northwest portion of the city, and from the central downtown core extending south to 41 Avenue SW. Edmonton previously had a municipal airport approximately 2 km from the downtown core, which began as an airfield in 1927 (Griwkowsky 2017) and operated until 2013.

Edmonton's current average airborne contaminant concentrations are estimated at 13–19 ppb nitrogen oxides (NOx), 19.7–24.8 ppb ozone (O_3), <1–1.7 ppb sulphur dioxide (SO_2), and <1 ppb sour gas (H_2S) (Alberta Capital Airshed 2017). From 1998 to 2014, many pollutants trended downwards (Kindierski & Bari 2015). Most nitrates and sulfates are hypothesized to be generated by local vehicle exhaust and industrial activities, coal combustion from west of Edmonton, larger-scale regional activities such as oil and gas extraction and production in Alberta, British Columbia, and Saskatchewan, and animal feeding operations south of Edmonton to Montana, U.S.A. In 2017, Edmonton ranked 9th highest of 16 Canadian cities for SO_2, 3rd of 24 cities for NO_2, 22nd of 24 cities for O_3, and 5th of 24 cities for fine particulate matter ($PM_{2.5}$) (Alberta Capital Airshed 2017).

Ecologically, Edmonton is within the Parkland Natural Region and Central Parkland Natural Subregion of Alberta, which can be summarized vegetatively as an aspen forest–grassland mosaic. The Central Parkland is considered a transitional Natural Subregion between the Grasslands Natural Region to the south and Boreal Mixedwoods Natural Subregion to the north (Natural Regions Committee 2006). Edmonton thus shares climatic and vegetation characteristics with several natural regions. These transitional characteristics are critical to the city's overall biodiversity, as the resulting diverse plant communities create distinct habitats and wildlife assemblages unique to the Parkland.

Native Parkland is an ecological system found only in North America (Natural Regions Committee 2006). It is characterized by rich soils, a canopy of aspen and balsam poplar (*Populus tremuloides* Michx. and *Populus balsamifera* L.), and a species-rich understory of shrubs. Typical habitats, dictated by local geology, topography, soils, and hydrology, include forested river valley and ravine slopes, riparian habitats, patches of mixedwood boreal forest, deciduous woodlands, lakes and smaller wetlands, and small areas of grassland, with some remnant sand dune, peatland and shrubland habitats. Today, Parkland habitat is scarce, with >78% of the Natural Region directly altered by anthropogenic activity (ABMI 2018).

Edmonton can be divided into two distinct geomorphic areas: the tablelands and the river valley and ravine system. The tablelands area is by far the larger of the two and is relatively flat, varying approximately between 650–675 meters in elevation. Much of the area is under urban and industrial development or cultivation but remnants of the historical Central Parkland, aspen-grassland mosaic remain in small regions of the city. The river valley and ravine system occupy 10% of the land base and consist of natural areas, including the North Saskatchewan River that runs through the middle of the city and its associated ravines, as well as wetlands and forests that dot the tablelands above the valley. Edmonton's river valley constitutes the longest stretch of connected urban parkland in North America (City of Edmonton 2013). Natural disturbances historically shaped the landscape, with most of the North Saskatchewan River Valley reset to early successional *Populus* stands by a fire prior to 1879 (Wein 2006). After the 1900s, stand age and biodiversity were mostly impacted by riparian logging, hillside tunnel mining for coal, and gravel dredging for gold (Wein 2006).

Edmonton has a continental climate and receives most of its precipitation in the summer, with an average 94 mm of rain in the wettest month of July and 25 mm of snow in the snowiest month of January, and a total of 456 mm of precipitation annually (climate normals 1981-2010, Government of Canada 2010). Daily average temperatures range from -10.4 ± 4.8°C (SD) in January to 17.7 ± 1°C in July. Average relative humidity varies from 76% at 6:00 am to 54% at 3:00 pm.

Data sources. I. Field surveys. – We conducted three types of surveys: opportunistic surveys in lichen-diverse areas (2013 onwards), systematic surveys of epiphytic lichens growing on the boles of deciduous trees as part of a University of Alberta (U of A) class project (2019), and surveys of rare tree species growing on the U of A campus (2021).

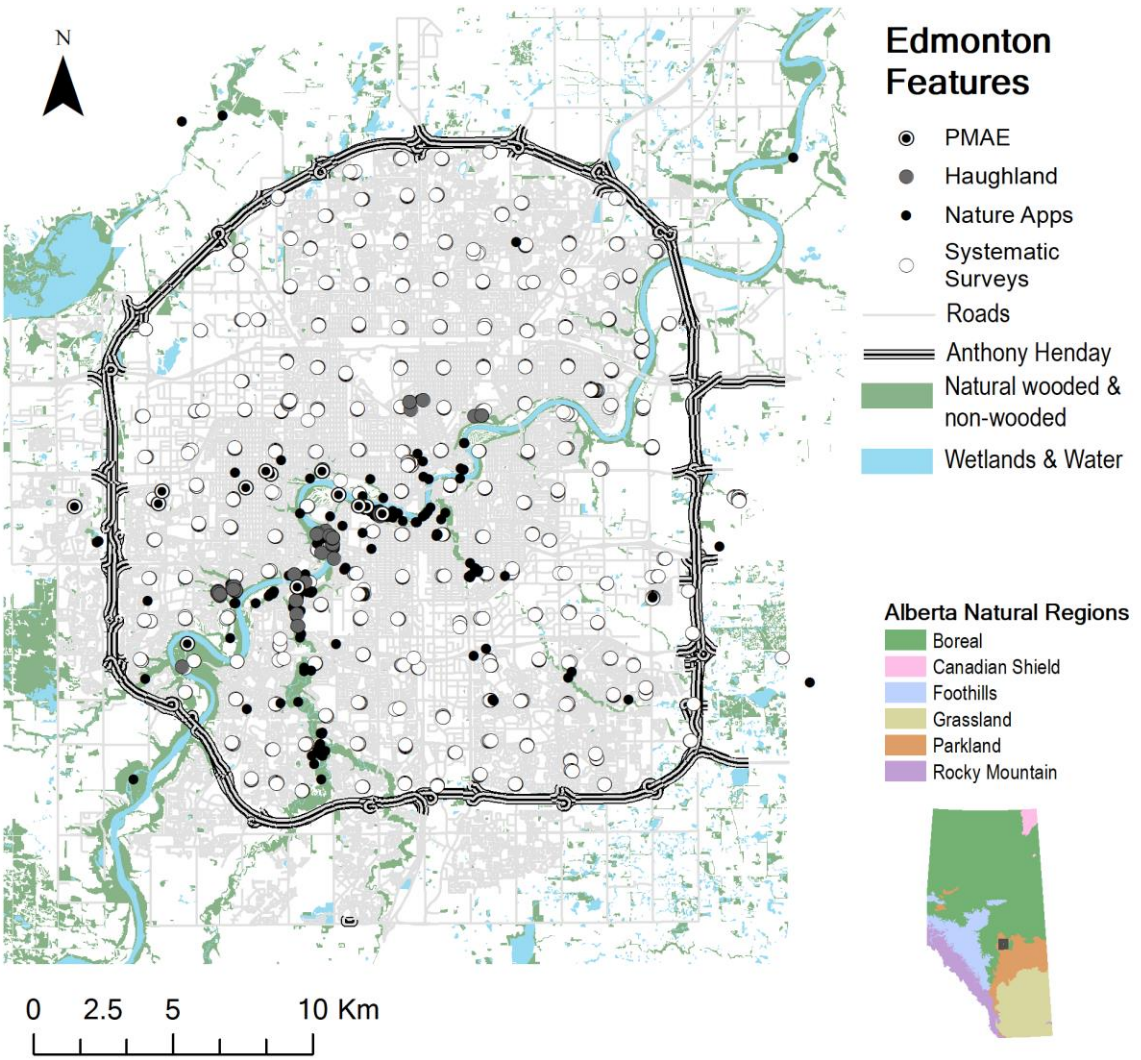

Figure 1. City of Edmonton, Alberta, Canada (53°34'24" N, 113°25'06" W, 670 m elevation), with lichen survey locations and observations mapped. The Anthony Henday is a major ring road approximately delimiting the area of focus. Not shown are two air quality stations surveyed that lie east of the city. Edmonton is within the Parkland Natural Region, surrounded by the Boreal Natural Region to the north, east, and west (inset map).

2019 Systematic surveys. – To systematically survey epiphytic lichens, we surveyed 191 sites located across Edmonton. We defined the area of interest as a 440 km^2 region contained within Edmonton's outer ring road, Anthony Henday Drive (Fig. 1). We chose a 1.5 km grid spacing to make our study comparable to that of McCarthy et al. (2009) and because it generated a logistically feasible number of sites (n=135) for our initial survey effort in February and March. An additional 49 sites were added to enhance coverage wherever possible in industrial zones. We also conducted more intensive surveys near seven permanent air quality monitoring stations for a total of 1,095 trees examined across 191 sites.

We generated a map for each site showing nearby potentially suitable trees using the Open Edmonton Tree Database (City of Edmonton 2019) and ArcGIS. The database contains information on >350,000 city-owned trees located in urban parks, on boulevards, and road right-of-ways. Each tree in the database has a unique identification number, planting year, species, and diameter at breast height (DBH; 1.37 m). We targeted deciduous trees in the genera *Fraxinus, Populus* and, *Ulmus* with a planting year of 1990 because of a long history of planting these genera in Edmonton, ensuring that relatively mature trees were available in many neighborhoods. Other deciduous species were surveyed if the target genera were not available. The planting year was a placeholder for trees planted prior to or in 1990. However, when trees are replaced by the city, the planting date and species are rarely updated. To address this unanticipated source of error, we independently recorded the tree species (or genus where species could not be assessed), circumference, as well as the latitude and longitude of each tree surveyed when we could not unambiguously assign a tree a known tree identification number.

At each survey location, participants surveyed the five closest target trees with a minimum DBH of 15 cm. At air quality monitoring stations, we increased survey intensity to 25 trees. We avoided trees with potentially anomalously high exposure to traffic exhaust such as those at bus stops, next to intersections, and along roads with more than one lane in each direction. Wherever possible we also avoided trees where snow was piled more than 0.5 meters high around the base or that had significant bark damage.

Surveys were conducted between 25 February 2019 and 25 July 2019. The early survey period was marked by below-average cold weather, with temperatures reaching -40°C with wind chill. We thus minimized survey duration and avoided methods that required dexterity (such as attaching quadrats to trees for frequency counts) and instead measured relative cover. Surveyors recorded the presence of each of 21 target species or genera (Table 3) on the north-, south-, east-, and west-facing sides of each tree, between approximately 0.5 m to 1.5 meters off the ground (to avoid snow-covered or nutrient-enriched tree bases, and to make the survey area more comparable between surveyors of different heights). The target taxa were chosen by the senior author based on prior observation within Edmonton and because we hypothesized they could be accurately determined by novice surveyors. Each species was scored as absent (0) or present with a relative abundance of 1, 2, 3 or 4 (i.e., the number of sides the species was present on). While this simplified differences in cover between species, reducing the time spent estimating cover allowed us to scan a larger proportion of tree surface area and capture more species. When surveyors could not identify a lichen, they collected representative small vouchers for later verification. Lichens that could be identified in the field but which were not on the target list were added to the site list and surveyed as above. Initially, only macrolichens were included in the target list, however, on the first day of the survey we added the crustose genera *Caloplaca* and *Candelariella* due to their abundance and hypothesized detectability. Samples of crustose lichens were taken at a subset of sites for later identification.

There were three groups of surveyors. The trained novices consisted of undergraduate, graduate, and open-learning students (n=8) that had completed the first half of a course on the lichens of Alberta. This group completed approximately 14 hours of laboratory study of lichens prior to the project, including weekly testing that covered all but one of the species on the target list. The intermediate group included a former student, a new lichen technician, the lichen course Teaching Assistant, and an experienced ABMI field supervisor (n=4). All had received training and participated in some lichen-related fieldwork prior to the project. The experts consisted of the senior author and a lichen technician each with more than ten years of laboratory and field experience (n=2).

Participants received approximately 1–2 hours of field training on survey methodology on their first day of monitoring by one of the experts. Experts provided additional field assistance and quality checks. To estimate observer effects, 50 sites were audited by pairs of intermediate and expert surveyors. Thirty-four additional sites were revisited to better document the crustose lichen flora once it was determined the original surveyors had not captured those species (based on audits and information from surveyors).

2021 Rare tree surveys. **–** Two authors (K. Schafer and J. Singh) surveyed tree species that are relatively rare in Edmonton as part of the 2021 U of A Lichens of Alberta class. Trees growing on the U of A North Campus were chosen because they were not represented in existing surveys, and included species of conifers in the genera *Larix, Picea, Pinus, Taxu*s, and *Thuja*, as well as deciduous species in the genera *Acer, Aesculus, Betula, Fraxinus, Quercus, Salix, Syringa*, and *Ulmus*. In total, 44 individual trees were surveyed, and all accessible surfaces of those trees (bole, branches, twigs) were examined for crustose, calicioid, and macrolichens. Representative samples were taken from each tree and identified or confirmed in the laboratory with the help of the senior author. These data were added to the combined dataset for mapping and inclusion in the annotated species list.

Data sources. II. Historical and herbarium records. – To establish a list of lichens previously recorded in Edmonton, we searched the literature, databases of the Royal Alberta Museum (PMAE), a small portion of the University of Alberta (ALTA) lichen records (most of the lichen records are not databased at this time and the herbarium was closed to visitors due to the COVID pandemic), and the Canadian Forestry Centre in Edmonton (provided by G. Pohl, pers. comm.), as well as the Government of

Alberta's online species tracking dataset BIOTICS (Government of Alberta 2020). Any specimens that could be located were verified or reidentified. We did not consider a 1:1 taxonomic change a misidentification. For example, a correctly determined *Melanelia albertana* or *Parmelia albertana* (currently *Melanelixia albertana*) was recorded as a confirmed identification. We also searched the Consortium of North American Lichen Herbaria (https://lichenportal.org, CNALH 2020) for records, and T. Spribille searched a draft modern catalog of lichens from the prairie provinces (Deneka et al. in prep.), which includes a comprehensive summary of species cited in literature.

Data sources. III. Nature-reporting applications. – We searched two citizen science applications ("apps") for submitting photography-based observations of biodiversity, NatureLynx (2020) and iNaturalist (2020), for lichen records within our geographic area. Data were downloaded directly from iNaturalist using Edmonton as a geographic filter and a "fungi including lichens" taxon filter, providing 191 potential records. The geographic locations of observations uploaded to NatureLynx are masked for privacy and protection of potentially sensitive data, so accurate location data was provided by the ABMI (J. Bell, ABMI unpublished data, 2020). After filtering all provided records by location, 136 records from the "bryophytes and lichens" category remained. All records were visually examined, records for bryophytes and non-lichenized fungi were removed, and lichen photographic records were verified or reidentified where possible, while also noting their substrate and location within Edmonton.

Identification. – We used Leica MZ6 or M60 stereo microscopes and Leica DM750 or Medilux 12 compound microscopes to examine anatomy under bright field or polarized light, noting the presence (POL+) or absence (POL-) of birefringent crystals. Anatomical measurements are given as a range (minimum–maximum) because of the small number of specimens available from Edmonton. Where applicable we used chemical spot tests to support our determinations, including 10% potassium hydroxide (K), sodium hypochlorite (C), Lugol's iodine (I), paraphenylenediamine (PD, either dissolved in ethanol or in the form of Steiner's solution), ultraviolet light (either short wave [UV_{254}] or long wave [UV_{365}]), largely following Brodo et al. (2001). Some collections were examined using thin-layer chromatography (TLC), mostly following Orange et al. (2010). We used 10 × 20 cm glass plates with solvents A, B′, and C (Orange et al. 2010), checked for fatty acids using water spray, and boiled the acetone-specimen mixtures three times in a water bath prior to spotting (as per I. Brodo, pers. comm.). For photography, we used one of the following: Leica MC170 HD camera (stereoscope), Leica ICC50 HD (compound microscope), Dinolite Edge Digital Microscope AM4515Z7T, or a microscope-mounted Canon D6. We color-corrected and created composite images from images taken at multiple focal depths to increase resolution in Photoshop (Adobe 2008-2021). Sections of specimens were mounted in water unless otherwise indicated.

Molecular methods. – To verify or aid in the identification of a subset of collections, the internal transcribed spacer (ITS ribosomal DNA; internal transcribed spacer regions 1 and 2 as well as the embedded 5.8S region of the ribosomal rDNA and adjacent sections of the large and small ribosomal subunits, LSU and SSU) was Sanger sequenced by T. Spribille's lab at the U of A. ITS is the single most sequenced locus in fungi and widely used as a barcode (Hoffman & Lendemer 2018, Schoch et al. 2012,). DNA was extracted using the Qiagen DNeasy Plant Mini Kit following the manufacturer's instructions, or, in the case of sparse material, the QIAmp DNA Investigator Kit. PCR was performed using ITS1-F (Gardes & Bruns 1993) and ITS4 primers (White et al. 1990), and the KAPA 3G Plant PCR Kit (KAPA Biosystems). The PCR cycle used was: pre-denaturation for 5 min at 95°C, 35 cycles of amplification, each cycle 30 sec at 95°C, 30 sec at 57°C, and 30 sec at 72°C. After the 35 cycles, extension occurred over 7 min of 72°C and then samples were stored at 4°C. PCR products were visualized on agarose gel after electrophoresis and sent for sequencing if a product was seen. Samples with multiple bands were not sent for sequencing due to poor chance of a clear sequence. Prior to sequencing, samples were purified using standard ExoSap protocol. PCR products were sequenced by Psomagen, Inc., USA, and forward sequences were visually examined for errors or ambiguities prior to screening.

Phylogenetic analyses. – We screened sequences with BLAST searches against the NCBI nucleotide database to identify sequences that may represent non-target organisms (NCBI Resource Coordinators 2018). The sequences generated for this study were complemented with sequences from GenBank representing additional species and specimens, as well as a small number of sequences from the senior author. For queried sequences of species adequately represented in GenBank, we report similarity metrics with accessioned sequences in the annotated species list. Further analyses including de novo tree construction were conducted for Candelariaceae, *Endocarpon, Lecidella, Flavopunctelia, Lecanora dispersa* group, *Peltigera*, *Physconia*, and *Punctelia*, as BLAST results were insufficient.

For genera requiring phylogenetic analyses, the following steps were common across analyses; specifics for each phylogeny are provided below. Sequences for each analysis were aligned with our query sequence(s) using MAFFT via a web platform (MAFFT ver. 7.49, Katoh et al. 2002, Katoh & Standley 2013, Katoh et al. 2019) or in MegAlign Pro v. 17 (DNASTAR 2021), and visually inspected in BioEdit 7.7.1 (Hall 1999). We used ITSx 1.1 (Bengtsson-Palme et al. 2013) to split sequences into ITS, small subunit, and large subunit files to aid in sequence vetting and where appropriate create partitions for nucleotide substitution model fitting. We visually examined final alignments in BioEdit and trimmed all sites from the alignment present in ≤10% of sequences. Alignments were screened using GUIDANCE2 for ambiguous sites, and analyses were completed with and without ambiguous regions and the resultant trees visually compared. Original fasta files and final alignments are deposited in Dryad (DOI https://doi.org/10.5061/dryad.sqv9s4n6d). Sequence voucher data are provided in Supplementary Appendix 2, also available in the Dryad deposit. We generated maximum likelihood phylogenetic trees in W-IQ-TREE 1.6.12 (Nguyen et al. 2015, Trifinopoulos et al. 2016) via http://iqtree.cibiv.univie.ac, specifying partitions (partition model: Chernomor et al. 2016), linked branch lengths, automatic model selection (ModelFinder: Kalyaanamoorthy et al. 2017), and free rate heterogeneity. Branch support was analyzed by 1,000 ultrafast bootstraps (UFBoot: Hoang et al. 2018) as well as SH-aLRT single branch tests with 1,000 replicates. Trees were visualized and organized in Dendroscope 3.7.6 (Huson & Scornavacca 2012) and/or MegAlign Pro, and exported to Microsoft Office Professional Plus Powerpoint 2016 for editing.

The Candelariaceae phylogeny was generated *de novo* with seven new sequences from the senior author, GenBank sequences with high BLAST similarity to our new sequences, and sequences from Westberg et al. (2011), Liu & Hur (2018), and Liu et al. (2019). Additional sequences for *Candelaria* were added from GenBank to increase taxon sampling in that clade. The *Endocarpon* phylogeny was generated *de novo* using two new sequences from the senior author, GenBank sequences with high BLAST similarity to our new sequences, and sequences from Zhang et al. (2017). The *Flavopunctelia* phylogeny was constructed using all accessioned sequences of *Flavopunctelia* in GenBank, sequences from this study, and GenBank sequences with high BLAST similarity to our new sequences, regardless of determination. The *Lecanora dispersa* group phylogeny was created by adding new sequences from this study, their top-scoring megablast GenBank sequences, and the ITS of the type of *L. lendemeri* E. Tripp & C.A. Morse (Tripp et al. 2019) to the multiple sequence alignment from Śliwa et al. 2012 (Treebase study #12681, using 'mafft—add' (https://mafft.cbrc.jp/alignment/server/add.html, Katoh & Frith 2012). Similarly, the *Physconia* phylogeny was compiled using the 60 sequences from Esslinger et al. (2017, deposited in Dryad as https://doi.org/10.5061/dryad.bh7mc), and additional sequences from the senior author, GenBank, and this study. Finally, we aligned five new *Punctelia* sequences to the ITS portions of the concatenated alignment of Alors et al. (2016), and the ITS alignment of Lendemer & Hodkinson (2010) using 'mafft—add'. ITS was concatenated with the other loci in Mesquite, and the new multiple sequence alignments were reanalyzed with partitions.

For *Peltigera* sequences, we also used NCBI BLAST with megablast to check the percent of our sequence that was identical to sequences published by F. Lutzoni and J. Miadlikowska *Peltigera* projects, which we mapped to currently undescribed molecular species delimited by Pardo-De la Hoz et al. (2018) and Magain et al. (2018). For *Peltigera* section *Peltigera* we also checked for the presence of species-specific hypervariable region sequences described in Magain et al. (2018).

A sterile crust that could not be assigned to genus on morphology or chemistry alone (*Haughland 2020-28*) was analyzed using the workflow in Hodkinson & Lendemer (2012). We first queried the sequence in NCBI BLAST with megablast. Based on the combination of the best BLAST hits, as well as possible species matches from the literature based on TLC results (Lendemer 2010, 2013; Malíček et al. 2017), a multi-genus dataset was created to show the placement of the sequence within the potential genera *Buellia*, *Lecanora*, *Lecidella* and *Lepraria*. Based on those results, we used the most recent *Lecidella* phylogeny from Zhao et al. (2015; TreeBase Study ID #17997), downloaded the seven loci dataset, added selected ITS sequences from GenBank and this study to the existing alignment (mafft--add, Katoh & Frith 2012), manually edited and trimmed the new alignment, and generated a new phylogenetic tree using methods described above, with partitions for each locus. For the multi-genus tree, we post-hoc graphically simplified and collapsed clades within *Lecidella* to focus on the broader, genus-level placement of our sequence.

Nomenclature and new records. – Nomenclature and taxonomic authorities largely follow Esslinger (2019). Exceptions are outlined at the beginning of each morphogroup section in the annotated species list below, and for species for which we have adopted relatively recent taxonomic changes or conversely retained older taxonomy we provide recent synonyms (e.g., names in Brodo et al. 2001). To assess whether species were newly reported from Edmonton and Alberta, we searched salient literature, a draft modern catalog of lichens for the prairie provinces (Deneka et al. in prep.), as well as the databases previously mentioned (see section Data sources. II. Historical and herbarium records), using both currently accepted nomenclature and synonyms.

Preliminary assessment of species' utility as citizen science indicators. – In addition to being responsive to the gradients of interest (air quality and climate), we decided a citizen science biomonitor should be widely distributed across Edmonton, be easily perceptible and identifiable, and show high survey repeatability. Here we address the latter; sensitivity to gradients will be addressed in a future paper. Distribution was assessed using our composite dataset. We summarized species by the number of records as well as their presence in each of three major habitat types: tablelands (largely represented by boulevard trees), parklands (forested parks and natural areas within the tablelands), and river valley and ravine forests. We used presence and abundance of records in nature-reporting apps as a metric of perceptibility to the public. We compared the original, user-submitted identifications to our determinations to assess the ability of the public to accurately identify lichens to genus or species. We assessed survey repeatability using Pearson correlations and t-tests for significance between a species score on original surveys and audits at 50 sites for the 19 macrolichen species and 2 crustose genera included in the systematic surveys. We set a cut-off of a statistically significant $R \geq 0.5$ to consider a surveyed species repeatable. Analyses were run in Microsoft Office Professional Plus Excel 2016. Species maps were created using looping scripts in ESRI ArcGIS Pro 9.2.0, based on a map created in ESRI ArcMap 10.7.1.

RESULTS

Phylogenetic analyses. – Our proximate goal was to confirm the taxonomic placement of a subset of Edmonton collections. Of 44 collections for which DNA was extracted, we obtained sequences for 35 representing 33 putative species. Six collections were not *a priori* identified with confidence; sequencing allowed us to at least tentatively identify four of those species. Of the remaining 27 species, molecular data supported all of our phenotype identifications to genus, and 59% (16) of our identifications to species. Of the remaining 41% (11), we could not confidently resolve the species-level taxonomy of 30% (8) due to insufficient molecular data (lack of reference sequences, low BLAST values, and/or unresolved polyphyletic species in phylogenetic analyses). We concluded our species-level identifications were incorrect for 3 species (11%), and molecular data allowed us to correct those. In total we generated nine phylogenies based on ITS, and these analyses provide some insight into the broader taxonomy of these taxa, explored by taxon below.

Candelariaceae. **–** The first phylogeny for Candelariaceae and the nrITS sequences generated for that study (Westberg et al. 2007) form the core of all subsequent analyses (e.g., Liu & Hur 2018, Kondratyuk 2020, this study, Fig. 2). After alignment, trimming, and removal of ambiguous regions (guidance score of <0.93), our dataset was composed of 86 sequences and 490 sites, of which 185 were parsimony-informative, 64 were singletons, and 241 were constant. The best fit models by partition were SSU: TN+F+G4, ITS1: GTR+F+G4, 5.8S: K2P, ITS2: TPM2+F+G4, and LSU: JC. The basal branches remain poorly resolved, and some species as currently understood are poorly discriminated by ITS (e.g., *Candelariella vitellina* (Hoffm.) Müll. Arg). Given the need for additional loci and intra-specific representation, here we do not propose taxonomic changes based on our analyses, instead highlighting areas where revisions may be required in the future. One branch of the tree that has benefited from additional data is *Candelaria* Clade III (following Westberg et al. 2007), including *Candelaria concolor* (Dicks.) Arnold and the recently described *Candelaria asiatica* D. Liu & J.S. Hur (Liu & Hur 2018). Our Alberta sequence clusters with a highly supported clade of *C. concolor* from eastern North America, sister to a *Candelaria asiatica* clade (Fig 2). In contrast, *C. concolor* sequences from Europe form a highly supported clade distinct from other regions (Fig. 2). Recent sequences of *C. asiatica* from China (Kondratyuk et al. 2020) have not been deposited to a public repository, so geographic representation of

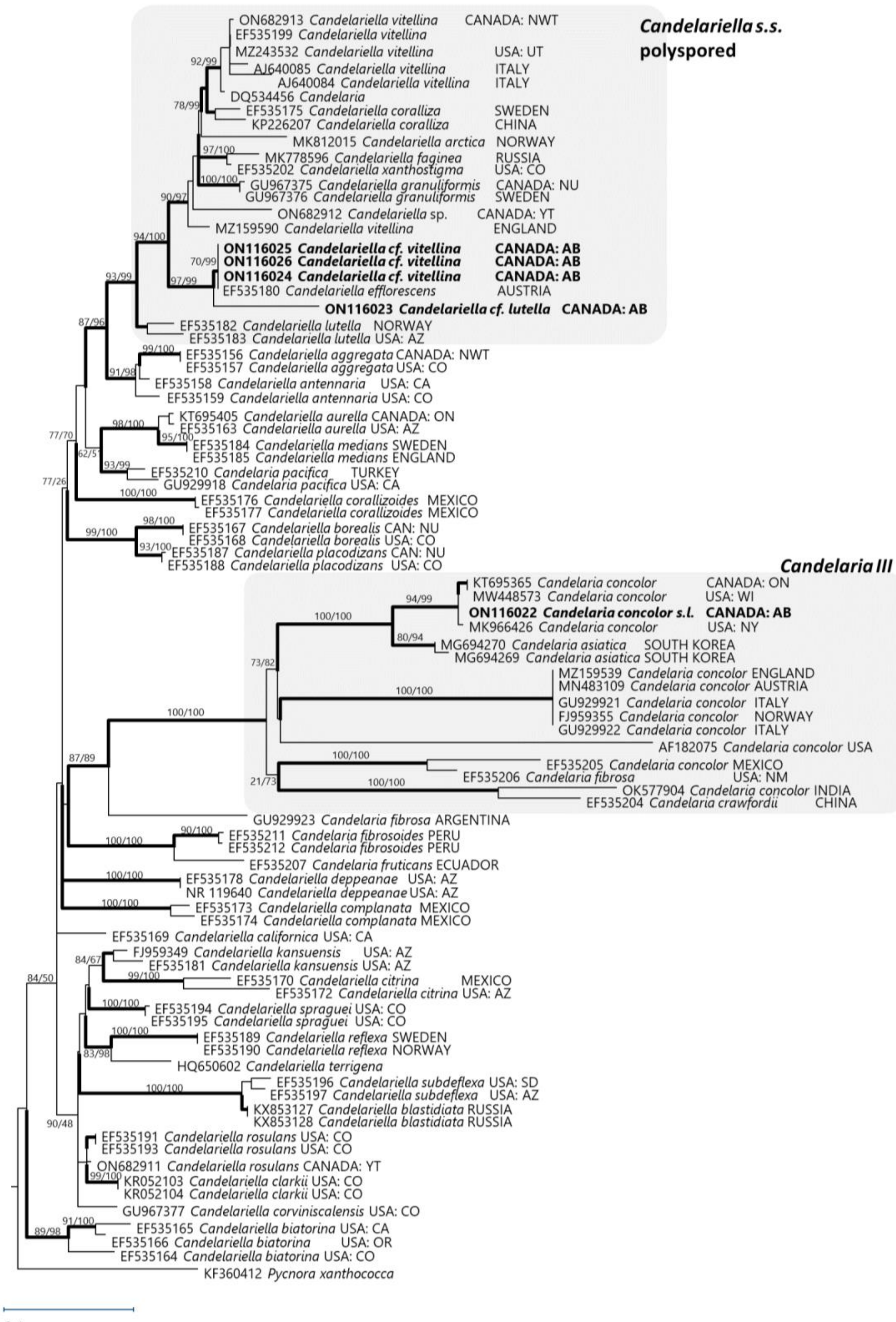

Figure 2. The maximum likelihood tree of Candelariaceae species based on nrITS. The tree was unrooted for analyses, and rooted for visualization on *Pycnora xanthococca*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values ≥70% are drawn with thicker lines. GenBank sequences are labelled by their accession number and collection location. Newly-generated sequences are in bold. Scale = nucleotide substitutions per site.

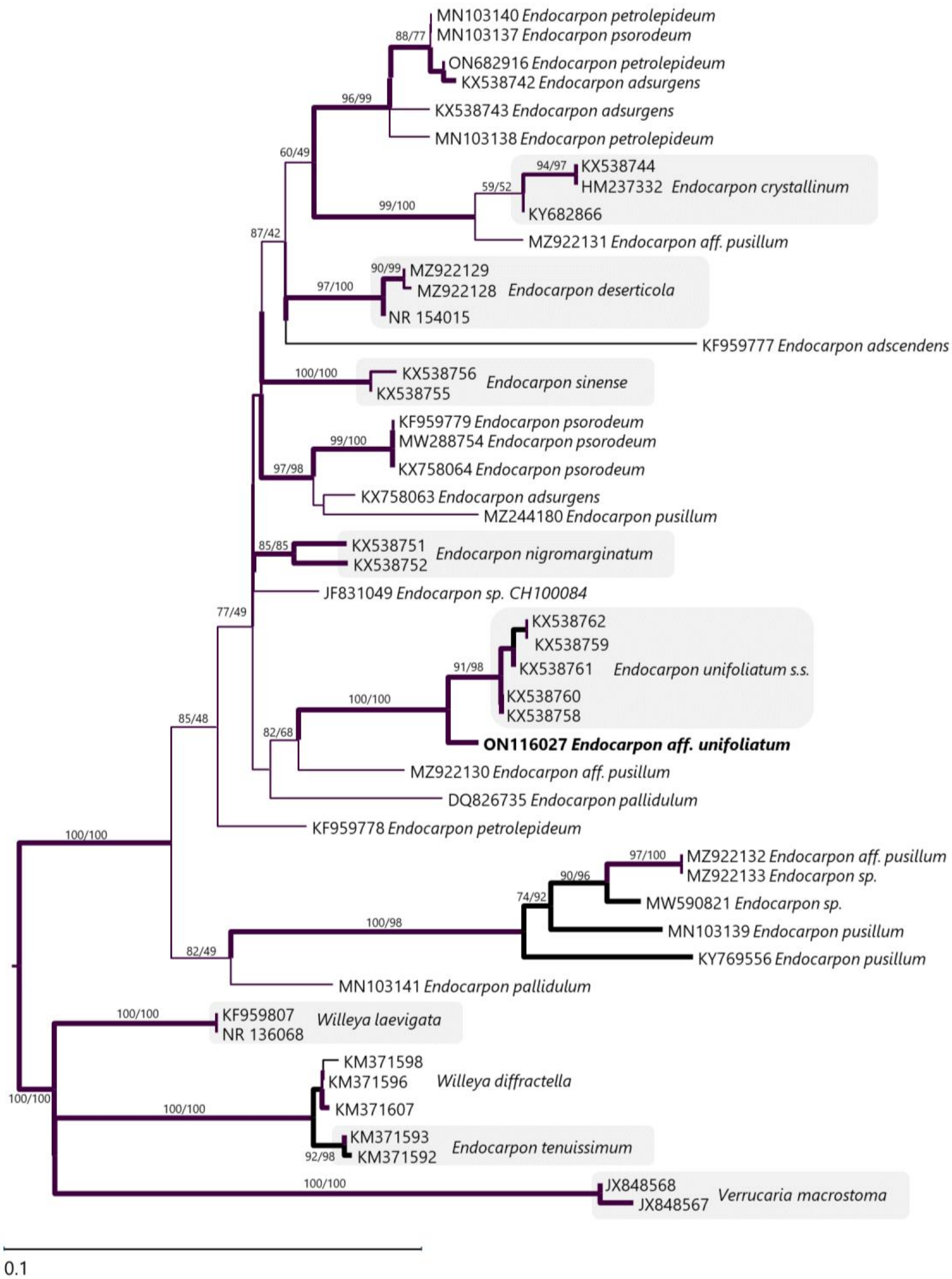

Figure 3. The maximum likelihood tree of *Endocarpon* based on nrITS. The tree was unrooted for analyses, and rooted for visualization on *Verrucaria macrostoma*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. GenBank sequences are labelled by their accession number and name, and monophyletic species are highlighted with grey polygons. Newly-generated sequences are in bold. Scale = nucleotide substitutions per site.

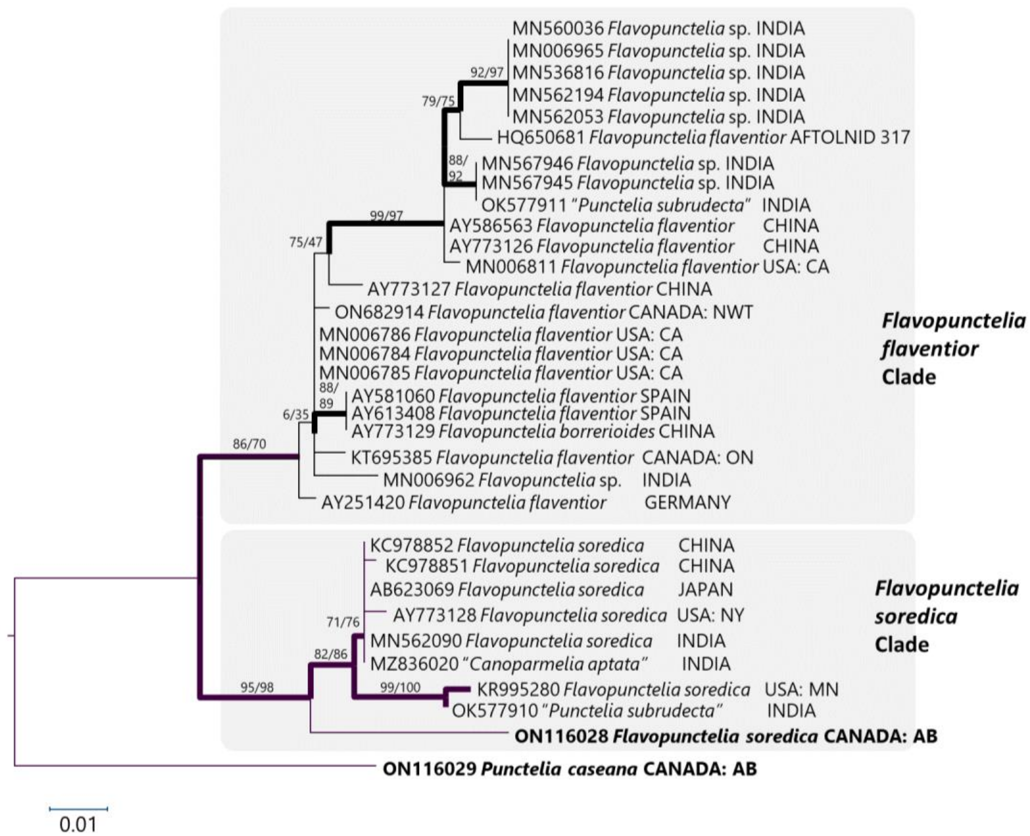

Figure 4. The maximum likelihood tree of *Flavopunctelia* species based on nrITS. The tree was unrooted for analyses, and rooted for visualization on *Punctelia caseana*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. GenBank sequences are labelled by their accession number and name. Newly-generated sequences are in bold. Names in quotes are putative misidentifications in GenBank. Scale = nucleotide substitutions per site.

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that species within our analysis is limited. Kondratyuk et al. (2020) interpreted a single specimen from Canada based on 28S nrLSU as *C. asiatica*; this sequence came from the same specimen as KT695365 (ITS used herein), but it appears that for unexplained reasons those authors did not use the corresponding ITS sequence in their phylogeny.

Our sequences of what we morphologically classified as epiphytic *Candelariella vitellina* are identical to the single available sequence of *Candelariella efflorescens* R.C. Harris & W.R. Buck, an epiphytic, sorediate, rarely fertile species that occurs predominantly on broadleaved trees in eastern North America (Harris & Buck 1978). Only additional data will differentiate between alternate interpretations of this; either ITS is insufficient to discriminate species within this clade, or *C. efflorescens* is an epiphytic species that varies phenotypically across its range. Harris and Buck (1978) noted in their description of *C. efflorescens* that "given an isolated apothecium, we would not be able to distinguish which of the three species [*efflorescens*, *vitellina* and *xanthostigma* (Ach.) Lettau] it came from." Because our specimens were never found to be sorediate, here we treat them as *C.* cf. *vitellina* pending further phylogenetic work. Similarly, since our single *C. lutella* sequence did not cluster with existing sequences of *C. lutella*, and instead was basal to the *C. efflorescens* clade, we treat those collections as *C.* cf. *lutella*.

Endocarpon. – After alignment and trimming, the final dataset consisted of 48 sequences and 848 sites, of which 263 were parsimony-informative and 71 were unique. The best fit models by partition were SSU: K2P+G4, ITS1: TNe+G4, 5.8S: K2P+I, ITS2: TIMe+R2, and LSU: K2P+I. These analyses should be interpreted cautiously as only 14 of the circa 75 currently accepted *Endocarpon* species are represented in GenBank. Our single ITS sequence is basal to a highly supported clade of *E. unifoliatum* T. Zhang, X. L.

Wei & J. C. Wei recently described from China (Zhang et al. 2017), and here reported new to North America (Fig. 3). In acknowledgement of the lack of representation of described species, as well as the relatively large number of differences in our sequence versus the five sequences from China, we report our determination as *E.* aff. *unifoliatum*.

Flavopunctelia. – Six *Flavopunctelia* species are accepted at present (Index Fungorum, www.indexfungorum.org), and sequences exist for the three species reported to be sorediate: *F. flaventior* (Stirton) Hale, *F. soredica* (Nyl.) Hale, and *F. borrerioides* Kurok. After alignment and trimming, the final dataset was composed of 33 sequences and 511 sites, of which 40 were parsimony-informative and 123 were unique. No ambiguous regions were detected in guidance (alignment score=1.0), and the best fit models by partition were ITS1: TNe, 5.8S: K2P, and ITS2: TNe+I by BIC (Kalyaanamoorthy et al. 2017). This tree is the most comprehensive *Flavopunctelia* tree published to date, and overall supports the separation of *F. flaventior* and *F. soredica* with high support (Fig. 4). These species often intergrade phenotypically in Alberta. A single sequence of *F. borrerioides* groups in a highly supported clade with two *F. flaventior* from Spain. Future work should re-examine these collections to determine if this clade represents *F. borrerioides* s.str. Given we found no records of *F. borrerioides* in the CNALH, Consorcio de Herbarios de Líquenes en América Latina (https://lichenportal.org/chlal/), or GBIF (https://www.gbif.org/), additional work is needed to determine if this species is overlooked or whether it should be reduced to synonymy with *F. flaventior*. Additional structure within *F. flaventior* is addressed in a submitted publication (K.C, Rajeshkumar, B.O. Sharma and S. Fatima, pers. comm.). Our single ITS sequence of *F. soredica* is basal to a well-supported clade of *F. soredica* sequences. Three sequences from other genera with high BLAST similarity to our sequence may be misidentifications (denoted by quotes within the tree).

Lecanora dispersa group – Given the recent flux in generic designations within *Lecanora* (Zhao et al. 2016, Kondratyuk et al. 2019), here we retain *Lecanora* in the broad sense. After alignment and trimming, the final dataset was composed of 66 sequences and 511 sites, of which 180 were parsimony-informative and 56 were unique. The best fit models by partition were ITS1: TIM2+F+G, 5.8S: K2P, and ITS2: TNe+G4 according to BIC (Kalyaanamoorthy et al. 2017). The final maximum likelihood tree suggests many of the same relationships as in Śliwa et al. (2012) and Tripp et al. (2019), and also presents the same unresolved problems (Fig. 5). Our principal concern was the placement of *L. hagenii* (Ach.) Ach. and *L.* cf. *persimilis* (Th. Fr.) Arnold sequences from Edmonton. It is clear *L. hagenii* as currently understood is polyphyletic. It is not clear whether any of the four clades containing *L. hagenii* sequences correspond to that species in the strict sense. Śliwa et al. (2012) hypothesized that the clade marked "*hagenii* II" on our tree may correspond to *hagenii* s.str., due to its close relationship to *L. crenulata* Hooker (Fig. 5). This clade is widely distributed and contains both pruinose and epruinose collections, including our *L.* cf. *persimilis*. Conversely, our single Edmonton sequence of *L. hagenii* clusters in a new, highly supported clade of North American pruinose specimens ("*hagenii* III"; Fig. 5), outside of all prior *hagenii* clades (numbered I, II, and IV). In summary, the analyses confirmed only that our sequences cluster within the highly supported *L. dispersa* group, and that the sequences represent distinct taxonomic entities. Without further resolution, we acknowledge the uncertainty by modifying both epithets with "cf."

Lecidella. – A specimen that could not be identified without molecular data (isolate DLH1 from *Haughland 2020-28*) was first analyzed to determine its generic affinities using sequences of phenotypically similar species from different genera (Fig. 6B). Species we considered in addition to matches generated in BLAST include *Buellia arborea* Coppins & Tønsberg, *Lecanora alboflavida* Taylor, *L. allophona* (Ach.) Nyl., *L. impudens* Degel., and *Lepraria rigidula* (B. de Lesd.) Tønsberg. Other potential sterile sorediate/granular species that we did not find ITS data for (*Cliostomum, Lecanora, Lepraria,* and *Rinodina*) could be excluded by TLC results (our specimen contained atranorin and two possible xanthones that fluoresce orange under UV_{365} light). After BLAST, sequence selection, alignment, and removal of ambiguous sites (guidance score <0.93), our tree-building alignment was composed of 48 sequences and 421 sites, of which 105 were parsimony-informative, 110 were singletons, and 206 were constant. The best fit model was TNe+R2 using BIC. Analyses suggested our sequence fell within *Lecidella*, close to a single GenBank sequence of *Lecidella albida* Hafellner (Fig. 6B). The second analysis focused on placement within *Lecidella,* contained 78 sequences and 4084 sites, of which 1460 were parsimony informative, 1828 were singletons, and 796 were constant. The best fit models by BIC for each locus were: TIM2+F+G4 for ITS, TNe+R4 for nuclear ribosomal large subunit (LSU), TN+F+R2 for

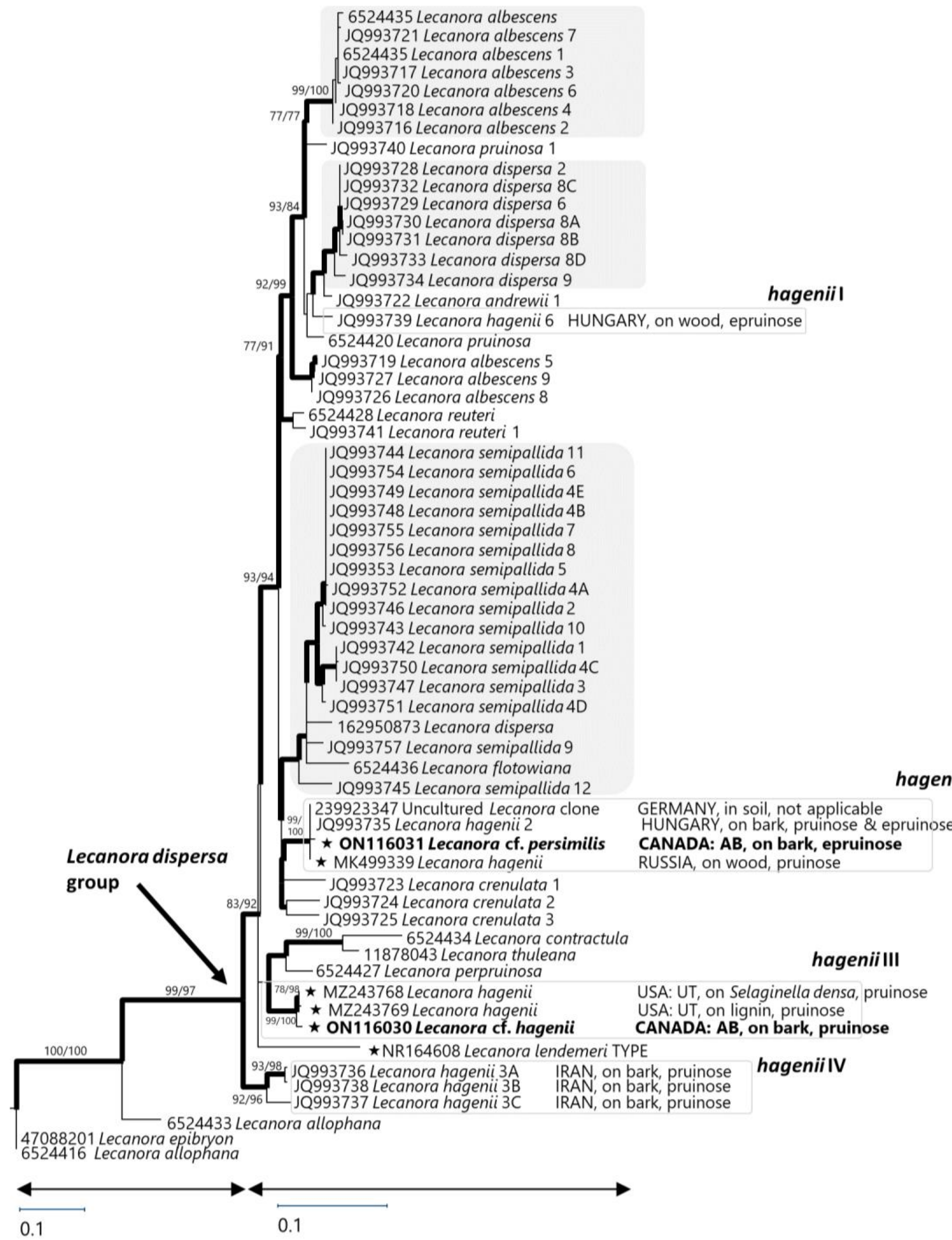

Figure 5. The maximum likelihood tree of the *Lecanora dispersa* group based on nrITS. The tree was unrooted for analyses, and rooted for visualization on *Lecanora allophana*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches with both values ≥70% are drawn with thicker lines. GenBank sequences are labelled by their accession number and specific epithet. Newly-segregated genera previously within *Lecanora* are labelled as *Lecanora* regardless of GenBank genus for ease of comparison. Monophyletic species are highlighted with grey polygons, and polyphyletic clades of *L. "hagenii"* are outlined in empty polygons. Newly-generated sequences are in bold, and sequences new to the Śliwa et al. 2012 dataset are prefaced with '★'. Scale = nucleotide substitutions per site.

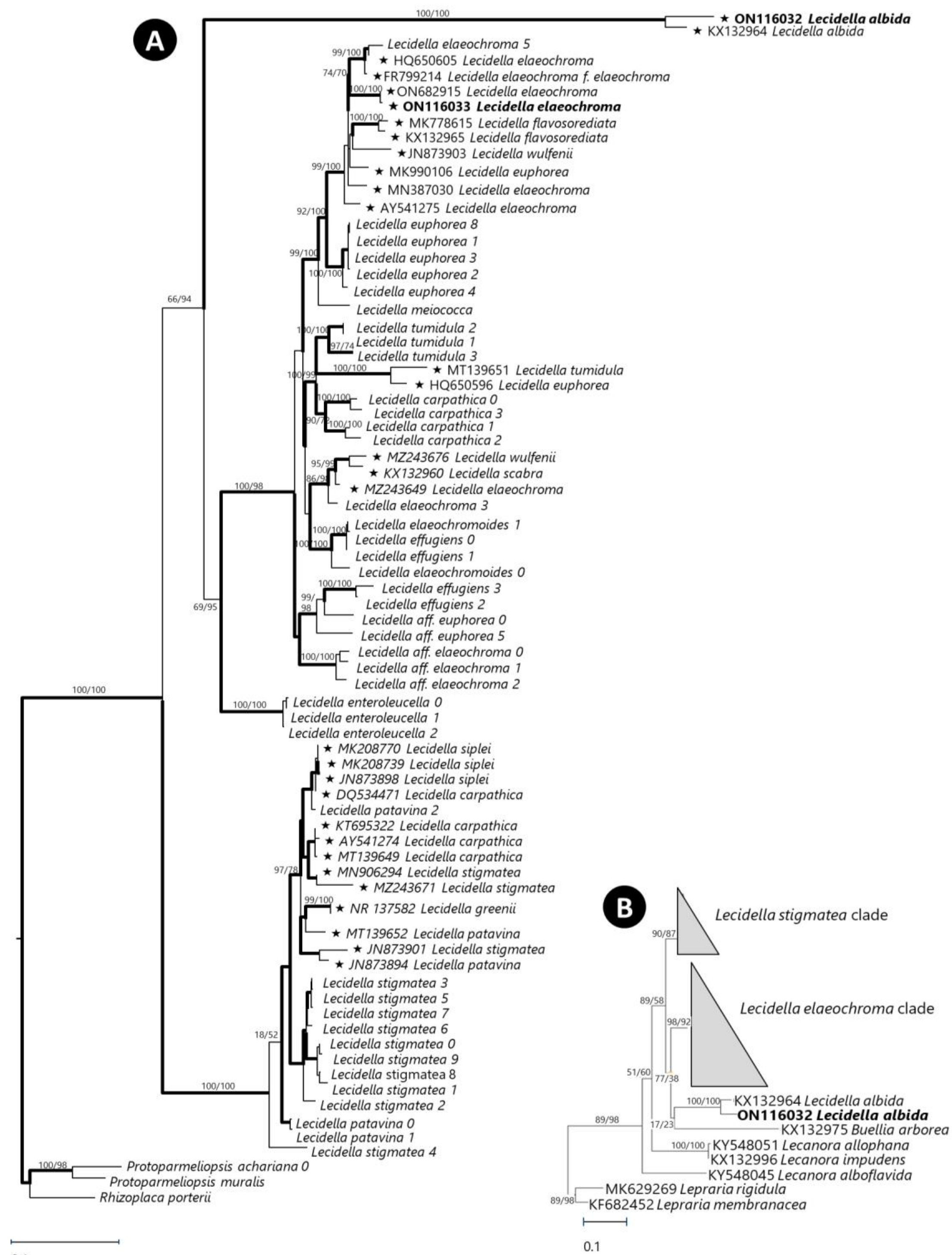

Figure 6. The maximum likelihood trees showing (**A**) placement of Edmonton sequences within *Lecidella* based on Zhao et al. (2015) and (**B**) placement of Edmonton sequences within a range of phenotypically-similar yet phylogenetically-distant species, based on nrITS. The trees were unrooted for analyses, and rooted for visualization with (A) *Rhizoplaca porteri* and (B) *Lepraria membranacea*. Values above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. GenBank sequences are labelled by their ITS accession number and name. Newly-generated sequences are in bold, and sequences new to the Zhao et al. 2015 dataset are prefaced with '★'. In tree B, the species within the *Lecidella elaeochroma* and *L. stigmatea* clade are collapsed to emphasize the deeper phylogenetic structure. Scale = substitutions per site.

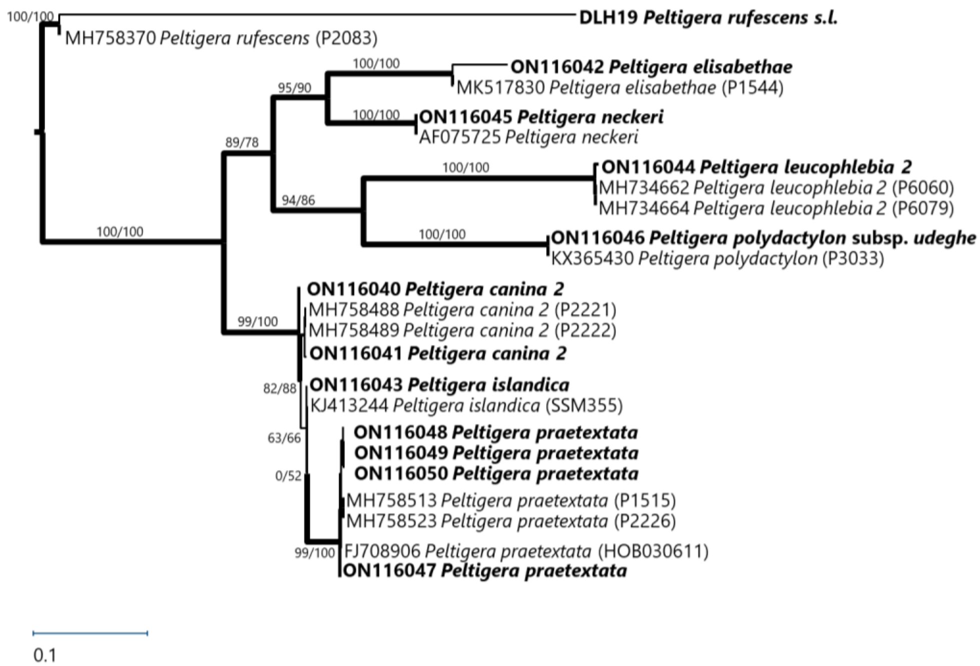

Figure 7. The maximum likelihood tree of *Peltigera* species based on the nrITS. The tree was unrooted for analyses, and rooted for visualization on *Peltigera rufescens*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. GenBank sequences are labelled by their ITS accession number and name. Newly-generated sequences are in bold. Scale = nucleotide substitutions per site.

mitochondrial small subunit (mtSSU), TNe+G4 for minichromosome maintenance complex component 7 (MCM7), TN+F+R3 for the largest subunit of the RNA polymerase II gene (RPB1), K2P+G4 for the second largest subunit of RNA polymerase II gene (RPB2), and K2P for ribosome biogenesis gene (TSR1). Similarly, our sequence formed a highly supported clade with a single sequence of *Lecidella albida*, distant from other sequenced *Lecidella* species (Fig. 6A). *Lecidella albida* is apparently new to North America. Future analyses should consider whether *L. albida* belongs outside of *Lecidella* s.str. and should be treated as distinct.

The *Lecidella* clades from Zhao et al. (2015) were also recovered in our analyses, with our additional sequences largely forming their own branches within those clades. *Lecidella elaeochroma* (Ach.) M. Choisy was recovered as polyphyletic, and our second *Lecidella* sequence, originally determined as *L. euphorea* (Flörke) Kremp. (isolate DLH11 from *Haughland 2020-43*), is positioned on a well-supported branch separate from but close to a clade with *L.* "*elaeochroma 5*" from Europe (Zhao et al. 2015). Because of this relationship, we amended the identification of our *L. euphorea* to *L. elaeochroma*. We anticipate our taxonomy will require further revision, particularly given Lendemer et al. (2019) concluded that at least some of the type material of *L. elaeochroma* does not match the material to which the name is currently being applied. Much more work is required to untangle *Lecidella.*

Peltigera. **–** Molecular data confirmed the identity of eight of the 11 *Peltigera* species found in Edmonton (Fig. 7). It also reinforced the challenge of accurately identifying members of *Peltigera* section *Peltigera*. For example, a specimen originally identified as *P. membranacea* (Ach.) Nyl. was recovered within the *P. praetextata* clade; the latter species shows considerable phenotypic plasticity, even within localities in close proximity, growing in common urban conditions. We formally report *P. islandica* Goward & S.S. Manoharan-Basil as new to Alberta, previously documented within Alberta by the ABMI (unpublished, in collaboration with C. Pardo-De la Hoz, F. Lutzoni, J. Miadlikowska, T. Goward, and I. Medeiros).

Figure 8. The maximum likelihood tree of *Physconia* species based on the nrITS, and the phylogeny in Esslinger et al. (2017). The tree was unrooted for analyses, and rooted for visualization on *Anaptychia elbursiana*. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. GenBank sequences are labelled by their ITS accession number and name. Newly-generated sequences from Edmonton are in bold, and sequences new to the Esslinger et al. dataset are prefaced with '★'. Scale = nucleotide substitutions per site.

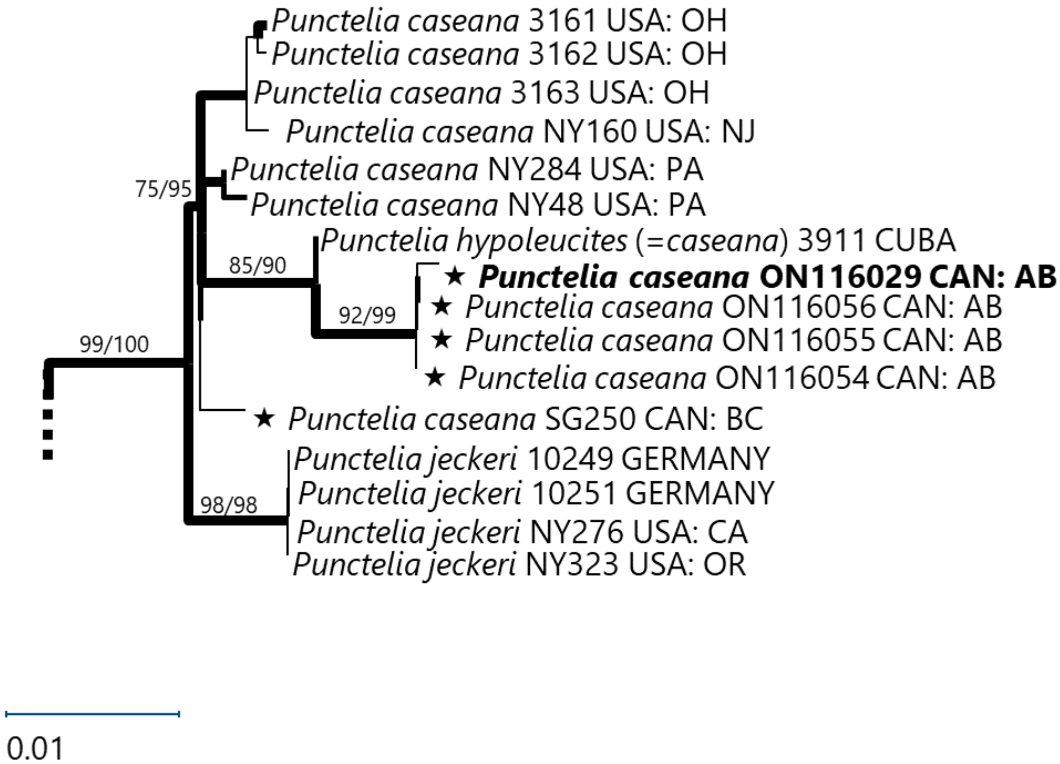

Figure 9. The maximum likelihood tree of clade C from the addition and reanalysis of Alors et al. (2016), based on the nrITS. The numbers above each branch represent the single branch support (%)/ultrafast bootstrap support (%); branches where both values exceed 70% are drawn with thicker lines. Sequences are labelled following the TreeBase supplementary data of Alors et al., sequences new to the Alors et al. dataset are prefaced with '★'and the newly-generated sequence from Edmonton is in bold. Scale = nucleotide substitutions per site.

Physconia. **–** After alignment and trimming, the final dataset consisted of 86 sequences and 486 sites, of which 111 were parsimony-informative and 43 were unique. Sequences included 60 from Esslinger et al. (2017), two from Edmonton, 11 from northern Canada from the senior author, and 13 additional GenBank sequences chosen for their high similarity to new sequences or to represent species missing in the original tree. Of the 14 species known from North America (Esslinger 2019), ten were well-represented in Esslinger et al. (2017), and we added sequences of *P. isidiomuscigena* Essl. to represent 11 North American species in total. The three species missing sequence data are the esorediate *P. californica* Essl., the fertile and lobulate *P. subpallida* Essl., and *P. fallax* Essl., which forms "nest-like" soralia; none of these species are likely to be confused with our sorediate collections. Globally, approximately 31 *Physconia* species are recognized (depending on which synonymies are accepted), 19 of which are represented in our analyses (Fig. 8). The best fit models by partition were ITS1: TIM2e+G4, 5.8S: K2P+I+G4, ITS2: TNe+G4. The analyses support our identification of *P. detersa* and *P. enteroxantha*, with the latter nesting within a well-supported monophyletic clade (Fig. 8). A single, newly added specimen of *P. jacutica* Urbanav., Ahti & Loht. from GenBank nests within an otherwise monophyletic clade of *P. detersa*. Most *Physconia* species form well-supported monophyletic clades. A noteable exception is *P. muscigena* (Ach.) Poelt. In addition, some sequences of specimens originally identified as *P. perisidiosa* (Erichsen) Moberg from northern Canada cluster with *P. rossica* Urbanav., known only from Russia and China prior to these analyses. Re-examination of these specimens suggest that they fit within the morphological circumscription of *P. rossica*. Additional work is ongoing with T. Esslinger and S. Leavitt on the Physciaceae.

Data source	# collections examined	# species confirmed	# unique records	# unique first AB records
Opportunistic surveys (2013–present)	180	89	26	3 + 2 putative undescribed species
Herbarium historical records (1974–1988)	129	47	3	0
U of A deciduous epiphytes grid-based surveys	>5000 observations, 191 mixed collections	43	19	3
U of A rare tree surveys	190 observations, 44 mixed collections	23	1	0
Nature-reporting app submissions	195	47	5	1
NatureLynx	(128)	(40)	(3)	(1)
iNaturalist	(67)	(20)	(0)	(0)
Literature reports	N/A	19	0	N/A

Table 1. Species detected by data source and their relative contribution to unique (not found in any other source) or new species records.

Punctelia. **–** Our sequences grouped with *Punctelia caseana* in both our re-analysis of Lendemer & Hodkinson (2010, isolate DLH10, results not shown), and Alors et al. (2016). Here we show just the branch of the phylogeny with *P. caseana* and *P. jeckeri* (Clade C in Alors et al. 2016) to support our identification of *P. caseana* (Fig. 9).

Additional taxa with molecular data. **–** We provide sequence comparative data within the annotated species list for the following species: *Bacidia circumspecta* (Nyl. ex Vain.) Malme, *Blennothallia crispa* (Hudson) Otálora, P. M. Jørg. & Wedin, *Caloplaca feracissima* H. Magn., *C. tominii* (Savicz) Ahlner, *Lecania naegelii* (Hepp) Diederich & van den Boom, and *Lepraria finkii* (B. de Lesd.) R. C. Harris. Analyses for these sequences were restricted to BLAST comparisons due to their high percent identity, BLAST scores and query coverage with multiple accessioned sequences that matched our original, phenotypic determination. The Edmonton sequence of *Ramalina pollinaria* (Westr.) Ach. is analyzed in Haugland et al. (in prep.), and it forms a monophyletic clade with previously published sequences of *R. pollinaria* s.str.

Diversity. – We found herbarium or literature records for 53 lichens within Edmonton. The species recorded in nature-reporting apps, largely generated over the last five years, contributed observations of 17 additional species, for a total species richness of 70. With field work, we were able to verify and find extant populations for all but five of those 70 species, and we generated records for an additional 44 species (largely crustose, calicioid or allied fungi). In total, we documented 133 species from across all data sources, including >620 collections and >5,000 field observations (Table 1). Below, we present an annotated list for 114 species (see also Supplementary Appendix 1). Of the remaining 18 species, seven represented misidentifications (*Bryoria fremontii* (Tuck.) Brodo & D. Hawksw., *B. glabra* (Motyka) Brodo & D. Hawksw., *Cladonia ecmocyna* Leighton, *Peltigera aphthosa* (L.) Willd., *Phaeophyscia hispidula* (Ach.) Essl., *Physcia millegrana* Degel., and *Usnea dasopoga* (Ach.) Nyl.). Data from the ABMI's systematic, province-wide surveys suggests these species are not likely found in Edmonton because a) their distribution is largely limited to the Foothills and/or Montane Natural Regions of Alberta (*B. fremontii, B. glabra, C. ecmocyna*) or to the cooler Boreal region (*Peltigera aphthosa*), or b) they are very rare, restricted in their distribution, or even absent from Alberta (*Phaeophyscia hispidula,*

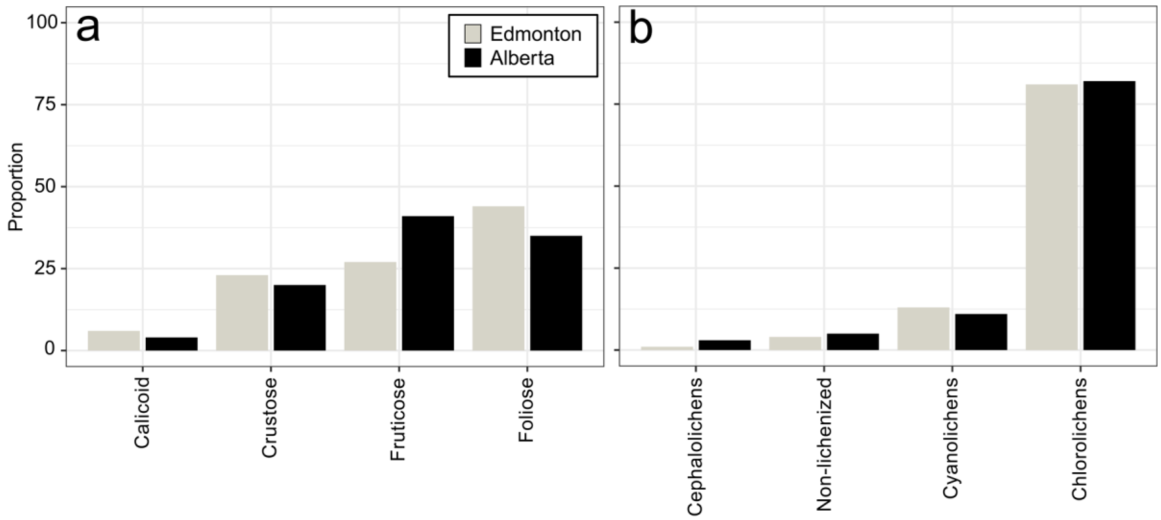

Figure 10. Proportion of lichens by a) growth forms and b) photobiont classifications detected in the city of Edmonton in comparison to those known for the province of Alberta (980 species, Government of Alberta 2017).

Physcia millegrana). Another three species records were based on outdated taxonomy (*Caloplaca holocarpa* (Hoffm. ex Ach.) A.E. Wade, *Physconia grisea* (Lam.) Zahlbr., and *Ramalina fastigiata* (Pers.) Ach.) and were revised.

We had information supporting the presence of an additional six species but were not able to confirm those records; we consider these open investigations and will continue to seek specimens to corroborate their presence. They include *Pseudevernia consocians* (Vain.) Hale & W. L. Culb., *Melanohalea subolivacea* (Nyl.) O. Blanco et al., and *Micarea melaena* (Nyl.) Hedl., which were based on herbarium collections catalogued in BIOTICS (Government of Alberta 2020) or PMAE. Unfortunately, these specimens are missing, even after herbaria searches by us or colleagues at ALTA (T. Spribille and C. La Farge-England, pers. comm.) under similar species and synonyms. In addition, *Ochrolechia arborea* (Kreyer) Almb. was reported by Elsinger et al. (2007), and Brodo (1991) cited a collection of this species from a protected area west of Edmonton, but we could not verify its presence within Edmonton. Two species we could not confirm fit multiple categories. Collections of putative *Cladonia rei* Schaerer and *Usnea glabrata* (Ach.) Vain. were redetermined to other species, but geographically and ecologically it is possible that they will yet be found within Edmonton (ABMI 2020, Haughland et al. 2018). Finally, we have specimens representing four species (*Caloplaca* sp., *Candelariella xanthostigma*, cf. *Lepra* sp., *Rinodina* cf. *albertana* Sheard) that are too sparse or poorly developed to present with any confidence at this time.

Species richness was highest in foliose lichens (48 species), followed by crustose, calicioid and allied fungi (41 species), and lowest in fruticose lichens (25). Edmonton's lichen flora is largely representative of that of Alberta with some notable divergences. Crustose lichens, fruticose lichens, cephalodiate lichens, and epiphytic cyanolichens were under-represented in Edmonton's flora (Figs. 10 and 11), while we documented a surprising number of terricolous cyanolichens, almost exclusively *Peltigera*. No epiphytic *Leptogium*, *Lobaria*, or *Nephroma* species were detected, despite searches of large-diameter trees in mixedwood and deciduous riparian forests that commonly house these genera in the Boreal Natural Region surrounding Edmonton. Finally, we found only three Collemataceae species in Edmonton, and Cladoniaceae are under-represented relative to their high diversity in the province (Fig. 11).

Opportunistic surveys resulted in the greatest number of species records with the smallest overall effort, but the U of A systematic and rare tree surveys provided a similar number of unique records, largely of crustose species (Table 1). PMAE specimens were representative of the macrolichen species from Edmonton, but few crustose lichens were represented.

New records. – In addition to the two putative new records for North America (*Endocarpon* aff. *unifoliatum* and *Lecidella albida*), we report an additional twelve species new to Alberta: *Amandinea dakotensis* (H. Magn.) P. May & Sheard, *Bacidia circumspecta*, *Candelaria pacifica*, *Candelariella*

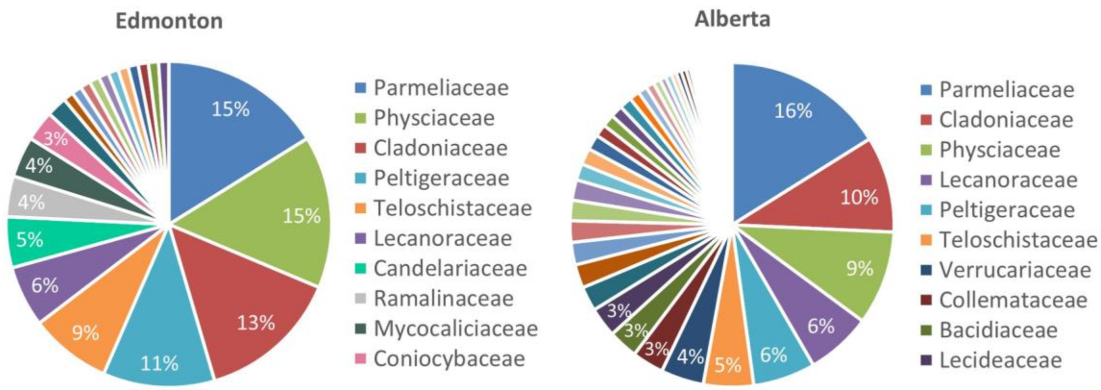

Figure 11. Comparison of taxonomic families represented in Edmonton's flora (23 different families) in comparison to Alberta (58 families: Government of Alberta 2017; Lücking et al. 2017a, b). Only the top ten families are listed, the remainder contribute <2% of the species each. Families are organized by highest to lowest percentage and the colors of the top 10 families are consistent across charts.

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antennaria Räsänen, *Heterodermia japonica* (M. Satô) Swinscow & Krog., *Lecania naegelii*, *Lecanora sambuci* (Pers.) Nyl., *L. stanislai* Guzow-Krzemińska, Łubek, Malíček & Kukwa, and *Lecidea erythrophaea* Flörke ex Sommerf., *Peltigera islandica*, *Phaeocalicium* aff. *tremulicola* (Norrlin ex Nyl.) Tibell, and *Xanthoria parietina* (L.) Th. Fr. (Table 1, Supplementary Appendix 1, annotated list below). The ABMI has publicly accessible records of the macrolichens *Candelaria pacifica*, *Heterodermia japonica*, and *Peltigera islandica*, dating back to 2003; however, ours are the first published reports of these species for Alberta. Five of the crustose species new to Alberta are apparently rare and were collected almost exclusively from riparian and ravine habitats. In comparison, *L. sambuci* and *C. antennaria* were collected largely from tableland habitats, and the latter species is surprisingly common considering it has evaded detection until now.

In addition, two putative new species to science are reported for the genus *Phaeocalicium*, and collections that could not confidently be attributed to a known North American species are reported from *Caloplaca s.l.* and Lichinaceae. Molecular work on the calicioid lichens and allied fungi is underway in collaboration with S. Selva and T. McMullin. Here we present a preliminary description to alert others to these potential new species so that additional records may be sought. We also report records of *Physcia* collections traditionally placed in existing species, but which ongoing molecular analyses suggest should be separated as new species to science: *Physcia* aff. *dimidiata* (Arnold) Nyl. and *Physcia* aff. *stellaris* (L.) Nyl. We defer further discussion of those taxonomic novelties to a future publication with S. Leavitt and T. Esslinger. We also provide modern day reports of *Alyxoria varia* (Pers.) Ertz & Tehler for Alberta. Previous records (Raup 1928, 1930) are from the northern Canadian Shield Natural Region in the province. There may be a historical collection of *A. varia* from Edmonton in PMAE (under *Opegrapha varia*), however the specimen is currently missing.

Assessment of species utility as citizen science indicators. – Approximately 25% (27 spp.) detected occur in two or more of the three major habitat types, and another 13% (14 spp.) were detected exclusively in the dominant tablelands habitats. Of those 41 species, we estimate 29 were widely distributed and detectable enough to include in a preliminary target lichen survey list (Supplementary Appendix 1). In comparison, 62% (68 spp.) were detected solely in the highly restricted river valley and ravine habitats. The nature-reporting apps suggest that the most perceptible genus to the public was *Peltigera*, followed by *Xanthomendoza* and *Cladonia* (Table 2).

The accuracy of genus-level identification was high overall. However, accuracy was lower for genera of species in Alberta that are morphologically similar to common genera from eastern North America that often dominate records in the apps, but are rare or absent from Alberta (e.g., *Flavopunctelia* was commonly misidentified as *Flavoparmelia caperata* (L.) Hale in Alberta). Species-level identification

Genus	User Identification Correct	Total # Sightings
Brown foliose (*Melanelixia, Phaeophyscia, Physconia)*	**100%**	6
Cladonia	**100%**	16
Flavopunctelia	47%	15
Parmelia	60%	15
Peltigera	**98%**	49
Physcia	**85%**	13
Ramalina	**100%**	6
Xanthoria s.l. (Rusavskia, Xanthomendoza)	75%	28
All other genera (*Candelaria, Candelariella, Chaenotheca, Punctelia, Hypogymnia, Lepraria, Vulpicida*)	**88%**	8
Not verifiable	N/A	16
Total	78%	185

Species	User Identification Correct	Total # Sightings
Cladonia spp.	53%	15
Flavopunctelia flaventior	45%	11
Fruticose species (*Bryoria fuscescens, Evernia mesomorpha, Usnea* spp.)	17%	6
Parmelia sulcata	47%	15
Peltigera canina group	47%	17
Peltigera elisabethae	44%	9
Other *Peltigera* (*didactyla, leucophlebia, neckeri*)	50%	4
Physcia adscendens, P. aipolia group, P. aff. *dimidiata, P.* aff. *stellaris*	73%	11
Ramalina pollinaria	**100%**	5
Xanthomendoza fallax	50%	22
All other species	75%	16
Not identifiable	N/A	19
Total	47%	150

Table 2. Accuracy of user-submitted identifications at genus and species level, for taxa with ≥5 records combined across NatureLynx and iNaturalist. For comparison, 58% (75 of 129) of PMAE specimens were considered accurate at species-level using current taxonomy. Entries in bold indicate ≥80% accuracy.

accuracy was lower (47% for species vs. 78% for genera) but was similar to or exceeded PMAE overall accuracy for *Cladonia* spp., *Physcia* spp., *Ramalina pollinaria*, and an assortment of species with few reports (Table 2). Audits of U of A surveys found that seven of the 21 species were too rare to assess, seven species met our cut-off of R≤0.5, and seven species had high inter-observer variability, and failed to meet our cut-off (Table 3). While rare, the presumably sensitive fruticose lichens met that cut-off, both individually or lumped together after the survey. *Usnea* specimens were often too small and poorly developed to be identified to species. Of the foliose lichens, the three most common species showed high repeatability (*Xanthomendoza fallax, Phaeophyscia orbicularis*, and *Physcia adscendens*; Table 3). *Physcia* was otherwise a difficult genus for student surveyors to differentiate in the field: while almost all species were under-detected by students, *P.* aff. *dimidiata* was over-detected, and *P. aipolia* group and *P.* aff. *stellaris* were often confounded. For the latter two species, post-hoc lumping increased survey repeatability to our cut-off (Table 3). Of the two crustose genera added to the target list, *Caloplaca* met our repeatability

Original species list	# Original/Audit sites detected	R	T	P
***Caloplaca* spp.**	17/46	**0.506**	**4.06**	**<0.001**
Candelaria concolor/pacifica	5/13	0.371	2.77	0.008
Evernia mesomorpha	2/1	**0.700**	**6.79**	**<0.001**
**Candelariella* spp.	3/47	0.174	1.23	0.226
Flavopunctelia flaventior	11/14	**0.684**	**6.50**	**<0.001**
Hypogymnia physodes	0/0		Too rare to assess	
Melanelixia albertana	0/2		Too rare to assess	
Melanelixia subaurifera	0/0		Too rare to assess	
Melanohalea exasperatula	0/1		Too rare to assess	
Parmelia sulcata	1/4	-0.042	0.29	0.771
Phaeophyscia orbicularis	50/50	**0.757**	**8.03**	**<0.001**
Physcia adscendens	44/48	**0.555**	**4.63**	**<0.001**
Physcia aipolia group	16/16	0.197	1.40	0.169
Physcia aff. *dimidiata*	17/6	0.171	1.20	0.236
Physcia aff. *stellaris*	29/41	0.409	3.10	0.003
Physconia spp.	0/1		Too rare to assess	
Punctelia caseana	0/0		Too rare to assess	
***Usnea* spp.**	3/4	**0.757**	**8.03**	**<0.001**
Vulpicida pinastri	1/0		Too rare to assess	
Xanthomendoza fallax	50/50	**0.864**	**11.91**	**<0.001**
Xanthomendoza hasseana	11/22	0.337	2.48	0.017

Post-hoc groups	# Original/Audit sites detected	R	T	P
***Physcia* aff. *stellaris*/ *P. aipolia* group**	39/42	**0.624**	**5.53**	**<0.001**
Usnea/Evernia	3/4	**0.757**	**8.03**	**<0.001**

Table 3. Repeatability of species assessments for lichens on the original survey list, as assessed with Pearson Correlations between the original and audited values at 50 sites. An asterisk (*) marks crustose genera added late to the survey list. Significance of the correlations was determined with a two-tailed T-test (df=48, column T). Post-hoc groupings were calculated as the maximum value (from 1–4) observed of the species in the group at each tree. Bolded entries indicate species with statistically significant R>0.5 (column R).

criterion. We summarize the Edmonton species that we feel meet enough criteria to form a preliminary target list of potential lichen indicator species (Table 4).

DISCUSSION

Our primary goals were to address the deficit of lichen knowledge for Edmonton and to document the species available for citizen science monitoring by publishing the first annotated lichen list for the city. We doubled the known lichen richness, largely through systematic and opportunistic field work, complemented by observations in nature-reporting apps. We also added 14 species to our provincial flora, with the potential for additional species that are putative new species to science or currently evade classification. This first annotated list presents data for 114 species within Edmonton, but we anticipate many more species remain to be discovered. Saxicolous, conifer-dwelling, and crustose lichens require additional survey effort. Leprarioid taxa require significantly more study in our region.

	Species/Group	Growth form	Photo-biont	Veg. Repro.	Habitats			Obs.	Chall-enges
1	*Caliciopsis calicioides*	calicioid	n/a	none		P		1	det?
2	*Phaeocalicium populneum*	calicioid	n/a	none	R	P		7	det?
3	*Caloplaca pyracea*	crustose	chl	none	R	P	T	58	
4	*Caloplaca cerina*	crustose	chl	none	R	P	T	5	det?
5	*Candelariella antennaria*	crustose	chl	none			T	6	
6	*Candelariella* cf. *vitellina/lutella*	crustose	chl	none	R	P	T	37	
7	*Lecanora impudens*	crustose	chl	sor	R	P		8	
8	*Lecanora dispersa* group	crustose	chl	none	R	P	T	14	det?
9	*Rinodina* spp.	crustose	chl	none			T	57	det?
10	*Flavopunctelia* spp.	foliose	chl	sor	R	(P)	(T)	>50	
11	*Melanelixia albertana*	foliose	chl	sor	R	P		>10	
12	*Melanohalea exasperatula*	foliose	chl	isi	R		(T)	5	
13	*Parmelia sulcata*	foliose	chl	sor	R	P	(T)	15	
14	*Peltigera* spp.	foliose	cya	varied	R		(T)	>28	
15	*Phaeophyscia kairamoi*	foliose	chl	sor	R	P		3	
16	*Phaeophyscia nigricans*	foliose	chl	sor	R	P	T	15	det
17	*Phaeophyscia orbicularis*	foliose	chl	sor	R	P	T	>191	
18	*Physcia adscendens*	foliose	chl	sor	R	P	T	183	
19	*Physcia aipolia* group	foliose	chl	none	R	P	T	61	id
20	*Physcia dimidiata*	foliose	chl	sor	R	P	(T)	19	id
21	*Physcia* aff. *stellaris*	foliose	chl	none	(R)	P	T	>157	id
22	*Vulpicida pinastri*	foliose	chl	sor	R			3	
23	*Xanthomendoza fallax*	foliose	chl	sor	R	P	T	>191	
24	*Evernia mesomorpha*	fruticose	chl	sor_isi	R	P	(T)	5	
25	*Ramalina* spp.	fruticose	chl	most sor	R		(T)	>7	
26	*Usnea* spp.	fruticose	chl	sor_isi	R	(P)	(T)	>9	

Table 4. Proposed preliminary epiphytic lichen list for citizen science biomonitoring in Edmonton based on detectability, distribution across different habitats, and accuracy of identification. Photobiont: chl=chlorolichen, cya=cyanolichen, n/a=non-lichenized calicioid fungus. Veg. Repro.=vegetative reproduction; sor=sorediate, isi=isidiate. Habitats: R=river valley and ravines, P=parkland forests on the flat tablelands, T=tableland habitats, largely boulevard trees and anthropogenic substrates. Parentheses indicate the species/group is rare in that habitat. Obs.=number of observations across the various sources. Challenges: det=low detectability, id=identification accuracy below desired cutoff, requires additional training.

We have not focused on species currently considered provincially rare as the Alberta NatureServe ranks require updating. However, we highlight a calicioid species found in Edmonton that our experience suggests is truly rare and deserving of protection: *Chaenotheca stemonea* (Ach.) Müll. Arg. (ranked S1, rare and tracked, Government of Alberta 2017) was a surprising find and is only the sixth collection known to the senior author from Alberta. It was collected from a humid riparian zone with dense vegetation and large diameter *Picea* (living and dead), where we also recorded two other calicioids and very high *Peltigera* diversity. These habitats seem to be critical reservoirs of lichen diversity within the otherwise dry tablelands upon which the majority of Edmonton lies. The importance of these riparian habitats is further emphasized when we consider that while they occupy only 10% of the study area, 85% of the species confirmed in this study were found at least once in a river valley or ravine habitat, and 62% were found there exclusively.

Edmonton's current lichen richness is comparable to estimates of urban lichen richness elsewhere, including New York City, U.S.A (103 spp., Allen 2020), Geneva, Switzerland (127 spp., Habashi & Clerc 2013), and Grenoble, France (83 spp., Gombert et al. 2004). However, it pales in comparison to municipalities in southern Ontario, one of Canada's most densely populated and climatically mild regions. While inclusive of relatively large, intact natural areas, a study of Toronto lists 180 species (McMullin et al. 2019), and 543 species are now documented within a 50 km radius of Ottawa (Brodo 1988, Brodo et al. 2021b). Many studies that report lower species richness are restricted to epiphytes, making comparisons between species lists difficult. However, Edmonton's epiphytic calicioid lichen and allied fungi richness appears to be high (nine species versus a mode of one in other studies; notable exceptions are four species in Coxson et al. [2014] and 11 in McMullin et al. [2019]); this may be due to the interest of the authors in calicioids or these urban areas could be genuine biological hotspots. Calicioid ecology and diversity are poorly known in the continental interior of North America.

Studies from different cities in diverse jurisdictions including eastern Canada (Ontario, Nova Scotia), Brazil, Spain, Sri Lanka, and the eastern United States continue to support the use of lichens as air quality bioindicators (Koch et al. 2016, 2019; McCarthy et al. 2009; McMullin et al. 2017, 2019; Sergio et al. 2016; Tulumello 2010; Will-Wolf et al. 2015; Yatawara & Dayanada 2019). Urban areas with poor air quality were found to have low lichen species diversity (Coffey & Fahrig 2012, Koch et al. 2016, 2019, McCarthy et al. 2009, Stringer & Stringer 1974, Yatawara & Dayanada 2019). Lichen recolonization observed in conjunction with improvements in air quality in recent decades is further evidence of this relationship (e.g., Allen 2020, Rose & Hawksworth 1981, Seaward & Letrouit-Galinou 1991). Urban areas tend to be dominated by nitrophytic lichen species such as *Candelaria concolor* and *Physcia* spp. that are less sensitive to industrialization (McCarthy et al. 2009, Sergio et al. 2016, Tulumello 2010). Comparatively, these species are less abundant in areas further from urbanization with higher air quality, where sensitive, fruticose species such as *Usnea* and *Ramalina* are present (McCarthy et al. 2009, Sergio et al. 2016). Koch et al. (2019) found that cyanolichens, relatively loosely attached lichens, isidiate lichens, and lichens partnered with *Trentepholia* indicated areas of low urbanization and low contaminant levels, while chlorococcoid algae, narrow-lobed foliose species, sorediate species, and pruinose thalli were indicators of medium-to-high urbanization and contaminant levels. The latter describes well the lichens that dominate Edmonton's tablelands.

However, researchers have long realized that patterns of urban lichen diversity are not shaped by air quality alone (e.g., Brodo et al. 2021b, Golubkova & Malysheva 1978, Skye 1968). Urban areas tend to be drier and warmer than rural areas, further lowering lichen diversity and abundance (McMullin et al. 2016, Yatawara & Dayanada 2019). The urban heat island was hypothesized to contribute to the lack of lichens in downtown Winnipeg, Manitoba (termed a lichen desert by Stringer & Stringer 1974) given the area's low estimated sulphur dioxide. Even in the face of high sulphur levels, the tolerance of some species to sulphur dioxide in dry, continental climates may be higher than in more oceanic climates (Hawksworth et al. 1973). This suggests that complex interactions between climate, substrate, and pollutants should be considered in future studies of urban lichen diversity. Future analyses of the data presented herein will attempt to parse out the impacts of climate versus air quality in shaping species' realized niche.

Survey limitations & directions for future research. – When interpreting these results, it is important to recognize the limitations inherent in each data source. Survey effort is unequal across substrates and habitats, and systematic surveys are restricted to deciduous trees. Rocks and similar anthropogenic substrates such as buildings, sidewalks, walls, and cemeteries are particularly poorly represented here. Downed wood and conifers also are under-surveyed, but to a lesser extent as they have been better addressed through opportunistic surveys by the senior author and rare tree surveys in 2021. Opportunistic surveys are biased towards naturalized areas and parks, as are nature application reports. Absences cannot be inferred from locations with opportunistic, nature app, and herbarium records because of unquantified survey effort. Crustose lichens were not collected at all systematic biomonitoring sites for laboratory identification. Future gradient analyses will likely be restricted to a subset of sites where samples were taken or for the city as a whole, and only to genus-level or morphological grouping. This limitation affects our understanding of the distribution of those species, so maps presented herein underestimate the niche and range of some species. Future surveys focused on under-sampled substrates may remedy these issues and help form a more comprehensive view of diversity within the city.

With a minimum estimated error rate of 11%, our limited molecular analyses show the value of barcode-level analyses in increasing the accuracy of determinations. It also suggests that despite our best efforts, identification errors remain in the list presented here. Alberta in general would benefit from inclusion in more taxonomic treatments. Lichen taxonomic treatments in North America often have either an eastern or western focus, with relatively few collections from the continental interior where the two floras intersect (e.g., Halonen et al. 1998, Lendemer 2009). In Alberta, we have documented species previously thought to be restricted to eastern North America (e.g., *Cladonia robbinsii* A. Evans, *Pseudevernia consocians* [ABMI 2020]), as well as species otherwise largely restricted to west of the Rocky Mountains (e.g., *Seirophora contortuplicata*, (Ach.) Frödén, *Hypogymnia imshaugii* Krog, *Xanthomendoza montana* (L. Lindblom) Søchting, Kärnefelt & S.Y. Kondr. [ABMI 2020, Haughland, unpub.]). The paucity of molecular work in the interior and the intersection of eastern and western species means that we are challenged to discriminate morphologically similar species that elsewhere can be discriminated based on geographic range. Our expectation is that these species should be identified accurately to properly understand their status, niche, and sensitivity. To do so will require more molecular and morphological study in the quest of high-fidelity diagnostic traits.

With these limitations in mind, we make suggestions regarding which taxa should be investigated further as urban biomonitors.

Suggestions for future biomonitoring. – Across macrolichen growth forms, genera were more accurately identified than species in nature apps (Table 2) and by trained novices (Table 3). Genera that were recognized, identified accurately, and met our repeatability cut-off include *Flavopunctelia* (if we *a priori* exclude *Flavoparmelia caperata*), fruticose genera (*Evernia, Usnea*), and *Physcia*. Genera that are relatively abundant, perceptible, and accurately identified by nature app observers, but which are almost entirely limited to the river valley and riparian zones, include *Bryoria*, *Cladonia, Parmelia, Peltigera*, *Ramalina*, and *Vulpicida.* Their limited distribution likely excludes them as biomonitors for air quality, but they may be useful in monitoring climatic or other ecological shifts in urban parklands. The gradient exerting the strongest effect on lichen community composition in Edmonton may be climate, a hypothesis we will test in a future study.

At the species level, trained novices were successful surveying for *Xanthomendoza fallax* and the abundant but morphologically variable *Phaeophyscia orbicularis*. *Xanthomendoza* is an eye-catching genus, and given the rarity of the two other species documented in Edmonton (*X. fulva* and *X. hasseana*), focusing hypothetical surveys on *X. fallax* is a logistically and ecologically acceptable loss of taxonomic precision. Our results align with Sivanesan et al. (2005), who found that high school students were able to conduct highly repeatable, focused lichen surveys, both in blind comparisons between students and between students and instructors.

Based on our analyses of repeatability, field identification of individual *Physcia* species proved difficult. Preliminary observations suggest that *P.* aff. *stellaris* and *P. adscendens* have broader niches than *P. aipolia* group and *P.* aff. *dimidiata.* Future work will explore the loss of information in surveying for *Physcia* at the genus level.

Another genus commonly included on bioindicator lists but that may be too challenging for novice surveyors in Edmonton is *Candelaria*. *Candelaria* showed low detectability (Table 3), low perceptibility (mostly misidentified and only one confirmed observation within the apps), and the two species present appear to have divergent niches, which means that misidentifications would obscure ecological information their presence may contribute. Whereas *C. pacifica* is common in the river valley parks, we made multiple collections of *C. concolor s.l.* on boulevard trees in the tablelands. More collections are needed to test this niche hypothesis.

Some crustose species or genera may be good biomonitors, but not surprisingly they were under-represented in both student-based systematic surveys and within nature-reporting apps. Future work will explore the subset of sites surveyed by more experienced lichenologists for the responsiveness of crustose lichens to ecological gradients as well as potential groupings that could be tested with novice surveyors in Edmonton.

We sourced two EMAN indicator lichen lists, one for mixed hardwood forests and one for boreal forests (Brodo & Craig undated; D. McCarthy, unpublished). In total, these lists recommended 45 species for air quality monitoring in Canada. When comparing our Edmonton lichen list to the composite EMAN indicator species list, there was an overlap of only 21 species. The other 24 species were not detected in Edmonton. Of those 21 overlapping species, ten were restricted to river valley and ravine parks. Of the remaining 11 species, two are rare in the tablelands (*Evernia mesomorpha, Parmelia sulcata*) and two are difficult to detect (*Candelaria concolor s.l., Xanthomendoza hasseana*). These findings illustrate the importance of grounding biomonitoring studies in a strong foundation of local knowledge.

CONCLUSION

This is one of the first detailed studies of urban lichens and allied fungi diversity in continental North America. Survey methods complemented each other: nature-reporting apps and opportunistic surveys contributed unique records from habitats frequented by the public, while systematic surveys provided data on species' distribution and relative abundance across the city (Fig. 1). Molecular barcode data allowed us to confirm or correct some identifications, and illuminated taxa that require additional phylogenetic work and sampling. These datasets also provide guidance on which species are candidate bioindicators, i.e., those species or genera that are both broadly distributed and easily identifiable (Table 4). Future work will explore the sensitivity of these target lichens to known ecological and contaminant gradients in Edmonton.

ANNOTATED LIST OF SPECIES AND KEYS

In a departure from convention, the following list is organized first into 14 morphological groups that we considered amenable to use by novices. Species are listed alphabetically within those groups. A spreadsheet is also provided so that the list may be searched or organized by the reader (Supplementary Appendix 1).

Many collections were mixed and are thus cited under multiple species. We also include observations of specimens not collected (indicated with "unvouchered observation") when we deemed them reliable, including visually verified reports from nature-reporting applications. Collections of some species are limited because of rarity, demonstrated ability to identify with confidence in the field, and/or reluctance to sample from a highly visible location within a city park. Unless indicated otherwise, all collections cited were examined for this study by the authors. All spot test results reflect testing done on Alberta material. TLC results without references indicate analyses of Alberta material, largely through work by D. Thauvette and D. Haughland through the ABMI.

We indicate uncertainty in the application of a given name in one of two ways. We use "cf." (Latin indicating to confer or to compare) where further study is required, and "aff." (Latin *ex affiniatis*) where taxonomic work involving Alberta material is ongoing and evidence to date suggests that the species in question is not identical to the type specimen and represents a currently undescribed species.

Dichotomous keys are provided with caveats. The keys include only species currently confirmed for Edmonton; including all possible additional or easily confused species would be beyond the scope of this paper. As our knowledge of Edmonton's flora is incomplete, users are cautioned to use the keys herein as a starting point, and to then check their specimen against the included detailed species descriptions. If any traits do not fit, they should consult the key literature listed for that group; their collection may represent a new species for Edmonton. The first author welcomes all additional records and feedback. Edmonton distribution maps for all species are provided in alphabetic order Supplementary Appendix 3 after the literature cited section of this contribution.

SUMMARY OF NOTATIONS AND ABBREVIATIONS

* = New to Alberta; ** = New to North America; *** = New to science
† = non-lichenized fungi
aff. = affinity
cf. = confer
s.l. = *sensu lato*, in the broad sense
s.s. = *sensu stricto*, in the strict sense
UoA-CC-# = University of Alberta Class Collections (students did not create individually numbered collections; instead, all collections made during the biomonitoring surveys were contributed to and renumbered as part of a UofA-CC collection)

MORPHOGROUP KEY

1a. Crustose lichens, thallus immersed in substrate or forming a thin episubstratic to areolate crust that cannot be separated from the substrate intact **2**
1b. Not as above, thallus foliose (leaf-like, with distinct upper and lower surface) or fruticose (three-dimensional, hair-like, shrubby, cupped, or like a tiny dressmaking pin) **8**

2a. Apothecial rim and disk dark grey, black, or brown...**3**
2b. Apothecia at least in part orange, yellow, or white, or apothecia lacking **5**

3a. Apothecial rim easily visible and contrasting in color with the disk (lecanorine), the rim typically grey-brown to dark brown with a dark disk ....**Group 1: Brown-rimmed lecanorine crustose lichens**
3b. Apothecia often black, either both rim and disk concolorous (lecideine) or with rim apparently lacking (biatorine) **4**

4a. Apothecia circular in outline .... **Group 2: Lecideine and biatorine crustose lichens**
4b. At least some apothecia elongate, script-like ....**Group 3: Lirellate lichens**

5a. Apothecia with yellow disk and rim, K-........................... **Group 4: Yellow lecanorine crustose lichens**
5b. Apothecia various but not with yellow disk and rim, K-, K+yellow or K+purple **6**

6a. Apothecia with orange disk and/or rim, orange tissues K+purple at least in part ....
....**Group 5: Orange lecanorine crustose lichens**
6b. Apothecia with white rim (typically with a contrasting disk color, often with a white thallus), or apothecia lacking, K- or K+yellow...**7**

7a. Apothecia with white rim and contrasting disk ....**Group 6: *Lecanora s.l.***
7b. Thallus sorediate or granular, typically lacking apothecia ....
....**Group 7: Sorediate or granular crustose lichens**

8a. Thallus leaf-like (foliose), two-dimensional, often with distinct upper and lower surfaces **9**
8b. Thallus three-dimensional (fruticose) at least in part, may have a crustose or squamulose primary thallus, generally cortex similar throughout **13**

9a. Leaf-like lichens of various colors, lobes typically ≤1cm wide, green algal photobiont only, becoming greener when moistened **10**
9b. Thallus with cyanobacterial photobiont at least in part, either in wart-like cephalodia or as dominant photobiont in thallus, becoming darker (grey or black) when moistened; size varied..................................**12**

10a. Leaf-like thallus orange, bright yellow or usnic pale yellow, with the latter reacting KC+ oily yellow ...
....**Group 8: Orange and yellow foliose lichens**
10b. Leaf-like thallus predominantly white, grey, brown or green, KC-...**11**

11a. Leaf-like lichens that are predominantly white or grey .... **Group 9: White and grey foliose lichens**
11b. Leaf-like lichens that are predominantly brown to green . **Group 10: Brown and green foliose lichens**

12a. Lobes <0.5 cm wide, on soil or rock, black and gelatinous when wet ...**Group 11: Small cyanolichens**
12b. Lobes ≥ 0.5 cm wide and typically much larger, apothecia when present forming saddle-like structures at the lobe tips, lower surface with rhizines and/or veins .... **Group 12: *Peltigera***

13a. Thallus ≤ 2 mm tall, minute fruiting bodies that resemble dressmaker pins ....
....**Group 13: Calicioid lichens and fungi**
13b. Thallus >1 cm long/tall, fruiting bodies vary from globose terminal proliferations to disks **14**

14a. Thallus in the shape of cups, wands, shrubs, or clubs, mostly hollow, often found growing from a squamulose or crustose primary thallus, common on soil, downed wood, and the bases of trees.....................
....**Group 14: *Cladonia***
14b. Thallus form hair-like, or coral-like thalli, mostly with solid interior, typically with a single attachment point, either erect or pendulous, commonly epiphytic .... **Group 15: Epiphytic fruticose lichens**

GROUP 1: BROWN-RIMMED LECANORINE CRUSTOSE LICHENS

Four species. Key literature: McCune 2017a, 2017b; Sheard 2010; Sheard 2018; Sheard & May 1997. For confident identification, examination of spores under oil immersion (1000x) is necessary. *Rinodina albertana* may also be present, but additional collections are required for confirmation.

1a. Spores constricted at septum, forming a figure-eight in outline; hypothecium red-brown..***Amandinea dakotensis***
1b. Spores not constricted at septum; hypothecium clear to pale brown...**2**

2a. Immature spores with septal and apical wall thickenings, becoming thin walled with maturity (*Physconia*-type spores); spores often slightly curved or "bean-shaped"..............................***Rinodina pyrina***
2b. Spores with apical walls remaining thick through maturity **3**

3a. Spores not swelling at septum in K (*Physcia*-type spores)..***Rinodina freyi***
3b. Spores swollen at septum, becoming more pronounced in K (*Dirinaria*-type spores)...***Rinodina metaboliza***

***Amandinea dakotensis** (H. Magn.) P. May & Sheard

FIGURE 12.

Apparently rare river valley epiphyte. New to Alberta, a single collection of what was initially thought to be *Rinodina* was made from the bark of a downed tree. The spores indicated otherwise; rather than having smooth walls typically thickened at least in part, these spores were minutely ornamented, uniformly thin-walled, and had a distinctly constricted septum, creating a figure-eight shape. Widely distributed in the eastern interior of the United States into southern Ontario, Sheard and May (1997) reported this species from a similar latitude in the neighboring province of Saskatchewan. A prior collection may exist from Wagner Natural Area east of Edmonton (Derek Johnson, pers. comm.), however, the collection could not be located.

Edmonton material: grey-brown low areoles with closely aggregated lecanorine apothecia. Apothecia lecanorine, <0.5 mm diameter, epihymenium dark brown, hymenium hyaline, hypothecium red-brown. Thalline exciple scurfy, grey-brown. Spores 10–13.5 × 7–8 µm, brown, uniseptate, ovate, and constricted at the septum, minutely rugose/ornamented, ornamentation visible only at 1000x magnification, 8 per ascus. Chemistry: all spot tests negative, no secondary metabolites detected by TLC (Sheard and May 1997). Molecular support: none, no sequences in GenBank, no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Sir Wilfrid Laurier Park, 2019, 53.50834, -113.560926, on *Populus* branches on downed tree, *D. Haughland 2019-121D & P. Williams* (hb. Haughland).

Rinodina freyi H. Magn.

FIGURE 13 E-F.

Apparently rare tableland epiphyte. Edmonton material: copper-brown areoles to 0.75 mm in diameter, with 1–3 aggregated lecanorine apothecia. Spores 14–17 × 7–8 µm, brown, uniseptate, *Physcia*-type development (Sheard 2010) with apical walls remaining thick throughout development, creating an hourglass shape within the spore, unornamented, 8 per ascus. Spores often exhibit a well-developed torus, an electron-dense, pigmented band at the septum (Sheard 2010). Hypothecium hyaline, epihymenium brown to red-brown. Chemistry: all spot tests negative, no secondary metabolites detected by TLC (Sheard 2010). Molecular support: none, one mtSSU sequence in GenBank, no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 56, 53.520506, -113.570687, 2019, on trunk of *Tilia*, *D. Haughland & A. Hood s.n. [UoA-CC-66]* (hb. Haughland); Sherwood Park, Air Quality Monitoring Station, 53.532016, -113.321511, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Thauvette & J. Birch s.n. [UoA-CC-105]* (hb. Haughland).

Rinodina metaboliza Vain.

FIGURE 13 C-D.

Apparently rare tableland epiphyte. Edmonton material: clustered apothecia with prominent, raised grey-brown thalline margins. Spores 14–22 × 7–9 µm, brown, uniseptate, some spores lightly ornamented,

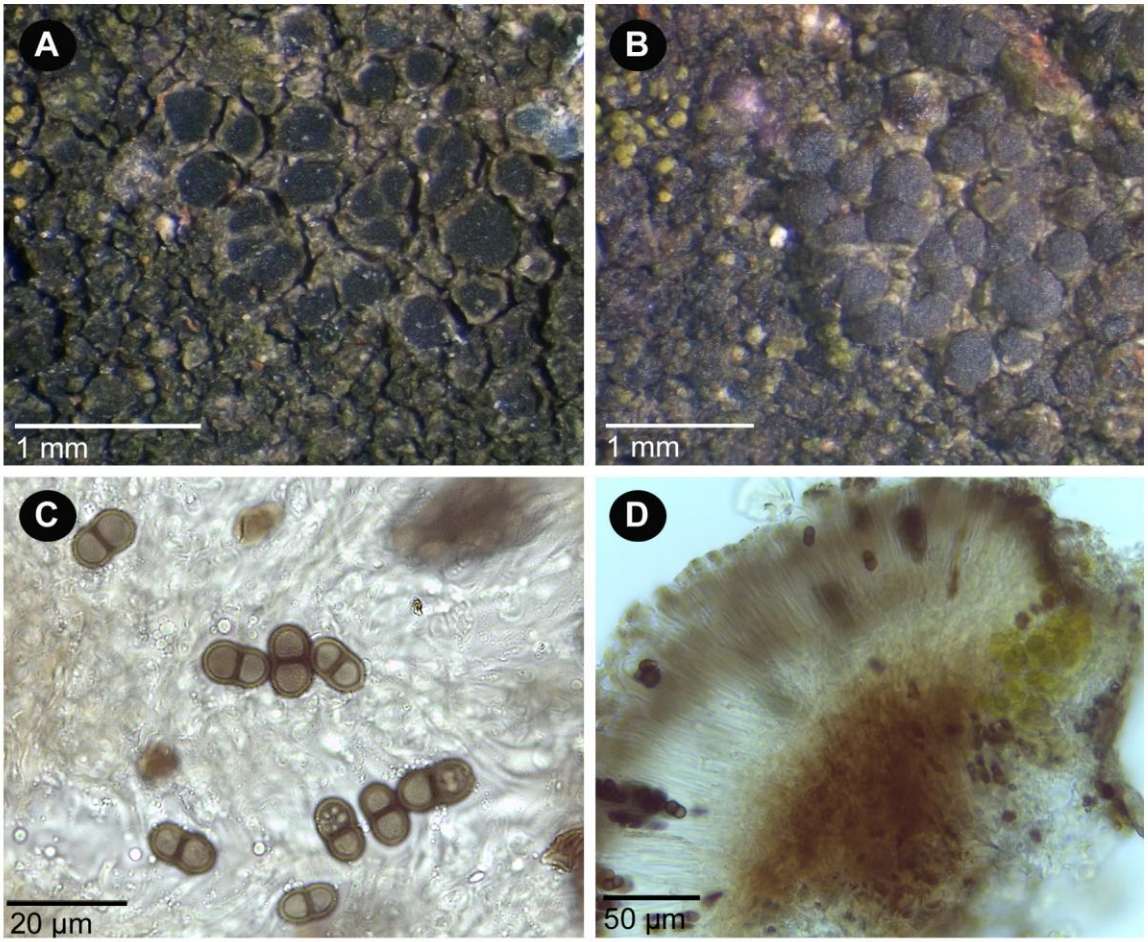

Figure 12. *Amandinea dakotensis* morphology and anatomy, Edmonton, *Haughland 2019-121D*. **A,** Thallus dry. **B,** Thallus wet. **C,** Spores showing minute warty ornamentation, thick spore wall, and constricted septum. **D,** Apothecial cross section in water mount illustrating brown hypothecium, and thalline exciple.

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with *Dirinaria*-type development (apical walls remaining thick throughout development, creating an hourglass shape within the spore, Sheard 2010), 8 per ascus. At maturity the spore tips become mucronate (with an elongated nipple-like projection) and the spores widen at the septum, the latter becoming more pronounced with the addition of K. Chemistry: All spot tests negative, no secondary metabolites detected by TLC (Sheard 2010). Molecular support: none, four ITS sequences in GenBank, no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, South Air Quality Monitoring Station, 53.501914, -113.524177, 2019, on trunk of *Fraxinus*, *D. Thauvette & J. Birch s.n. [UoA-CC-104]* (hb. Haughland); Sherwood Park, Air Quality Monitoring Station, 53.532016, -113.321511, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Thauvette & J. Birch s.n. [UoA-CC-105]* (hb. Haughland); Edmonton, University of Alberta North Campus, 53.527244, -113.519258, 2021, on *Pinus sylvestris*, *J. Singh & K. Schafer s.n. [UoA-CC21-23]*.

Rinodina pyrina (Ach.) Arnold

FIGURE 13 A-B.

Common tableland epiphyte. While this is overwhelmingly the most common *Rinodina* on open-growing trees in Edmonton, collections should be critically examined to exclude rarer species. Edmonton material: variable in morphology but commonalities include clustered apothecia with visible thalline rims with relatively large-celled trebouxioid algae in cross-section, and a dark brown, epruinose disk. The thalline exciple varied in color from brown to grey-brown. Apothecia characterized by the brown pigments

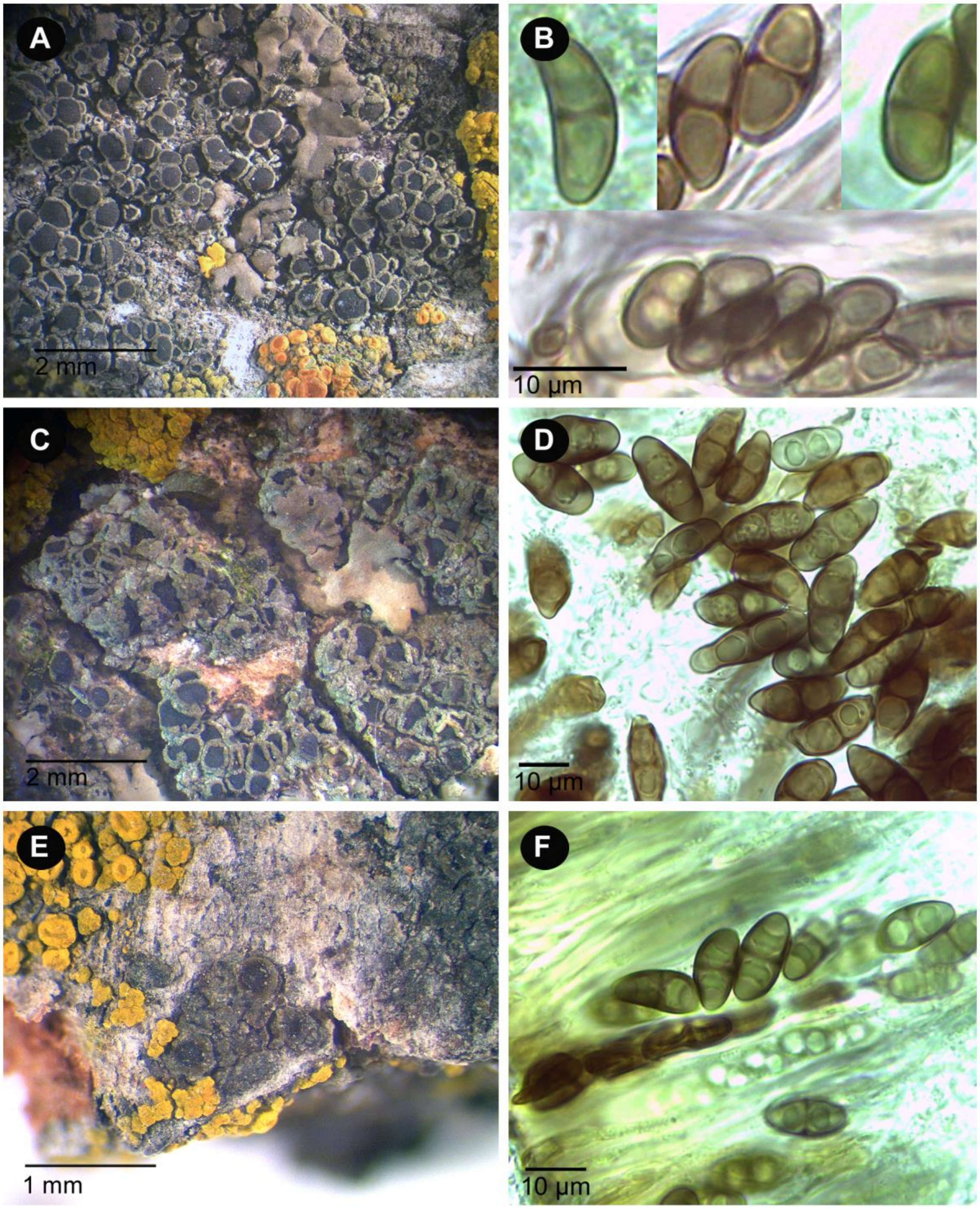

Figure 13. *Rinodina* species of Edmonton, thallus (dry) and spores in water mount. **A-B,** *R. pyrina*, showing curved spores, *UoA-CC-26*. **C-D,** *R. metaboliza*, showing widening at septum, *UoA-CC-105*. **E-F,** *R. freyi*, showing torus. **E,** *UoA-CC-66*, **F,** *UoA-CC-105*.

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in the epihymenium, the hyaline hymenium and hypothecium, and brown, uniseptate spores 12–14 × 6–7 µm, 8 per ascus. Spores are *Physconia*-type (Sheard 2010), with thin spore walls and rounded locules at maturity, typically with a visible torus, and often curved ("kidney bean"-shaped) at maturity, with no swelling or constriction at the septum. Chemistry: All spot tests negative, no secondary metabolites detected by TLC (Sheard 2010). Molecular support: none, >10 sequences in GenBank, no new sequences generated.

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 3, 53.440376, -113.484487, 2019, on trunk of *Ulmus americana*, *D. Thauvette & J. Wasyliw s.n. [UoA-CC-108]* (hb. Haughland); Edmonton, Urban Monitoring Site 33, 53.479311, -113.413258, 2019, on trunk of *Tilia*, *D. Thauvette et al. s.n. [UoA-CC-46,81]* (hb. Haughland); Edmonton, Urban Monitoring Site 107E, 53.548554, -113.617129, 2019, on trunk of *Salix, D. Haughland s.n. [UoA-CC-97]* (hb. Haughland); Edmonton, Urban Monitoring Site 119, 53.602014, -113.458033, 2019, on trunk of *Fraxinus pennsylvanica, D. Royko & D. Fielder s.n. [UoA-CC-176]* (hb. Haughland); Edmonton, Urban Monitoring Site 121E, 53.561280, -113.609950, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland s.n. [UoA-CC-10]* (hb. Haughland); Edmonton, Urban Monitoring Site 52E, 53.494372, -113.597330, 2019, on trunk of *Ulmus americana, D. Haughland s.n. [UoA-CC-21]* (hb. Haughland); Edmonton, Beverly Air Quality Monitoring Station, 53.566860, -113.397464, 2019, on trunk of *Ulmus americana, D. Thauvette & J. Birch s.n. [UoA-CC-26]* (hb. Haughland); Edmonton, South Air Quality Monitoring Station, 53.501946, -113.5249, 2019, on trunk of *Fraxinus, D. Thauvette & J. Birch s.n. [UoA-CC-132]* (hb. Haughland).

GROUP 2: LECIDEINE AND BIATORINE CRUSTOSE LICHENS

Nine species. Key literature: Björk 2013; Ekman 1996; McCune 2017a, 2017b; Smith et al. 2009. This group is under-collected, with a relatively high species discovery rate in examined material, and three species new to Alberta. Another species reported for Edmonton that we could not confirm is *Micarea melaena* (under *Bacidia melaena*, Rainbow Valley, Edmonton, 1961, *G.W. Scotter 706* [CANL], reported in BIOTICS [Government of Alberta 2020], not examined here). For confident identification, examination of apothecia cross-sections and spores with a compound microscope is necessary.

1a. Apothecia biatorine, beige, pink, yellow, grey or dark-red to almost black, proper exciple often visible and paler than disk **2**
1b. Apothecia lecideine, with a black disk and black proper exciple **5**

2a. Growing on soil and mosses, sometimes on tree bases but not directly on bark; hypothecium orange-brown in apothecia cross-sections; spores with 3–5 transverse septa and minute warty ornamentation on perispore .... ***Bilimbia sabuletorum***
2b. Epiphytic, growing directly on/in bark; hypothecium hyaline in apothecia cross-sections; spores with ≤3 transverse septa, unornamented **3**

3a. Apothecia beige to yellow; on a grey-blue, rough, verrucose thallus .... ***Lecanora symmicta***
3b. Apothecia pink, piebald or darkening to brick-red or black; on a pale green thin to areolate episubstratic thallus **4**

4a. Spores simple .... ***Lecidea erythrophaea***
4b. Spores with 1-3 transverse septa .... ***Lecania naegelii***

5a. Thallus dark-green and granular; spores curved to S-shaped, ≥3 septate, spiralling around each other within the asci .... ***Scoliciosporum umbrinum***
5b. Thallus white to grey-green, varying from immersed to dust-like, verrucose, or placodioid; spores never S-shaped **6**

6a. Thallus white, immersed to dust-like; hypothecium black in apothecia cross-sections; spores with one transverse, constricted septum and cells of unequal size .... ***Arthonia patellulata***
6b. Thallus grey and episubstratic at least in part; hypothecium hyaline or rust to orange-brown in apothecia cross-sections; spores varying from simple to septate but cells of equal size and septa not constricted **7**

7a. Spores simple; hypothecium rust to orange-brown .... ***Lecidella elaeochroma***
7b. Spores transversely septate; hypothecium hyaline **8**

8a. Spores >8 per ascus, bean-shaped or slightly curved, ≤12 μm in length, with 1–3 transverse septa; common .... ***Arthrosporum populorum***
8b. Spores 8 per ascus, narrowly bacilliform, ≥18 μm in length, with ≥3 transverse septa; rare .... ***Bacidia circumspecta***

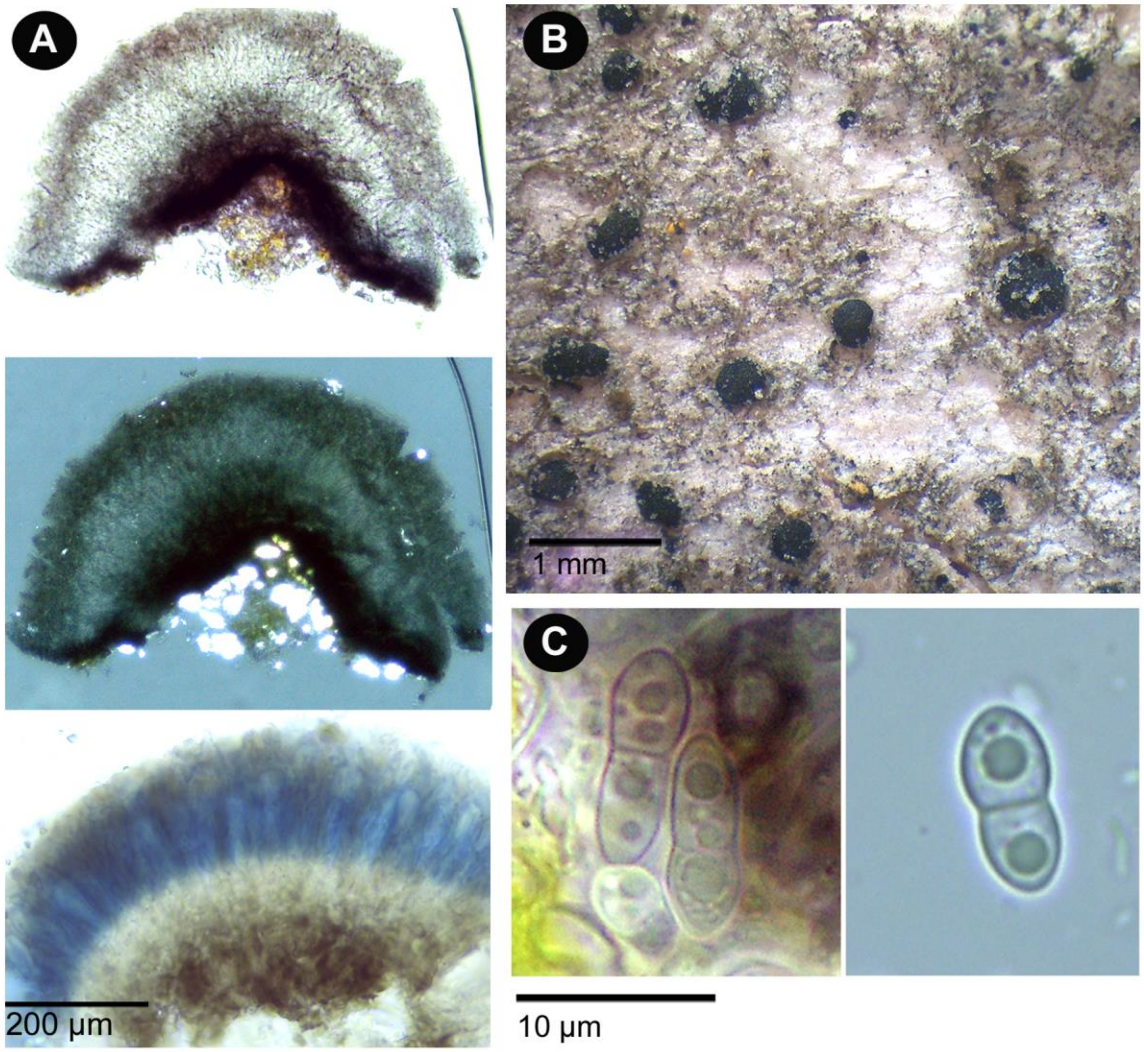

Figure 14. *Arthonia patellulata* morphology and anatomy, Edmonton, *UoA-CC-71*. **A,** Apothecial cross sections – top in water, bright light; middle section in water, polarized light; bottom section treated with KI. **B,** Habit, on *Populus tremuloides* in parkland habitat. **C,** Spores in water mount, showing unequal cell size.

Arthonia patellulata Nyl.

FIGURE 14.

Apparently rare river valley epiphyte. Edmonton material: thallus white and dust-like to immersed and non-apparent, with scattered black, matte lecideine apothecia. Spores hyaline, uniseptate, narrowly obovate, septum constricted, cells of unequal size, unornamented, 10–12 × 4–5 µm, 8 per ascus. Hymenium hyaline, ~65 µm thick, epihymenium faintly black, paraphyses without brown caps, hypothecium black, proper exciple black, poorly developed. Asci with well-developed torus. Apothecia slightly convex. Photobiont trebouxioid. Hymenium K+brownish, K/I+blue. Chemistry: all thallus spot tests negative, no lichen substances known (Björk 2013). Molecular data: 3 eDNA nrITS sequences in GenBank, 1 new sequence generated (isolate DLH39 from *UoA-CC-71*), however BLAST indicated it is most similar to GenBank-accessioned *Candelariella vitellina*, perhaps due to a processing or sampling error. No further analyses conducted.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 23E, 53.478452, -113.620128, 2019, on trunk of *Populus*, *D. Haughland s.n*. *[UoA-CC-71]* (hb. Haughland).

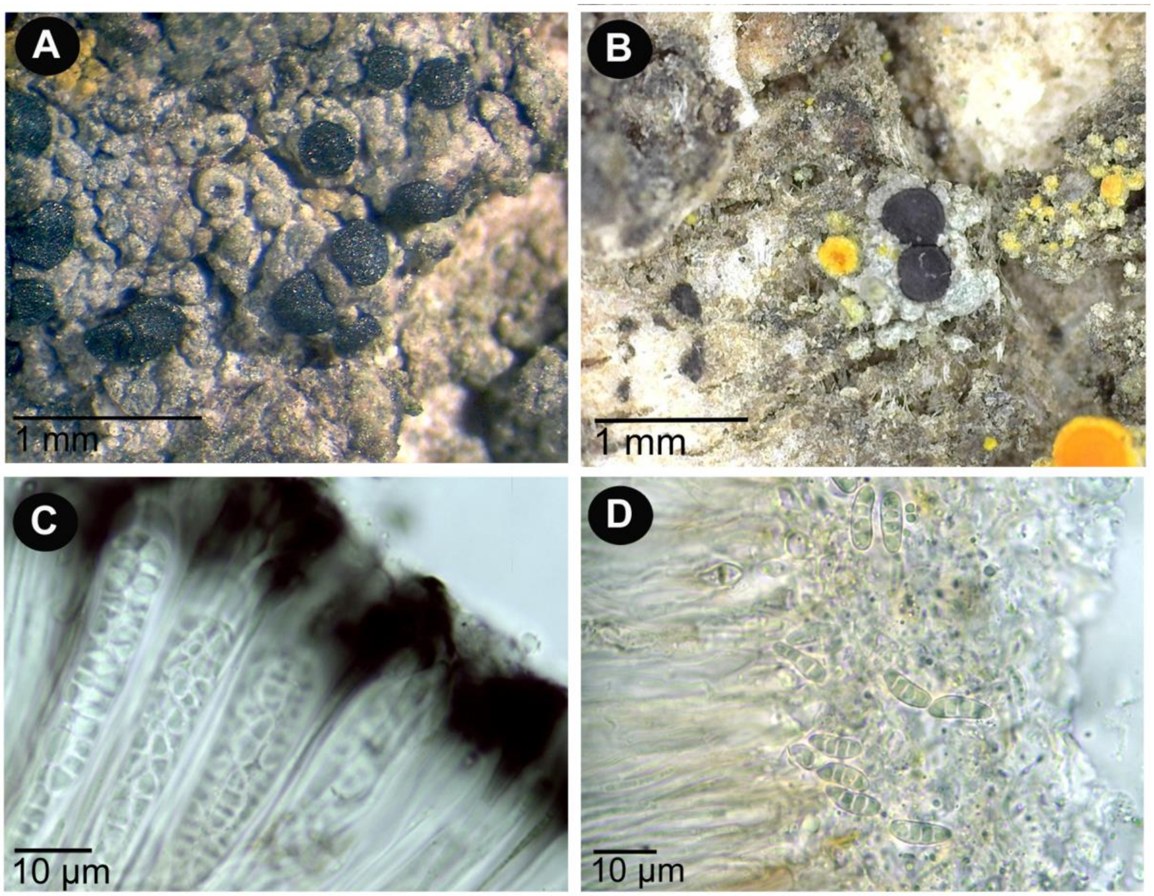

Figure 15. *Arthrosporum populorum* morphology and anatomy, Edmonton. **A,** Habit, on *Fraxinus pennsylvanica*, *UoA-CC-1*. **B,** Habit, on *Ulmus americana* growing in a grassy boulevard, *UoA-CC-120*. **C,** Asci and spores in water mount, *UoA-CC-1*. **D,** Spores in water mount, *UoA-CC-93.*

Arthrosporum populorum A. Massal.

(≡ *Toninia populorum* (A. Massal.) Kistenich, Timdal, Bendiksby & S. Ekman; Kistenich et al. 2018)

FIGURE 15.

Common tableland and river valley and ravine system epiphyte on a diversity of deciduous tree species. Björk (2013) hypothesized that Alberta material is not *A. populorum s.s.* as the apothecia and spores are smaller than reported elsewhere, and tentatively called it *A.* "*nanum* Björk ined." Edmonton material: thallus indistinct to grey placodioid, with black lecideine apothecia, diameter to 0.54 mm, proper margin often persistent, well-developed. Spores 9–12 × 3–5 µm, 1–3 transverse septate, rounded ends, hyaline, slightly curved, >8 per ascus. Photobiont trebouxioid. Hyaline hymenium and hypothecium, epithecium black, proper exciple black externally and pale rusty brown internally. Paraphyses free in water, slightly capitate, septate. Chemistry: all thallus spot tests negative, no lichen substances known (Björk 2013). Molecular support: Kistenich et al. (2018) show this species in a well-supported clade of *Toninia* species, no new sequences generated.

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 17, 53.466685, -113.571654, 2019, on trunk of *Populus*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-98]* (hb. Haughland); Edmonton, Urban Monitoring Site 36, 53.494272, -113.620171, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-1]* (hb. Haughland); Edmonton, Urban Monitoring Site 45E, 53.480176, -113.429404, 2019, on trunk of *Populus* hybrid, *S. Toni & M. Lewis s.n. [UoA-CC-93]* (hb. Haughland); Edmonton, Urban Monitoring Site 86, 53.561777, -113.547997, 2019, on trunk of *Ulmus americana*, *D. Haughland & A. Hood s.n. [UoA-CC-120]* (hb. Haughland); Edmonton, Urban Monitoring Site 127, 53.6111, -113.4608, 2019, on trunk of *Ulmus*, *D. Haughland s.n. [UoA-CC-41]* (hb. Haughland); Edmonton, Urban Monitoring Site 149E, 53.6111, -113.4608, 2019, on

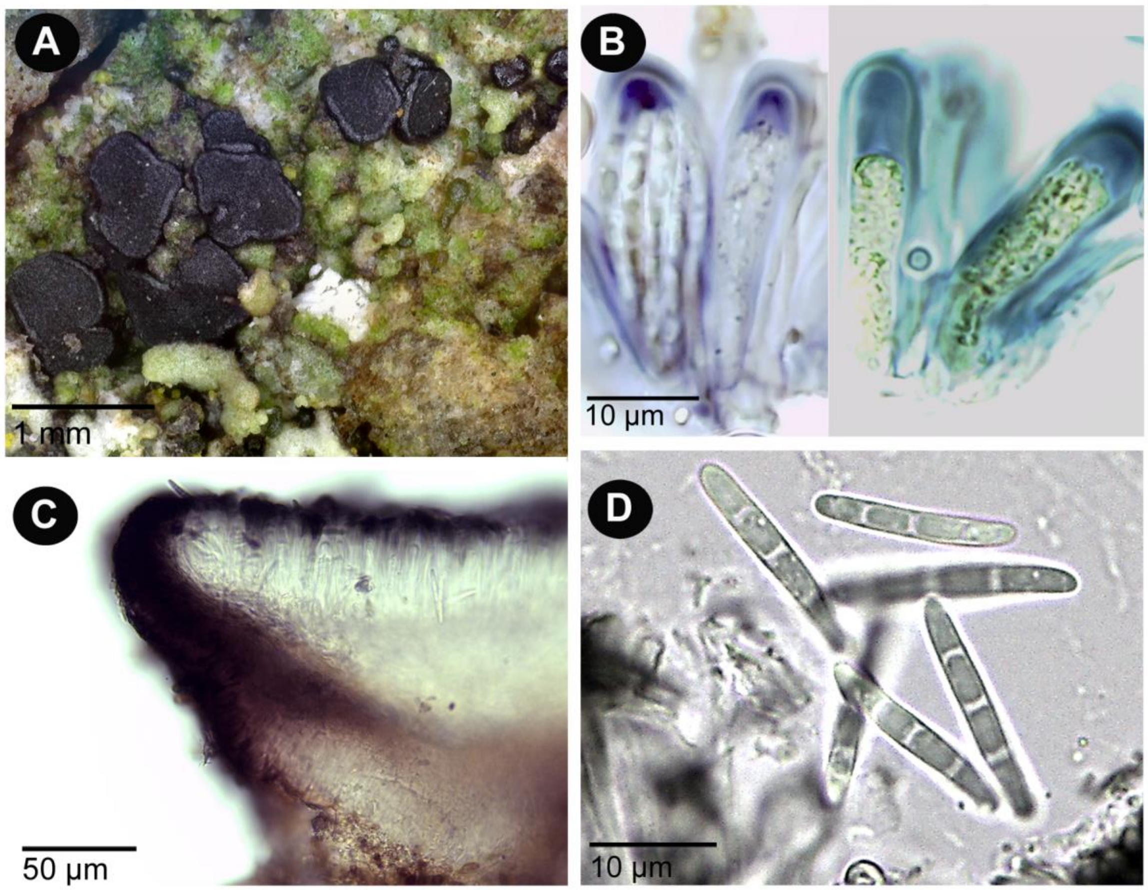

Figure 16. *Bacidia circumspecta* morphology and anatomy, Edmonton. **A,** Thallus, wet, on *Populus balsamifera, Haughland 2021-1*. **B,** Asci treated with K followed by Lugol's I, mature (left) and immature (right), *UoA-CC-84*. **C,** Apothecial cross-section under white light, *UoA-CC-84*. **D,** Spores in water mount, *UoA-CC-84*.

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trunk of *Salix* cf. *pentandra*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-100]* (hb. Haughland); Ardrossan, Air Quality Monitoring Station, 53.554824, -113.143457, 2019, on trunk of *Populus* cf. *balsamifera*, *D. Thauvette & J. Birch s.n. [UoA-CC-69]* (hb. Haughland).

Bacidia circumspecta (Nyl. ex Vain.) Malme

FIGURE 16.

Apparently rare river valley and parkland epiphyte. New to Alberta, the nearest prairie province record is from Prince Albert National Park, Saskatchewan (Ekman 1996). Edmonton material: discontinuous grey to grey-green to brown areolate thallus. Apothecia lecideine, to 1 mm diameter, cup-shaped when immature, becoming flat to slightly convex, disc black and concolorous with proper exciple, epruinose. Excipular cells thick-walled, wider towards rim, clearly differentiated from paraphyses. Paraphyses black capitate, to 4 µm wide at tip, simple to sparsely branched at very tip. Spores 18–22 × 3 µm, straight, bacilliform (*sensu* Ekman 1996), hyaline, unornamented, mostly 3–4 transverse septa, occasionally up to 6 septa present, 8 per ascus. No polarizing crystals in apothecia cross-sections. Co-occurring with *Phaeophyscia kairamoi* in both collections. Epihymenium and proper exciple N+reddish-purple, K-, C-, hypothecium hyaline, N+ yellowish, K-, C-. Chemistry: all thallus spot tests negative, no secondary metabolites detected (Ekman 1996). Molecular support: a single ITS sequence (isolate DLH35 from *UoA-CC-84*), is most similar to *Bacidia circumspecta* GenBank Accessions AF282124 (Sweden, 97% percent identity, 12 positions different, 479 bp overlap, Ekman 2001) and MH539764 (Russia, 96% percent identity, 21 positions different, 549 bp overlap, Gerasimova et al. 2018). These differences are smaller than the difference between the two previously accessioned sequences (23 positions different, 476 bp overlap).

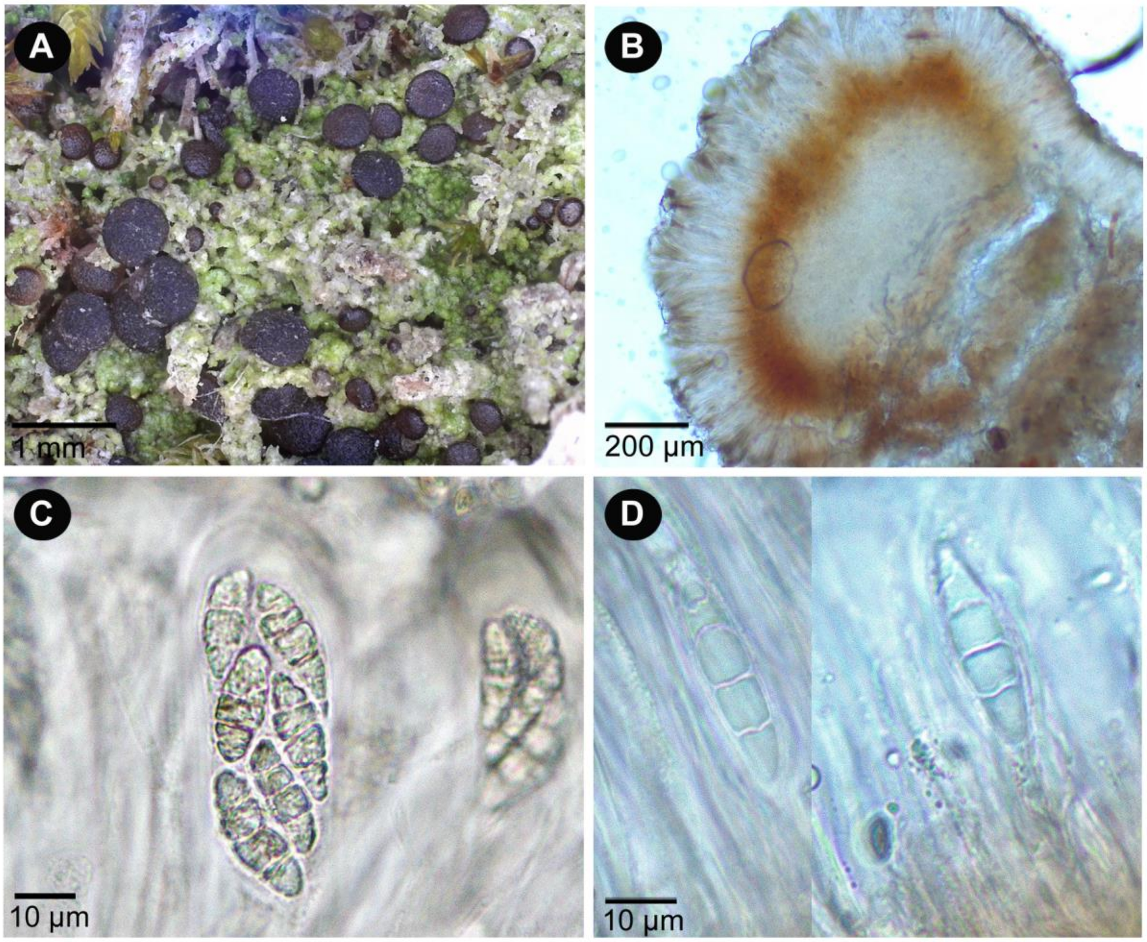

Figure 17. *Bilimbia sabuletorum* morphology and anatomy, Edmonton, *Haughland 2020-61*. **A,** Thallus growing on mineral soil and moss, wet. **B,** Apothecial cross-section showing orange-brown hypothecium. **C,** Asci and spores after treatment with K. **D,** Spores in water mount.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 47, 53.505866, -113.553095, 2019, on trunk of *Populus balsamifera*, *D. Haughland s.n. [UoA-CC-86]* (hb. Haughland); Edmonton, Urban Monitoring Site 47, 53.505866, -113.553095, 2019, on trunk of *Populus balsamifera*, *D. Haughland 2021-1*(hb. Haughland); Edmonton, Urban Monitoring Site 163E, 53.608013, -113.590864, 2019, on trunk of *Populus balsamifera*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-84]* (hb. Haughland).

Bilimbia sabuletorum (Schreber) Arnold
(≡ *Mycobilimbia sabuletorum* (Schreber) Hafellner)

FIGURE 17.

Apparently rare river valley terricole. Edmonton material: thallus thin, pale grey-green, granular, with abundant black-red brown to grey biatorine apothecia. Epithecium with fine, polarizing crystals, hymenium hyaline to pale yellow, 100–150 µm thick, hypothecium orange-brown. Spores fusiform, hyaline, perispore with minute warty ornamentation that can be difficult to see, 23–30 × 5–8 µm, with 3–5 transverse septa, swelling slightly in K, 8 per ascus. Chemistry: all thallus spot tests negative, no lichen substances known (Björk 2013). Molecular support: genus and to a lesser extent species supported in Kistenich et al. (2018), no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.517853, -113.54035, 2020, on exposed mineral soil and moss, *D. Haughland 2020-61 & K. Tichkowski* (hb. Haughland).

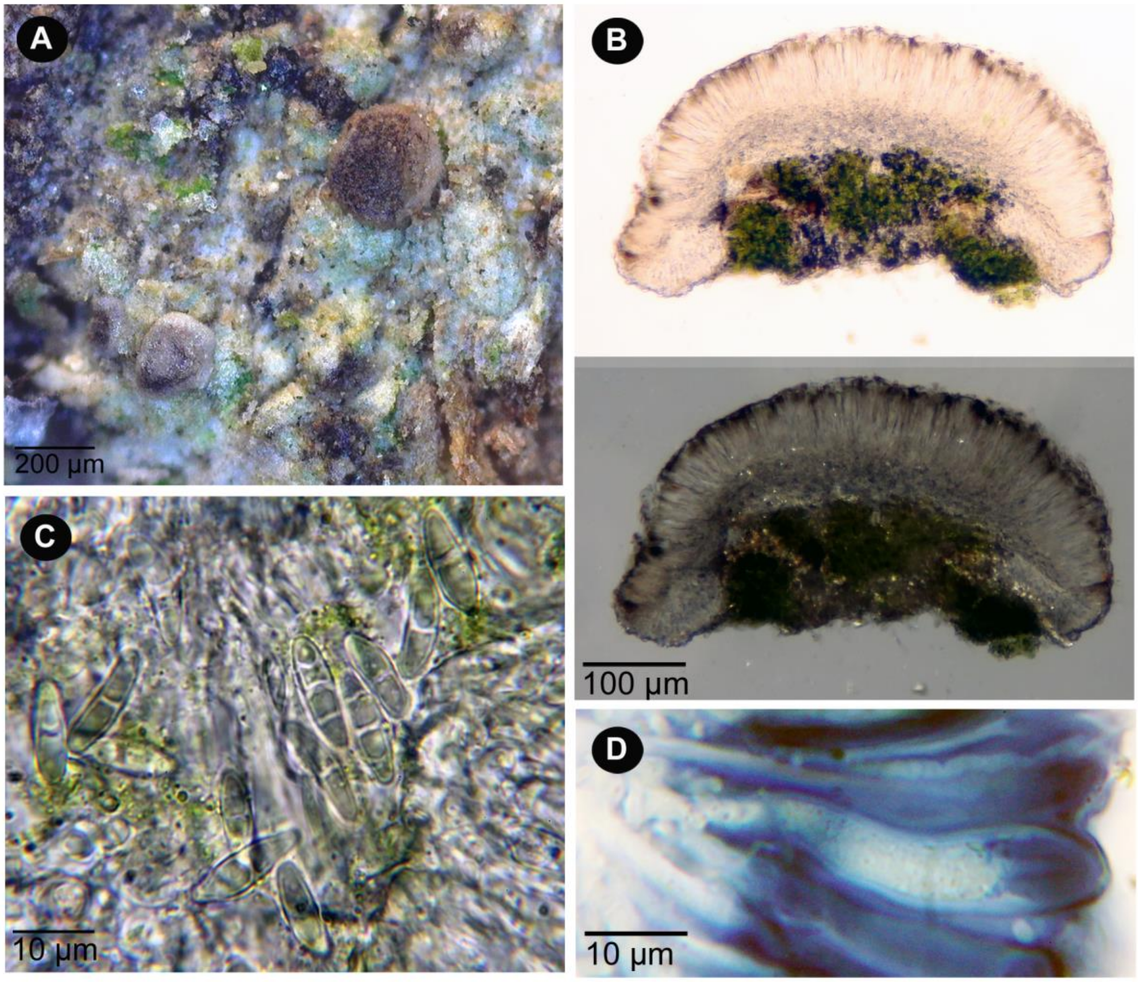

Figure 18. *Lecania naegelii* morphology and anatomy, Edmonton, *UoA-CC-49*. **A,** Thallus, on *Populus tremuloides*. **B,** Apothecial cross-section under white (top) and polarized light (bottom). **C,** Spores in water mount. **D,** Ascus treated with K followed by Lugol's I.

Lecania naegelii (Hepp) Diederich & van den Boom

FIGURE 18.

Apparently rare river valley epiphyte. This collection fits within the documented niche of this species: nutrient-rich, smooth-barked trees (van den Boom & Ryan 2004). While listed as unrankable on Alberta's List of Elements (rank SU, Government of Alberta 2017), we could not locate any previous records so here we report it as new to Alberta. Edmonton material: thin whitish thallus with convex pale green areoles. Apothecia plane, <0.5 mm in diameter, with a pink partially blackened disk and paler contrasting rim. In cross-section, no polarizing crystals were found except near the algal layer at the base and point of attachment; the rim was composed of hyaline, radiating thick-walled hyphae; the epithecium was largely hyaline with dispersed black pigments on the slightly swollen tips of the septate, simple paraphyses. Hymenium and hypothecium hyaline. Asci biatorine-type, staining K/I+blue, with an elongated, non-amyloid axial mass in a darkly amyloid tholus. Spores 1-3 transverse septate, hyaline, straight to slightly curved or bean-shaped, 12–17 × 4–5 µm, 8 per ascus, with rounded ends. Photobiont trebouxioid, restricted to the base of the apothecia. Chemistry: all thallus spot tests negative, no secondary metabolites detected (van den Boom & Ryan 2004). Molecular support: A single ITS sequence (isolate DLH14 from *UoA-CC-49*) has >97% percent identity with four accessioned *Lecania naegelii* GenBank sequences (Accession AM292691, 12 positions different, 496 bp overlap; KT695396 & KT695323, Canada, 15 positions different, 547 bp overlap; FR799198, United Kingdom, 15 positions different, 521 bp overlap).

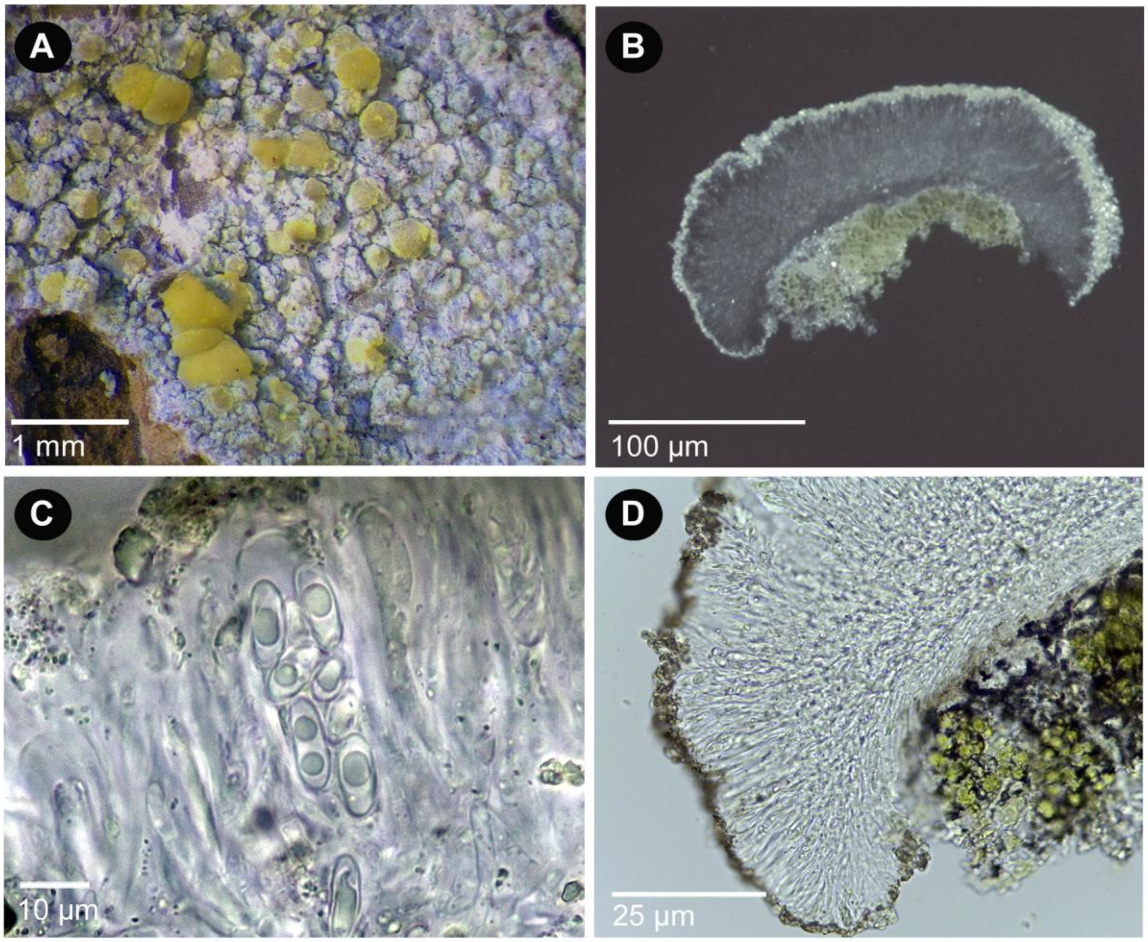

Figure 19. *Lecanora symmicta s.l.* morphology and anatomy, Edmonton. **A,** Thallus on dead *Alnus*, *Haughland 2020-15A*. **B,** Apothecial cross-section in polarized light showing fine crystals that dissolve in K, *Haughland 2020-15A*. **C,** Ascus, *UoA-CC21-18*. **D,** Apothecial cross-section in white light, *Haughland 2020-15A*.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 23E, 53.470689, -113.620142, 2019, on trunk of *Populus tremuloides*, *D. Haughland s.n. [UoA-CC-49]* (hb. Haughland).

Lecanora symmicta (Ach.) Ach. *s.l.*

FIGURE 19.

Apparently rare river valley and tableland epiphyte, likely present in parkland. Edmonton material: thallus pale blue-grey, episubstratic in part with small, rough verrucae that give rise to apothecia and/or dissolve into coarse granules. Apothecia biatorine, beige to yellow, convex and crowded, becoming "molten" and fused, no algae found in margin, proper exciple thin. Spores non-septate to rarely 1-septate, hyaline, unornamented, ellipsoidal, 8–12 × 4–5 µm. Polarizing crystals present in epihymenium and subhymenium that dissolve in K. Hymenium K/I+ fleeting blue. Chemistry: all thallus spot tests negative, usnic acid, zeorin, arthothelin, theophanic acid, 4,5-dichloronorlichexanthone (trace), norlichexanthone (trace) by TLC (Ryan et al. 2004). Molecular data: no new sequences generated. Given our material is atypical in some respects (occasional septate spores, granules) and other species have been recently split from this species (Pérez-Ortega & Kantvilas 2018), it is a priority for future molecular work.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Whitemud Ravine, 53.491661, -113.55914, 2020, on bark of dead *Alnus* snag, *D. Haughland 2020-15A & P. Williams* (hb. Haughland); Edmonton, University of Alberta North Campus, 53.525395, -113.525717, 2021, on *Pinus mugo*, *J. Singh*

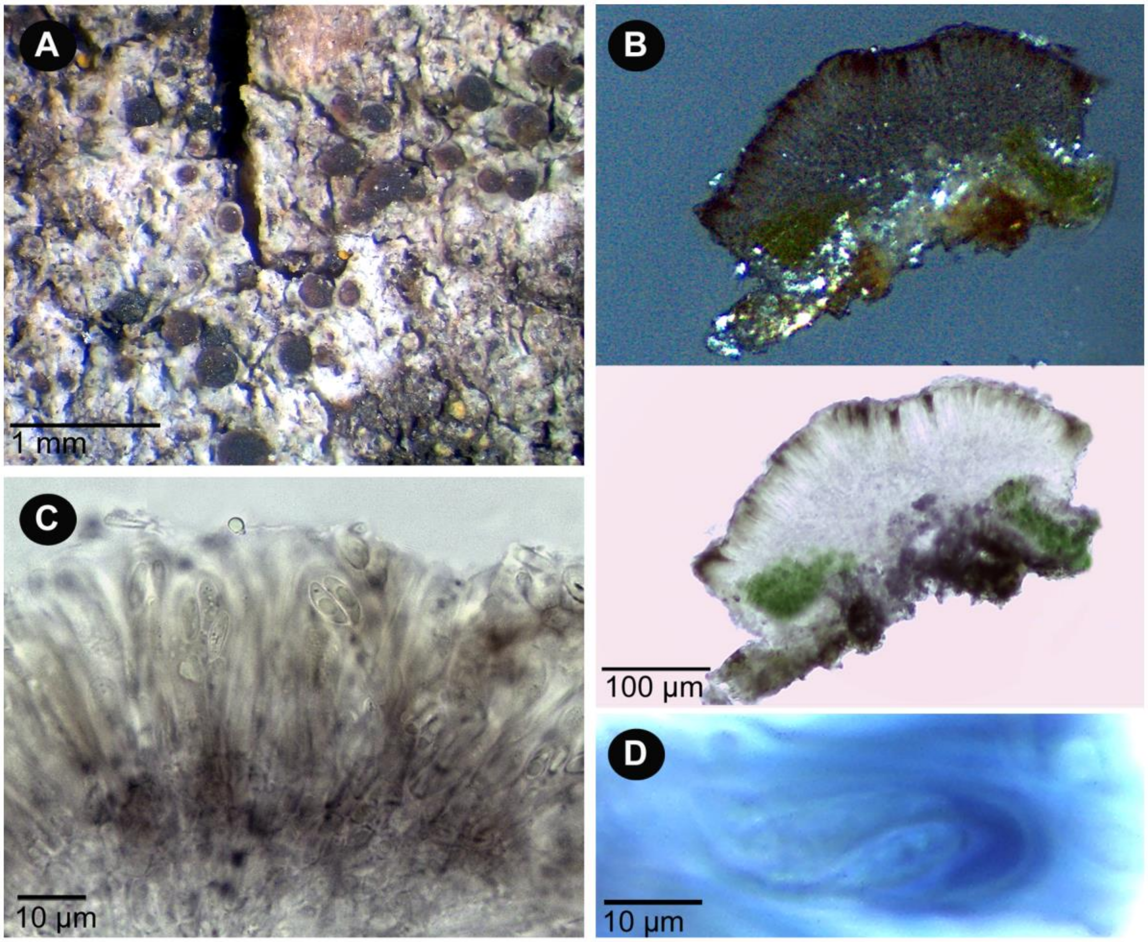

Figure 20. *Lecidea erythrophaea* morphology and anatomy, Edmonton, *UoA-CC-67*. **A,** Thallus on large-bole *Populus balsamifera*. **B,** Apothecial cross-section under white (bottom) and polarized light (top). **C,** Asci and spores in water mount. **D,** Ascus treated with K followed by Lugol's I.

& K. Schafer s.n. [UoA-CC21-18] (hb. Haughland); Edmonton, University of Alberta North Campus, 53.5254522, -113.526155, 2021, on *Pinus mugo*, *K. Schafer & J. Singh s.n. [UoA-CC21-29]* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on rotting log, *D.C. Lindsay s.n.* (PMAE- B77.24.41).

Lecidea erythrophaea Flörke ex Sommerf.

FIGURE 20.

Apparently rare river valley epiphyte. New to Alberta, we detected a single specimen from the North Saskatchewan River Valley on a large diameter *Populus balsamifera*. The closest known collection is from Wells Gray Provincial Park, British Columbia, from a swamp forest (*C. Björk 25583*, NY [n.v.], CNALH 2020). Edmonton material: apothecial disk brick-red to dark brown, thallus pale greenish-grey, smooth, thin. Spores non-septate, 8–9 × 2.5–3 µm, hyaline, unornamented, narrowly ellipsoid, 8 per ascus. Epihymenium tan brown, hymenium and subhymenium hyaline. Chemistry: all thallus spot tests negative, no secondary metabolites detected by TLC (Hertel & Printzen 2004). Molecular data: no sequences in GenBank, no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 57x, 53.521192, -113.548532, 2019, on trunk of *Populus balsamifera, D. Haughland & A. Hood s.n. [UoA-CC-67]* (hb. Haughland).

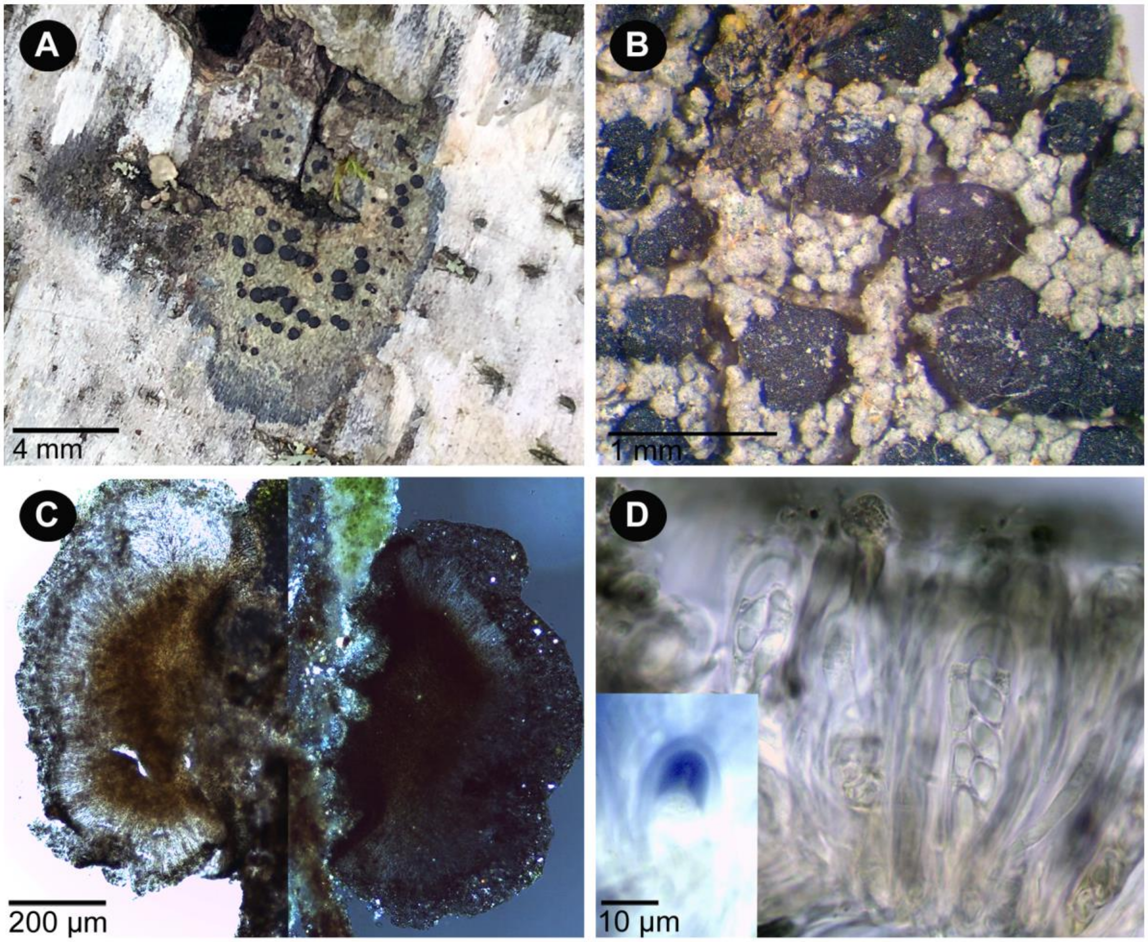

Figure 21. *Lecidella elaeochroma* morphology and anatomy, Edmonton, **A-B,** D. Haughland 2020-43, **D-C**, *UoA-CC-125*. **A-B,** Habit, on downed *Betula*. **C,** Apothecial cross-section under white (left) and polarized light (right). **D,** Asci and spores in water mount, inset treated with K followed by Lugol's I.

Lecidella elaeochroma (Ach.) M. Choisy

FIGURE 21.

Occasional river valley and ravine system and parkland epiphyte. Edmonton material: thallus thinly verrucose to cracked, grey-green, with black prothallus in some collections, with black lecideine apothecia with distinct exciple when young, becoming convex with age, to 1 mm diameter. Spores simple, 10–14 × 5–8 µm, broadly ellipsoid to lemon-shaped, hyaline, unornamented, 8 per ascus. In apothecia cross-sections the epihymenium and proper exciple are blue-black, the exciple cells are hyaline to almost violet and not carbonized, the hypothecium is rusty/orange-brown, and the hymenium hyaline. Apothecium interspersed with crystals in hypothecium and thinly in epihymenium. Asci with axial body and K/I+blue thollus. Chemistry: thallus K+ yellow, PD-, C-, KC-, complex of xanthones by TLC (Knoph and Leuckert 2004). Molecular support: we originally identified this material as *Lecidella euphorea* (Flörke) Hertel, but redetermined it based on our analyses of a single ITS sequence (isolate DLH11 from *Haughland 2020*-43). Previous authors have suggested that molecular data or high-performance liquid chromatography is required to definitively differentiate these two species (e.g., McCune 2017b). The *L. elaeochroma* clade is polyphyletic, and our western North American sequences fall on a well-supported branch separate from but close to a clade with *L.* "*elaeochroma 5*" from Europe (Zhao et al. 2015; Fig. 6 herein).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 56, 53.520506, -113.570687, 2019, on trunk of *Tilia*, *D. Haughland & A. Hood s.n.* [*UoA-CC-66]* (hb. Haughland); Edmonton, Urban Monitoring Site 148E, 53.587522, -113.640605, 2019, on trunk of *Populus balsamifera, D. Haughland & L. Hjartarson s.n. [UoA-CC-125]* (hb. Haughland); Edmonton, Urban Monitoring Site 57X, 53.521192, -113.548532, 2019, on trunk of *Populus balsamifera, D. Haughland & A.*

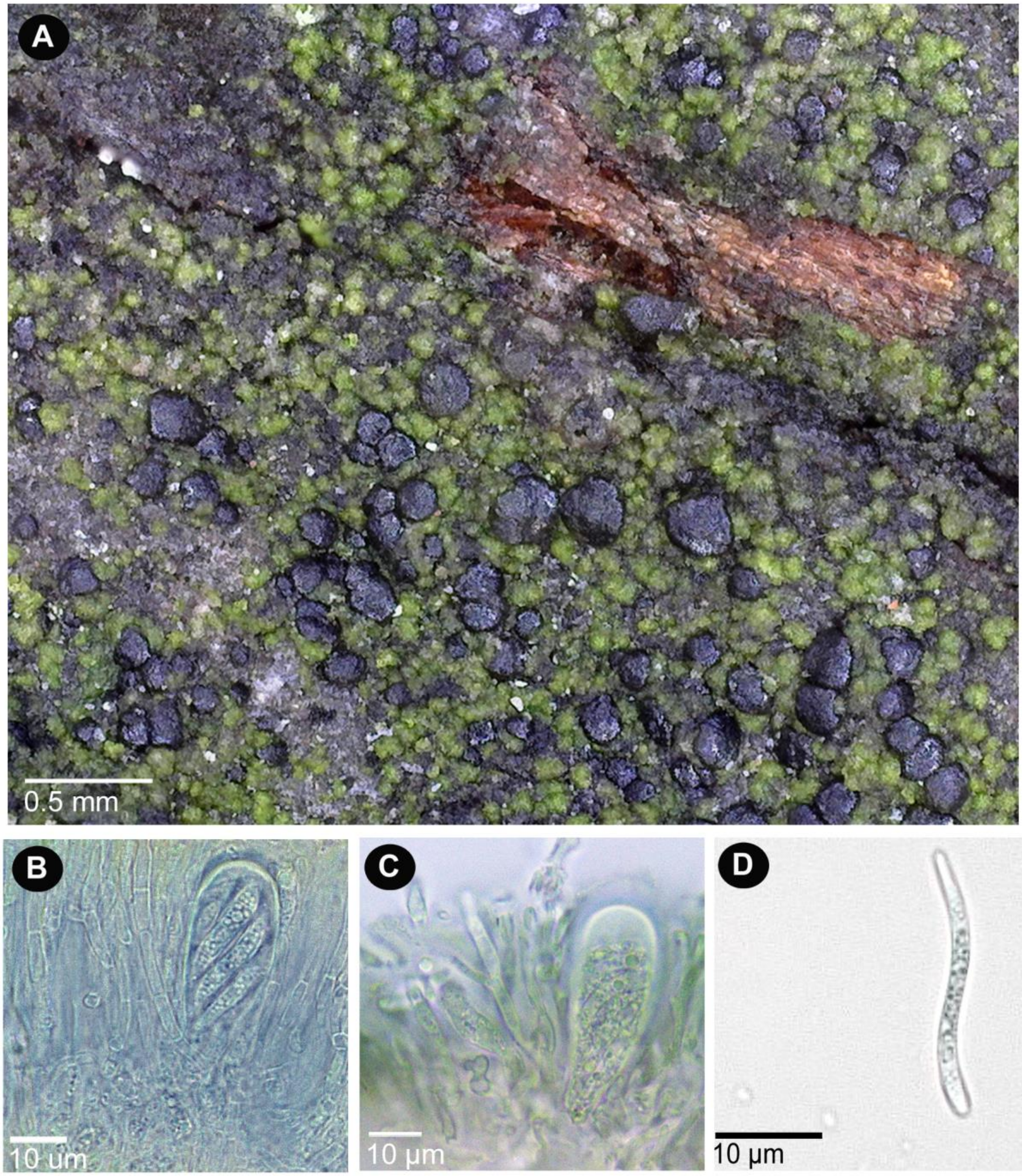

Figure 22. *Scoliosporum umbrinum* morphology and anatomy, Edmonton, *UoA-CC21-18*. **A,** Thallus, on *Pinus mugo* bark. **B,** Apothecial cross-section under white light with Leica optical shading, showing spores spiralling in ascus. **C,** Asci and branched paraphyses in water mount. **D,** Spore in water mount.

Hood s.n. [UoA-CC-67] (hb. Haughland); Edmonton, Patricia Ravine, 53.503105, -113.592863, 2020, on bark of recently downed *Betula papyrifera*, *D. Haughland 2020-43 & A. Hood* (hb. Haughland); Edmonton, University of Alberta North Campus, 53.527244, -113.519258, 2021, on *Pinus sylvestris*, *K. Schafer & J. Singh s.n. [UoA-CC21-23]* (hb. Haughland).

Scoliciosporum umbrinum (Ach.) Arnold

FIGURE 22.

Apparently rare tableland epiphyte. Edmonton material: thallus of dark-green, matte granules, lacking soredia, isidia or prothallus. Apothecia black, shiny, to 0.25 mm wide, with proper exciple (evident when young, becoming largely excluded), apothecia becoming slightly convex with age. Branching, septate paraphyses in gelatinous matrix, not swollen at tips, 3 µm wide, also forming proper exciple. Asci *Lecanora*-type. Epithecium grey to blue-green, hymenium and hypothecium hyaline. Spores hyaline, unornamented, fusiform, 23–30 × 3–3.5 µm, 3–4 septate, mostly curved to S-shaped, spiralling in asci, apparently 8 per ascus but hard to be definitive. Apothecial tissues in wet mount largely lacking polarizing crystals (a few tiny crystals on surface), K-, asci KI+blue, hypothecium and paraphyses KI-. Chemistry: all spot tests on the thallus negative, no lichen substances known (Björk 2013). Molecular support: good genus-level and limited species-level support (Fryday et al. 2020), no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, University of Alberta North Campus, 53.5253952, -113.525717, 2021, on trunk of *Pinus mugo, J. Singh & K. Schafer s.n. [UoA-CC21-18]* (hb. Haughland); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513211, -113.538619, 2021, on *Picea* twigs, *D. Haughland 2021-30* (hb. Haughland).

GROUP 3: LIRELLATE LICHENS

One species. Key literature: Ertz & Egea 2007; Torrente & Egea 1989.

Alyxoria varia (Pers.) Ertz & Tehler
(≡ *Opegrapha varia* Pers.)

FIGURE 23.

Occasional river valley and ravine system epiphyte. Rediscovered for Alberta; see the results section for more information on prior reports. Extensive colonies were found on mature *Populus balsamifera* in the riparian zone of creeks and the North Saskatchewan River. Edmonton material: lirellae on a farinose crust, photobiont appearing trebouxioud, individual algal cells to 15–20 µm in diameter. Lirellae rounded, irregular or elongate, sessile, superficial, and slightly constricted at base, 0.2–1 mm long and 0.16–0.3 mm wide. Lirellae lacking thalline exciple, proper exciple shiny, epruinose and strongly carbonaceous so that anatomy obscured in section, curving over an open hymenium and appearing closed beneath the subhymenium. The hymenium varies from epruinose to lightly greenish-yellow pruinose. Spores narrowly obovate, 8 per ascus, 20–25 × 6–8 µm, mostly with 5 transverse septa and an enlarged middle cell, cell walls only slightly thickened at septa. Spores hyaline with dark walls, halonate, at maturity darkening and becoming warty. Apothecial tissues were almost exclusively K/I- except very minimal K/I+blue reactions in limited areas of the hymenium in a single section. Chemistry: all thallus spot tests negative, no secondary metabolites detected by TLC (Ertz & Egea 2007). Molecular support: a complex of species in need of revision, sequences analysed to date forming a distinct clade within the genus (Ertz et al. 2020), no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.501505, -113.601141, 2019, on bark of mature *Populus balsamifera* in riparian zone, *D. Haughland et al. 2019-116* (hb. Haughland); Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on trunk of live >75 cm DBH *Populus balsamifera* along trail, *D. Haughland 2020-54 & A. Hood* (hb. Haughland); Edmonton, Rat Creek, Kinnaird Ravine, 53.5582, -113.453925, 2020, on trunk of live *Populus balsamifera* along trail, *D. Haughland 2020-105 & P. Williams* (hb. Haughland).

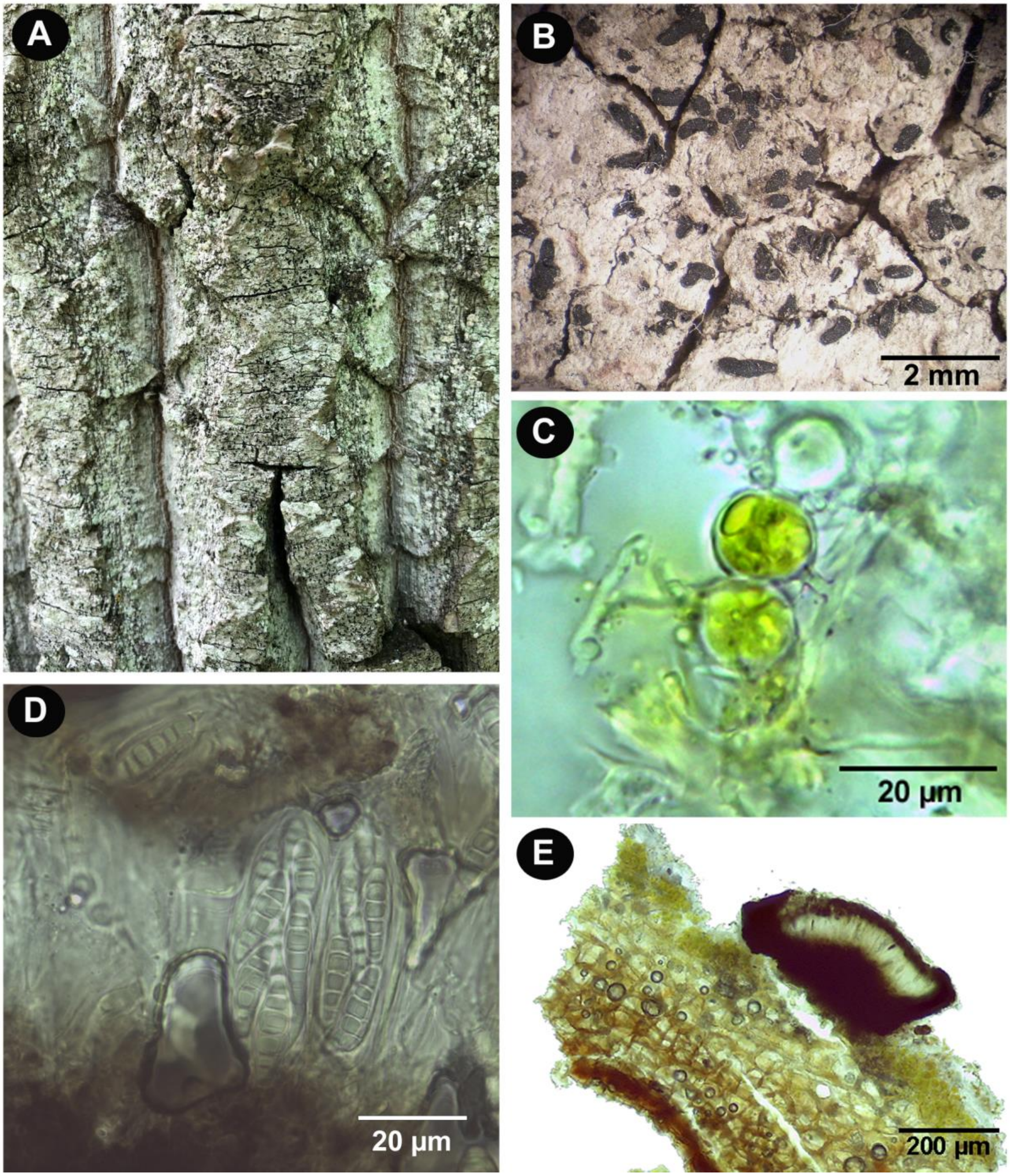

Figure 23. *Alyxoria varia* morphology and anatomy, Edmonton, *Haughland 2019-116*. **A-B,** Habit, on *Populus tremuloides* in riparian zone. **C,** Green algae in farinose thallus. **D,** Asci and spores in water mount. **E,** Cross-section of apothecium and substrate.

Group 4. Yellow lecanorine crustose lichens

Four species. Key literature: Brodo 2016; McCune 2017a, 2017b; Westberg 2004, 2005, 2007a, 2007b; Westberg et al. 2011. Additional species from this group that may be present in Edmonton include *Candelariella xanthostigma*, but existing collections are too small for confident determination. Preliminary identification is possible using morphology and substrate alone; confident identification requires examination of the spores. K is helpful in excluding co-occurring Group 5 *Caloplaca s.l.* (K+ purple in *Caloplaca s.l.* vs. K- to K+ reddish in *Candelariella*).

1a. Growing on rock or concrete; 8 spores per ascus ....***Candelariella aurella***
1b. Growing on bark or wood or other anthropogenic substrates; 8 or more spores per ascus **2**

2a. Thalllus grey, may appear minutely tomentose; proper exciple grey to yellow; 8 spores per ascus
.... ***Candelariella antennaria***
2b. Thallus yellow, never tomentose; proper exciple either yellow or not visible; 12 or more spores per ascus **3**

3a. Thallus of small, flat, dispersed areoles ≤0.1 mm wide; proper exciple not visible ....
....***Candelariella* cf. *lutella***
3b. Thallus larger, becoming subsquamulose, to 0.5 mm wide, often aggregated; proper exciple typically visible ....***Candelariella* cf. *vitellina***

******Candelariella antennaria*** Räsänen

FIGURE 24 A-C.

Occasional tableland epiphyte. This species is reported as new to Alberta. We checked PMAE under the names *Candelariella aurella* (Hoffm.) Zahlbr. and *C. deflexa* (Nyl.) Zahlbr. for specimens with grey thalli but found none. This species is reported to have a wide ecological amplitude; alternatively, it may represent a complex of similar species (Westberg & Sohrabi 2012). In the neighboring provinces of British Columbia and Saskatchewan, it has been found on rock, soil, *Populus* snags, *Artemisia*, *Ulmus*, and *Krascheninnikovia* (CNALH 2020, Freebury 2014), and the senior author observed it on *Populus* along the South Saskatchewan River, east of Saskatoon (D. Haughland, 2020, unvouchered observation). In other parts of its range including Russia, Kazakhstan, and Nepal, it grows on a wide variety of deciduous trees and shrubs (Yakovchenko et al. 2012). Edmonton material: epiphytic on a variety of deciduous trees, thallus pale to dark grey to green-grey, indistinct, thin, or thick and amorphous. Apothecia scattered to crowded, 0.1–0.3 mm diameter, disk yellow, flat to somewhat convex, yellow or grey thalline margin (smooth or appearing slightly tomentose), proper margin indistinct. Spores hyaline, simple to 1-septate, narrowly ellipsoid, 11–17 × 5–7 µm, 8 per ascus. Chemistry: all spot tests negative, calycin, pulvinic acid, pulvic acid lactone and vulpinic acid in yellow parts by HPLC (Westberg 2007b). Molecular data: limited species-level support as a sister clade to *C. aggregata* M. Westb. (Liu et al. 2019) but more analyses needed, no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 40, 53.493796, -113.504715, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & M. Cao s.n. [UoA-CC-16]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520757, -113.432138, 2019, on trunk of *Ulmus americana*, *S. Toni & A. Hood s.n. [UoA-CC-28]* (hb. Haughland); Edmonton, Urban Monitoring Site 135, 53.642107, -113.502186, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & M. Cao s.n. [UoA-CC-30]* (hb. Haughland); Edmonton, Urban Monitoring Site 106E, 53.546421, -113.641504, 2019, on trunk of *Ulmus americana*, *D. Haughland s.n. [UoA-CC-103]* (hb. Haughland); Edmonton, Urban Monitoring Site 150E, 53.590394, -113.588685, 2019, trunk of *Ulmus americana*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-27]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on bark of large downed *Populus*, *D. Haughland 2019-122C & P. Williams* (hb. Haughland); Edmonton, University of Alberta North Campus, 53.527511, -113.519763, 2021, on *Aesculus glabra*, *K. Schafer & J. Singh s.n. [UoA-CC21-46]* (hb. Haughland).

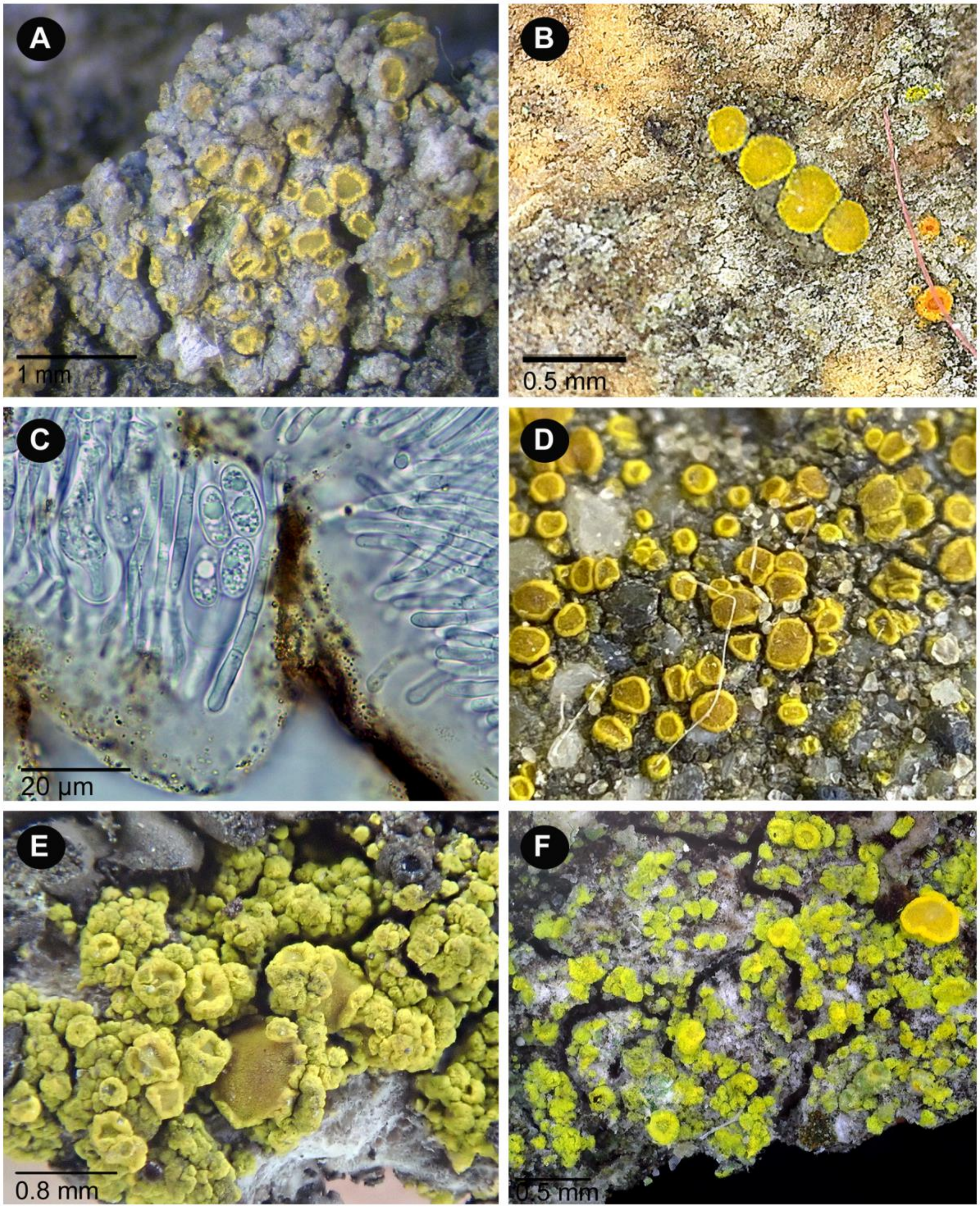

Figure 24. Yellow lecanorine crustose *Candelariella* of Edmonton. **A-C,** *C. antennaria*, new to Alberta. **A,** Specimen with well-developed thallus, *UoA-CC-103*. **B,** Typical specimen with thallus limited to areoles bearing apothecia, *Haughland 2019-122C*. **C,** Asci, paraphyses and spores in water mount, *UoA-CC-103*. **D,** *C. aurella* on sidewalk, *Spribille* https://www.inaturalist.org/observations/44151398. **E,** *C.* cf. *vitellina* on *Fraxinus pennsylvanica*, *UoA-CC-113*. **F,** *C.* cf. *lutella* on bark of *Populus balsamifera*, *UoA-CC-23*.

Candelariella aurella (Hoffm.) Zahlbr.

FIGURE 24 D.

Anthropogenic saxicole. Thallus of yellow to orange-yellow areoles with abundant lecanorine apothecia. Spores hyaline, narrowly ellipsoidal, simple to 1-septate, unornamented, 13–16 × 6–8 µm, 8 per ascus. Chemistry: thallus K- or KC+ reddish, C-, PD-, UV-, calycin, pulvinic acid, pulvinic dilactone and vulpinic acid by TLC (Westberg 2004). Molecular data: species well-supported phylogenetically (Liu et al. 2019, Westberg & Arup 2011) no new sequences generated.

Specimen cited. – **CANADA. ALBERTA:** Edmonton, Strathcona, 9736 90 Ave. NW, 53.525645, -113.481477, 2018, on sidewalk concrete, *T. Spribille 42799* (hb. Spribille: iNaturalist record https://www.inaturalist.org/observations/44151398).

Candelariella* cf. *lutella (Vain.) Räsänen

FIGURE 24 F.

Occasional river valley, parkland, and tableland epiphyte. Edmonton material: greenish yellow to yellow small, flat areoles 0.05–0.1 mm wide, forming scattered or crowded patches 0.5–3.5 mm wide. Apothecia 0.1–0.5 mm diameter, disk and thalline exciple colored like thallus, proper exciple indistinct, thalline exciple often beaded. Spores 7–12 × 4–5 µm, simple, asci with 24–32 spores. Similar to *C.* cf. *vitellina* but this species' areoles are smaller, more dispersed, and typically do not form overlapping aggregates, and the proper exciple usually is not visible. Chemistry: thallus K- or KC+ reddish, C-, PD-, UV-, secondary metabolites not investigated (Westberg 2004). Molecular support: in our phylogeny a single ITS sequence (isolate DLH39 from *Haughland 2019-121A*) does not group with *C. lutella* sequences from Westberg (Fig. 2 herein). Instead it forms a highly supported basal branch to four identical sequences determined as *C. efflorescens* (Westberg et al. 2007) and *C.* cf. *vitellina* (Fig. 2 herein). Additional work is required to resolve the taxonomy of epiphytic *Candelariella* in Edmonton.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 28, 53.479694, -113.549752, 2019, on trunk of *Populus balsamifera*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-52]* (hb. Haughland); Edmonton, Urban Monitoring Site 40, 53.493790, -113.504979, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & M. Cao s.n. [UoA-CC-8]* (hb. Haughland); Edmonton, Urban Monitoring Site 47, 53.505933, -113.552966, 2019, on trunk of *Populus balsamifera*, *D. Haughland s.n. [UoA -CC-23]* (hb. Haughland); Edmonton, Urban Monitoring Site, 56, 53.520506, -113.570687, 2019, on trunk of *Tilia*, *D. Haughland & A. Hood s.n. [UoA-CC-66]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520757, -113.432138, 2019, on trunk of *Ulmus americana*, *S. Toni & A. Hood s.n. [UoA-CC-28]* (hb. Haughland); Edmonton, Urban Monitoring Site 150E, 53.590394, -113.588685, 2019, on trunk of *Ulmus americana*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-27]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on *Populus* twigs on downed tree, *D. Haughland 2019-121A & P. Williams* (hb. Haughland).

Candelariella* cf. *vitellina (Hoffm.) Müll. Arg.

FIGURE 24 E.

Common river valley, parkland, and tableland epiphyte. This is the most common epiphytic *Candelariella* in Edmonton across a diversity of deciduous trees on boulevards and in river valley parks. In other regions this species is more commonly found on non-calcareous rock (Westberg 2007a, but see Björk 2013), suggesting molecular work would be beneficial. Edmonton material: thallus of bright yellow abundant granules or areoles, esorediate, varying from rounded and granular to subsquamulose, slightly flattened and irregularly incised, often crowded and overlapping, forming pulvinate clusters. Apothecia usually with the thallus but may be disjunct in space; apothecia bright yellow with similar colored thalline exciple and distinct proper exciple. Spores 8–12 × 3–5 µm, simple or with a thin septum, 12–24 per ascus. Chemistry: K- or KC+ reddish, C-, PD-, UV-, calycin, pulvinic acid, pulvinic dilactone and vulpinic acid in yellow parts by TLC (Westberg 2004). Molecular support: three ITS sequences are identical to the single published sequence of *C. efflorescens* (Westberg et al. 2007; Fig. 3 herein). Additional work is required to resolve the taxonomy of epiphytic *Candelariella* in Edmonton.

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 9, 53.453708, -113.527608, 2019, on trunk of *Fraxinus*, *D. Haughland s.n. [UoA-CC-144]* (hb. Haughland); Edmonton, Urban Monitoring Site 45, 53.507783, -113.592490, 2019, on trunk of *Ulmus americana*, *M. Villeneuve & M. Lewis s.n. [UoA-CC-7]* (hb. Haughland); Edmonton, Urban Monitoring Site 107E, 53.548249, -113.617818, 2019, on trunk of *Elaeagnus angustifolia*, *D. Haughland s.n. [UoA-CC-9]* (hb. Haughland); Edmonton, Urban Monitoring Site 149E, 53.587099, -113.610922, 2019, on trunk of *Salix* cf. *pentandra*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-100]* (hb. Haughland); Edmonton, Urban Monitoring Site 37x, 53.494526, -113.597236, 2019, on trunk of *Ulmus americana*, *M. Villeneuve & M. Lewis s.n. [UoA-CC-115]* (hb. Haughland); Woodcroft, Air Quality Monitoring Station, 53.563708, -113.563508, 2019, on trunk of *Prunus virginiana*, *D. Haughland & A. Hood s.n*. *[UoA-CC-107]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on fallen *Populus* twigs, *D. Haughland 2019-121C & P. Williams* (hb. Haughland).

GROUP 5. ORANGE LECANORINE CRUSTOSE LICHENS

Three species. Key literature: Arup 2009; Björk 2013; Brodo 2016; McCune 2017a, 2017b; Šoun et al. 2011; Wetmore 2001, 2007a, 2007b. Additional species from this group may be present in Edmonton but existing collections are too sparse to be confident. Identification of these three species is possible using morphology and substrate.

1a. Growing on rock or concrete; all tissues orange, never grey................................. ***Caloplaca feracissima***
1b. Growing on bark or wood; thalline tissues may be grey or orange **2**

2a. Thalline exciple orange, proper exciple often visible.. ***Caloplaca pyracea***
2b. Thallus exciple thick and grey, proper exciple indistinct/not visible ....***Caloplaca cerina***

Caloplaca pyracea (Ach.) Zwackh
(≡ *Athallia pyracea* (Ach.) Arup, Frödén & Søchting)

FIGURE 25 C-D.

Common river valley, parkland, and tableland epiphyte. In Alberta records of this species were historically included with *Caloplaca holocarpa*, but Arup (2009) considers *C. holocarpa* almost exclusively saxicolous. Edmonton material: thallus pale grey to greyish orange-yellow, thin, inconspicuous, or moderately-areolate. Apothecia abundant, scattered to crowded, usually flat to slightly convex, round to irregular, 0.3–1.0 mm diameter, orange disk, thalline exciple slightly lighter orange than disk with proper exciple visible and slightly raised or level with disk. Spores hyaline, uniseptate, polarilocular, ellipsoidal, 9–15 × 5–9 µm, septum 3-6 µm wide, 8 per ascus. Common across many deciduous tree species. Chemistry: orange tissues K+ purple, C-, PD-, UV-, parietin, ± traces of fallacinal, emodin, teloschistin, and parietinic acid (Arup 2009). Molecular data: no new sequences generated, genus-level and limited species-level support in Arup et al. (2013).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 20, 53.464867, -113.505729, 2019, on trunk of *Populus*, *D. Haughland & M. Cao s.n. [UoA-CC-33]* (hb. Haughland); Edmonton, Urban Monitoring Site 74, 53.548831, -113.592412, 2019, on trunk of *Populus*, *M. Lewis & M. Villeneuve s.n. [UoA-CC-99*] (hb. Haughland); Edmonton, Urban Monitoring Site 83, 53.559556, -113.642705, 2019, on trunk of *Ulmus americana*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-34]* (hb. Haughland); Edmonton, Urban Monitoring Site 149E, 53.587099, -113.610922, 2019, on trunk of *Salix* cf. *pentandra*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-100]* (hb. Haughland); Woodcroft, Air Quality Monitoring Station, 53.563693, -113.563604, 2019, on trunk of *Prunus virginiana*, *D. Haughland & A. Hood s.n. [UoA-CC-35]* (hb. Haughland); Edmonton, Urban Monitoring Site 194E, 53.63778, -113.52964, 2019, on trunk of *Fraxinus*, *D. Thauvette & M. Cao s.n. [UoA-CC-61]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on bark of large downed *Populus*, *D. Haughland 2019-122B & P. Williams* (hb. Haughland); Edmonton, 180 St and 99 Ave, 1976, on twigs and dead branches, *D.C. Lindsay s.n.* (PMAE-B77.24.75); Edmonton, Terwillegar Park, 1977, on rotting wood, *D.C. Lindsay, s.n.* (PMAE-B77.24.85).

Caloplaca cerina (Ehrh. ex Hedwig) Th. Fr.

FIGURE 25 E-F.

Occasional river valley, parkland, and tableland epiphyte. This species can be confused with *Caloplaca pyracea*, but *C. cerina* is rarer, has a thicker grey thalline margin, and lacks a visible orange proper exciple. Edmonton material: thallus grey (pale to slate to dark grey), immersed to well-developed, areolate or continuous. Apothecia single or clustered, 0.3–1.0 mm diameter, thalline exciple similar in color to thallus (pale to dark grey), disk yellow to orange, sometimes white pruinose, proper exciple not visible. Spores hyaline, uniseptate, polarilocular, 10–18 × 6–9 µm, septum 3–7 µm wide, 8 per ascus. Chemistry: orange tissues K+ purple, C-, PD-, UV-, parietin, fallacinal, and teloschistin by TLC (Wetmore 2007a). Molecular support: no new sequences generated, limited species level support (Frolov et al. 2021).

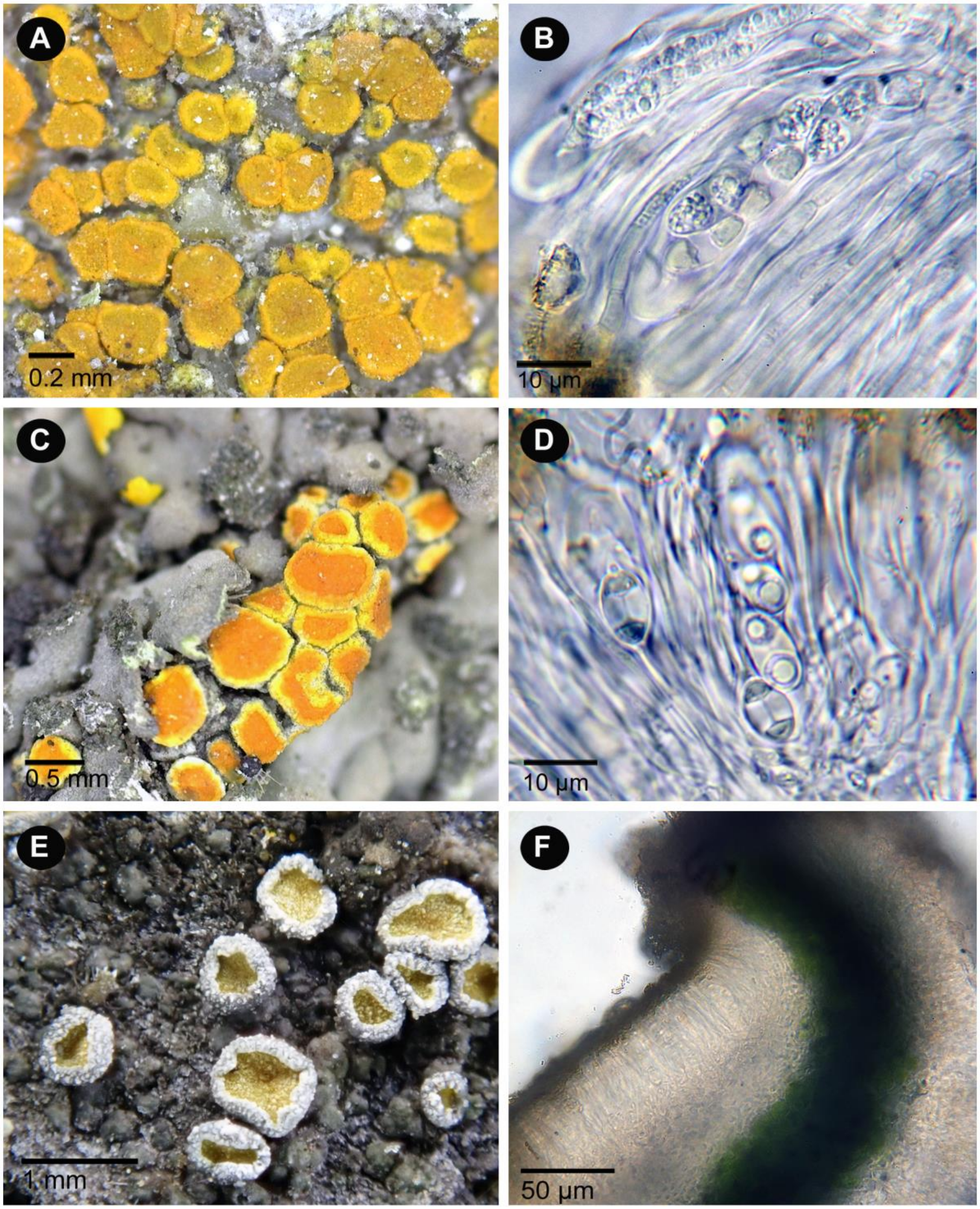

Figure 25. Orange lecanorine crustose *Caloplaca s.l.* of Edmonton. **A-B,** *C. feracissima*, *Haughland 2020-95*. **A,** Apothecia on old concrete. **B.** Polarilocular spores with relatively narrow septa. **C-D,** *C. pyracea.* **C,** Apothecia on *Fraxinus pennsylvanica* with proper exciple visible, surrounded by *Phaeophyscia orbicularis*, *UoA-CC-31*. **D,** Polarilocular spores with wide septa, *UoA-CC-45*. **E-F,** *C. cerina*, *UoA-CC-45*. **E,** Pruinose apothecia on *Populus tremuloides*, **F,** Apothecial cross-section showing thick thalline exciple.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 40, 53.493796, -113.504715, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & M. Cao s.n. [UoA-CC-8]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520757, -113.432138, 2019, on trunk of *Ulmus americana*, *S. Toni & A. Hood s.n. [UoA-CC-28]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520926, -113.432139, 2019, trunk of *Ulmus americana*, *D. Royko & D. Fielder s.n. [UoA-CC-15]* (hb. Haughland); Edmonton, Urban Monitoring Site 107E, 53.548554, -113.617129, 2019, on trunk of *Salix*, *D. Haughland s.n. [UoA-CC-97]* (hb. Haughland); Edmonton, Urban Monitoring Site 23E, 53.470636, -113.620232, 2019, on trunk of *Populus tremuloides*, *D. Haughland s.n. [UoA-CC-45]* (hb. Haughland); Edmonton, East Air Quality Monitoring Station, 53.548202, -113.367545, 2019, on trunk of *Populus*, *D. Thauvette & J. Birch s.n. [UoA-CC-6]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on bark of large downed *Populus*, *D. Haughland 2019-122A & P. Williams* (hb. Haughland); Edmonton, Terwillegar Park, 1977, on rotting wood, *D.C. Lindsay s.n.* (PMAE-as minor component of B77.24.85); 180 St. and 99 Ave., Edmonton, 1976, on twigs and dead branches, *D.C. Lindsay s.n.* (PMAE-as minor component of B77.24.75).

Caloplaca feracissima H. Magn.
(≡ *Xanthocarpia feracissima* (H. Magn.) Frödén, Arup & Søchting)

FIGURE 25 A-B.

Anthropogenic saxicole. Given the inconspicuous to absent primary thallus, the small apothecia, spore size, and septum:length ratio, our material falls within the *Caloplaca crenulatella* complex. This poorly resolved complex may represent a suite of phenotypically similar species (Arup 2009; McCune 2017b; Vondrák et al. 2011, 2017). Edmonton material: apothecia single to clustered, 0.2–0.5 mm diameter, disk dull or dingy orange, proper and thalline exciple visible, orange. Spores simple, hyaline, 12–16 × 5–6 µm, septum 2.5–4 µm wide, 8 per ascus. Chemistry: orange tissues K+ purple, C-, PD-, UV-, secondary metabolites not investigated. Molecular support: a single ITS sequence (isolate DLH33 from *Haughland 2020-95A*) is 99% percent identical to two *Xanthocarpia feracissima* GenBank sequences (MK110661, 4 positions different, 570 bp overlap, Kantor et al. 2018 unpublished; KC179129, U.S.A., 2 positions different, 497 bp overlap, Arup et al. 2013). A sequence of uncultured fungus from house dust and indoor air collected in Kansas City, U.S.A., was also 99% identical (KF800113, 4 positions different, 571 bp overlap, Rittenour et al. 2014), possible evidence of propagules in other urban environments.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Spruce Avenue neighborhood, 53.563562, -113.498138, 2020, on old concrete sidewalk, *D. Haughland 2020-95A* (hb. Haughland).

GROUP 6. *LECANORA S.L.*

Eight species, five described here. See Group 2 for the biatorine *Lecanora symmicta*, Group 7 for sorediate *L. impudens* and *L. stanislai.* Key literature: Björk 2013; Brodo 1984, 2016; McCune 2017a, 2017b; Śliwa 2007. Given recent taxonomic flux (Kondratyuk et al. 2019; Zhao et al. 2016) we retain *Lecanora* in the broad sense and provide updated synonyms. Given the diversity of this genus, we anticipate additional species will be found in Edmonton. Spot tests and examination of sections and spores at high magnification and with polarized light is required for confident identification of most species.

1a. Apothecia biatorine or apothecia typically lacking and thallus composed of soredia **2**
1b. Apothecia lecanorine, thallus immersed or episubstratic and areolate to subfoliose................................**3**

2a. Apothecia biatorine ....**see Group 2 Key**
2b. Apothecia typically lacking and thallus composed of soredia..**see Group 7 Key**

3a. Growing on concrete or rock; thallus well-developed, subfoliose..........................***Protoparmelia muralis***
3b. Growing on bark or wood; thallus never subfoliose, at most areolate, often immersed............................**4**

4a. Thalline exciple PD+ orange to red, best tested on apothecia cross-sections...............***Lecanora pulicaris***
4b. Thalline tissues PD- **5**

5a. Apothecial rim grey; spores 12-16 per ascus; primary thallus often visible as distinct white stain or verrucae .... ***Lecanora sambuci***
5b. Apothecial rim white; spores 8 per ascus; primary thallus typically lacking or indistinct **6**

6a. Apothecia typically lacking pruina, polarizing crystals sparse in cross-sections ....***Lecanora* cf. *persimilis***
6b. Apothecia typically pruinose, pruina, epihymenium and thalline exciple typically with abundant polarizing crystals in sections..***Lecanora* cf. *hagenii***

Lecanora* cf. *hagenii (Ach.) Ach.
(≡ *Polyozosia hagenii* (Ach.) S.Y. Kondr., Lőkös & Farkas, ≡ *Myriolecis hagenii* (Ach.) Śliwa, Zhao Xin & Lumbsch)

FIGURE 26 B.

Tableland, parkland, river valley and ravine system epiphyte. Common and variable on a diversity of deciduous trees. Edmonton material: thallus immersed to indistinct, white to grey. apothecia pruinose (immature and mature), at maturity with raised, white, crenulate rim. Apothecia 0.3–0.9 mm diameter, crowded. Spores hyaline, simple, 10–12.5 × 5 µm, 8 per ascus. Epihymenium brown, hymenium hyaline, hypothecium hyaline. Pruina, epihymenium and thalline exciple POL+. Epihymenium/hymenium C-. Chemistry: all spot tests on thallus and thalline exciple negative, no secondary metabolites detected by TLC (Ryan et al. 2004). Molecular support: unresolved. Sequences including the single sequence generated here (isolate DLH15 from *UoA-CC-61*) fall into four distinct clades within the *Lecanora dispersa* group. Given the uncertainty around the status of *L. hagenii s.s*. (see results section), we can confirm only that our sequence is within the highly supported *L. dispersa* group, and that it is distinct from our single sequence of *L.* cf. *persimilis.*

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 31, 53.477955, -113.494143, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & A. Stordock s.n. [UoA-CC-29]* (hb. Haughland); Edmonton, Urban Monitoring Site 83, 53.559591, -113.642062, 2019, on trunk of *Ulmus americana, D. Haughland s.n. [UoA-CC-160]* (hb. Haughland); Edmonton, Urban Monitoring Site 111, 53.587075, -113.457605, 2019, on trunk of *Fraxinus pennsylvanica, S. Toni & A. Hood s.n. [UoA-CC-96]* (hb. Haughland); Edmonton, Urban Monitoring Site 117, 53.600887, -113.501394, 2019, on trunk of *Ulmus pumila, D. Haughland & M. Cao s.n.* [*UoA-CC-63]* (hb. Haughland); Edmonton, Urban Monitoring Site 194E, 53.63778, -113.52964, 2019, on trunk of *Fraxinus, D. Thauvette & M. Cao s.n. [UoA-CC-61]* (hb. Haughland); Edmonton, Urban Monitoring Site 2E, 53.438762, -113.557303, 2019, on trunk of *Ulmus americana, L. Hjartarson & D. Haughland s.n. [UoA-CC-94]* (hb. Haughland).

Lecanora* cf. *persimilis (Th. Fr.) Arnold
(≡ *Polyozosia persimilis* (Th. Fr.) S.Y. Kondr., Lőkös & Farkas, ≡ *Myriolecis persimilis* (Th. Fr.) Śliwa, Zhao Xin & Lumbsch)

FIGURE 26 D.

Occasional tableland epiphyte. Separated (with difficulty) from *Lecanora cf. hagenii* by scarcity of pruina on even immature apothecia. Edmonton material: thallus immersed or lacking, apothecia sessile, matte to slightly shiny, plane to slightly convex, with thin thalline margin, appearing almost biatorine, diameter to 0.86 mm. Disk peach brown to medium brown, epihymenium brown in apothecia cross-sections. Trebouxioud algae patchy, present as a thick layer in part below hypothecium. Spores 8–14 × 5.5–6 µm, simple, 8 per ascus. Paraphyses wider at tips and sparsely branching. Very sparse polarizing crystals present, scattered in hymenium and thalline exciple, lacking epipsamma. Chemistry: All spot tests negative, no secondary metabolites detected by TLC (Ryan et al. 2004). Molecular data: no sequences in GenBank. A single ITS sequence generated for this study (isolate DLH16 from *UoA-CC-62*) clustered in a clade previously hypothesized to represent *L. hagenii s.s.* (Śliwa et al. 2012). Given the uncertainty around the status of *L. hagenii s.s*. (see Results), we can confirm only that our sequence is within the highly supported *L. dispersa* group, and that it is distinct from our single sequence of *L.* cf. *hagenii.*

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 17, 53.466785, -113.5710074, 2019, on trunk of *Populus balsamifera, D. Haughland & L. Hjartarson s.n. [UoA-CC-62]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520926, -113.432139, 2019, on trunk of *Ulmus americana, D. Royko & D. Fielder s.n. [UoA-CC-15]* (hb. Haughland); Edmonton, Urban Monitoring Site 150E, 53.590394, -113.588685, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-27]* (hb. Haughland).

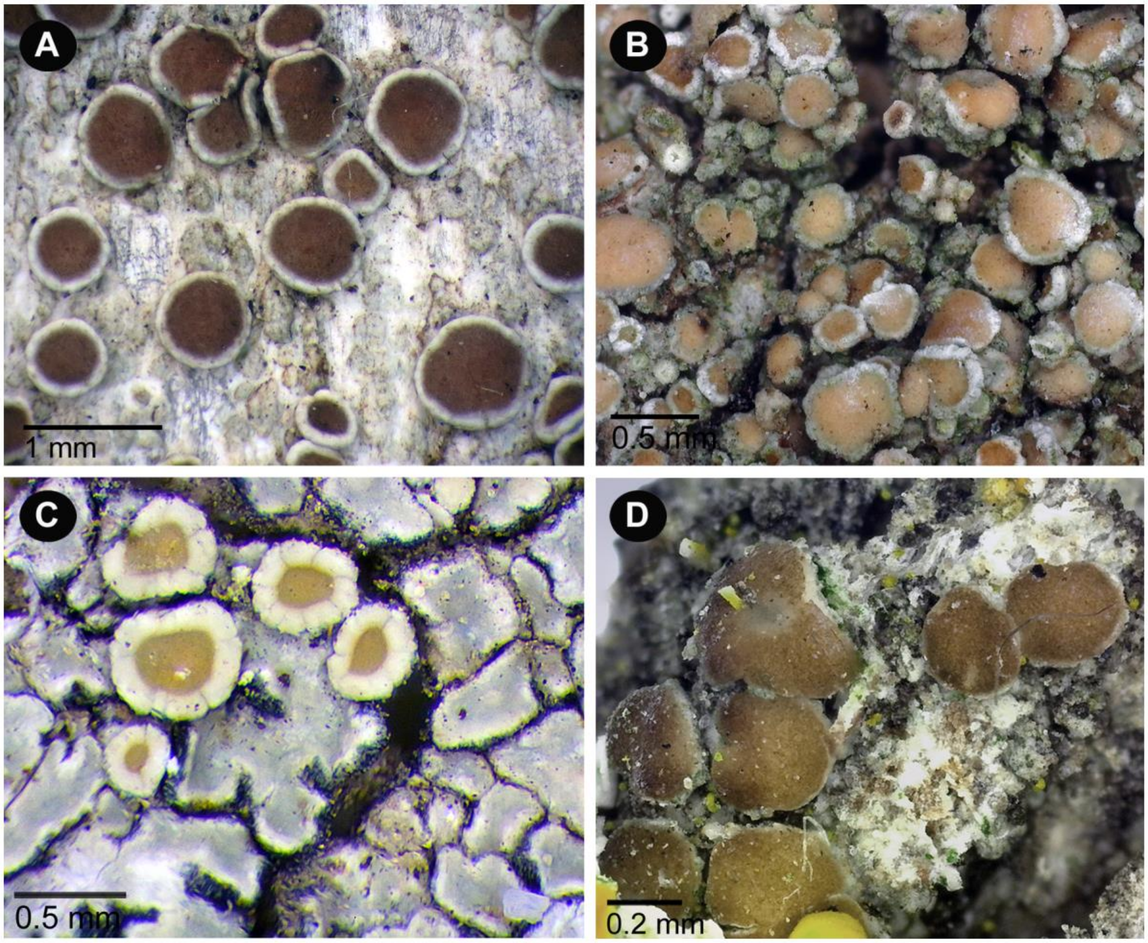

Figure 26. Thalli of *Lecanora s.l.* with 8-spored asci, Edmonton. **A**, *L. pulicaris* on fallen *Betula papyrifera, Haughland 2020-42*. **B,** *L.* cf. *hagenii* on *Ulmus pumila, UoA-CC-63*. **C,** *Protoparmeliopsis muralis* on top of concrete retaining wall, *Haughland 2020-96*. **D,** *L.* cf. *persimilis* on *Ulmus americana, UoA-CC-15*.

Lecanora pulicaris (Pers.) Ach.

FIGURE 26 A.

River valley epiphyte. Edmonton material: thallus white, appearing as a shiny stain on bark, incipient apothecia in thalline verrucae. Apothecia with visible proper and white thalline exciple, disk red-brown to pale brown, epruinose, to 1.2 mm diameter, constricted at base. Thalline exciple with cortex 13–20 µm thick near edge, to >30 µm thick near base, with sparse, large, polarizing clumps of crystals, PD+ red, K+ yellow to orange, C-, UV- in section. Epihymenium tan with abundant tiny polarizing granules throughout, PD-, C-, K+ yellow in section. Hymenium and subhymenium hyaline. Spores globose to ellipsoidal, 8–13 × 5–10 µm, hyaline, non-septate, 8 per ascus. Chemistry: thallus PD+ orange or PD-, K+ yellow, KC-, C-, UV-, atranorin, ± chloroatranorin (trace), confumarprotocetraric acid (trace), fumarprotocetraric acid (major), roccellic acid (major) (Ryan et al. 2004). Molecular support: no new sequences generated, limited phylogenetic support for this species in Malíček et al. (2017) and Lee & Hur (2020).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503105, -113.592863, 2020, on bark of recently downed *Betula papyrifera*, *D. Haughland 2020-42 & A. Hood* (hb. Haughland); Edmonton, University of Alberta North Campus, 53.5253952, -113.525717, 2021, on *Pinus mugo*, *J. Singh & K. Schafer s.n. [UoA-CC21-18]* (hb. Haughland)

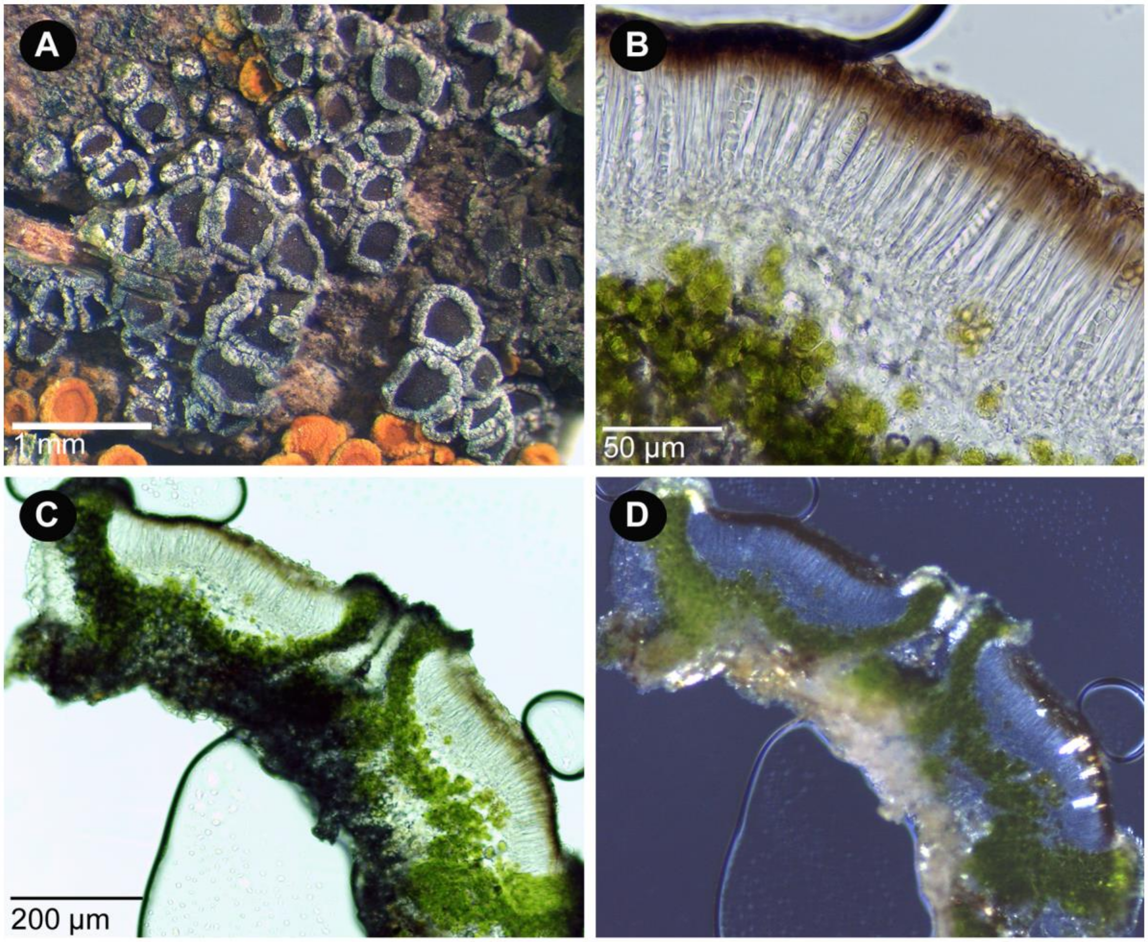

Figure 27. *Lecanora sambuci* morphology and anatomy, Edmonton, *UoA-CC-101*. **A**, Thallus on *Fraxinus pennsylvanica*. **B,** Asci with 12-16 simple spores. **C,** Apothecia cross-sections under white light. **D,** Apothecia cross-sections under polarized light showing crystals in thalline exciple.

Lecanora sambuci (Pers.) Nyl.
(≡ *Polyozosia sambuci* (Pers.) S.Y. Kondr., Lőkös & Farkas, ≡ *Myriolecis sambuci* (Pers.) Clem.)

FIGURE 27.

Tableland and parkland epiphyte. The type species of the recently resurrected genus *Myriolecis* (Zhao et al. 2016), formerly referred to as the *L. dispersa* group, these are the first records for Alberta. The species has been recorded from both neighboring provinces as well as states to the south (CNALH 2020, Thomson 1997). Edmonton material: apothecia clustered, brown epruinose disk with prominent grey smooth to coarse thalline rim. Spores hyaline, simple, 7–8.5 × 3–5 µm, 12–16 per ascus, asci *Lecanora*-type with K/I+blue thollus and non-staining central axis. Thalline exciple with polarizing crystals. Chemistry: all spot tests negative, no secondary metabolites detected by TLC. Molecular support: none, one ITS sequence in GenBank, no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 11, 53.450690, -113.474695, 2019, on trunk of *Fraxinus pennsylvanica, D. Thauvette & J. Wasyliw s.n. [UoA-CC-101]* (hb. Haughland); Edmonton, Urban Monitoring Site 36, 53.494916, -113.620094, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & L. Hjartarson s.n. [UoA-CC-113]* (hb. Haughland); Edmonton, Urban Monitoring Site 185E, 53.62906, -113.56883, 2019, on trunk of *Populus, D. Thauvette & M. Cao s.n. [UoA-CC-91]* (hb. Haughland).

Protoparmeliopsis muralis (Schreber) M. Choisy
(≡ *Lecanora muralis* (Schreber) Rabenh.)

FIGURE 26 C.

Anthropogenic saxicole. A distinctive placodioid species, we recorded a single specimen from concrete. Edmonton material: appressed flat to slightly concave-lobed thallus with pale greenish-yellow upper cortex and blue-black lobe edges. In the transverse section of the lobes, hyphae of the upper cortex can be seen regularly invading down through the algal layer. Similarly, hyphae of the thalline exciple can be seen invading the algal layer below the hypothecium in apothecia cross-sections. The apothecia were clustered centrally, characterized by their tan to peach-brown epruinose disk and broad, flat thalline exciple. Epihymenium tan with fine polarizing crystals that largely dissolved in K, hyaline hymenium to 70 µm thick. Paraphyses similar in width through their length, regularly septate, branching near the base. Asci 8-spored, spores hyaline, simple, sub-globose to ovoid, 9–11 × 5–6 µm. Thalline exciple with polarizing crystals. Chemistry: all spot tests are negative in the medulla; the upper cortex is K-, C-, KC+ yellow in older regions, PD-, UV_{365}-, UV_{254}-. Secondary metabolites detected by TLC: usnic acid, zeorin, leucotylin, unknown fatty acids. Molecular support: strong genus and species-level support (Zhao et al. 2016, Tripp et al. 2019), no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Spruce Avenue Neighborhood, 53.562815, -113.497646, 2020, on top of old, low concrete retaining wall, *D. Haughland 2020-96 & K. Tichkowski* (hb. Haughland).

GROUP 7. SOREDIATE/GRANULAR CRUSTOSE LICHENS

Five species. Key literature: Brodo 1984, 1991; Lendemer 2010, 2011, 2013; Lendemer & Hodkinson 2013; Malíček 2014; Malíček et al. 2017; McCune 2017a, 2017b; Vondrák et al. 2009. This group is undoubtedly underrepresented in our study, and we cannot say whether most species are rare or common with any certainty. *Ochrolechia arborea* is an additional species we could not confirm. Brodo (1991) reported this species from nearby Wagner Natural Area, which we've excluded geographically from this study; Elsinger et al. (2007) also reported it from the industrial zone east of Edmonton. The identification of some species remains uncertain, and TLC is necessary to distinguish others.

1a. Thallus initially episubstratic and smooth to areolate, forming discrete soralia **2**
1b. Thallus formed entirely of soredia, no cortex present **3**

2a. Orange areolate thallus on anthropogenic substrates, with marginal soralia .... ***Caloplaca tominii***
2b. Greyish episubstratic thin to verrucose thallus on trees, forming round, laminal soralia ....
.... ***Lecanora impudens***

3a. Placodioid, soredia embedded in a deep (to 1 cm thick) hypothallus, resembling drier lint, PD+ orange ..
.... ***Lepraria finkii***
3b. Discrete soredia not embedded in hypothallus, at most 1 mm thick, PD- **4**

4a. Atranorin and 2 orange fluorescing unknowns in 365nm light (TLC) .... ***Lecidella albida***
4b. Usnic acid, zeorin (TLC) .... ***Lecanora stanislai***

Caloplaca tominii (Savicz) Ahlner
(≡ *Xanthocarpia tominii* (Savicz) Frödén, Arup & Søchting)

FIGURE 28 F.

Anthropogenic terricole/saxicole. In the most inclusive treatment of sorediate *Caloplaca s.l.* (Vondrák et al. 2009), our material keyed to the *C. citrina* (Hoffm.) Th. Fr. group (≡ *Flavoplaca citrina* (Hoffm.) Arup, Frödén & Søchting), specifically *C. austrocitrina* Vondrák, Říha, Arup & Søchting (Arup 2006). However, ITS showed our material to belongs to *C. tominii,* reinforcing the difficulty in accurately identifying infertile *Caloplaca s.l.*, particularly within currently accepted genera. The only other Alberta record of this species is from the Rocky Mountains Natural Region (Wetmore 2001). Edmonton material: thalli areolate, attached firmly throughout, to 0.5–2.0 mm in diameter and 180–290 µm thick in cross-section. Areoles are yellow, with soralia developing marginally. In larger thalli, soralia appear to first develop on the margins of the upper surface and then towards the center, occasionally becoming covered

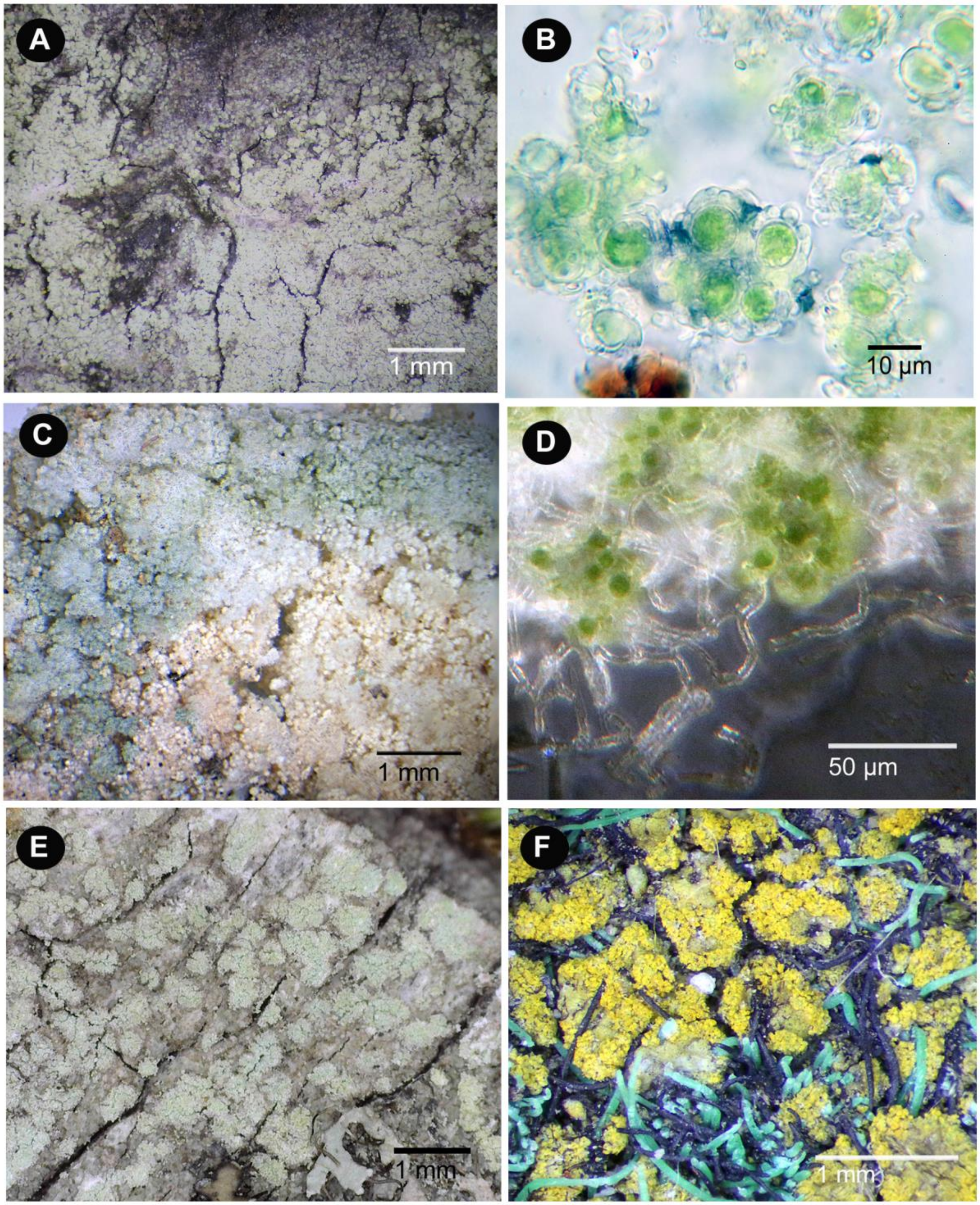

Figure 28. Sorediate crustose lichens of Edmonton, plate 1 of 2. **A-B,** *Lecidella albida*, *Haughland 2020-28*. **A,** Thallus on *Picea* bark flake. **B,** Granules in water mount. **C-D,** *Lepraria finkii*, *Haughland 2020-21*. **C,** Vertical section showing thick hypothallus. **D,** Granules with protruding hyphae and persistent crystals after treatment with K, in polarized light. **E,** *Lecanora impudens, UoA-CC-51*. **F,** *Caloplaca tominii, Haughland 2020-97A.*

in granular soredia, apothecia occasional, but no mature asci or spores found. Apothecial thalline rim sorediate. See Wetmore (2001) for detailed comparison with other sorediate *Caloplaca*. Chemistry: medulla and cortex K+ purple, parietin, fallacinal, emodin and teloschistin by TLC (Wetmore 2007a). Molecular support: a single ITS sequence (isolate DLH7 from *Haughland 2020-97A*) was most similar in megablast to *C. tominii* specimens from Europe and Asia (Genbank accessions HQ69950, MG954185, HQ699626, query cover 87–97%, percent identity 96–99%). No accessioned *C. citrina* or *C. austrocitrina* exceeded 87% percent identity despite similar query cover (92–97%).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Spruce Avenue neighborhood, 53.563562, -113.498138, 2020, on old concrete sidewalk, *D. Haughland 2020-95B* (hb. Haughland), on weathered and mossy indoor-outdoor carpet, *D. Haughland 2020-97A* (hb. Haughland).

Lecanora impudens Degel.

FIGURE 28 E.

Predominantly river valley and parkland epiphyte. A relatively common species described as having a thin, grey episubstratic thallus with irregular to more or less circular excavate soralia that produce granular soredia (Brodo 1984, Lendemer 2010). We used two specimens identified by I. Brodo in PMAE as our morphological benchmark; they were similarly suggestive of *Pertusaria* in morphology and color (Moose Factory Island, Ontario, 1969, bark of *Populus balsamifera*, 51.25, -80.63, *Brodo 14672*; Boulder, Colorado, 1964, bark of fallen spruce, Fourth of July Campground 8 miles NW of Nederland, *Sierk 2479*). Edmonton material: thalli typically continuous, episubstratic, grey to grey-yellow, most forming verrucae that dissolved apically into soralia. Soralia varied from discrete, circular, and excavate with granular to powdery white soralia (as in the specimens cited above) to irregular, crowded, but not becoming completely confluent due to persistence of soralia thalline rims. In the latter specimens the granular soredia were greenish-white in fresh material, cream to pale yellow in older collections. The soralia became excavate as they enlarged and towards the center of the thallus. The specimen on *Sorbus* was unique; it had sparse, poorly formed, almost globular apothecia. No mature asci or spores were found, and the thalline exciple was *allophana*-type (following Brodo 1984). Photobiont trebouxioid. Chemistry: PD-, C-, K+ yellow, KC-, UV_{365}+ dull white, UV_{254}+ dull orange. Secondary metabolites by TLC: atranorin, ± unknowns including trace fatty acid (Rf 3/4/?), unknown blue-fluorescing trace compound (Rf 4/5–6/6). Atranorin is the only metabolite common across the literature, with occasional additional fatty acids or terpenoids noted in some reports (Brodo 1984, Malíček 2014). Molecular support: this species is difficult to discriminate from *Lecanora allophana* f. *sorediata* Vain., and the limited molecular evidence to date suggests they may be conspecific (Malíček et al. 2017). More work is needed.

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, McKinnon Ravine, 1976, on tree bark, *D.C. Lindsay s.n.* (PMAE-B77.24.152), *D.C. Lindsay s.n.* (PMAE-B77.24.170); Edmonton, Urban Monitoring Site 185E, 53.62988, -113.56831, 2019, trunk of *Fraxinus, D. Thauvette & M. Cao s.n. [UoA-CC-51]* (hb. Haughland); Edmonton, Urban Monitoring Site 28, 53.479694, -113.549752, 2019, on trunk of *Populus balsamifera, D. Haughland & L. Hjartarson s.n. [UoA-CC-52]* (hb. Haughland); Edmonton, Urban Monitoring Site 47, 53.505933, -113.552966, 2019, on trunk of *Populus balsamifera, D. Haughland s.n. [UoA-CC-47]* (hb. Haughland); Edmonton, Urban Monitoring Site 68, 53.530342, -113.553482, 2019, on trunk of *Ulmus, D. Haughland s.n. [UoA-CC-11]* (hb. Haughland); Edmonton, Urban Monitoring Site 86, 53.561366, -113.548002, 2019, on trunk of *Ulmus americana, D. Haughland & A. Hood s.n. [UoA-CC-50]* (hb. Haughland); Edmonton, Urban Monitoring Site 148E, 53.587522, -113.640605, 2019, on trunk of *Populus balsamifera, D. Haughland & L. Hjartarson s.n. [UoA-CC-48,125]* (hb. Haughland); Edmonton, Urban Monitoring Site 23E, 53.470689, -113.620142, 2019, on trunk of *Populus tremuloides, D. Haughland s.n. [UoA-CC-49]* (hb. Haughland).

****Lecanora stanislai*** Guzow-Krzemińska, Lubek, Malíček & Kukwa

FIGURE 29.

River valley epiphyte. Leprarioid, sterile lichens containing usnic acid and zeorin are poorly understood in North America (Lendemer & Hodkinson 2013). Species in this group include *Lecanora expallens* Ach., a variable, typically sterile lichen that contains thiophanic acid as a major metabolite (Ryan et al. 2004); the latter may be in low concentration in shaded microhabitats and difficult to detect with TLC (Guzow-Krzemińska et al. 2017). *Lecanora thysanophora* R.C. Harris, common in eastern North America and present in the pacific northwest (J. Lendemer, pers. comm.), typically has a well-developed fibrous prothallus and additional compounds such as porphyrillic acid and unknown substances (Harris et al. 2001).

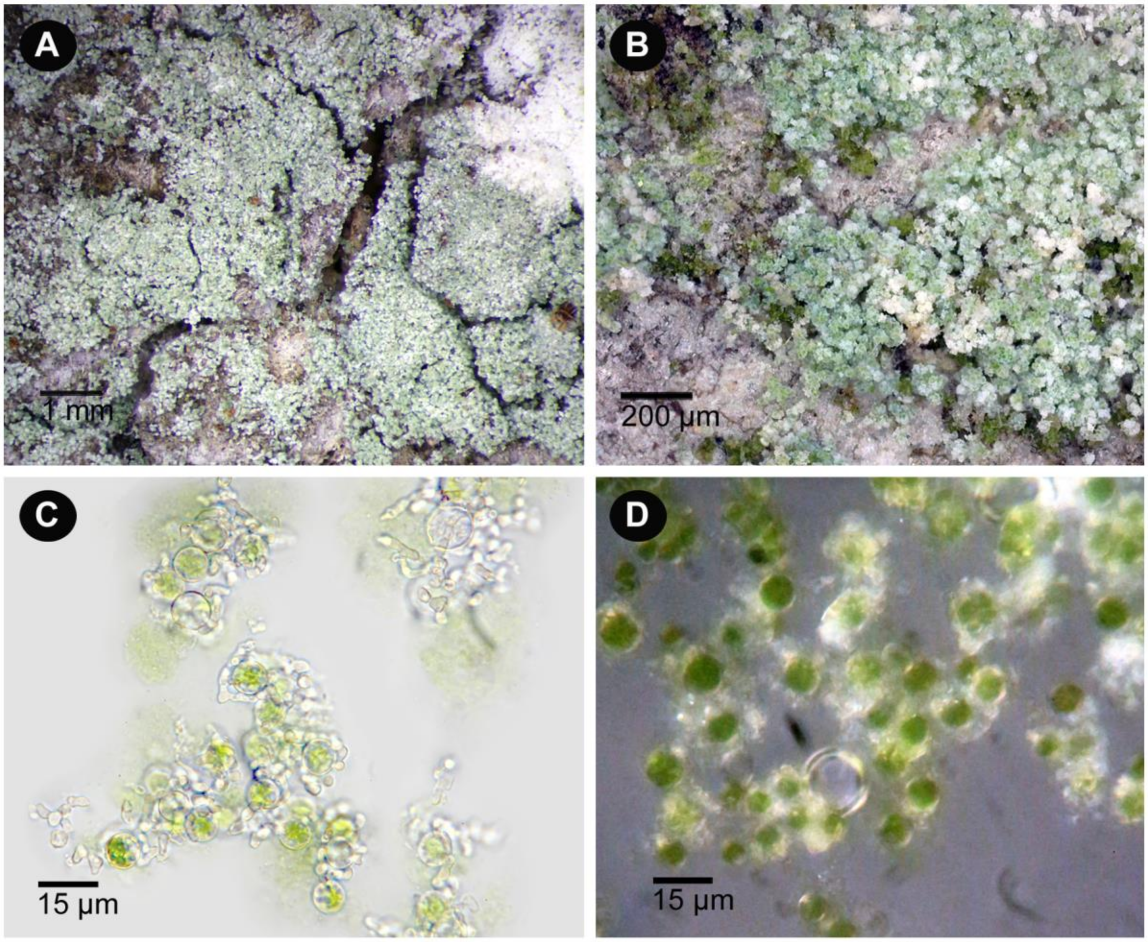

Figure 29. Sorediate crustose lichens of Edmonton, plate 2 of 2. *Lecanora stanislai*, growing on *Picea glauca* snags, *Haughland 2020-103*. **A,** Thallus. **B,** Close-up of aggregate soredia/granules. **C,** Soredia in water mount showing trebouxioid algae and knobby, septate hyphae. **D,** Soredia under polarized light, showing fine polarizing crystals prior to treatment with K.

Lecanora compallens Herk & Aptroot, described from Europe and not known from North America, has soralia that start as punctiform openings in a thin to verrucose thallus and medulla is evident below the soredia (van Herk and Aptroot 1999, Guzow-Krzemińska et al. 2017). The saxicolous *Lithocalla ecorticata* (J.R. Laundon) Orange known from Europe (Orange 2021, Smith et al. 2009) was excluded from the North American flora by Lendemer & Hodkinson (2013), and reports of zeorin are now attributed to contamination (Orange et al. 2017, Orange 2021). Lendemer & Hodkinson (2013) described *Leprocaulon knudsenii* Lendemer & Hodkinson, a saxicolous leprarioid species with usnic acid and zeorin from southern California, but they lacked adequate material to describe additional, phenotypically similar but molecularly distinct collections that belong to *Lecanora*, as did Guzow-Krzemińska et al. (2017). More recently, *Lecanora stanislai* was described from Europe, Asia, and western North America including British Columbia (Guzow-Krzemińska et al. 2017). The morphological description is the best fit for our material. Edmonton material: extensive, thin granular aggregate varying from pale blue-green to cream in color, granules 40–50 µm in diameter, over a thin, white episubstratic prothallus. Hypothallus and delimited soralia lacking and granules largely without projecting hyphae except in senescing, cream-colored patches. Photobiont trebouxioid, cells 9–12 µm in diameter, each algal cell surrounded by a single layer of knobby, septate, branching hyphae, each hyphal segment 2–3 × 3–7 µm. Granules with fine POL+ crystals that dissolve entirely in K. Cream-colored granules contain dead, cavitated algal cells. No apothecia or pycnidia found except black apothecia of an unidentified, apparently non-lichenized ascomycete fungus. Chemistry: granules PD-, K+ pale yellow, KC-, C-, UV_{365}-, UV_{254}-. Secondary metabolites by TLC: usnic acid, zeorin (trace). Molecular support: currently lacking for Edmonton collections, two samples failed to amplify cleanly enough to sequence. See Guzow-Krzemińska et al. (2017) for phylogenetic placement.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, along Rat Creek, Kinnaird Ravine, 53.558953, -113.459253, 2020, on trunks of *Picea glauca* snags, *D. Haughland 2020-103* (hb. Haughland).

*****Lecidella albida*** **Hafellner**

FIGURE 28 A-B.

Ravine system epiphyte. Molecular data was necessary to place this collection, as there are sterile crusts that produce atranorin in multiple genera including *Bacidia, Cliostomum, Lecanora,* and *Lecidella*. Edmonton material: on the flaky bark of the trunk of a slightly leaning *Picea* snag, on the snow-collecting upward surface, growing with *Candelaria pacifica* and *Ramalina*. Thallus consists of a thin layer of pale greenish-yellow discrete granules (aggregate-type, *sensu* Lendemer 2011) that start as larger granules and dissolve into a thin layer of smaller granules over a pale grey prothallus. Granules are discrete bundles of hyphae around green trebouxioid algae measuring 7–9 µm in diameter that lack projecting hyphae or a *Lepraria*-like hypothallus. Abundant POL+ fine crystals that dissolve with K coat the bundles. Chemistry: K+ pale yellow, PD-, C-, KC-, UV_{365}+ dull orange, UV_{254}-. Secondary metabolites detected by TLC: atranorin, two possible xanthones that fluoresce orange under UV_{365}. Molecular support: A single ITS sequence (isolate DLH1 from *Haughland 2020-28*) forms a well-supported clade basal to the clades of *Lecidella* sequenced to date, with a sequence of *L. albida* from Switzerland (GenBank Accession KX132964; Fig. 6 herein). Additional work is required to be confident these specimens belong in the genus *Lecidella*.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, along Rat Creek, Kinnaird Ravine, 53.558953, -113.459253, 2020, on trunk of *Picea glauca* snag, *D. Haughland 2020-28* (hb. Haughland).

Lepraria finkii (B. de Lesd.) R.C. Harris

FIGURE 28 C-D.

River valley and ravine system epiphyte. Edmonton material: placodioid (*sensu* Lendemer 2011), consisting of granules embedded in a thick hypothallus. Up to 1 cm thick, the pale green-blue granules have abundant, septate, hydrophobic, projecting hyphae 3–4 µm in diameter that branch regularly, with globose green algae 6 µm in diameter. Abundant POL+ crystals that persist after treatment with K coat the outside of the hyphae. Chemistry: K+ pale yellow, PD(ethanol)+ slow orange, UV_{365}+ dull white, UV_{254}-. Secondary metabolites detected by TLC: atranorin, zeorin, stictic acid (major or in trace amounts), ± norstictic acid (trace). Molecular support: weak. Using megablast, our single sequence of *Lepraria finkii* (isolate DLH9 from *Haughland 2020-100*) scored highest with accessioned *L. finkii* sequences; however, despite high query coverage (>90%), the percent identities were ≤75%. For example, our ITS sequence differed by 130 positions from GenBank Accession MK629287 (Bolivia, 504 bp overlapping range, 75% percent identity, Barcenas-Peña et al. 2021). Because our sole sequence contained a relatively high number of ambiguous positions, and there are relatively few ITS sequences for comparison, we refrained from further phylogenetic analyses.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak off-leash trail, 53.520696, -113.541533, 2020, on tree base, *D. Haughland 2020-21* (hb. Haughland); Edmonton, along Rat Creek, Kinnaird Ravine, 53.558953, -113.459253, 2020, on trunk of *Picea glauca* snag, *D. Haughland 2020-100* (hb. Haughland); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on decayed stump, *D. Haughland 2021-23B* (hb. Haughland).

GROUP 8. ORANGE AND YELLOW FOLIOSE LICHENS

Thirteen species. Key literature: Brodo 2016; Brodo et al. 2001; Lindblom 1997; Stapper 2012.

1a. Lobes orange, K+purple cortex (anthraquinones) **2**
1b. Lobes greenish yellow, pale yellow or bright yellow, K-...**8**

2a. Rhizines present, white, often visible beyond lobe tips... **3 (*Xanthomendoza*)**
2b. Rhizines lacking, may be attached with sparse, stubby, peg-like hapters hidden beneath lobes.................
....**5 (*Xanthoria s.l.* including *Polycaulionia* & *Rusavskia*)**

3a. Esorediate; apothecia typically present; laminal pycnidia visible as orange bumps....................................
....***Xanthomendoza hasseana***
3b. Sorediate; apothecia occasionally present; pycnidia mostly not apparent..**4**

4a. Lobes appressed, relatively robust, with abundant marginal, crescent- or "bird nest"-shaped soralia formed between the upper and lower cortex; ubiquitous.. ***Xanthomendoza fallax***
4b. Lobes ascending, thin, delicate, with labriform, terminal soralia; rare...................***Xanthomendoza fulva***

5a. Thallus of narrow, subfruticose, ascending lobes; forming terminal blastidia/soredia, apothecia rare ....
....***Polycauliona candelaria***
5b. Thallus of flat, appressed lobes or cushion-like, ill-formed lobes; esorediate, apothecia common...........**6**

6a. Thallus cushion-like with lumpy, ill-differentiated, lobes; on wood or bark........***Polycauliona polycarpa***
6b. Thallus of flat, appressed, clearly foliose lobes; on wood, bark or rock **7**

7a. Lobes broad, petal-like, concave; thallus appressed but apothecia in center of thallus becoming raised; only records in Alberta are from ornamental trees and shrubs ....***Xanthoria parietina***
7b. Lobes, narrow, tightly adnate to almost crustose; apothecia adnate to thallus; commonly found on rock or on anthropogenic substrates ....***Rusavskia elegans***

8a. Lobes bright yellow...**9**
8b. Lobes pale to greenish yellow **11**

9a. Lobes relatively broad and large, ≥0.5 cm wide, ascending, with abundant, continuous marginal soralia containing abundant powdery soredia .... ***Vulpicida pinastri***
9b. Lobes narrow and tiny, ≤0.3 mm wide; soralia restricted to lobe tips or rarely, most of the thallus dissolving into coarse soredia...**10 (*Candelaria*)**

10a. Lobes appressed; lower surface corticate, white with well-developed white rhizines; relatively rare in Alberta, more common in tableland habitats.. ***Candelaria concolor s.l.***
10b. Lobes typically ascending; lower surface largely ecorticate and greenish, lacking well-developed rhizines; common in Alberta, particularly in riparian and wetland habitats .... ***Candelaria pacifica***

11a. Lobes small, narrow (width typically ≤2 mm), appressed and linear .... ***Parmeliopsis ambigua***
11b. Lobes large (typically wider than 1 cm), rounded, ruffled ....**12 (Shield lichens)**

12a. Upper cortex more grey than yellow; lower cortex near lobe tips beige to tan, with abundant short, simple rhizines to the lobe edge; cortex K+ yellow, medulla PD- ....***Punctelia caseana***
12b. Upper cortex more yellow than grey; lower cortex brown to black, rhizines sparse; cortex K-, KC+ yellow, medulla PD- or PD+ orange-red ....**13 (Yellow shield lichens)**

13a. Pseudocyphellae absent; soralia laminal; medulla PD+ orange-red ....
............*Flavoparmelia caperata* [If present, rare in Alberta; see discussion under *Flavopunctelia flaventior*]
13b. Pseudocyphellae present, sparse to abundant; soralia laminal and/or marginal; medulla PD-
.... **14 (*Flavopunctelia*)**

14a. Soralia marginal and laminal; pseudocyphellae obvious and up to 1 mm across, elongate and branched, developing into laminal soredia ....***Flavopunctelia flaventior***
14b. Soralia primarily marginal, horseshoe-shaped, on suberect lobes; pseudocyphellae rare or inapparent and punctiform; upper surface often with faint white angular maculae visible with magnification;.................
.... ***Flavopunctelia soredica***

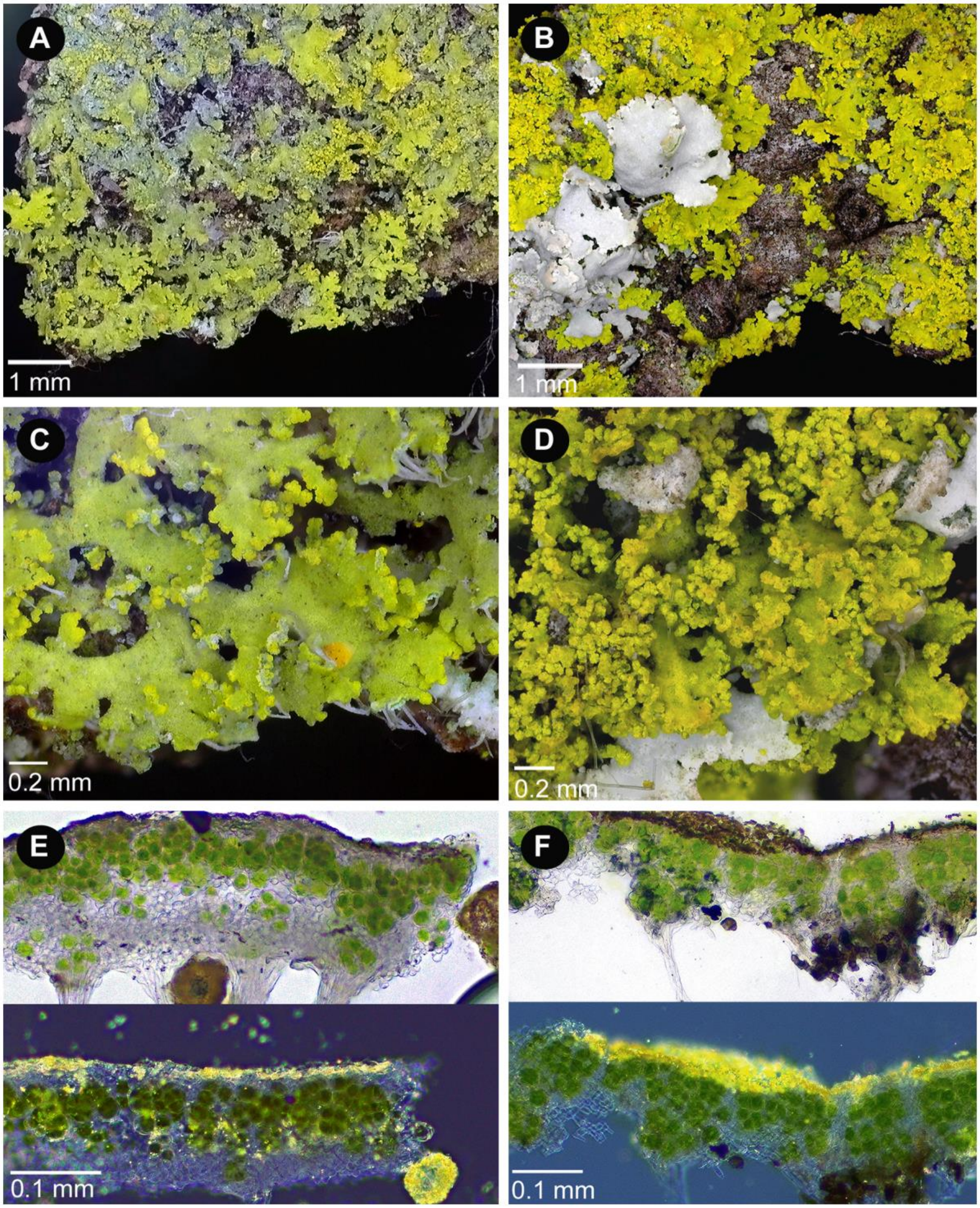

Figure 30. Yellow sorediate foliose lichens of Edmonton, plate 1 of 2: anatomy and morphology of the minute *Candelaria*. **A, C, E,** *C. concolor s.l.* on *Fraxinus pennsylvanica*, *UoA-CC-123*. **A,** Colony showing shade-grown thalli in part. **C,** Close-up of lobes with rhizines projecting beyond lobe tips. **E,** Transverse lobe sections showing well-developed lower cortex and rhizines, under white (top) and polarized light (bottom). **B, D, F,** *C. pacifica* on *Picea* twigs, *Haughland 2021-32*. **B,** Thallus. **D,** Close-up of lobes showing ascending habit and blastidia-like soredia. **F,** Transverse lobe sections showing absence of lower cortex and penetration of upper cortex through the medulla, under white (top) and polarized light (bottom).

Candelaria concolor (Dickson) Stein *s.l.*

FIGURE 30 A, C, E.

Tableland epiphyte. With the separation of *Candelaria pacifica* from *C. concolor* (Westberg & Arup 2011), all historical Alberta collections require re-determination. Based on collections received to date, *C. concolor* is rare in Alberta (ABMI 2020, unpub. data) so we were surprised to make multiple collections within Edmonton. This is a tiny yellow foliose lichen with lobes that typically do not exceed 0.5 mm in width. It lies appressed to the substrate and forms terminal soralia; apothecia are rare. This species differs from the more common *C. pacifica* in having a relatively well-developed white lower cortex and white rhizines that are often visible around the edges of the lobes. If material is fertile, it has >30 spores per ascus (vs. eight in *C. pacifica*). Edmonton material: lobes typically appressed, soralia more granular-sorediate (vs. blastidiate in *C. pacifica*); see Stapper (2012) for excellent illustrations of both species. All detections to date on boulevard trees (vs. *C. pacifica*, which is common within river valley parks). Chemistry: K-, KC-, PD-, UV-, calycin and pulvinic dilactone by TLC (Westberg & Nash 2002). Molecular support: a single ITS sequence (isolate DLH37 from *UoA-CC-96*) differed by four positions from *C. concolor* GenBank Accession KT695365 (Ontario, Canada: 528 bp overlapping range, 99% percent identity) and MK966426 (New York, USA: 497 bp overlap, 99% percent identity). Our phylogeny places our material, along with eastern North American collections, in a clade distinct from *C. concolor* in Europe, and sister to *Candelaria asiatica* from South Korea (Liu & Hur 2018) and China (Kondratyuk et al. 2020).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 39, 53.494127, -113.525569, 2019, on trunk of *Fraxinus pennsylvanica, D. Evans & S. Toni s.n. [UoA-CC-116]* (hb. Haughland); Edmonton, Urban Monitoring Site 60, 53.520974, -113.480625, 2019, on trunk of *Fraxinus pennsylvanica, D. Thauvette & J. Wasyliw s.n. [UoA-CC-82]* (hb. Haughland); Edmonton, Urban Monitoring Site 111, 53.587075, -113.457605, 2019, on trunk of *Fraxinus pennsylvanica, S. Toni & A. Hood s.n. [UoA-CC-96]* (hb. Haughland); Edmonton, Urban Monitoring Site 135, 53.642026, -113.501278, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & M. Cao s.n. [UoA-CC-123]* (hb. Haughland).

****Candelaria pacifica*** M. Westb. & Arup

FIGURE 30 B, D, F.

Predominantly river valley and ravine system and parkland epiphyte. This is the first published report of this species in Alberta, aside from publicly available data from the Alberta Biodiversity Monitoring Institute (ABMI 2020). Common west of the Rocky Mountains, this tiny, variable species forms bright yellow rosettes up to 5 mm wide, sometimes dissolving into blastidia with few visible lobes. Individual lobes rarely exceed 0.4 mm wide, and they typically ascend off the substrate. The lower cortex is poorly developed or lacking, the medulla thin. See *Candelaria concolor* for distinguishing traits. Chemistry: K-, KC-, PD-, UV-, pulvinic acid, pulvic acid lactone, calycin detected by high performance TLC, and vulpinic acid by high performance liquid chromatography (Westberg & Arup 2011). Molecular support: no new sequences generated, the separation from *C. concolor* is well-supported in phylogenetic analyses (Westberg & Arup 2011, Fig. 2 herein).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 3, 53.440376, -113.484487, 2019, on trunk of *Ulmus americana, J. Birch & J. Wasyliw s.n. [UoA-CC-200]* (hb. Haughland); Edmonton, Urban Monitoring Site Beverly Air Quality Monitoring Station, 53.566860, -113.397464, 2019, on trunk of *Ulmus americana, D. Thauvette & J. Birch s.n. [UoA-CC-138]* (hb. Haughland); Saskatchewan Drive off-leash area, in ravine, 53.52, -113.54, 2017, on lower dead twigs of live *Picea glauca, D. Haughland 2017-1 & P. Williams* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.159), *D.C. Lindsay s.n.* (PMAE-B77.24.168); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513197, -113.53866, 2021, on *Picea* twigs, *D. Haughland 2021-32* (hb. Haughland); Edmonton, MacKenzie Ravine, by boardwalk, 53.52914, -113.5603, 2020, on downed *Picea glauca* twigs at the edge of mineral seep, *D. Haughland 2020-106B* (hb. Haughland); Edmonton, River Loop Trail south of Fort Edmonton, 53.500627, -113.576611, 2021, on *Betula papyrifera, D. Haughland 2021-18 & S. Toni* (hb. Haughland); Edmonton, Mill Creek ravine, 53.517222, -113.473889, 2020, on *Picea glauca, D. Haughland 2020-115A & P. Williams* (hb. Haughland).

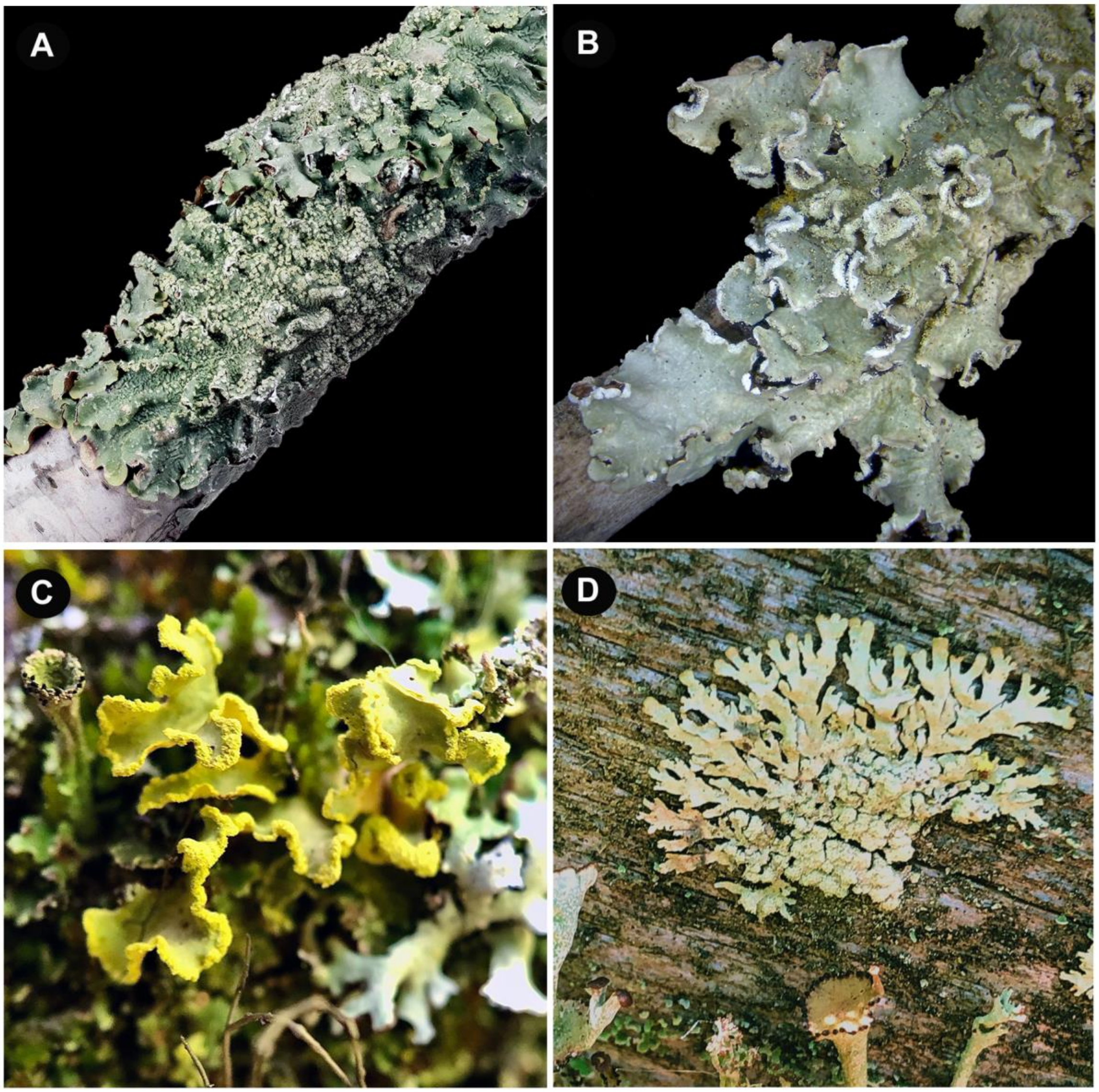

Figure 31. Yellow (to green-yellow) sorediate foliose lichens of Edmonton, plate 2 of 2: species with thalli ≥1 cm in diameter. **A,** *Flavopunctelia flaventior* on *Betula*, *Haughland s.n.* **B,** *Flavopunctelia soredica* on *Picea glauca* twigs, *Haughland 2020-106A*. **C,** *Vulpicida pinastri* on *Betula*, *Haughland* unvouchered observation. **D,** *Parmeliopsis ambigua* on lignin, *Haughland 2021-2A.*

Flavopunctelia flaventior (Stirton) Hale

FIGURE 31 A.

Common river valley epiphyte, rare in tableland and parklands. Thalli can exceed palm-size, with large, rounded, ruffled lobes with abundant, laminal pseudocyphellae, and typically granular soredia mostly in laminal soralia (with a few in crescent-shaped marginal soralia). Some thalli are difficult to distinguish from *F. soredica* which has less conspicuous, sparse pseudocyphellae and largely marginal soralia with finer soredia. This genus has a dark-brown to black lower cortex with sparse, simple rhizines, which helps distinguish it from similarly-sized *Punctelia* (grey-green upper cortex and pale, tan, or pale brown lower cortex). Locally this genus often is confused with *Flavoparmelia caperata*, which is very rare or perhaps absent in Alberta; it can be distinguished by the lack of pseudocyphellae on the upper surface and the PD+ red medulla. Chemistry: upper cortex KC+ yellow, medulla C+ red, KC+ red, PD-, all other tests negative, Secondary metabolites detected by TLC: usnic acid and lecanoric acid. Molecular support: no new sequences generated, the separation from *F. soredica* is well-supported in our phylogenetic analyses.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Whitemud Park, near Alfred H. Savage Centre, 53.501791, -113.559168, 2020, on *Betula*, *J. Bell* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/11785/details); Edmonton, Kinsmen Park, 53.528793, -113.518148, 2019, epiphytic, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/8155/details); Edmonton, MacKenzie Ravine, 1976, on *Populus* wood, *D.C. Lindsay s.n.* (PMAE-B77.24.34); Edmonton, Stony Plain Rd. and 100 Ave. at 148 St., 1976, on wooden footbridge, *D.C. Lindsay s.n.* (PMAE-B77.24.61); Edmonton, Emily Murphy Park, 1976, on *Betula* bark, *D.C. Lindsay, s.n.* (PMAE-B77.24.91); Edmonton, Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.112); Edmonton, Terwillegar Footbridge, 53.483201, -113.600184, 2021, on *Betula papyrifera*, *D. Haughland 2021-11* (hb. Haughland); Edmonton, Hawrelak Trail off-leash park, 53.522361, -113.54378, 2020, on decorticate *Picea* twigs, *D. Haughland 2020-25* (hb. Haughland).

Flavopunctelia soredica (Nyl.) Hale

FIGURE 31 B.

River valley epiphyte. Similar to *Flavopunctelia flaventior* except *F. soredica* has primarily marginal soralia giving rise to crescent-shaped, powdery lobe tips and less abundant pseudocyphellae. It is also rarer than *F. flaventior*; see that species for comparisons with other shield lichens. Chemistry: upper cortex KC+ yellow, medulla C+ red, KC+ red, all other tests negative. Secondary metabolites detected by TLC: usnic acid and lecanoric acid. Molecular support: a single ITS sequence of *Flavopunctelia soredica* (isolate DLH13 from *Haughland 2020-16*) is basal within a well-supported clade of *F. soredica* sequences.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.520696, -113.541533, 2020, on *Betula* bark, *D. Haughland 2020-16* (hb. Haughland); Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, epiphytic, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12492/details); Edmonton, MacKenzie Ravine, 53.52914, -113.5603, 2020, on downed *Picea glauca* twigs at edge of mineral seep, *D. Haughland 2020-106A* (hb. Haughland; NatureLynx record https://naturelynx.ca/sightings/14351/details); Edmonton, Hawrelak Park, 53.51665, -113.538811, 2020, on *Betula papyrifera*, *D. Haughland 2020-113* (hb. Haughland).

Parmeliopsis ambigua (Wulfen) Nyl.

FIGURE 31 D.

River valley and ravine system lignicole. A common boreal species characterized by pale yellow, appressed, narrow lobes (to 2 mm wide) with round laminal soralia. It can be confused with *Parmeliopsis hyperopta* (Ach.) Arnold, a relatively common co-occurring species that differs in its whitish-grey coloration (lacks usnic acid in the cortex); to date *P. hyperopta* has not been detected in Edmonton. Chemistry: medulla UV+ blue-white, cortex KC+ yellow, all other tests negative, usnic acid, divaricatic acid, nordivaricatic acid detected by TLC. Molecular support: monophyly confirmed by Tehler & Källersjö (2001), no new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502711, -113.60241, 2020, lignicolous on downed log, *D. Haughland & C. Shier* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14354/details); Edmonton, MacKenzie Ravine, 1976, on wood, *D.C. Lindsay s.n* (PMAE-B77.24.35); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on *Picea* snag, *D. Haughland 2021-2A* (hb. Haughland).

Polycauliona candelaria (L.) Frödén, Arup, & Søchting
(≡ *Xanthoria candelaria* (L.) Th. Fr.)

FIGURE 32 A.

Occasional river valley epiphyte. Thalli form small cushions typically less than the size of a quarter, the bright-orange lobes are narrow, flattened, branched, and usually ascending to erect. Granular soredia form at the lobe tips and along the lobe margins. Lacking rhizines, instead with small peg-like haptors attaching proximal lobes to the substrate. Sometimes mistaken for *Candelaria*, this species can be distinguished by the orange cortex and the K test. Chemistry: orange-pigmented parts K+ purple (vs. K- in *Candelaria*), all other spot tests negative, parietin, fallacinal, emodin, teloschistin, and parietinic acid by TLC (Lindblom 2004b). Molecular support: a variable species in need of phylogenetic work, no new sequences generated.

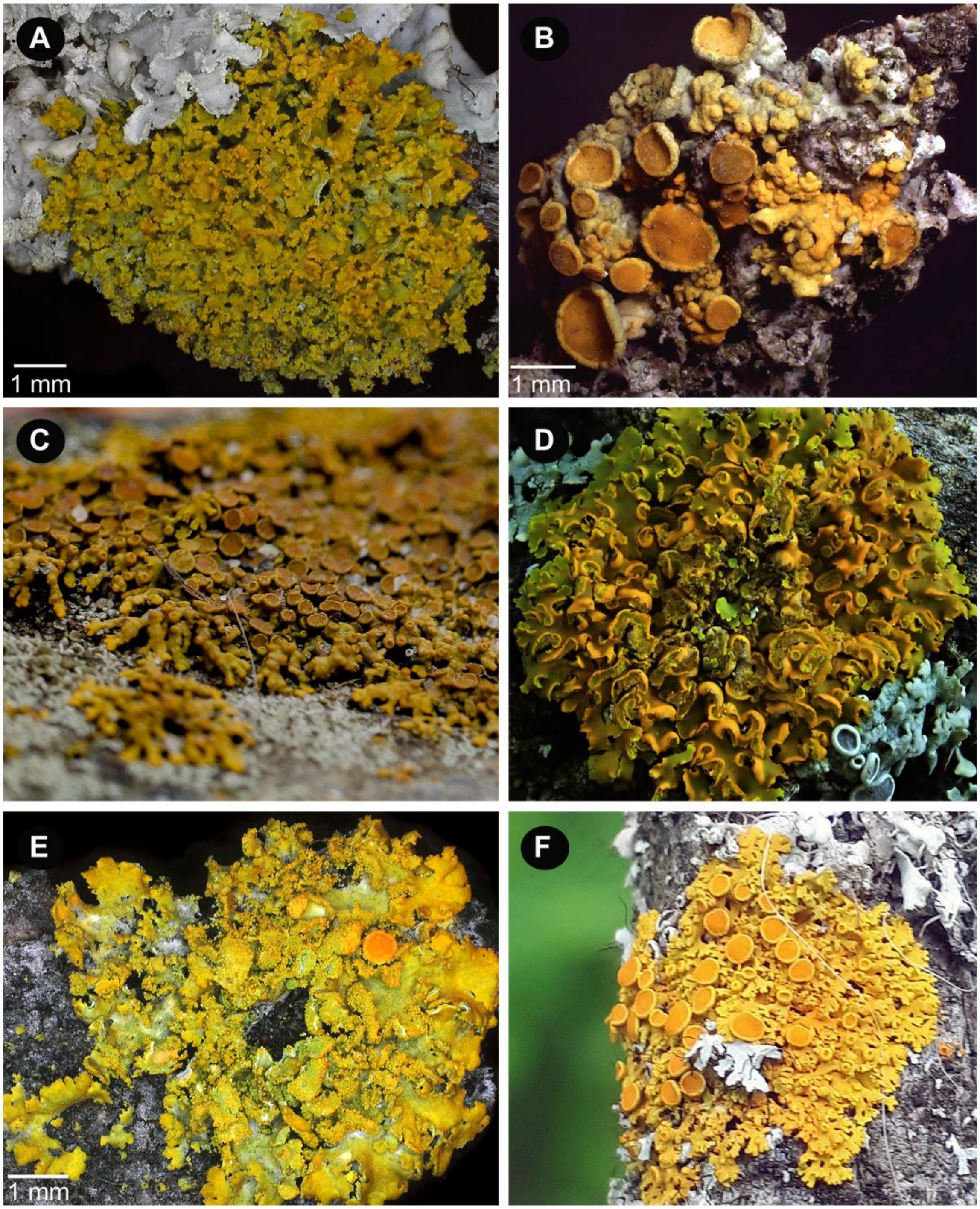

Figure 32. Orange foliose lichens of Edmonton, plate 1 of 2: native species. **A,** *Polycauliona candelaria* on *Picea* twigs, *Haughland 2021-34*. **B,** *Polycauliona polycarpa* on *Picea* twigs, *Haughland 2021-28*. **C,** *Rusavskia elegans* on metal bridge girders, *Dueck* https://naturelynx.ca/sightings/9806/details. **D,** *Xanthomendoza fallax* on *Populus*, *Haughland* unvouchered observation. **E,** *X. fulva* on *Ulmus americana*, *UoA-CC-143*. **F,** *X. hasseana*, *Hjartarson* https://naturelynx.ca/sightings/12112/details.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503638, -113.593736, 2020, on bark at base of large, live *Picea glauca*, *D. Haughland 2020-49 & A. Hood* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.158); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513197, -113.53866, 2021, on *Picea* twigs, *D. Haughland 2021-34* (hb. Haughland).

Polycauliona polycarpa (Hoffm.) Frödén, Arup, & Søchting
(≡ *Xanthoria polycarpa* (Hoffm.) Th. Fr. ex Rieber)

FIGURE 32 B.

Rare river valley and parkland epiphyte. Thalli form small, rounded, bright-orange cushions typically less than the size of a quarter. Stipitate apothecia typically are common but are lacking in one of the Edmonton collections. Laminal, immersed pycnidia present, conidia averaging 2.7 × 1.3 µm. No vegetative propagules. Like *P. candelaria*, this species lacks rhizines, instead attaching with small peg-like haptors. Unlike *P. candelaria*, the lobes tend to be short and rounded. Historically the much more common *Xanthomendoza hasseana* was misidentified as this species in Alberta; they can be differentiated by the well-developed white rhizines often visible around the edges of the lobes of *X. hasseana*. Edmonton material is poorly developed, but the morphology and pycnidia measurements fit those in Lindblom (1997). Chemistry: orange-pigmented parts K+ purple (vs. K- in *Candelaria*), all other spot tests negative, parietin, fallacinal, emodin, teloschistin, and parietinic acid by TLC (Lindblom 2004b). Molecular support: a variable species in need of phylogenetic work, no new sequences generated. Genus-level support provided by Arup et al. (2013).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513211, -113.538619, 2021, on *Picea*, *D. Haughland 2021-28* (hb. Haughland); Edmonton, Mill Creek ravine, 53.517222, -113.473889, 2020, on *Picea glauca*, *D. Haughland 2020-115B & P. Williams* (hb. Haughland).

Rusavskia elegans (Link) S. Y. Kondr. & Kärnefelt
(≡ *Xanthoria elegans* (Link) Th. Fr.)

FIGURE 32 C.

River valley and parkland saxicole. More common in arid habitats, this dusky-orange species is almost crustose in habit, closely attached to the substrate, and lacks rhizines. Thalli are composed of narrow, convex, radiating lobes, typically with abundant apothecia centrally, and lacking isidia or soredia. To discriminate it from *Caloplaca*, check that the lobes have an intact, white lower cortex, attached with short peg-like hapters (often sparse). Typically, there is also space between the lobes where the substrate is visible. The only record in Edmonton is from an online app, however recent informal observations suggest it is common on headstones in cemeteries. Chemistry: orange-pigmented parts K+ purple (vs. K- in *Candelaria*), all other spot tests negative, parietin, fallacinal, emodin, teloschistin, and parietinic acid by TLC (Lindblom 2004b). Molecular support: well-supported at genus-level in existing phylogenetic analyses (Arup et al. 2013), no new sequences generated.

Specimen observation. – **CANADA. ALBERTA:** Edmonton, Mill Creek Ravine South, 53.508699, -113.461606, 2019, on metal footbridge, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/9806/details).

Vulpicida pinastri (Scop.) J.-E. Mattsson & M. J. Lai

FIGURE 31 C.

River valley epiphyte. This common boreal species forms almost fluorescent yellow, ascending, irregular, foliose rosettes, most commonly on *Betula* in river valley parks in Edmonton. The ruffled lobe edges are lined with marginal, powdery soralia marginally. The color can vary to pale greenish-yellow in shade forms. The rhizines are sparse, brownish-white, and develop from the whitish, wrinkled lower cortex. Apothecia are not known from Alberta. Chemistry: all spot test negative, usnic acid, pinastric acid, zeorin, and vulpinic acid by TLC (Brodo et al. 2001). Molecular support: the species is well-supported by phylogenetic analyses in Saag et al. (2014) and is the sole soredia-forming clade within the genus, no new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Hawrelak Park, 53.52, -113.54, 2017, *Betula papyrifera*, *D. Haughland et al.* (unvouchered observation); Edmonton, Rio Park, 53.505094, -113.595550, 2020, on *Betula*, *L. Hjartarson* (unvouchered observation:

NatureLynx record https://naturelynx.ca/sightings/12101/details); Edmonton, MacKenzie Ravine, 1976, on rotting log, *D.C. Lindsay s.n.* (PMAE-B77.24.41).

Xanthomendoza fallax (Hepp ex Arnold) Søchting, Kärnefelt & S. Y. Kondr.
(≡ *Xanthoria fallax* (Hepp ex Arnold) Arnold)

FIGURE 32 D.

Ubiquitous and abundant epiphyte across all habitats. This species is characterized by yellow-orange to dark orange appressed, foliose thalli with crescent-shaped marginal soralia developing greenish-yellow powdery to grainy soredia. The soralia form "bird nest"-like shapes in a split between the upper and lower cortices. Somewhat similar to *X. fulva* except for soralia development (submarginal to labriform in *X. fulva*), *X. fallax* also has more abundant rhizines and typically wider lobes. Chemistry: orange parts K+ purple, all other spot tests negative, parietin, fallacinal, emodin, teloschistin and parietinic acid by TLC (Lindblom 2004a). Molecular support: sequences in GenBank form a well-supported clade in preliminary analyses (Haughland, unpub. data), no new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 16, 53.468373, -113.59264, 2019, on trunk of *Fraxinus pennsylvanica, M. Villeneuve & M. Lewis s.n. [UoA-CC-73]* (hb. Haughland); Edmonton, Urban Monitoring Site 46, 53.509321, -113.574933, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-155]* (hb. Haughland); Edmonton, Urban Monitoring Site 78, 53.547665, -113.502375, 2019, on trunk of *Tilia, D. Haughland & M. Cao s.n. [UoA-CC-159]* (hb. Haughland); Edmonton, Urban Monitoring Site 111, 53.587075, -113.457605, 2019, on trunk of *Fraxinus pennsylvanica, S. Toni & A. Hood s.n. [UoA-CC-96]* (hb. Haughland); Edmonton, Urban Monitoring Site 185E, 53.62906, -113.56883, 2019, on trunk of *Populus, D. Thauvette & M. Cao s.n. [UoA-CC-91]* (hb. Haughland); Woodcroft, Air Quality Monitoring Station, 53.563708, -113.563508, 2019, on trunk of *Prunus virginiana, D. Haughland & A. Hood s.n. [UoA-CC-107]* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on bark of large downed *Populus, D. Haughland 2019-115 & P. Williams* (hb. Haughland); Edmonton, Government House, 53.542066, -113.545148, 2013, on mature *Ulmus* in lawn W of building, *D. Haughland 2013-01* (hb. Haughland); Edmonton, Henrietta Muir Edwards Park, near Accidental Beach, 53.538684, -113.470833, 2019, on downed wood, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/7470/details); Edmonton, between Provincial Museum parking lot and Wellington Crescent, 1976, on N sides of trunks of deciduous trees, D.C. Lindsay *s.n.* (PMAE-B77.24.46); Edmonton, between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on wooden footbridge, *D.C. Lindsay s.n.* (PMAE-B77.24.66); Edmonton, Terwillegar Park, 1977, on wood, *D.C. Lindsay s.n.* (*PMAE-B77.24.81*); Edmonton, Emily Murphy Park, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.87); Edmonton,Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.109).

Xanthomendoza fulva (Hoffm.) Søchting, Kärnefelt & S. Y. Kondr.
(≡ *Xanthoria fulva* (Hoffm.) Poelt & Petut.)

FIGURE 32 E.

Overlooked tableland epiphyte. A diminutive species forming thalli under 1 cm in diameter, it can be confused with poorly developed *X. fallax*. Characterized by small, dark-red to orange thalli with rounded or finely divided lobes that end in submarginal to labriform soralia. It often grows in small quantities with the more abundant *fallax*. Given its air quality indicator value (Schulze et al. 2020), we predict this lichen has been overlooked and is more abundant on boulevard trees in Edmonton than our data suggests. Chemistry: orange parts K+ purple, all other spot tests negative, parietin, fallacinal, emodin, teloschistin and parietinic acid by TLC (Lindblom 2004a). Molecular support: sequences in GenBank form a well-supported clade in preliminary analyses (Haughland, unpub. data), no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 4, 53.443624, -113.461366, 2019, on trunk of *Ulmus americana, D. Haughland & A. Stordock s.n. [UoA-CC-141]* (hb. Haughland); Edmonton, Urban Monitoring Site 7, 53.452098, -113.573622, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-40,143]* (hb. Haughland); Edmonton, Urban Monitoring Site 83, 53.559591, -113.642062, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-34,160]* (hb. Haughland).

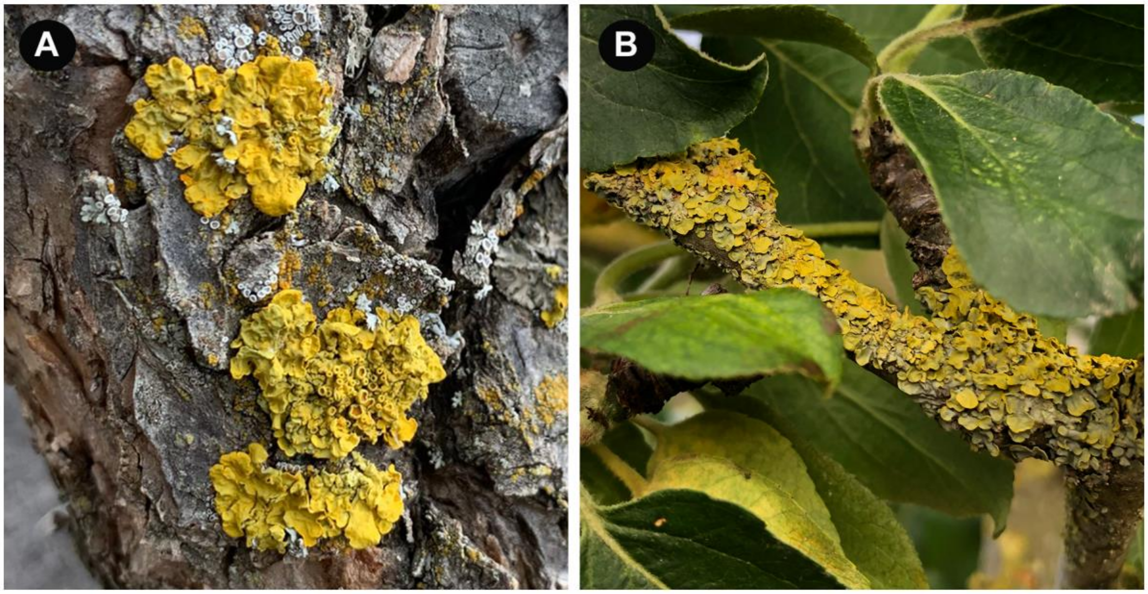

Figure 33. Orange foliose lichens of Edmonton, plate 2 of 2: introduced *Xanthoria parietina.* **A,** Colonies on planted suburban *Hydrangea* tree, *Garvey* https://naturelynx.ca/sightings/15817/details. **B,** Colonies on horticultural *Malus* trees imported to Alberta from a greenhouse in Surrey, British Columbia, *Haughland* unvouchered observation.

Xanthomendoza hasseana (Räsänen) Søchting, Kärnefelt & S. Y. Kondr.
(≡ *Xanthoria hasseana* Räsänen)

FIGURE 32 F.

Occasional tableland, parkland, and river valley and ravine system epiphyte. Forming orange rosettes, this species typically has at least some apothecia and laminal, slightly protuberant orange pycnidia. Rhizines often are visible around the edges of the overlapping, convex lobes. Historically this species was misidentified as *Xanthoria polycarpa* in Alberta, a species that lacks rhizines and has a more compact growth habit (see *Polycauliona polycarpa* entry above). *Xanthomendoza hasseana* thalli are diminutive within Edmonton and easily overlooked and misidentified as *X. fallax*, which commonly is fertile in the city. It differs from *X. fallax* in lacking soredia and the more prominent contrasting pycnidia. *Xanthomendoza montana* (L. Lindblom) Søchting, Kärnefelt & S. Y. Kondr. is a very similar species that appears to be less common in Alberta, and is differentiated from *X. hasseana* with difficulty by spore and septum size (Lindblom 1997; measurements from Brodo 2016: *X. montana* spores (11.5–)12.5–15.5 × 5–7.5 µm, septum about one-third the length of the spore or less, 1.5–4 µm wide vs. *X. hasseana* spores 15–18 × 7.0–8.0(–9.5), septum more than one-third the length of the spore, 4–8.5 µm wide). In our experience, spores often show intermediate values or the spore size fits one species while the septum width fits the other. Chemistry: orange parts K+ purple, all other spot tests negative, parietin, fallacinal, emodin, teloschistin and parietinic acid by TLC (Lindblom 2004a). Molecular support: no new sequences generated, in preliminary analyses (Haughland, unpub. data) sequences in GenBank form multiple well-supported clades, some intermixed with *X. montana*. Species-level phylogenetic analyses are needed.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 33, 53.479311, -113.413258, 2019, on trunk of *Tilia*, *D. Thauvette et al. s.n. [UoA-CC-147]* (hb. Haughland); Edmonton, Urban Monitoring Site 85, 53.560830, -113.567591, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & A. Hood s.n. [UoA-CC-162]* (hb. Haughland); Edmonton, Urban Monitoring Site 0E, 53.442169, -113.584786, 2019, on trunk of *Ulmus americana*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-64]* (hb. Haughland); Edmonton, Urban Monitoring Site 175E, 53.616551, -113.562121, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland s.n. [UoA-CC-24]* (hb. Haughland); Edmonton, Urban Monitoring Site 34E, 53.471215, -113.371731, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Thauvette & S. Toni s.n. [UoA-CC-148]* (hb. Haughland); Edmonton, South Air Quality Monitoring Station, 53.501931, -113.523499, 2019, on trunk of *Fraxinus*, *D. Thauvette & J. Birch s.n. [UoA-CC-189]* (hb. Haughland); Edmonton, Patricia Ravine, 53.503513, -113.59324, 2020, epiphytic, *L.*

Hjartarson (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12112/details); Edmonton, approx. 180 St. and 99 Ave., 1976, on twigs and dead branches, *D.C. Lindsay s.n* (PMAE-B77.24.176); Edmonton, Terwillegar Park, 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.177).

***Xanthoria parietina** (L.) Th. Fr.

FIGURE 33.

Rare introduced tableland epiphyte. This is a distinctive yellow-orange foliose lichen, with thin, broad, concave lobes that resemble petals, with abundant apothecia centrally. No vegetative propagules. The only lichen we are confident was introduced to Alberta, it appears to be limited to ornamental horticultural trees and shrubs originally grown on the west coast and shipped to Alberta for sale (see also Brodo et al. 2021a). We previously examined nature app records for proof of this species in Alberta, but reports were misidentifications. Here we provide two verified observations, one of multiple thalli on a *Hydrangea* tree that was planted approximately ten years ago, and a second, recent observation of additional thalli on newly imported greenhouse trees and shrubs from Abbotsford, British Columbia. Chemistry: yellow-orange parts K+ purple, all other spot tests negative, parietin, fallacinal, emodin, teloschistin and parietinic acid by TLC (Lindblom 2004a). Molecular support: no new sequences generated, in preliminary analyses (Haughland, unpub. data) sequences in GenBank form multiple well-supported clades. The biogeography and genetic structure within X. *parietina* potentially could be a fascinating study of range expansion in a “weedy” lichen.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, 53.504211, -113.66915, 2021, on ornamental *Hydrangea* tree, *H. Davidson s.n.* (hb. Spribille, NatureLynx record https://naturelynx.ca/sightings/15817); Edmonton, Spruce Avenue neighbourhood, 53.563562, -113.498138, 2020, on ornamental *Syringia* shrub, *D. Haughland s.n.*

GROUP 9. WHITE AND GREY FOLIOSE LICHENS

Nine species. Key literature: Brodo et al. 2013; Brodo 2016; Esslinger 2016a, 2016b, 2016c; Esslinger et al. 2020; Goward et al. 1994; Lendemer 2009; Lendemer & Hodkinson 2010.

1a. Lobes hollow tubes, lacking cilia or rhizines; soralia terminal, hood-shaped ....***Hypogymnia physodes***
1b. Lobes solid and flattened, typically with cilia or rhizines; soralia variable..**2**

2a. Lobes >3 mm wide **3**
2b. Lobes 0.5-2.5 mm wide..**4**

3a. Upper surface smooth to wrinkled, lobe edges rounded, pseudocyphellae laminal, punctiform to slightly elongate, soralia marginal to laminal; lower surface tan, with short, pale, simple rhizines..............................
....***Punctelia caseana***
3b. Upper surface with hammered appearance, lobe edges angular, pseudocyphellae forming a network along laminal ridges and lobe margin, developing into linear soralia; lower surface black with black rhizines that become ‘bottle-brush-like’ with squarrose branching......................................***Parmelia sulcata***

4a. Upper cortex with a subtle combed or flowing appearance; lower cortex lacking; rhizines black, with ‘bottle-brush’ squarrose branching ....***Heterodermia japonica***
4b. Upper cortex with smooth, matte, shiny or hammered appearance; lower cortex present, white to pale brown to black; rhizines variable, mostly simple or sparsely branched, concolorous with lower cortex **5**

5a. Lower cortex dark at least centrally; rhizines typically bristling around lobes, black with white tips; soralia laminal, rounded to irregular in outline; apothecia occasional, typically with cilia on thalline exciple; upper cortex K- ....***Phaeophyscia orbicularis***
5b. Lower cortex pale to tan throughout; rhizines sparse, white to pale brown; soralia present or absent, when present variable, apothecia present or absent but when present lacking cilia; upper cortex K+ yellow (atranorin).. **6 (*Physcia*)**

6a. Lobes ascending, with long marginal cilia; lobe tips with helmet-shaped inflated soralia; thallus highly variable from short rounded lobes to sparse elongate lobes ....***Physcia adscendens***
6b. Lobes appressed to substrate, lacking marginal cilia; esorediate or with marginal, elongate soralia **7**

7a. Soredia abundant in marginal soralia, apothecia common with sorediate thalline margin ....***Physcia* aff. *dimidiata***
7b. Esorediate, apothecia typically abundant and with smooth, esorediate thalline margin............................**8**

8a. Lobes convex, clasping substrate; apothecia slightly elevated above thallus and with relatively thick thalline rim; upper cortex white to pale grey, lacking maculae or maculae indistinct; medulla K-................... .... ***Physcia* aff. *stellaris***
8b. Lobes flattened to slightly concave; apothecia attached closely to thallus with relatively thin thalline rim; upper cortex often maculate and blueish grey; medulla K+ yellow.................**9 (*Physcia aipolia* group)**

9a. Apothecia in center of thallus often relatively large with smaller apothecia towards mid-thallus; lobes relatively wide (to >1 mm) with little substrate visible between lobes ....***Physcia aipolia***
9b. Apothecia typically similar in size from center to edge of thallus, smaller and spread out to lobe tips; lobes narrow (≤0.8 mm) and substrate visible between lobes ....*Physcia alnophila* [see discussion under *Physcia aipolia*]

Heterodermia japonica (M. Satô) Swinscow & Krog
(≡ *Polyblastidium japonicum* (M. Satô) Kalb)

FIGURE 34.

We have not adopted the taxonomy of Mongkolsuk et al. (2015) while we wait on the work of T. Esslinger and S. Leavitt on Physciaceae in North America, and collaborative molecular work with T. Spribille. Rare river valley and ravine system epiphyte. This species was first detected in Alberta by the ABMI and confirmed by J. Lendemer for the senior author in 2013, however, we have not formally reported its presence until now. In Canada, this species has also been recorded from British Columbia and Ontario (CNALH 2020). Herbarium collections show this species has been overlooked in Alberta for decades, historically misidentified as *Physcia tenella* (Scop.) DC. or *Heterodermia speciosa* (Wulfen) Trevisan (Haughland, unpubl.). It appears to be an occasional northern forest epiphyte. Lobes long, plane, appressed, epruinose, upper cortex prosoplectenchymatous, ecorticate lower surface. Soralia marginal. Rhizines marginal to terminal, dark and squarrose. A single historical specimen was located in Edmonton; recent searches in the area failed to find extant thalli, but contemporary specimens were observed immediately north of the city. Chemistry: K+ yellow, PD+ faint yellow, all other spot tests negative. Secondary metabolites detected by TLC: atranorin, zeorin, unknown terpenes. Molecular support: no new sequences generated, good species-level support for sequences from Costa Rica (Lücking et al. 2008).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, MacKenzie Ravine, 1976, on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.164); St. Albert, Riverlot 56 Natural Area, 53.6585, -113.5849, 2020, on *Populus balsamifera*, *D. Haughland 2020-112* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/14920/details).

Hypogymnia physodes (L.) Nyl.

FIGURE 35 A.

Occasional river valley and ravine system epiphyte in Edmonton. While relatively rare in the city, it is an extremely common epiphyte elsewhere in Alberta. Hollow-lobed, highly variable, white to greenish on upper half, with a blackened lower cortex lacking rhizines. Lobes can be long or short, appressed or ascending, usually 1–2.5(–5) mm across. Underside of lobe tips bursting into hooded soralia. One of the more commonly used species for biomonitoring. Chemistry: cortex K+ yellow, medulla K+ slow red to dingy brown, PD+ orange. Secondary metabolites detected by TLC: atranorin, physodic acid, physodalic acid, protocetraric acid, 3-hydroxyphysodic acid. Molecular support: species is monophyletic in Miadlikowska et al. (2011), no new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland & A. Hood* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14352/details); Edmonton, River Valley, Oleskiw, 53.499071, -113.59265, 2020, epiphytic, *samanthapedersen* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/42400752); Edmonton, MacKenzie Ravine, 1976, on rotting trunk, *D.C. Lindsay s.n* (PMAE-B77.24.42).

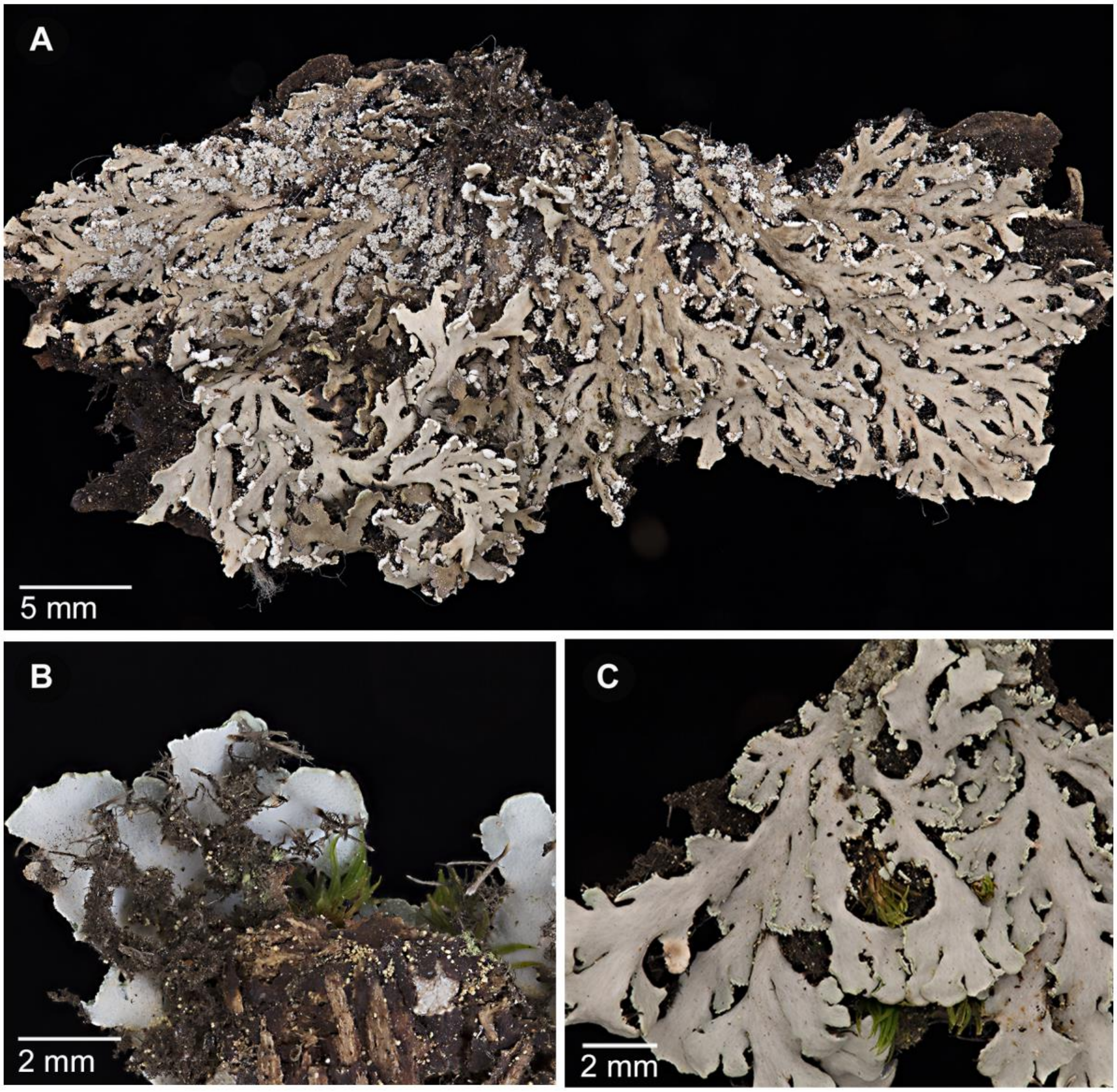

Figure 34. White and grey foliose lichens of Edmonton, plate 1 of 2: *Heterodermia japonica* (collections imaged are from outside of Edmonton, citations provided here). **A,** Thallus, ca. 26 km NE of Marten Beach, ABMI Site 720, 55.68, -114.67, 2003, on hard log, *E. Bainbridge & J. Bluetchen s.n.* **[***ABMI Lichen # 528428*]. **B-C,** ca. 51 km NE of Sandy Lake, ABMI Site 664, 55.85, -112.61, 2015, on log, *S. Venskaitis s.n.* **[***ABMI Lichen # 626478*]**. B,** Lower surface showing lack of cortex and squarrose rhizines. **C,** Upper surface with marginal soralia and prosoplectenchymatous upper cortex.

Parmelia sulcata Taylor

FIGURE 35 B.

River valley, parkland, and rare tableland epiphyte and xylicole. Perhaps the most abundant foliose epiphyte in Alberta, this species is surprisingly sparse in Edmonton outside of river valley parks. Thallus blue-grey with angled lobes, often browned at tips in exposed sites. Lobes with a network of sharp ridges and depressions and whitish pseudocyphellae, developing into powdery soredia on lobe margins and ridges. Rhizines typically densely squarrose-branched, but young rhizines often simple. Black lower cortex. Apothecia rare. Chemistry: cortex K+ yellow, PD-, medulla K+ red, PD+ orange, other spot tests negative. Substrances detected by TLC: atranorin, salazinic acid, ±consalazinic acid. Molecular support: strong species-level support (Molina et al. 2017), no new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Mill Creek Ravine, 2020, 53.507682, -113.465167, *gpohl* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/49307449); Edmonton, 10345 144 St. NW, 53.544996, -113.567651, 2017, epiphytic, *jwyattpsd70* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/7527077); Edmonton, Mill Creek Ravine, 53.527788, -113.479163, 2020, *tawneedupuis* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/56905704); Edmonton, Whitemud Park, 53.49903, -113.560691, 2020, on tree base, *hanna1025* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/59075224); Edmonton, MacKenzie Ravine, 1976, on tree, *D.C. Lindsay s.n.* (PMAE-B77.24.32); Edmonton, McKinnon Ravine, 1976, on *Populus* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.56); Edmonton, approx. 1 mile W of 95 Ave. and 170 St. intersection, 1975, on *Populus tremuloides*, *D.C. Lindsay s.n* (PMAE-B77.24.62); Edmonton, between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on wooden footbridge, *D.C. Lindsay s.n.* (PMAE-B77.24.63); Edmonton, approx. 180 St. and 99 Ave., 1976, on twigs and dead branches, *D.C. Lindsay s.n.* (PMAE-B77.24.69); Edmonton, Terwillegar Park, 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.77); Edmonton, Near Northland Sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.103); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on *Picea* snag, D. Haughland 2021-2B (hb. Haughland); Edmonton, Hawrelak Trail off-leash park, 53.522361, -113.54378, 2020, on decorticate *Picea* twigs, *D. Haughland 2020-25* (hb. Haughland).

Physcia adscendens (Fr.) H. Olivier

FIGURE 35 D.

Common and variable epiphyte across all treed habitats in Alberta, including Edmonton. Thalli to 2 cm in diameter, mostly irregular, with ascending lobes attaching to substrate centrally. Lobes widest at tips due to abundant helmet-shaped soralia. Marginal cilia abundant, darkening distally. Upper cortex white to grey, sometimes maculate, never pruinose, lower cortex typically white. Chemistry: cortex K+ yellow, all other spot tests negative. Secondary metabolites detected by TLC: atranorin. Molecular support: work is required given the morphological diversity evidenced even within Alberta, samples submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 11, 2019, on trunk of *Fraxinus pennsylvanica*, 53.450690, -113.474695, *D. Thauvette & J. Wasyliw s.n. [UoA-CC-101]* (hb. Haughland); Edmonton, Urban Monitoring Site 39, 53.494317, -113.525188, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & A. Stordoc s.n. [UoA-CC-154]* (hb. Haughland); Edmonton, Urban Monitoring Site 76, 53.547844, -113.549140, 2019, on trunk of *Ulmus americana*, *D. Haughland & A. Hood s.n. [UoA-CC-3,53]* (hb. Haughland); Edmonton, Urban Monitoring Site 102, 53.574582, -113.435207, 2019, on trunk of *Ulmus americana*, *D. Royko & R. Fielder s.n. [UoA-CC-170]* (hb. Haughland); Edmonton, Urban Monitoring Site 174E, 53.612602, -113.589391, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland s.n. [UoA-CC-22]* (hb. Haughland); Edmonton, Beverly Air Quality Monitoring Station, 53.566860, -113.397464, 2019, on trunk of *Ulmus americana*, *D. Thauvette & J. Birch s.n. [UoA-CC-13,26,138,188]* (hb. Haughland); Edmonton, Buena Vista Park, 53.518208, -113.548277, 2020, on tree-form *Salix*, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12611/details); Edmonton, between Provincial Museum parking lot and Wellington Crescent, 1975, on N sides of trunks of deciduous trees, *D.C. Lindsay s.n.* (PMAE-B77.24.48); Edmonton, approx. 180 St. and 99 Ave., 1976, on twigs and dead branches, *D.C. Lindsay s.n. (PMAE-B77.24.73)*; Edmonton, Terwillegar Park, 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.82); Edmonton, Emily Murphy Park, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.89); Edmonton, MacKenzie Ravine, 1976, on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.157).

Physcia aipolia (Ehrh. ex Humb.) Fürnr. group

FIGURE 35 E.

River valley, parkland, and tableland epiphyte. This species is rarer than the somewhat similar *P.* aff. *stellaris* in Edmonton. Here we use "group" as Edmonton likely has both *P. aipolia* and *P. alnophila* (Vain.) Loht., Moberg, Myllys & Tehler. Broader efforts through the ABMI to distinguish these two species based on morphology and TLC (e.g., Brodo et al. 2013) left us doubting our ability to accurately discriminate them (Haughland, unpublished data) so at present we prefer to group them. The key provides some field traits other authors have found useful to separate *P. alnophila* versus *P. aipolia*, however, TLC can aid in a definitive identification (Brodo et al. 2013). Edmonton material: thallus orbicular to irregular, up to 5 cm in diameter, whitish-grey to dark grey, typically maculate. Lobes flattened to slightly concave (especially at the tips, vs. convex and clasping in *P.* aff. *stellaris*). Lacking soredia or isidia, apothecia common, appressed on thallus (vs. stipitate in *P.* aff. *stellaris*), thalline margin relatively thin (vs. relatively thick in *P.* aff. *stellaris*), disk often pruinose (vs. typically epruinose in *P.* aff. *stellaris*). Chemistry: cortex and medulla K+ yellow (vs. medulla K- in *P.* aff. *stellaris*), all other spot tests negative. Secondary metabolites detected by TLC: atranorin, zeorin, multiple unknown fatty acids and terpenes. Molecular support: work is required, samples submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 9, 53.453715, -113.527142, 2019, on trunk of *Fraxinus, D. Haughland & A. Stordock s.n. [UoA-CC-144]* (hb. Haughland); Edmonton, Urban Monitoring Site 46, 53.509321, -113.574933, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-155]* (hb. Haughland); Edmonton, Urban Monitoring Site 86, 53.561118, -113.547994, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & A. Hood s.n. [UoA-CC-163]* (hb. Haughland); Edmonton, Urban Monitoring Site 100, 53.574491, -113.479536, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & M. Cao s.n. [UoA-CC-169]* (hb. Haughland); Edmonton. Urban Monitoring Site 175E, 53.616594, -113.562214,2019, on trunk of *Fraxinus pennsylvanica, D. Haughland s.n. [UoA-CC-25]* (hb. Haughland); Ardrossan, Air Quality Monitoring Station, 53.554823, -113.143428, 2019, on trunk of *Populus balsamifera, D. Thauvette & J. Birch s.n. [UoA-CC-187]* (hb. Haughland); Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on upper branches of downed *Populus balsamifera, D. Haughland 2020-55 & A. Hood* (hb. Haughland); Edmonton, between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on supports of wooden footbridge and on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.53); Edmonton, MacKenzie Ravine, 1976, on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.154); Edmonton, Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE- as minor component in B77.24.125); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513211, -113.538619, 2021, on *Picea* twigs, *D. Haughland 2021-29* (hb. Haughland).

******Physcia* aff. *dimidiata*** (Arnold) Nyl.

FIGURE 35 F.

River valley epiphyte, occasional in parkland and tableland habitats. In contrast to the Sonoran region where *P. dimidiata* occurs on northern-exposed rock (Moberg 2002), in Alberta these specimens are epiphytic, occasionally forming luxurious colonies on conifer twigs in riparian zones. Edmonton material: thallus loosely attached, grey-white with a dense crystalline pruina, and lobes with crenulate margins bearing granular soredia. Commonly apotheciate, with soralia forming on eroded thalline apothecial margin. Chemistry: cortex K+ yellow, medulla K-, all other spot tests negative, secondary metabolites not investigated. Molecular support: in Alberta, this species is not monophyletic and the material does not group with *P. dimidiata* from the southwestern United States (T. Esslinger, pers. comm.). Molecular work is ongoing as part of a comprehensive treatment of Physciaceae by T. Esslinger and S. Leavitt, but it is clear this material does not cluster with *Physcia dimidiata s.s.*

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 7, 53.452098, -113.573622, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-143]* (hb. Haughland); Edmonton, Urban Monitoring Site 38, 53.498347, -113.546635, 2019, on trunk of *Ulmus, D. Haughland & A. Stordoc s.n. [UoACC-152]* (hb. Haughland); Edmonton, Urban Monitoring Site 39, 53.494317, -113.525188, 2019, on trunk of *Fraxinus pennsylvanica, D. Haughland & A. Stordoc s.n. [UoA-CC-154]* (hb. Haughland); Edmonton, Urban Monitoring Site 46, 53.509380, -113.574106, 2019, on trunk of *Ulmus americana, D. Haughland & L. Hjartarson s.n. [UoA-CC-131]* (hb. Haughland); Edmonton, Urban Monitoring Site 69, 53.534195, 113.525517, 2019, on trunk of *Populus balsamifera, D. Haughland & S. Toni s.n. [UoA-CC-126]* (hb. Haughland); Edmonton, near Whitemud Park, S bank of North Saskatchewan River, 53.5058, -113.5551, 2017, epiphytic on branches and bark of young *Picea glauca, D. Haughland 2017-235a & P. Williams* (hb. Haughland), *D. Haughland 2017-235b & P. Williams* (hb. Haughland); Edmonton, Hawrelak Trail off-leash park, 53.51807, -113.5401, 2017, on *Picea glauca* branches & twigs, coating lower dead branches, *D. Haughland 2017-233 & P. Williams* (hb. Haughland); Edmonton, Hawrelak Trail off-leash park, 53.5134, -113.5395, 2017, on *Picea glauca* twigs & branches, coating lower dead branches, *D. Haughland 2017-234 & P. Williams* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on bark, *D.C. Lindsay, s.n.* (PMAE-B77.24.166); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513211, -113.538619, 2021, on *Picea* twigs, *D. Haughland 2021-27* (hb. Haughland); Edmonton, Hawrelak Trail off-leash park, 53.522361, -113.54378, 2020, on decorticate *Picea* twigs, *D. Haughland 2020-25* (hb. Haughland).

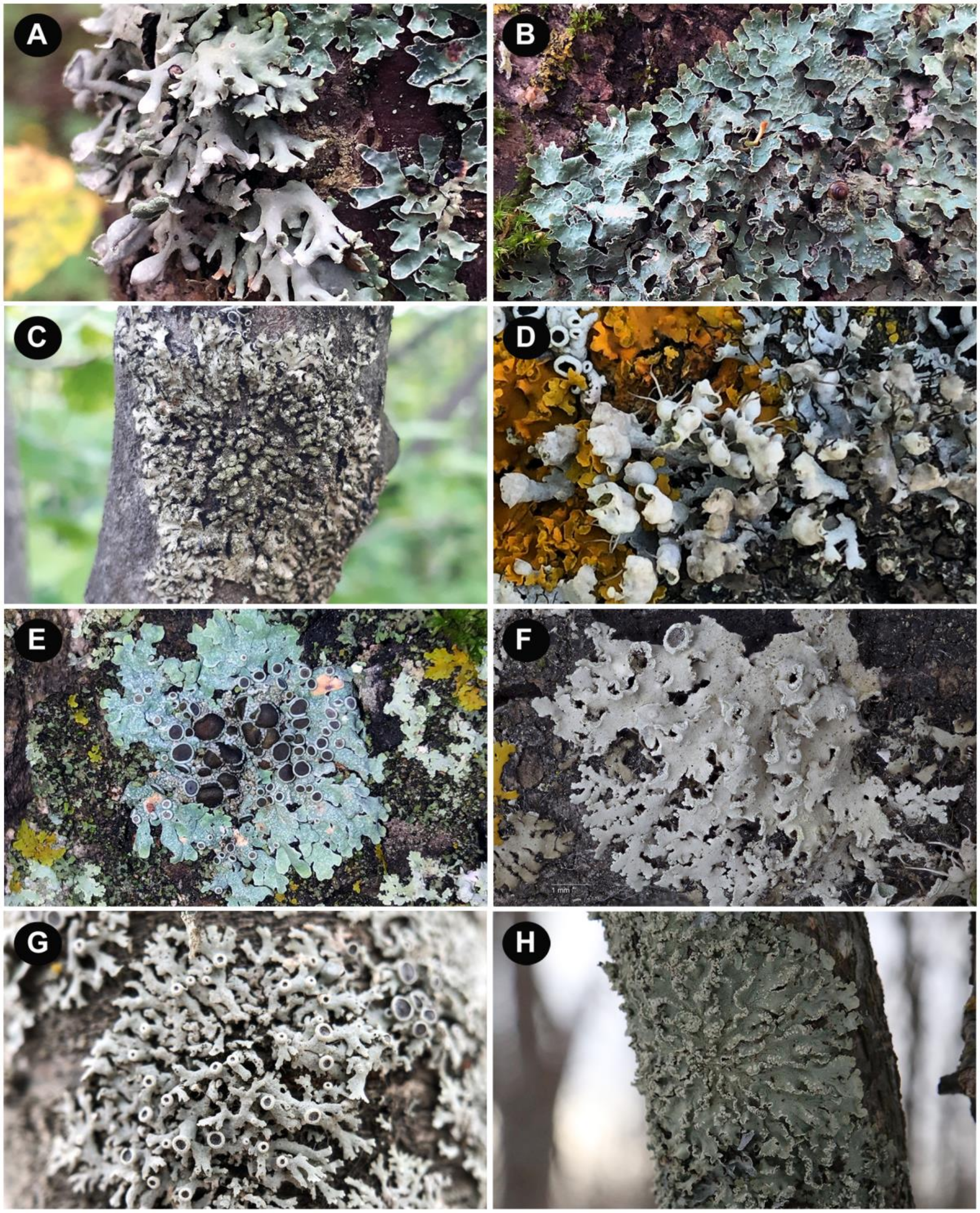

Figure 35. White and grey foliose lichens of Edmonton, plate 2 of 2. **A,** *Hypogymnia physodes* growing with *Parmelia sulcata* (right), *Haughland* https://naturelynx.ca/sightings/14287/details. **B,** *Parmelia sulcata, Haughland* unvouchered observation. **C,** *Phaeophyscia orbicularis*, *Hjartarson* https:// naturelynx.ca/sightings/11762/details. **D,** *Physcia adscendens, Haughland* https://naturelynx.ca /sightings/12611/details. **E,** *Physcia aipolia* group, *Haughland* unvouchered observation. **F,** *Physcia* aff. *dimidiata, Haughland* unvouchered observation. **G,** *Physcia* aff. *stellaris, Haughland* https://naturelynx.ca/sightings/12612/details. **H,** *Punctelia caseana, Haughland* unvouchered observation.

Physcia* aff. *stellaris (L.) Nyl.

FIGURE 35 G.

Common tableland and parkland epiphyte, occasional in the river valley. Esslinger et al. (2020) suggest that this species in the strict sense is not present in North America, instead, we have a complex of similar but largely undescribed species. Until the complex is resolved, we lump these under *P.* aff. *stellaris.* Material included here shares the following traits: thallus orbicular to irregular, to 5 cm in diameter. Thalli varying from narrow lobed with apothecia clustered centrally to thalli consisting largely of clustered apothecia. Lobes grey to white, upper surface may be maculate, pruinose or neither, typically convex and slightly elevated and clasping the substrate. Apothecia common, slightly stipitate with a relatively thick thalline margin, disk black and seldom pruinose. Includes wide-lobed, draping form with elevated apothecia. No vegetative propagules. See *P. aipolia* group entry for comparison. Chemistry: cortex K+ yellow, medulla K-, all other spot tests negative. Secondary metabolites detected by TLC: atranorin. Molecular support: work is required, samples submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 14, 53.447673, -113.412609, 2019, on trunk of *Ulmus americana, D. Royko & D. Fielder s.n. [UoA-CC-146]* (hb. Haughland); Edmonton, Urban Monitoring Site 33, 53.479375, -113.412798, 2019, on trunk of *Tilia*, *D. Thauvette et al. s.n. [UoA-CC-46]* (hb. Haughland); Edmonton, Urban Monitoring Site 119, 53.602014, -113.458033, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Royko & D. Fielder s.n. [UoA-CC-176]* (hb. Haughland); Edmonton, Urban Monitoring Site 150E, 53.590398, -113.588890, 2019, on trunk of *Ulmus americana*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-134]* (hb. Haughland); Edmonton, South Air Quality Monitoring Station, 53.503437, -113.523856, 2019, on trunk of *Fraxinus, D. Thauvette & J. Birch s.n. [UoA-CC-4]* (hb. Haughland); Edmonton, Buena Vista Park, 53.518211, -113.548263, 2020, on tree-form *Salix, D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12612/details); Edmonton, between Provincial Museum parking lot and Wellington Crescent, 1975, on N sides of trunks of deciduous trees, *D.C. Lindsay s.n.* (PMAE-B77.24.49); Edmonton, approx. 1 mile W of 95 Ave. and 170 St. intersection, 1975, on *Populus tremuloides*, *D.C. Lindsay s.n.* (PMAE-B77.24.64); Edmonton, Emily Murphy Park, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.86); Edmonton, Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.125); Edmonton, along Saskatchewan Drive, near the Biological Sciences Building of the University of Alberta, 1976, on bark (cf. *Salix*), *D.C. Lindsay s.n.* (PMAE-B77.24.179); Edmonton, 98 Ave. and 154 St. intersection, 1976, on bark, *D.C. Lindsay s.n.* (PMAE-B77.24.190); Edmonton, McKinnon Ravine, 1976, on *Populus* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.59); Edmonton, approx. 180 St. and 99 Ave., 1976, on twigs and dead branches, *D.C. Lindsay s.n.* (PMAE-B77.24.72).

Punctelia caseana Lendemer & Hodkinson

FIGURE 35 H.

Occasional river valley epiphyte. Historically our material was called *Punctelia subrudecta* (Nyl.) Krog in Alberta, but Lendemer & Hodkinson (2010) clarified that species and its North American distribution. Alberta material was cited as *P. jeckeri* (Roum.) Kalb based in part on the presence of pruina on the lobe tips (Lendemer & Hodkinson 2010; Elk Island National Park 1961, *G.W. Scotter 657* [CANL], not examined here). Our analyses show that material in Alberta is instead *P. caseana*, calling into question the utility of pruina in distinguishing these species, particularly in base-rich/alkaline environments like much of Alberta. Recognized by up-to-palm-sized thalli, with wide, rounded, grey lobes with primarily laminal soralia producing coarse granular soredia that often aggregate. The lobe tips vary from epruinose to sparsely pruinose, lobes are adnate except at the distal edges, and the lower surface is beige to pale brown with short, simple, "buzz-cut"-like rhizines. Can be confused with *Flavopunctelia* that are low in usnic acid, in which case examining the lower cortex (black in *Flavopunctelia*) or chemistry (cortex KC+ yellow in *Flavopunctelia*) will distinguish them. Chemistry: cortex K+ yellow, medulla C+ red, KC+ red, all other spot tests negative. Secondary metabolites detected by TLC: lecanoric acid, atranorin (trace). Molecular support: high at genus and species level. Analyses to date, as well as those conducted herein suggest relatively high support for *P. caseana* and reciprocal monophyly with *P. jeckeri* (Alors et al. 2016, Lendemer & Hodkinson 2010; Fig. 9 herein).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland & A. Hood s.n.* (unvouchered observation); Edmonton, Larch Sanctuary, 53.453522, -113.547402, 2020, epiphytic, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/10688/details);

Edmonton, Hawrelak Park, 53.51665, -113.538811, 2020, on *Betula papyrifera*, *D. Haughland 2020-111* (hb. Haughland).

GROUP 10. BROWN AND GREEN FOLIOSE LICHENS

Eleven species. Key literature: Breuss 2002; Brodo 2016; Esslinger 1977; Esslinger et al. 2017. A group of often overlooked species, typically camouflaging well with the bark they commonly grow on. With practise most species can be identified in the field.

1a. Squamulose; esorediate; with embedded perithecia .... ***Endocarpon* aff. *unifoliatum***
1b. Foliose; mostly sorediate and/or isidiate; if fertile with apothecia not perithecia **2**

2a. Lobes dark reddish to greenish brown, often shiny, typically appressed; lower cortex and rhizines similar in color and sheen to upper cortex or darkening; rhizines simple .....**3 (*Melanelixia* & *Melanohalea*)**
2b. Lobes dull green, brown or grey; lower cortex black at least centrally; rhizines branching to densely squarrose..**6**

3a. Esorediate; isidia, lobules and/or apothecia present **4**
3b. Sorediate; may also have very small granular isidia or sparse apothecia **5**

4a. Isidiate, isidia abundant, with a greasy luster, becoming large, hollow, and lobulate; apothecia rare; pycnidia not observed; in riparian and tableland habitats in Edmonton .... ***Melanohalea exasperatula***
4b. Lacking isidia but may develop lobules; apothecia common; pycnidia abundant, laminal, immersed, visible as black dots on upper surface; thus far known only from outskirts of Edmonton and not treated further here ....*Melanohalea subolivacea* (see Fig. 37D)

5a. Soralia marginal, labriform, white; lacking isidia .... ***Melanelixia albertana***
5b. Soralia central, laminal, golden-green; with tiny cylindrical isidia ....***Melanelixia subaurifera***

6a. Upper surface lacking pruina, lower surface pale to darkening centrally; rhizines often bristling around lobes, simple, black with white tips, but variable .... **7 (*Phaeophyscia*)**
6b. Upper surface typically pruinose around margins; lower cortex dark black to brown; rhizines dense, black and 'bottle-brush' squarrose .... **9 (*Physconia*)**

7a. Lower cortex pale througout; lobe tips with blastidia and tiny hyaline hairs; thalli tiny, often camouflaged against bark and easily overlooked ....***Phaeophyscia nigricans***
7b. Lower cortex darkening at least centrally; lobes with terminal granular soredia or with laminal, rounded soralia; thalli larger, more easily observed **7**

8a. Soralia marginal, with granular isidioid soredia/isidia with often conspicuous pale hairs; rare in Edmonton in humid habitats.. ***Phaeophyscia kairamoi***
8b. Soralia primarily laminal and sub-marginal, rounded in outline, the soredia mostly finely granular and lacking hairs; ubiquitous.. ***Phaeophyscia orbicularis***

9a. Soralia at end of lobes, labriform and discrete **10**
9b. Soralia along edges of lobes, often continuous especially towards the center of the thallus, linear........**11**

10a. Form ranges from rosettes to scattered lobes; lower surface typically pale and ecorticate; medullary hyphae visible on lower surface darkening to form fine brown/black striations near lobe tips and a dark, dull lower cortex forming towards the thallus center ....***Physconia perisidiosa***
10b. Typically forming rosettes; lower surface abruptly darkening with a well-developed cortex past soralia, obscuring medulla...***Physconia labrata***

11a. Medulla and soralia white, K-, KC-..***Physconia detersa***
11b. Medulla and soralia yellowish, K+ yellow, KC+ yellow to orange ....***Physconia enteroxantha***

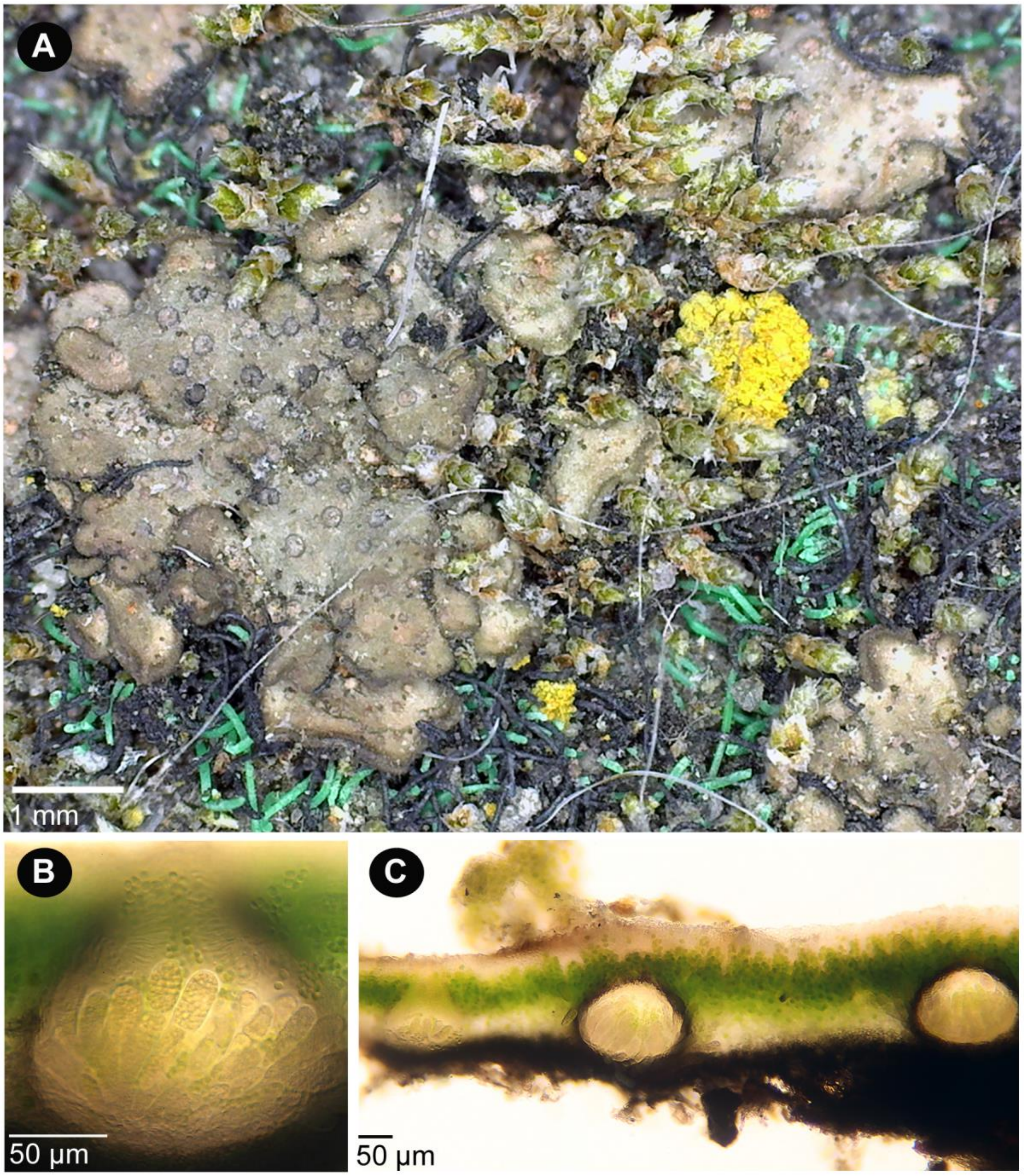

Figure 36. *Endocarpon* aff. *unifoliatum*, growing on indoor-outdoor carpeting in Edmonton, *Haughland 2020-98*. **A,** Squamules. **B,** Cross-section of perithecium. **C,** Squamule cross-section.

*****Endocarpon* aff. *unifoliatum*** T. Zhang, X. L. Wei & J. C. Wei

FIGURE 36.

Anthropogenic tableland habitat. The Verrucariaceae is a challenging family in Alberta, with many of the collections the senior author has received through the ABMI not fitting existing North American keys and species descriptions. This sample was no different. Molecular and morphological data suggest that this material constitutes the first North American record of a recently described species from China, *Endocarpon unifoliatum* (Zhang et al. 2017). Edmonton material: adnate grey-brown squamules from 2–7 mm diameter on their longest axis, with ascending, darkened margins at the very edges of the flat to concave, lobulate thalli. The squamules do not form imbricate colonies, covering the substrate in a mostly single layer. The squamules are 170–250 µm thick, thickest centrally, the upper cortex of paraplectenchymatous cells in vertical columns, 12.5–30.0 µm thick, penetrating the algal layer in places, and overlain with a very thin epinecral layer that is best visualized under polarized light. No other polarizing crystals were found in cross-section. The algal layer is irregular on both the top and bottom, and formed of vertical columns of algae. The medulla consists of cream to pale yellow subparaplectenchymatous to loosely interwoven fibrous hyphae, with some swollen and some cylindrical cells. The lower cortex is formed of paraplectenchymatous cells, mostly dark brown to black except where the squamules are lifted off the surface (at the edges and in some places in ripples in the middle of the squamules). Hyaline to dark rhizohyphae 3–4 µm in diameter form irregular wefts on the lower surface, and may form actual rhizines; the substrate (thin, tightly woven outdoor carpet glued on concrete) may be impeding their development. Abundant laminal, immersed perithecia are present, forming slightly darkened extruding bumps on the upper surface, and protrusions through the lower surface. Perithecia 150–170 µm wide and high, pyriform, with abundant paraphyses and a black exciple. Asci are 75–80 × 15 µm, bisporous, with hyaline, muriform spores measuring 30–34 × 13–15 µm. The perithecia house small globose algae, 1–2 celled, 4–5 µm in diameter. Chemistry: medulla K+faint yellow, C-, PD-. Secondary metabolites detected by TLC: none. Molecular support: A single ITS sequence (isolate DLH6 from *Haughland 2020-98*) has 98% percent identity with *Endocarpon unifoliatium* GenBank Accession KX538760 (China, eight positions different, 487 bp overlap, Fig. 3). Given most *Endocarpon* species have not been sequenced (NCBI Taxonomy, queried 5 November 2021), we prefer to acknowledge the uncertainty with “affinity” until further sequences are obtained.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Spruce Avenue neighborhood, 53.563562, -113.498138, 2020, weathered and mossy indoor-outdoor carpet, *Haughland 2020-98* (hb. Haughland).

Melanelixia albertana (Ahti) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
(≡ *Melanelia albertana* (Ahti) Essl.)

FIGURE 37 A.

River valley and ravine system and parkland epiphyte. An occasional boreal species found in mature mixedwood to deciduous stands. Characterized by an appressed olive-brown to red-brown thallus with numerous marginal, labriform, and typically downward-facing soralia. The surface often has a shiny, almost greasy lustre. The lobes are somewhat rounded, and pseudocyphellae absent. One of two fairly common *Melanelixia* species in the province, this species can be distinguished from *M. subaurifera* by the latter’s laminal soredia intermixed with tiny isidia. Chemistry: medulla C+ red, KC+ red, all other spot tests negative, lecanoric acid (Esslinger 1977). Molecular support: no sequences generated, low for the species globally. Leavitt et al. (2016) found poor support for a *M. albertana* clade composed of sequences from North America, Russia, China, and India. Regardless of future revisions, our material should retain this epithet as the type was collected from near Edmonton (Esslinger 1977).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 128, 53.614601, -113.439527, 2019, on deciduous tree, *A. Hood* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/5454/details); Edmonton, between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on wooden footbridge, *D.C. Lindsay s.n.* (PMAE-B77.24.58); Edmonton, Terwillegar Park, 1977, on *Populus* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.83); Edmonton, Emily Murphy Park, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.90).

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
(≡ *Melanelia subaurifera* (Nyl.) Essl.)

FIGURE 37 B.

River valley and ravine system epiphyte. A common boreal species with an olive to reddish brown epruinose thallus. Lobes rounded, flat, usually with both short cylindrical, unbranched isidia mixed with soredia in laminal and marginal soralia that result in yellow patches where abraded. Pseudocyphellae absent or inconspicuous; lacking hairs on the lobe tips. Commonly misidentified as *Melanelixia subargentifera* Nyl. in Alberta, but that species is rare or absent (ABMI 2020). Chemistry: medulla C+ red, KC+ red, all other spot tests negative. Secondary metabolites detected by TLC: lecanoric acid. Molecular support: no sequences generated, inferred to be strong from Leavitt et al. (2016), however, given their description of cryptic sister species to *M. subaurifera*, future work should confirm this.

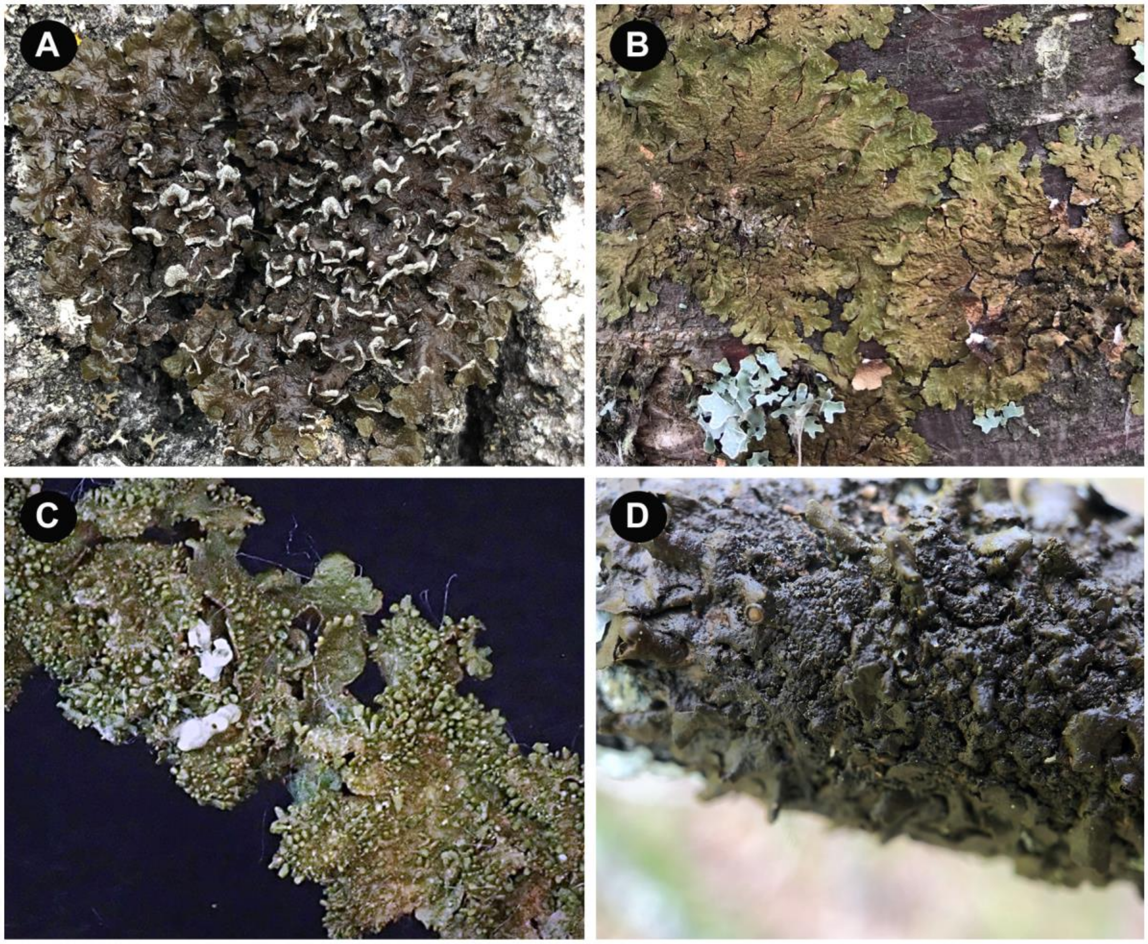

Figure 37. Brown Parmeliaceae of Edmonton. A, B & D are images of collections from outside of Edmonton. **A,** *Melanelixia albertana* ca. 45 km NE of Beaver Lake, ABMI Site 794, 54.97, -111.34, 2015, on *Populus*, *C. Copp s.n.* [*ABMI Lichen # 676192*], photo: Dominik Royko. **B,** *Melanelixia subaurifera*, Chickakoo Natural Area west of Edmonton, on *Betula*, *Haughland* unvouchered observation. **C,** *Melanohalea exasperatula*, *Haughland 2020-24*. **D,** *Melanohalea subolivacea, Haughland 2021-36.*

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland & A. Hood* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14353/details); Edmonton, MacKenzie Ravine, 1976, on *Betula* bark, *D.C. Lindsay s.n.* (PMAE-B77.24.167); Edmonton, approx. 180 St. and 99 Ave., 1976, on twigs and dead branches, *D.C. Lindsay s.n.* (PMAE-B77.24.70).

Melanohalea exasperatula (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch
(≡ *Melanelia exasperatula* (Nyl.) Essl.)

FIGURE 37 C.

River valley and occasionally tableland epiphyte. Thallus closely appressed, olive-brown and shiny, but becoming rather rough due to abraded isidia. Lacking pseudocyphellae or soredia. The isidia are hollow and constricted at the base, initially globular/spherical and becoming flattened to lobulate. There are several isidiate olive-brown lichens in Alberta that can be difficult to distinguish; the isidia at various developmental stages are the best diagnostic trait (for drawings see, Esslinger 1977). Chemistry: all spot tests negative. Secondary metabolites detected by TLC: none. Molecular support: strong at genus- and species-level even with 105 sequences and circumboreal sampling (Leavitt et al. 2013).

Specimens examined. – **CANADA. ALBERTA:** Sherwood Park, Air Quality Monitoring Station, 53.532016, -113.321511, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Thauvette & J. Birch s.n.* [*UoA-CC-105]* (hb. Haughland); Edmonton, Hawrelak trail off-leash park, 53.520696, -113.541533, 2020, on

Betula bark, *D. Haughland 2020-18* (hb. Haughland); Edmonton, Hawrelak trail off-leash park, 53.519809, -113.540503, 2020, on *Picea glauca* twigs, *D. Haughland 2020-24* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on *Betula*, *D.C. Lindsay s.n.* (PMAE-B77.24.160).

Phaeophyscia kairamoi (Vain.) Moberg

FIGURE 38 A-B.

River valley and parkland epiphyte. Like *Physcia* aff. *dimidiata*, this species is described in the southern part of its range as commonly saxicolous (Esslinger 2004). In Alberta it is a common forest epiphyte, often co-occurring with cyanolichens in mature deciduous or mixedwood stands. Characterized by irregular thalli that form patches up to 10 cm in diameter, with marginal granular soredia to soredio-isidia that develop hyaline "hairs," giving thalli a shaggy look. The upper cortex varies from dark grey to brown, the lower cortex is black and typically bristling with abundant, simple, white-tipped rhizines. It is difficult to differentiate from *Phaeophyscia hirsuta* (Mereschk.) Essl., however *P. kairamoi* always has cortical hairs present on the granular soredia, rarely on the lobe ends, whereas *P. hirsuta* often has cortical hairs on the lobe ends, but rarely on the soredia (Esslinger 2016a). Molecular support: work is required, samples submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 47, 53.505866, -113.553095, 2019, on trunk of *Populus balsamifera*, *D. Haughland s.n.* [*UoA-CC-86]* (hb. Haughland); Edmonton, Urban Monitoring Site 163E, 53.608013, -113.590864, 2019, on trunk of *Populus balsamifera*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-84]* (hb. Haughland); Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on trunk of live >75 cm DBH *Populus balsamifera* along trail, *D. Haughland 2020-52 & A. Hood* (hb. Haughland); Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on upper branches of downed *Populus balsamifera*, *D. Haughland 2020-56 & A. Hood* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on bark of *Populus, D.C. Lindsay s.n.* (PMAE-as minor component in B77.24.39).

Phaeophyscia nigricans (Flörke) Moberg

FIGURE 38 C-D.

Apparently an uncommon parkland, tableland and river valley epiphyte, but easily overlooked due to its small size and bark-like color. Characterized by very small lobes <0.5 mm wide on average, forming thalli up to 1 cm in diameter. Thalli often appear almost sub-fruticose, loosely attached, grey-brown to brown, blastidiate to soredio-isidiate along margins, rarely developing labriform and continuous marginal soralia. Distinguished from small, immature *Phaeophyscia orbicularis* and *P. pusilloides* (Zahlbr.) Essl. by size, the white lower cortex and the tiny, hyaline hairs on the lobe tips. Apothecia not observed. Chemistry: all spot tests negative, no secondary metabolites detected (Esslinger 2004). Molecular support: limited species-level support (Lohtander et al. 2000), two ITS sequences in GenBank, work is required, sample submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 62, 53.520926, -113.432139, 2019, on trunk of *Ulmus americana*, *D. Royko & D. Fielder s.n. [UoA-CC-15]* (hb. Haughland); Edmonton, Urban Monitoring Site 69, 53.534155, 113.525612, 2019, on trunk of *Populus balsamifera*, *D. Haughland & S. Toni s.n. [UoA-CC-78]* (hb. Haughland); Edmonton, Urban Monitoring Site 86, 53.561777, -113.547997, 2019, on trunk of *Ulmus americana*, *D. Haughland & A. Hood s.n. [UoA-CC-124]* (hb. Haughland); Edmonton, Urban Monitoring Site 160E, 53.583982, -113.372408, 2019, on trunk of *Fraxinus pennsylvanica*, *S. Toni & M. Cao s.n. [UoA-CC-80]* (hb. Haughland); Edmonton, Urban Monitoring Site 57X, 53.521192, -113.548532, 2019, on trunk of *Populus balsamifera, D. Haughland & A. Hood s.n. [UoA-CC-67]* (hb. Haughland); Sherwood Park, Air Quality Monitoring Station, 53.532016, -113.321511, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Thauvette & J. Birch s.n. [UoA-CC-105]* (hb. Haughland); Edmonton, Urban Monitoring Site 68, 53.530298, -113.554039, 2019, on trunk of *Ulmus*, *D. Haughland s.n. [UoA-CC-17]* (hb. Haughland).

Phaeophyscia orbicularis (Necker) Moberg

FIGURES 35 C, 38 E-F.

Extremely common tableland, parkland, and river valley epiphyte. A highly variable lichen in Edmonton and surrounding Parkland and Boreal forests. Characterized by its orbicular thallus (to 3 cm diameter) and flat, dull lobes, it can form large, confluent patches. The upper cortex is grey-brown to dark brown, with a black lower cortex, at least centrally. The rhizines tend to be shorter and sparser than in other

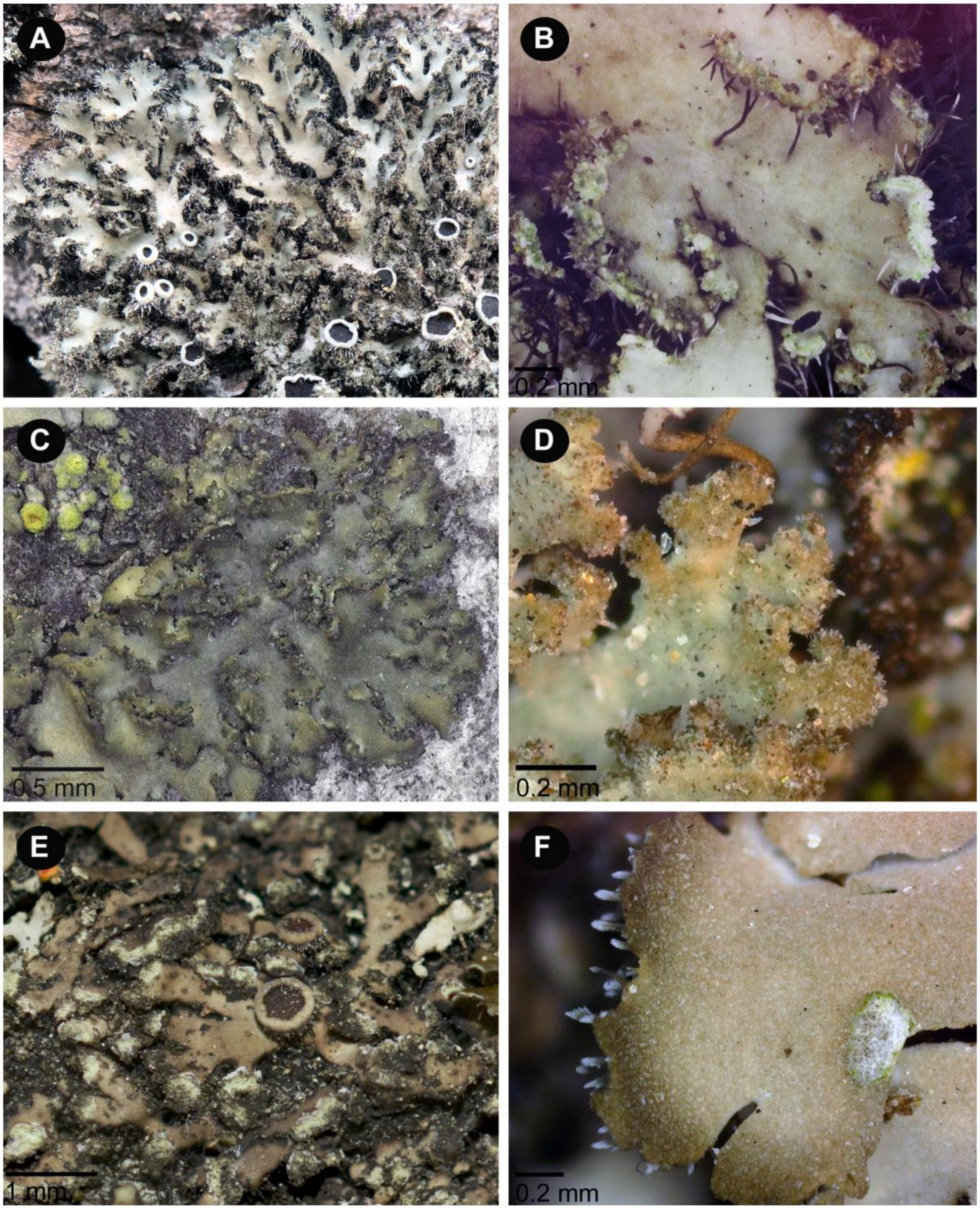

Figure 38. *Phaeophyscia* of Edmonton. **A-B,** *P. kairamoi, Haughland 2020-56*. **A,** Thallus. **B,** Lobe tips with soredia bearing hyaline hairs. **C-D,** *P. nigricans.* **C,** Thallus, *UoA-CC-124*. **D,** Lobe tips with minute hyaline hairs, *UoA-CC-82*. **E-F,** *P. orbicularis.* **E,** Thallus, *Haughland* s.n., photo: Joseph D. Birch. **F,** Smooth lobe tips with rhizines visible, *UoA-CC-82*.

Phaeophyscia species. The soralia are greenish, laminal, often circular, but can also be capitate, eroded, and/or marginal. Often parasitized and then with lumpy, laminal darkened outgrowths. Apothecia occasional, and then with sparse rhizines on the thalline margin. Shade forms with a whitish distal lower cortex can be confused with *Physciella melanchra* (Hue) Essl. but that species has a uniformly pale prosoplectenchymatous lower cortex (vs. paraplectenchymatous and dark at least centrally in *P. orbicularis*). To date we have not confirmed that *P. melanchra* occurs in our region. Chemistry: all spot tests negative, no secondary metabolites detected (Esslinger 2004). Molecular support: limited species-level support (Lohtander et al. 2000), work is required, samples submitted to T. Esslinger and S. Leavitt (unpublished data).

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 6, 53.454045, -113.595336, 2019, on trunk of *Populus* sp., *D. Haughland & A. Stordock s.n. [UoA-CC-142]* (hb. Haughland); Edmonton, Urban Monitoring Site 40, 53.493790, -113.504979, 2019, on trunk of *Fraxinus pennsylvanica*, *D. Haughland & M. Cao s.n. [UoA-CC-8,16]* (hb. Haughland); Edmonton, Urban Monitoring Site 62, 53.520684, -113.432139, 2019, on trunk of *Ulmus americana*, *D. Royko & D. Fielder s.n. [UoA-CC-157]* (hb. Haughland); Edmonton, Urban Monitoring Site 95, 53.570645, -113.588770, 2019, on trunk of *Ulmus americana*, *M. Lewis & M. Villeneuve s.n. [UoA-CC-166]* (hb. Haughland); Edmonton, Urban Monitoring Site 107E, 53.548249, -113.617818, 2019, on trunk of *Elaeagnus angustifolia*, *D. Haughland s.n. [UoA-CC-9]* (hb. Haughland); Edmonton, Urban Monitoring Site 148E, 53.587522, -113.640605, 2019, on trunk of *Populus balsamifera*, *D. Haughland & L. Hjartarson s.n. [UoA-CC-48]* (hb. Haughland); Edmonton, between Provincial Museum parking lot and Wellington Crescent, 1975, on N sides of trunks of deciduous trees, *D.C. Lindsay s.n.* (PMAE-B77.24.47); Edmonton, McKinnon Ravine, 1976, on tree bark, *D.C. Lindsay s.n.* (PMAE-B77.24.50); Edmonton, Terwillegar Park, 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.80); Edmonton, Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.126); Edmonton, along Saskatchewan Drive, near the Biological Sciences Building of the University of Alberta, 1976, on bark (cf. *Salix*), *D.C. Lindsay s.n.* (PMAE-B77.24.175).

Physconia detersa (Nyl.) Poelt

FIGURE 39 A.

Occasional river valley epiphyte. The squarrose rhizines and pruinose lobes are key in separating *Physconia* from similar genera. Characterized by dull, pruinose grey-brown to dark brown lobes, thalli may grow up to 6 cm in diameter. The lower cortex is well-developed and black with abundant squarrose rhizines. The upper cortex is scleroplectenchymatous. The medulla is white, and the soralia marginal. *Physconia enteroxantha* is similar in appearance, differing in its pale-yellow medulla that reacts K+ yellow, KC+ dark yellow. Chemistry: all spot tests negative, no secondary metabolites detected normally, variolaric acid may be an accessory in soralia (Esslinger 2002). Molecular support: a single ITS sequence (isolate DLH17 from *Haughland 2020-51*) is 100% identical to *P. detersa* GenBank Accession EF582760 (Finland, 486 bp overlap) and 99% identical to KT695314 (Canada, Ontario, two different positions, 498 bp overlap). Monophyletic with low support in Esslinger et al. (2017). In our analyses, a GenBank sequence of *Physconia jacutica* nests within an otherwise well-supported monophyletic clade of *P. detersa* (Fig. 8).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on trunk of live >75 cm DBH *Populus balsamifera* along trail, *D. Haughland 2020-51 & A. Hood* (hb. Haughland); Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on upper branches of downed *Populus balsamifera*, *D. Haughland 2020-57 & A. Hood* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on *Betula* bark, *D. C. Lindsay s.n.* (PMAE-B77.24.155); Edmonton, MacKenzie Ravine boardwalk, 53.528875, -113.558827, 2021, on decayed *Picea glauca* log, *D. Haughland 2021-10* (hb. Haughland); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on *Betula papyrifera*, *D. Haughland 2021-22A* (hb. Haughland).

Physconia enteroxantha (Nyl.) Poelt

FIGURE 39 B.

Occasional river valley epiphyte. Thalli to 5 cm diameter, closely attached, green-brown to dark brown, often with white pruina. The soralia are marginal, rarely labriform, occasionally becoming laminal, and the soredia can become lobulate centrally, verging on *Physconia grumosa* Kashiw. & Poelt. The lower cortex is brown to black with abundant squarrose rhizines. Medulla and soralia typically are yellowish. Distinguishing this species from *P. grumosa* and *P. detersa* is difficult when secondary metabolite

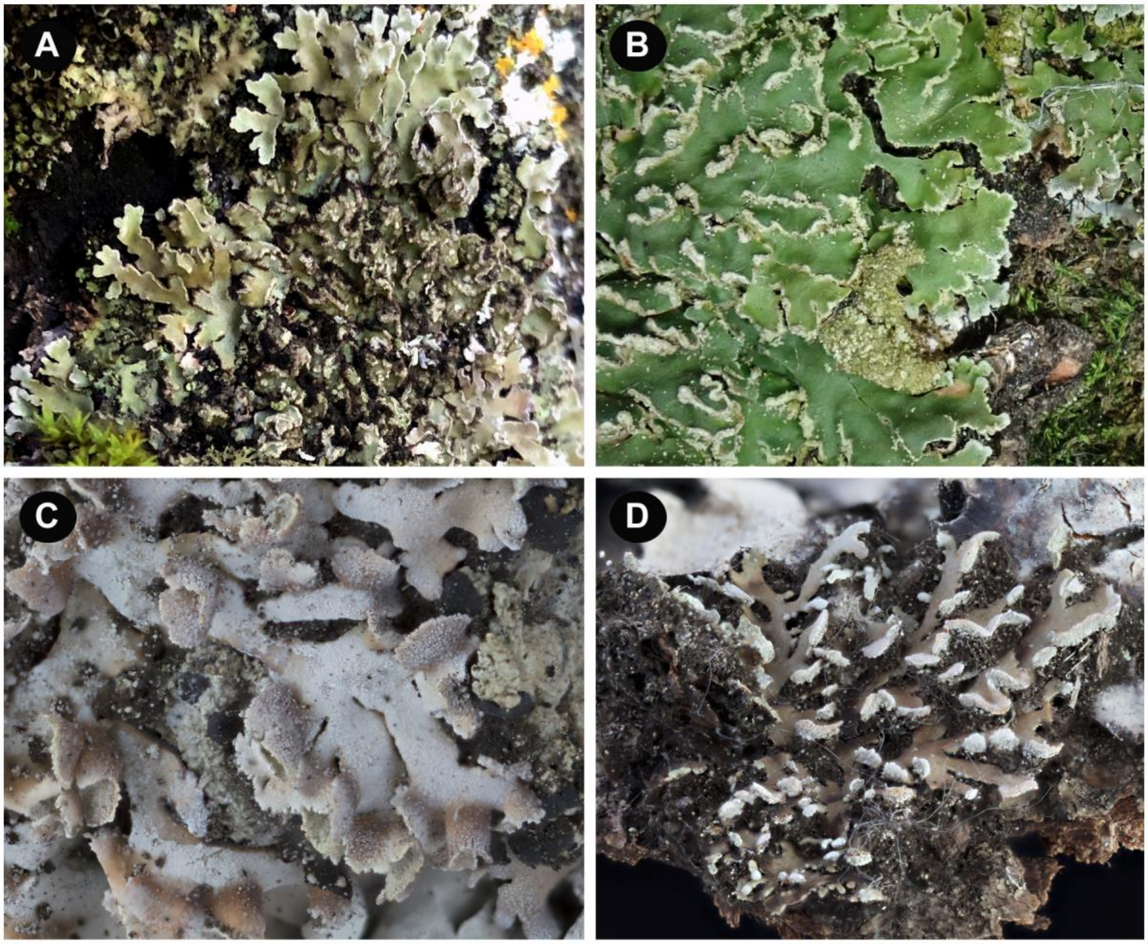

Figure 39. *Physconia* of Edmonton. **A,** *P. detersa*, *Haughland 2020-51*. **B,** *P. enteroxantha*, wet, *Haughland 2020-29*. The following two images are of collections are from outside of Edmonton. **C,** *P. labrata* thallus, dry, William Switzer Provincial Park, 2015, on *Picea glauca*, *Haughland 2015-1a*. **D,** *P. perisidiosa* thallus, dry, ca. 40 km SW of Fort Chipewyan, ABMI Site 208, 58.49, -111.69, 2010, on *Populus*, *T. Grainger s.n.* [*ABMI Lichen # 247465*].

concentrations are low, but these species have a scleroplectenchymatous upper cortex while *P. enteroxantha* is paraplectenchymatous (Esslinger 2016c). This is best seen in longitudinal sections about 2–3 mm from the lobe tips. In addition, *P. grumosa* has more granular, scattered soredia, forming branched isidioid soredia and lobules centrally. Chemistry: medulla and soralia K+ yellow, KC+ dark yellow, all other spot tests negative. Secondary metabolites detected by TLC: none, despite analyzing 11 specimens with positive K spot tests. The amount of secalonic acid A in the medulla and soralia can vary greatly (Esslinger 2002). Molecular support: A single ITS sequence (isolate DLH32 from *Haughland 2020-29*) is 99% identical to *Ph. enteroxantha* GenBank Accessions LS483215 (Spain, one position different, 697 bp overlap) and MK811936 (Norway, two positions different, 488 bp overlap). Monophyletic in Esslinger et al. (2017) and our analyses (Fig. 8).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, South Air Quality Monitoring Station, 53.501946, -113.5249, 2019, on trunk of *Fraxinus* sp., *D. Thauvette & J. Birch s.n. [UoA-CC-132]* (hb. Haughland); Edmonton, Hawrelak trail off-leash park, 53.520696, -113.541533, 2020, on *Betula* bark, *D. Haughland 2020-23* (hb. Haughland); Edmonton, Kinnaird Ravine, 53.558953, -113.459253, 2020, on *Picea glauca* snag, 2020, *D. Haughland 2020-29 & P. Williams* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on bark of *Populus*, *D.C. Lindsay s.n.* (PMAE-B77.24.39); Edmonton, Terwillegar Footbridge, 53.483201, -113.600184, 2021, on *Betula papyrifera*, *D. Haughland 2021-12* (hb. Haughland).

Physconia labrata Essl., McCune & Haughland

FIGURE 39 C.

Rare river valley epiphyte. A recently described species (Esslinger et al. 2017), formally considered part of the *Physconia perisidiosa* species concept. Both species are pruinose, form well-developed rosette-like thalli to sparse, poorly developed shingle-like thalli, and develop labriform, terminal soralia. *Physconia labrata* differs in its well-developed dark lower cortex (vs. poorly-developed lower cortex, pale with sparse, dark hyphae in *P. perisidiosa*) and paraplectenchymatous upper cortex (vs. scleroplectenchymatous in *P. perisidiosa*). Relatively abundant in the Boreal and Foothills Natural Region (ABMI 2020, Esslinger et al. 2017). Chemistry: all spot tests negative. Secondary metabolites detected by TLC: none. Molecular support: high species-level support, type from region of Hinton, Alberta, reciprocally monophyletic in Esslinger et al. (2017; Fig. 8 herein), no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.504611, -113.593583, 2020, on trunk of live >75 cm DBH *Populus balsamifera* along trail, *D. Haughland 2020-53 & A. Hood* (hb. Haughland).

Physconia perisidiosa (Erichsen) Moberg

FIGURE 39 D.

Rare river valley epiphyte. Like *Physconia labrata* but with a scleroplectenchymatous upper cortex and a poorly developed fibrous lower cortex (Esslinger et al. 2017). Chemistry: all spot tests negative. Secondary metabolites detected by TLC: none. Molecular support: forming a well-supported but unresolved clade ith *P. venusta* (Ach.) Nyl. (Esslinger et al. 2017; Fig. 8 herein), no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, ravine between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on tree bark, *D.C. Lindsay s.n.* (PMAE-B77.24.52).

GROUP 11. SMALL CYANOLICHENS

Four species. Key literature: Goward et al. 1994; Jørgenson & Nash 2004; Otáloro et al. 2008, 2014; Schultz & Büdel 2002. We did not document chemistry as it is not typically useful for identifying members of this group.

1a. Tiny gelatinous granules growing on concrete, hardly visible without >10x magnification; spores simple .... **Lichinaceae sp. 1**
1b. Small foliose to semi-fruticose thalli visible with the naked eye (but often camouflaged and difficult to detect) growing on soil; spores transversely septate to muriform **2**

2a. Appearing dwarf-fruticose but with foliose lobes at least proximately; apothecia abundant; lobes with cellular cortices visible in cross-section .... ***Scytinium tenuissimum***
2b. Lobes clearly foliose; apothecia present or absent; lobes lacking cortices in cross-section **3**

3a. Lobes margins swelling disproportionately when moist; spores muriform .... ***Enchylium tenax***
3b. Lobes swelling evenly when moistened; spores with up to 3 transverse septa..... ***Blennothallia crispa s.l.***

Blennothallia crispa (Hudson) Otálora, P. M. Jørg. & Wedin *s.l.*
(≡ *Collema crispum* (Hudson) Weber ex F. H. Wigg)

FIGURE 40 A-C.

River valley terricole. A relatively common lichen in southern Alberta (ABMI 2020). The Edmonton specimen is a rare example of fertile material. Edmonton material: lobes overlapping, isidia-like, semi-fimbriate, appressed, margins not swollen disproportionately when wet. Apothecia constricted at the base, spores with transverse septa, up to 4-celled, 25–35 × 10–12 µm, 8 per ascus. Apothecium with lobulate proper exciple, lobes ecorticate with heteromerous interior of elongated hyphae oriented at right angles, with small-celled *Nostoc* in short chains or clusters. Molecular support: uncertain. A single ITS sequence (isolate DLH31 from *Haughland 2020-60*) did not have query coverage >75% with any GenBank accessioned sequences, and of those with coverage 50–75%, no sequence exceeded 91% percent identity.

We did not find any accessioned ITS sequences for this species through NCBI Taxonomy Browser; additional loci and comparative reference sequences are required for phylogenetic analyses.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak trail off-leash park, 53.517625, -113.5402, 2020, on exposed mineral soil and moss, *D. Haughland 2020-60 & Kyla Tichkowski* (hb. Haughland).

Enchylium tenax (Sw.) Gray
(≡ *Collema tenax* (Sw.) Ach.)

FIGURE 40 D-E.

River valley terricole. Edmonton material: small black appressed lobes, immature lobes appearing globular. Apothecia forming laminally, spores hyaline, muriform, 25–30 × 11–18 µm. *Nostoc* in thallus forming long chains. Edmonton material corresponds morphologically to what was previously called *Collema tenax* var. *crustaceum* (Kremp.) Degel. (Goward et al. 1994). Molecular support: no new sequences generated; species paraphyletic with *E. polycarpon* (Hoffm.) Otálora, P. M. Jørg. & Wedin in recent phylogeny (Otálora et al. 2014).

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.527438, -113.514725, 2020, on moist N-facing mineral soil slope toe, along trail, *D. Haughland 2020-39 & P. Williams* (hb. Haughland).

*****Lichinaceae sp. 1**

FIGURE 41.

Growing on old, exposed, rough concrete in the inner city, with *Caloplaca feracissima* and *Caloplaca tominii*, these tiny thalli may belong to the genus *Lichinella* or *Gonohymenia* (M. Schultz, pers. comm.); more work is needed. Thalli consist of aggregates of cyanobacteria that form small granules with a polygonal surface in squash, with sparse hyphae visible in cross-section. The smallest of these granules are 35–25 × 25 µm, and some thalli consist solely of discrete tiny granules while others form larger aggregations. The larger aggregations regularly contain fruiting bodies that are all but invisible even under 40× magnification and appear to be embedded in the thallus with a layer of algae overlying the fruiting bodies. Upon squash or cross-section, asci can be found, apparently forming thallinocarps (Schultz & Büdel 2002). At maturity the asci are clavate, 8-spored, 18 × 35 µm. No paraphyses could be identified. The walls of mature asci stain K/I+ blue, and immature asci appear to show either a *Lecanora*-type or *Fuscidea*-type internal structure, with an amyloid tip. The spores are simple, hyaline, ovoid to bean-shaped, in rare instances slightly constricted in the middle or curved, 10–12 × 5–6 µm, and they stain yellow in K/I. The conidia are bacilliform, 2–4 × 1 µm, and are formed from unbranched conidiophores in globose, embedded pycnidia. The tissues showed no reaction to K or C alone as tested by drawing the chemicals under a cover slip while observing with a compound microscope. The photobiont could not be determined with certainty and appeared to be a mix of trebouxioid, *Chroococcus*-type and single-celled cyanobacteria, with some in clusters of 2–5 cells. Molecular support: none, a single specimen failed to amplify.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Spruce Avenue Neighborhood, 53.563562, -113.498138, 2020, on old concrete, *D. Haughland 2020-95C* (hb. Haughland).

Scytinium tenuissimum (Dickson) Otálora, P. M. Jørg. & Wedin
(≡ *Leptogium tenuissimum* (Dickson) Körber)

FIGURE 40 F-H.

Apparently rare river valley terricole. Growing on moist, trailside mineral soil and moss alongside *Peltigera* and *Cladonia.* Thallus composed mostly of fimbriate, coralloid isidia developing from foliose lobes that were difficult to find and may have been senescing. The dominance of the isidia was suggestive of *Scytinium teretiusculum* (Wallr.) Otálora, P. M. Jørg. & Wedin; however, the abundant apothecia and apothecial morphometrics support the placement of this collection in *S. tenuissimum*. Apothecia abundant, thalline margins becoming isidiate, disk reddish brown, concave to almost plane, to 1 mm in diameter. Hymenium 170 µm thick, spores hyaline, muriform, 29–35 × 12–15 µm. Molecular support: no new sequences generaqted. In Otálora et al. (2014) two sequences form a well-supported branch nested within a clade containing *S. subtile* (Schrad.) Otálora, P.M. Jørg. & Wedin and *S. palmatum* (Hudson) Gray. More work is needed.

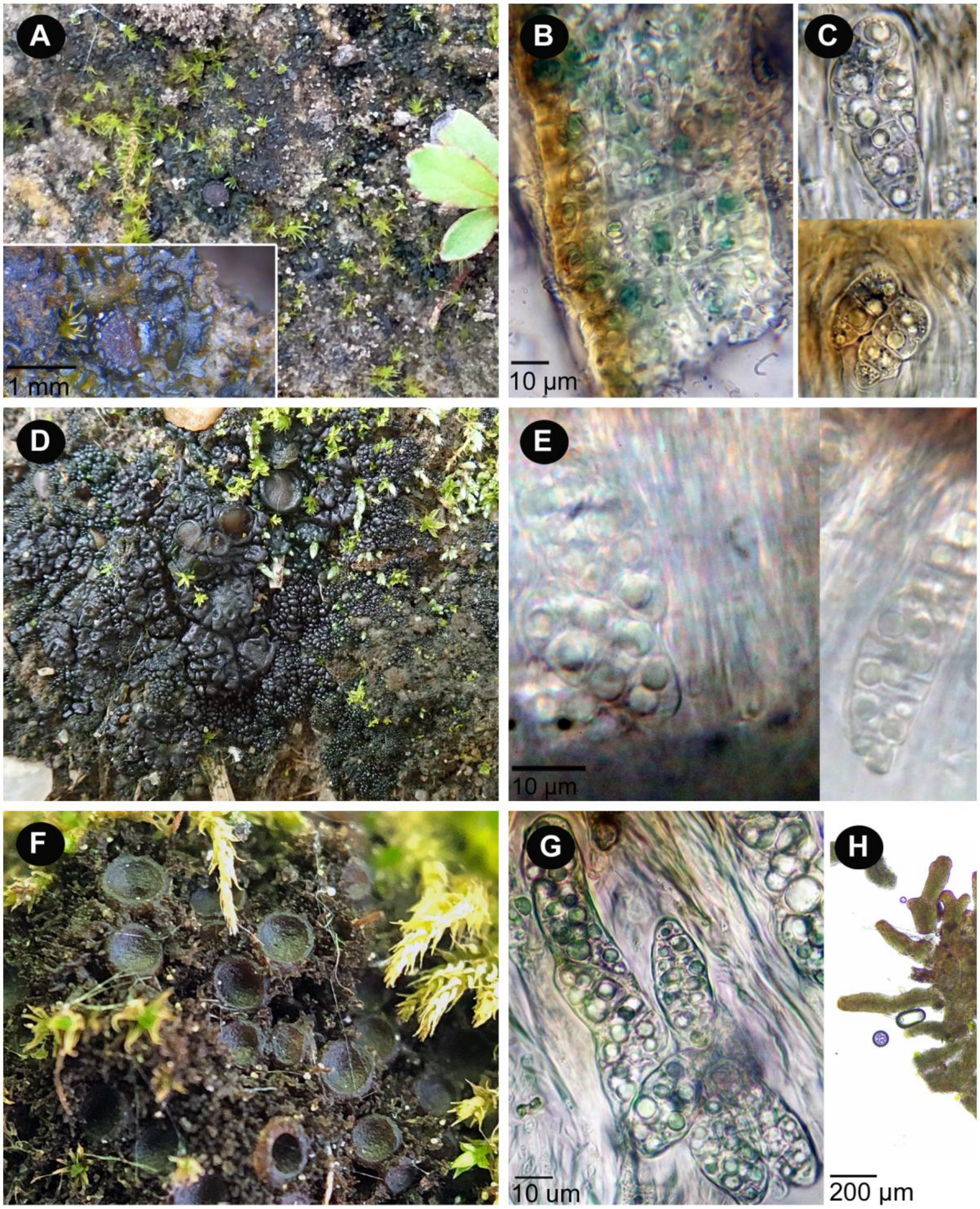

Figure 40. Terricolous cyanolichens of Edmonton. **A-C,** *Blennothallia crispa s.l.*, *Haughland 2020-60*. **A,** Thallus in the field, wet, inset showing lobes and apothecium under magnification. **B,** Lobe cross-section showing largely heteromerous interior of elongated hyphae oriented at right angles, lack of cortices and short chains of *Nostoc*. **C,** Transversely-septate spores within asci, same scale as B. **D-E,** *Enchylium tenax*, *Haughland 2020-39*. **D,** Thallus in the field, wet. **E,** Muriform spores within asci. **F-H**, *Scytinium tenuissimum*, *Haughland 2021-14* https://naturelynx.ca/sightings/17278/details. **F,** Thallus in the field. **G,** Spores in ascus. **H,** Isidiate lobe tips.

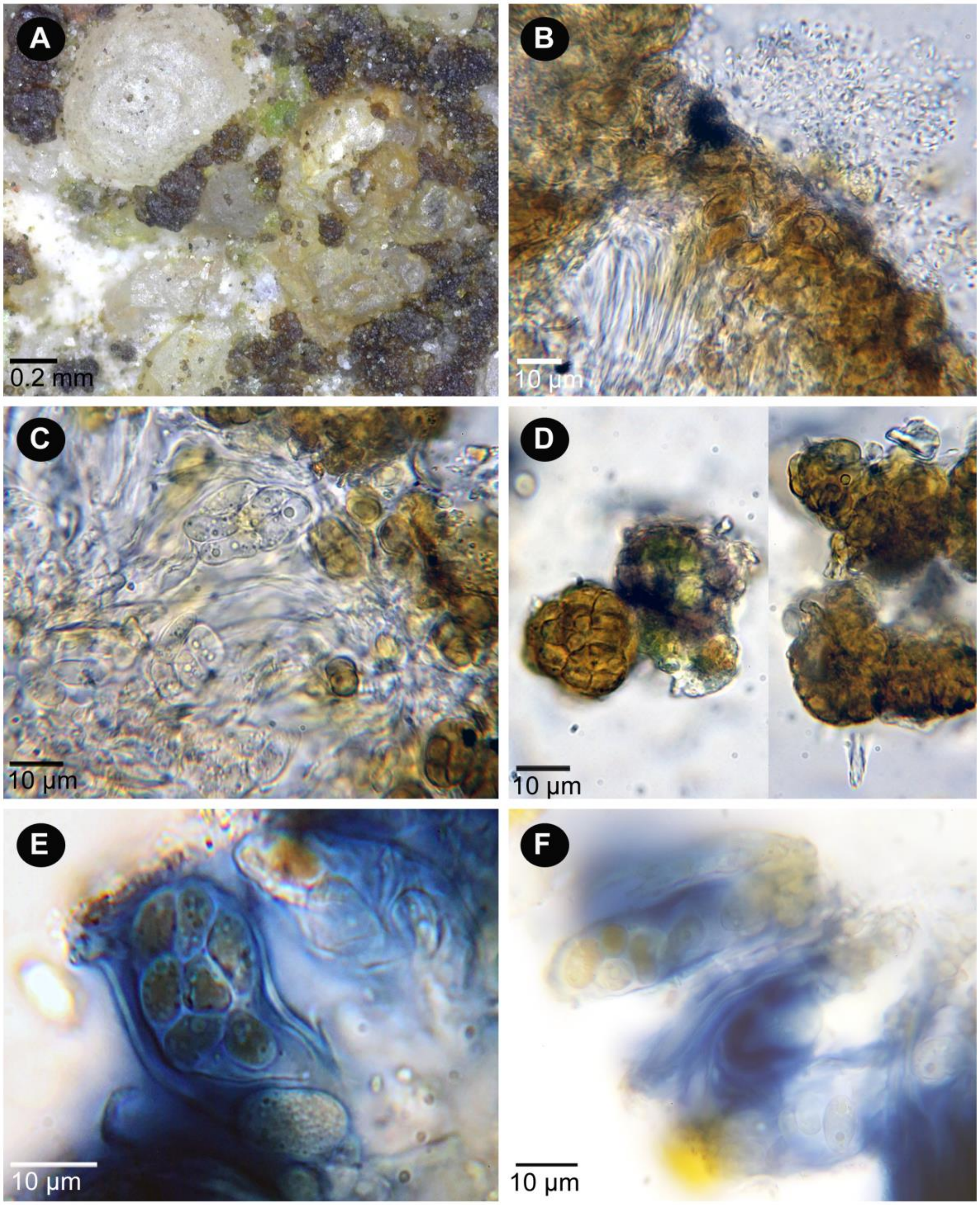

Figure 41. Concrete-dwelling Lichinaceae sp. 1 from Edmonton, *Haughland 2020-95C*. **A,** Macroscopic view of wet thallus, ranging from individual granules to aggregates. **B,** Pycnophores embedded in thallus and bacilliform conidia. **C,** Asci and spores in water-mount **D,** Individual algal granules in water. **E-F,** Asci after treatment with K and Lugol's Iodine.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Fort Edmonton Park region, 53.500919, -113.576036, 2021, on trailside mineral soil and moss, *D. Haughland 2021-14 & S. Toni* (hb. Haughland).

GROUP 12. *PELTIGERA*

Eleven species. An ongoing collaboration with F. Lutzoni, J. Miadlikowska, T. Goward, I. Medeiros and C. Pardo-De la Hoz has confirmed that Alberta is home to many morphologically similar, undescribed species of *Peltigera* (*sensu* Miadlikowska et al. 2003, 2018; Pardo-De la Hoz et al. 2018). With few Edmonton specimens sequenced, here we use currently accepted morphological species concepts as described in Goffinet and Hastings (1994) and Goward et al. (1995) as well as molecular species where available from Pardo-De la Hoz et al. 2018 (section *Chloropeltigera*) and Magain et al. 2018 (section *Peltigera*). Nature-recording app records exist for *P. ponojensis* Gyelnik, but images and collected material were insufficient to confirm this species for Edmonton. Because we have not used chemistry to distinguish species to date, we have not included references to secondary metabolites documented elsewhere.

1a. Tripartite "freckled" lobes, primary photobiont a green alga giving lobes a bright green color when hydrated, secondary photobiont the cyanobacterium *Nostoc* confined to wart-like cephalodia over the upper surface; a diverse group of which only a single species is confirmed in Edmonton to date .... ***Peltigera leucophlebia***
1b. Bipartite, lacking "freckle"-like cephalodia, primary photobiont the cyanobacterium *Nostoc*; lobes grey to brown to almost black **2**

2a. Soredia present, in laminal circular soralia **3**
2b. Soredia absent **4**

3a. Lobes deeply concave, mostly growing singly; rhizines simple, sparse .... ***Peltigera didactyla***
3b. Lobes often polyphyllous; rhizines flocculent, abundant .... ***Peltigera extenuata***

4a. Laminal isidia present, isidia mostly granular, cylindrical or corraloid; lobules typically absent .... ***Peltigera evansiana***
4b. Laminal isidia absent; lobules may be present along edges of cracks, scars, or along lobe edges **5**

5a. Upper cortex with spider web-like arachnoid tomentum **6**
5b. Upper cortex smooth, scabrid (with a scabby crust of crystals, dead cells and tomentum) or pruinose, but not tomentose **10**

6a. Lobe tips mostly upturned and concave **7**
6b. Lobe tips mostly downturned or ruffled, like an Elizabethian collar **8**

7a. Thalli asymmetrical, like small ascending hands; finger-like lobes bearing apothecia that $\leq$6 mm in length; soralial scars often present in center of thallus; upper surface with patchy, thin tomentum, typically lacking pruina; rhizines simple, discrete .... ***Peltigera didactyla*, fertile morph**
7b. Thalli often symmetrical, radiating lobes appressed throughout; when fertile, finger-like lobes bear apothecia $\leq$12 mm in length; lacking soralial scars; upper surface typically tomentose throughout, with pruina crusting central portions; rhizines dense, in hedgerows, becoming confluent centrally .... ***Peltigera rufescens***

8b. Lobes relatively large and wedge-shaped, with consistently down-turned edges; upper surface tomentose throughout; rhizines mostly squarrose-branched, often becoming confluent .... ***Peltigera canina***
8b. Lobes variable in size, edges ruffled; upper tomentum often patchy throughout or restricted to the outer lobe surface; rhizines mostly discrete **9**

9a. Upper surface often with wiggly pale lines from invertebrate grazing; lobe edges and surface stress cracks forming least some lobules (check centrally); veins raised, appearing overlapping near edges, often pinkish to cinnamon brown in color; rhizines mostly simple and smooth; a hypervariable species morphologically, overlapping with traditional concepts of *P. membranacea* and *P. ponojensis* ....***Peltigera praetextata***
9b. Upper surface typically ungrazed; lobules typically absent; veins raised but not overlapping, becoming chocolate brown to dark brown to black centrally; rhizines simple but developing some squarrose branching; difficult to confidently discriminate with morphology alone from related section *Peltigera* species .... ***Peltigera islandica***

10a. Upper surface grey, typically somewhat shiny, and often with rows of slight depressions or "dimples" across the lobes; lower surface with rhizines aligned in concentric rows and indistinct, broad, flat veins; when fertile, apothecia held flat and more or less parallel to lobe surface **11**
10b. Upper surface grey to deep green; lower surface with rhizines not aligned and typically with distinct veins; when fertile, apothecia forming tight "hot dog bun" rolls that are held upright **12**

11a. Upper surface typically with numerous stress cracks, developing abundant lobules and schizidia; veins dark brown to almost black, indistinct or apparently absent, interstices between veins shallow and rounded; common ....***Peltigera elisabethae***
11b. Upper surface lacking stress cracks and lobules; veins medium brown, broad to occasionally indistinct; interstices more or less numerous, often elongate; rare in Alberta .... ***Peltigera horizontalis***

12a. Upper surface steel grey to grey-blue when hydrated, often lightly pruinose, lacking lobules; apothecia black; veins abruptly darkening toward center; common ....***Peltigera neckeri***
12b. Upper surface deep green when hydrated, lacking pruina but often with lobules; apothecia reddish-brown, forming at the tips of long, ascending, deeply dissected lobes; veins reddish-brown to dark brown; rare...***Peltigera polydactylon* subsp. *udeghe***

Peltigera canina (L.) Willd.

FIGURE 42 A-B.

River valley and ravine system and rare tableland terricole. A taxonomically challenging species with many undescribed species currently included within—applied in the broad sense here to thalli that have large, downturned lobes, extensive tomentum on the upper surface, and squarrose to flocculent rhizines that become matted below. Lacking soredia, isidia or lobules. This is the only species of *Peltigera* found in a lawn niche outside of the river valley parks. Molecular support: two ITS sequences (isolate DLH24 from *Haughland 2019-120*, isolate DLH30 from *Haughland 2020-7*), are >99% similar to specimens corresponding to *Peltigera canina 2*, and they contain the *canina 2* hypervariable region from Magain et al. (2018; Fig. 7 herein).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502638, -113.602538, 2020, on debris and downed wood, *D. Haughland 2020-7 & C. Shier* (hb. Haughland); Edmonton, Alberta Avenue neighborhood, 53.564178, -113.490616, 2019, terricolous in mowed grass along boulevard, *D. Haughland 2019-120 & P. Williams* (hb. Haughland); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on soil, *D.C. Lindsay s.n.* (PMAE accession B77.24.102).

Peltigera didactyla (With.) J. R. Laundon

FIGURE 43 A-B.

Apparently rare river valley terricole. Elsewhere in Alberta this is a common early successional species (ABMI 2020). Characterized by small, deeply concave lobes with round, laminal soralia, and relatively sparse, long, simple rhizines below. This species intergrades with *Peltigera extenuata* and the under-detected and often misidentified *P. castanea* Goward, Goffinet & Miądl. in many regions of Alberta (ABMI 2020). Molecular support: one sample failed to amplify cleanly enough to sequence. The difficulty diagnosing these morphologically similar species means this species is a priority for future sequencing.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502638, -113.602538, 2020, terricolous, *D. Haughland 2020-9 & C. Shier* (hb. Haughland); Edmonton, west of Whitemud Park, along Grandview Stairs, 53.502565, -113.553934, 2020, on moss, *L. Hjartarson* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12369/details); Edmonton, MacKenzie Ravine, 1976, on soil, *D.C. Lindsay s.n.* (PMAE accession B77.24.43).

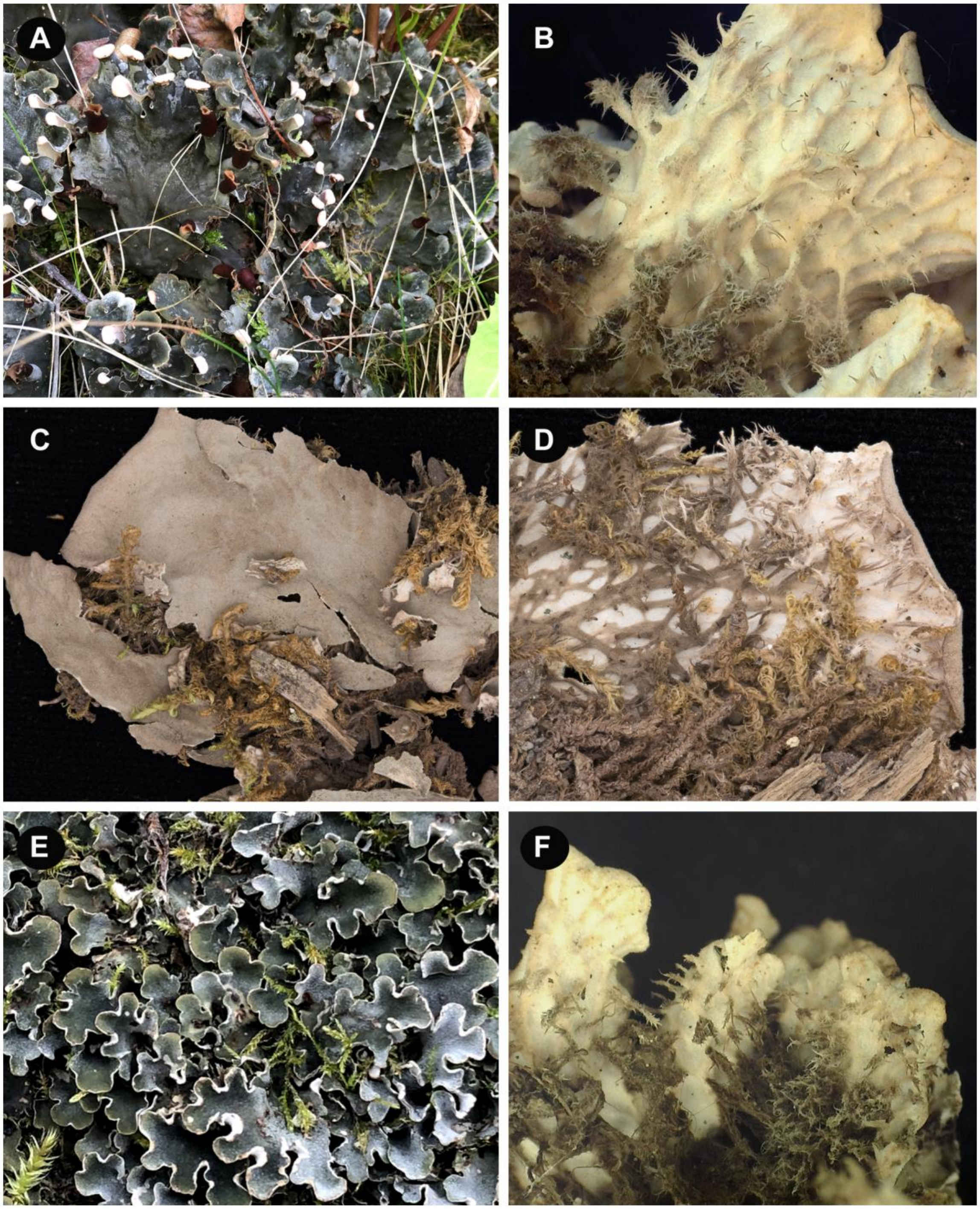

Figure 42. Tomentose *Peltigera* species of Edmonton, plate 1 of 2. Collections imaged in C-D are from outside of Edmonton. **A-B,** *P. canina*. **A,** Habit, *Haughland* unvouchered observation. **B,** Lower surface showing raised veins and flocculent rhizines, *Haughland 2020-7*. **C-D,** *P. islandica*, ca. 10 km SE of Cadomin, ABMI Site 1232, 52.97, -117.22, 2011, on downed wood, *M. Martel s.n.* [*ABMI Lichen # 292500*], identification verified using ITS. **C,** Upper surface. **D,** Lower surface with dark veins and discrete rhizines. **E-F,** *P. rufescens.* **E**, Habit, *Haughland 2020-38*. **F,** Lower surface with confluent rhizines, *Haughland 2021-17*.

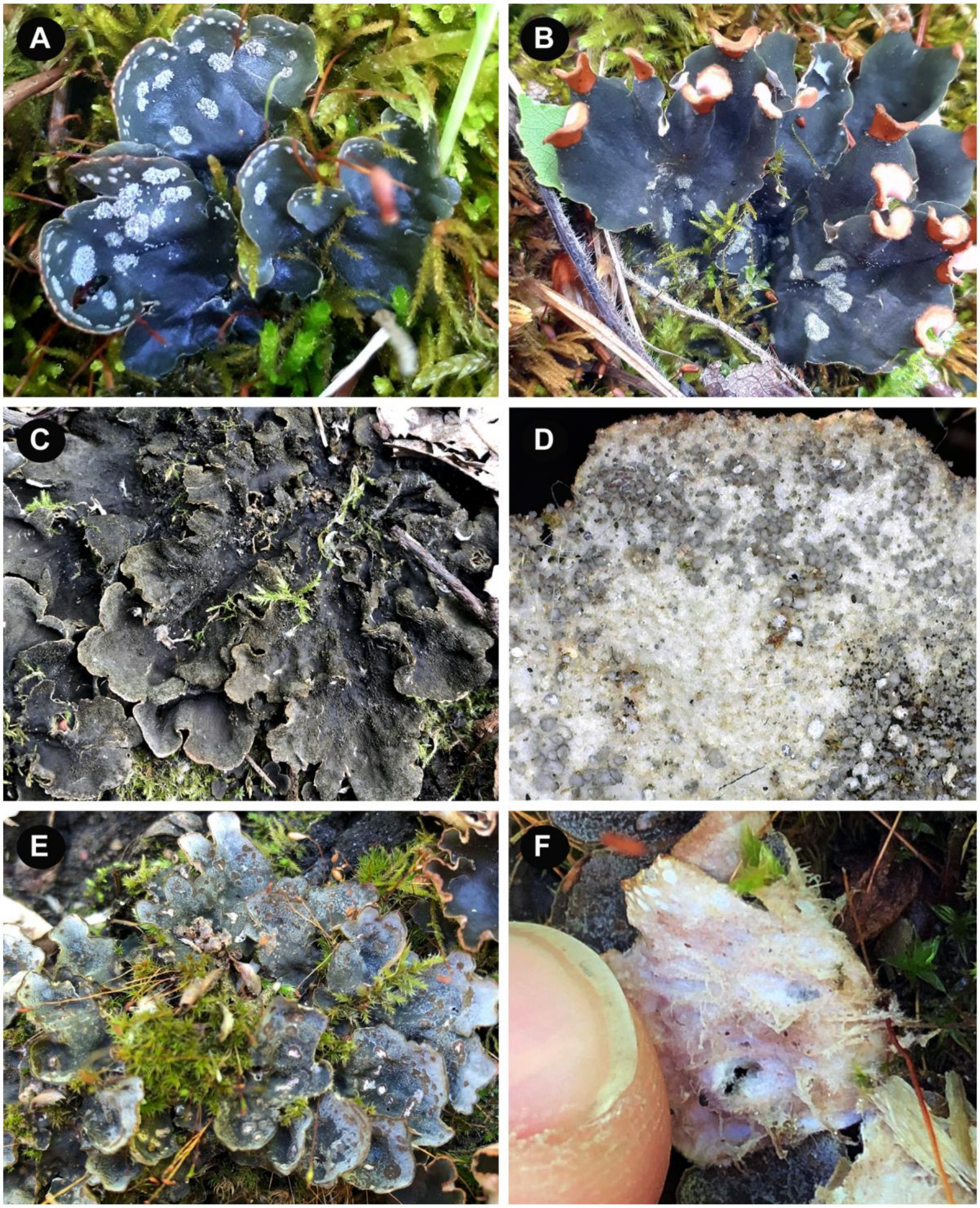

Figure 43. Sorediate and isidiate *Peltigera* species of Edmonton. **A-B,** *P. didactyla*, Laura Hjartarson, https://naturelynx.ca/sightings/12369/details. **A,** Habit and soralia. **B,** Fertile thallus with soralia. **C-D,** *P. evansiana*, *Haughland 2020-36.* **C,** Habit. **D,** Isidia on upper surface. **E-F,** *P. extenuata*, *Haughland 2020-21.* **E,** Habit and soralia. **F,** Rhizines on lower surface.

Peltigera elisabethae Gyelnik

FIGURE 44 A-B.

River valley and ravine system xylicole/terricole. One of Edmonton's most common lichens, forming extensive colonies (>1 m^2) over soil and downed wood. Characterized by large, often shiny grey lobes that lack tomentum, marginal lobules and stress cracks that result in schizidia, flat red-brown apothecia, rhizines aligned in rows, and round interstices on a largely veinless lower surface. Molecular support: one ITS sequence (isolate DLH25 from *Haughland 2020-12*) is 95% identical to *P. elisabethae* GenBank Accession MK517830; Fig. 7 herein).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.501775, -113.6017, 2020, on mossy slope, *D. Haughland 2020-12 & C. Shier* (hb. Haughland); Edmonton, Larch Sanctuary, 53.452705, -113.547888, 2020, terricolous, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/10686/details); Edmonton, Fort Edmonton Park, 53.499113, -113.58172, 2020, on moss, *cwf_michelleh* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/58992454); Edmonton, MacKenzie Ravine, 1976, on soil, *D.C. Lindsay s.n.* (PMAE-B77.24.28); Edmonton, MacKenzie Ravine, 1976, on damp soil, *D.C. Lindsay s.n.* (PMAE-B77.24.171); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on moss, *D. Haughland 2021-13 & S. Toni* (hb. Haughland).

Peltigera evansiana Gyelnik

FIGURE 43 C-D.

River valley and ravine system xylicole/terricole. Frequent in mature mixedwoods, this species is unmistakable due to its combination of large, down-turned, tomentose lobes and abundant laminal, granular isidia. The lower surface resembles *Peltigera praetextata*, with narrow, raised beige veins and simple rhizines. Molecular support: no new sequences generated; species-level support high (Magain et al. 2018).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.52742, -113.514617, 2020, on moist north-facing mineral soil slope toe, along trail, *D. Haughland 2020-36 & P. Williams* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/13878/details); Edmonton, Wolf Willow Creek Ravine, 53.5022, -113.60123, 2020, on moss/soil, *D. Haughland & C. Shier* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14355/details); Edmonton, MacKenzie Ravine, 1976, on soil, *D.C. Lindsay s.n.* (PMAE-B77.24.29); Edmonton, south bank of North Saskatchewan River, opposite 114 St. at Saskatchewan Drive, 1986, on side of trail, *J.E. Marsh 1647* (PMAE-B86.141.51).

Peltigera extenuata (Vain.) Lojka

FIGURE 43 E-F.

Apparently rare river valley terricole. Elsewhere in Alberta this is common on rotten wood (ABMI 2020). Characterized by small, concave, often-polyphyllous lobes with round, laminal soralia, and abundant, pale, flocculent rhizines below. This species intergrades with *Peltigera didactyla* and the under-detected and often misidentified *P. castanea* in many regions of Alberta (ABMI 2020). Molecular support: no new sequences generated, the difficulty diagnosing these morphologically similar species means this species is a priority for sequencing.

Specimen examined & observation. – **CANADA. ALBERTA:** Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-21 & S. Toni* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/17282/details).

Peltigera horizontalis (Hudson) Baumg.

FIGURE 44 C-D.

River valley xylicole/terricole. Intergrading with *Peltigera elisabethae* but far rarer than the latter in Alberta (ABMI 2020). Characterized by the large, smooth, grey, shiny dimpled upper surface, and aligned rhizines below. Discriminated from *P. elisabethae* by its lack of lobules and more numerous, elongate interstices that may form distinct veins. Historical records for the province have largely been revisited and redetermined as other species. Molecular support: a tentatively identified extant collection was sequenced but it grouped with *P. elisabethae*. The difficulty diagnosing these morphologically similar species means this species continues to be a priority for sequencing.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Whitemud Ravine, 1993, on moss, *R. Hastings s.n.* (PMAE accession C93.6.3).

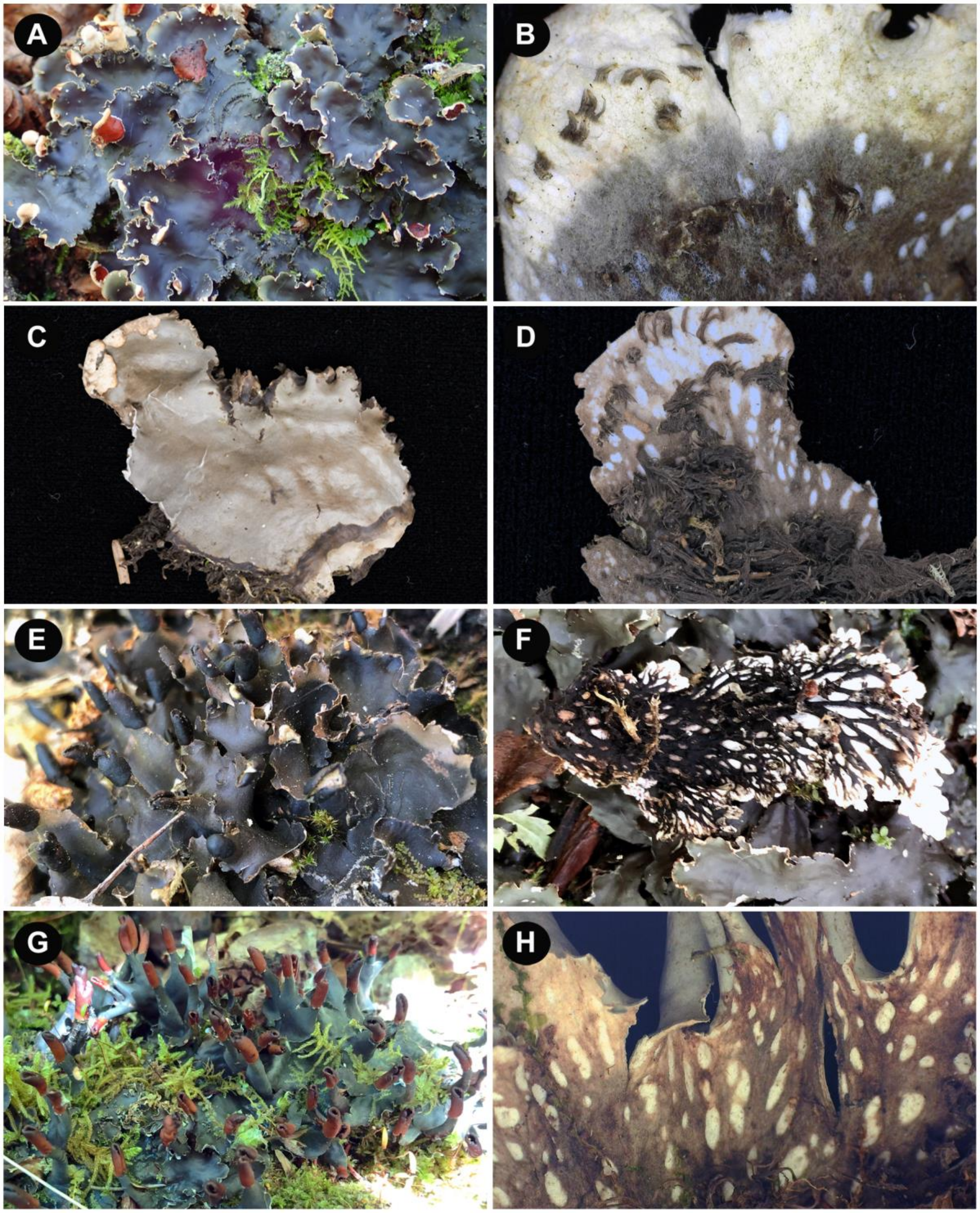

Figure 44. Glabrous *Peltigera* species of Edmonton. Collections imaged in C-D are from outside of Edmonton. **A-B,** *P. elisabethae.* **A,** Fertile colony with abundant lobules, D. Haughland, unvouchered observation. **B,** Lower surface showing poorly-defined veins and aligned rhizines, *Haughland 2020-12*. **C-D,** *P. horizontalis*, ca. 51 km NE of Sandy Lake, ABMI Site 664, 55.85, -112.60, 2015, on downed wood, *S. Venskaitis s.n.* [*ABMI Lichen # 677340*], identification verified using ITS. **C,** Upper surface. **D,** Lower surface showing elongate interstices and aligned rhizines **E-F,** *P. neckeri.* **G,** Fertile colony with hotdog bun, black apothecia, *Haughland* https://naturelynx.ca/sightings/17275/details. **H,** Lower surface with well-defined black veins, *Haughland 2020-59*. **G-H,** *P. polydactylon* subsp. *udeghe.* **G,** Fertile colony, *Haughland 2020-2*. **H,** Lower surface showing well-defined brown veins, *Haughland 2020-50*.

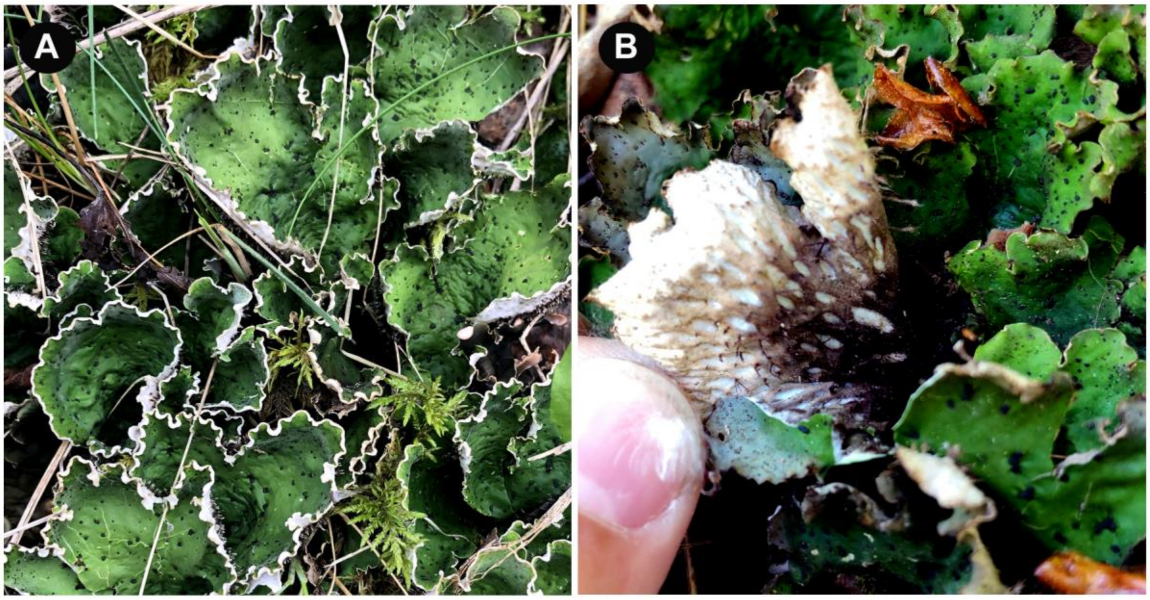

Figure 45. *Peltigera leucophlebia*, Edmonton. **A,** Habit, *Haughland 2020-34*. **B,** Lower surface with well-delimited veins, D. Haughland, https://naturelynx.ca/sightings/17274/details.

Peltigera islandica T. Goward & S.S. Manoharan-Basil

FIGURE 42 C-D.

River valley xylicole/terricole. This species appears to be relatively rare in Alberta in general, and Edmonton in particular (ABMI 2020). Characterized by broad thin lobes, with thin tomentum sometimes limited to the lobe tips, distinct veins that darken to chocolate brown or black, and typically simple rhizines that may become flocculent in part. It intergrades with the more common *Peltigera canina* and *P. praetextata*, as well as the much rarer *P. membranacea* (Ach.) Nyl. in Alberta; work is ongoing to determine if high fidelity traits exist to differentiate these species. Molecular support: a single ITS sequence (isolate DLH21 from *Haughland 2020-1*) is 100% identical to *P. islandica* GenBank Accession KJ413244 and has the *P. islandica/sp 20* hypervariable region from Magain et al. (2018; Fig. 7 herein).

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.52742, -113.514617, 2020, on moist N-facing mineral soil slope toe, along trail, *D. Haughland 2020-37A & P. Williams* (hb. Haughland).

Peltigera leucophlebia (Nyl.) Gyelnik

FIGURE 45.

River valley terricole. This broad-lobed, emerald-green, ruffled species is Edmonton's only confirmed cephalolichen. The cephalodia typically are abundant on the upper surface and are rounded to bulbous. The lower surface has distinct veins and rhizines. When fertile, there are distinct patches of cortex on the underside of the marginal, red-brown, saddle-shaped apothecia (vs. a more continuous cortex on the back of apothecia in the more boreal *P. aphthosa* (L.) Willd.). Molecular support: a single ITS sequence (isolate DLH20 from *Haughland 2020-34*) has 99% percent identity to *P. leucophlebia 2* GenBank Accessions MH734662 and MH734664 from Pardo-De la Hoz et al. (2018; Fig. 7 herein).

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.52742, -113.514617, 2020, on moist N-facing mineral soil slope toe, along trail, *D. Haughland 2020-34 & P. Williams* (hb. Haughland, NatureLynx record https://naturelynx. ca/sightings/13874/details); Edmonton, Rio Park, 53.502290, -113.592075, 2020, *mathew_specht* (unvouchered observation: iNaturalist record https://www.inaturalist.org /observations/42698504); Edmonton, MacKenzie Ravine, 1979, on soil, *D.C. Lindsay s.n.* (PMAE-B77.24.27); Edmonton, Whitemud Park, 1976, *D.C. Lindsay s.n.* (PMAE accession B77.24.108); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on moist trail-side soil, *D. Haughland & S. Toni* (unvouchered observation: Naturelynx record https://naturelynx.ca/ sightings/17274/details).

Peltigera neckeri Hepp ex Müll. Arg.

FIGURE 44 E-F.

River valley and ravine system xylicole/terricole. Frequent in Edmonton's river valley parks, this shiny, grey, etomentose species is differentiated from the more common *Peltigera elisabethae* by the tightly curled black "hot dog bun"-shaped apothecia (vs. flat red-brown apothecia in *P. elisabethae*), darkened rhizines that are not aligned (vs. aligned in *P. elisabethae*), and lack of lobules (vs. often abundantly lobulate *P. elisabethae*). While variable, this species typically has dark, clearly differentiated veins below. Molecular support: a single ITS sequence (isolate DLH23 from *Haughland 2020-59*) has 100% percent identity to *P. neckeri* GenBank Accession AF075725 (Fig. 7).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.527, -113.51442, 2020, epixylic on decayed wooden bridge edge, *D. Haughland 2020-31 & P. Williams* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/13876/details); Edmonton, Wolf Willow Creek, 53.502811, -113.602225, 2020, on downed wood, *D. Haughland 2020-4 & C. Shier* (hb. Haughland); Edmonton, Patricia Ravine, 53.503811, -113.593841, 2020, on wood in moist depression, *D. Haughland 2020-48 & A. Hood* (hb. Haughland); Edmonton, Patricia Ravine, 53.504141, -113.59432, 2020, on downed wood, *Haughland 2020-59 & A. Hood* (hb. Haughland); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on moist trail-side soil, *D. Haughland & S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/17275/details).

Peltigera polydactylon (Necker) Hoffm. **subsp. *udeghe*** Magain, Miadl. & Sérus.

FIGURE 44 G-H.

River valley xylicole/terricole. Like *Peltigera horizontalis*, this species appears to be uncommon across much of Alberta, and is typically found in mature moist and/or riparian forests. It is characterized by red-brown, tightly curled, erect apothecia on elongate lobes that typically have marginal lobules. *Peltigera polydactylon* subsp. *udeghe* was reported in Edmonton by Magain et al. (2016, *B. Goffinet 487*, herb. B. Goffinet[n.v.]; DNA-N1885). Molecular support: a single ITS sequence (isolate DLH26 from *Haughland 2020*-2) has 100% percent identity to *P. polydactylon* subsp. *udeghe* GenBank Accession KX365430 from Magain et al. (2016; Fig. 7 herein).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.5028, -113.602075, 2020, on moss, *D. Haughland 2020-2 & C. Shier* (hb. Haughland); Edmonton, Patricia Ravine, 53.50388, -113.594428, 2020, on downed wood, *D. Haughland 2020-50 & A. Hood* (hb. Haughland).

Peltigera praetextata (Flörke ex Sommerf.) Zopf

FIGURE 46.

River valley xylicole/terricole. Common across Alberta and in Edmonton, but phenotypically plastic and therefore difficult to differentiate from undescribed *Peltigera canina* group species, *P. membranacea, P. ponojensis* and *P. islandica*. Typical morphs have ruffled margins and simple, smooth rhizines with distinct beige veins below. The tomentum is typically restricted to the distal third of the lobes. A key feature found with diligent searching in the majority of specimens is lobules that form along cracks and to a lesser extent along lobe edges, although they should not be viewed as definitive evidence of *P. praetextata*—*P. islandica* and *P. wulingensis* L.F. Han & S.Y. Guo can also be lobulate in Alberta. Molecular support: four ITS sequences (isolates DLH22 from *Haughland 2020-37B*, DLH28 from *Haughland 2020-1* [originally identified as *P. membranacea*], DLH18 from *Haughland 2020-35*, and DLH29 from Haughland 2020-58) have 100% percent identity to published *P. praetextata* GenBank accessioned sequences as well as the *P. praetextata* hypervariable region from Magain et al. (2018; Fig. 7 herein).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.52742, -113.514617, 2020, on moist N-facing mineral soil slope toe, along trail, *D. Haughland 2020-35 & P. Williams* (hb. Haughland), *D. Haughland 2020-37B & P. Williams* (hb. Haughland); Edmonton, Wolf Willow Creek, 53.502638, -113.602538, 2020, terricolous, *D. Haughland 2020-8 & C. Shier* (hb. Haughland); Edmonton, Wolf Willow Creek, 53.50273, -113.602058, 2020, on moss, *D. Haughland 2020-1 & C. Shier* (hb. Haughland); Edmonton, Patricia Ravine, 53.504196, -113.594313, 2020, on downed wood, *D. Haughland 2020-58 & A. Hood* (hb. Haughland); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-16 & S. Toni* (hb. Haughland).

Figure 46. Tomentose *Peltigera* of Edmonton, plate 2 of 2: *Peltigera praetextata*. **A,** Typical habit with ruffled lobes and tomentum limited to tips, *Haughland 2020-58*. **B,** Broad-lobed form resembling *P. membranacea*, *Haughland 2020-1*. **C,** Lobules along margins and cracks, *Haughland 2021-16*. **D,** Lower surface with raised pinkish-beige veins and simple, discrete rhizines, *Haughland 2020-58*.

Peltigera rufescens (Weiss) Humb.

FIGURE 42 E-F.

River valley xylicole/terricole. Characterized by a tomentose to scabrid upper surface, typically with small, grey to brown concave lobes with upturned lobe tips. The lower surface is characterised by low, distinct veins, typically darkening centrally, and abundant rhizines, becoming enmeshed and hedgerow-like centrally. Some specimens are sparsely lobulate, particularly along cracks. Molecular support: while relatively poor, the single ITS sequence (isolate DLH19 from *Haughland 2020-38*) corresponds to *Peltigera rufescens 1*, including containing the hypervariable region from Magain et al. (2018; Fig. 7 herein).

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.52742, -113.514617, 2020, on moist N-facing mineral soil slope toe, along trail, *D. Haughland 2020-38 & P. Williams* (hb. Haughland); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-17 & S. Toni* (hb. Haughland).

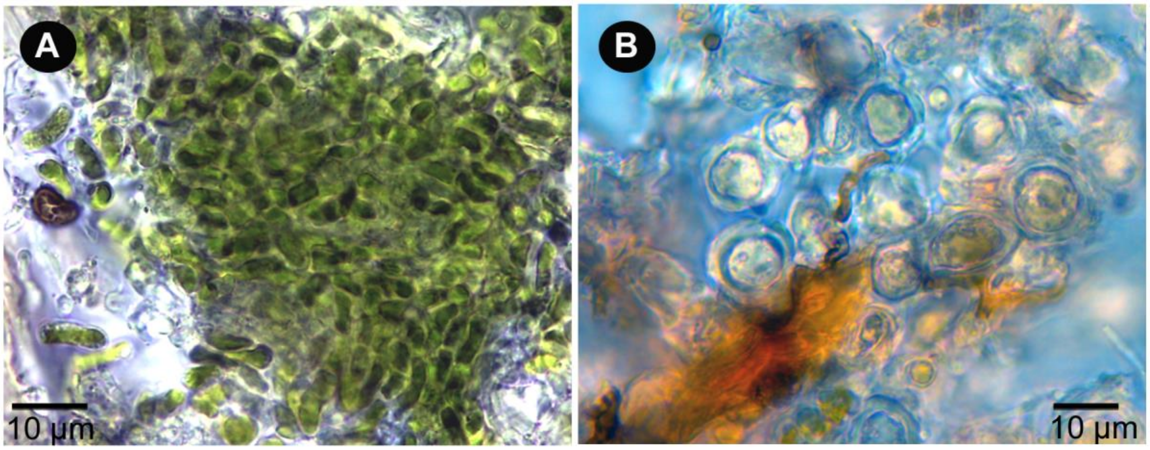

Figure 47. Photobionts from the primary thalli of *Chaenotheca* species found in Edmonton. B is from a collection outside of Edmonton. **A,** Filamentous, relatively small-celled alga *Stichococcus* from *C. trichialis*, *Haughland 2020-11B*. **B,** Thick-walled *Trentepohlia* from *C. hispidula*, ca. 64 km NW of Notikewin, ABMI Site 429, 57.54, -117.80, 2012, on bark, *A. Hillman s.n.* [*ABMI Lichen # 120959*].

GROUP 13. CALICIOID LICHENS AND FUNGI

Nine species. Key literature: McMullin et al. 2018; Selva 2013, 2014; Stordeur et al. 2013; Tibell 1996, 1999. The key below focuses on macroscopic features and niche; definitive identification requires microscopic examination including identification of the photobiont through examination of the primary thallus for lichenized species, and consultation with the resources listed. The two photobionts present in species documented to date are illustrated here (Fig. 47).

1a. Ascomata completely black or brown, lacking pruina; no primary thallus visible; epiphytic on various deciduous trees and shrubs; non-lichenized **2**
1b. Ascomata with pruina on stalk or capitulum; primary thallus often visible on substrate; often associated with *Picea glauca* in moist habitats; lichenized **6**

2a. Stalk swelling in the middle; growing on creviced *Populus* bark........ ***Caliciopsis calicioides***
2b. Stalk cylindrical, capitulum wider than stalk; host plant various **3**

3a. Growing on *Populus*; ascomata 0.5–1 mm tall........ ***Phaeocalicium populneum s.l.***
3b. Growing on *Betula*, *Alnus*, or *Rosa*; ascomata typically <0.6 mm tall........ **4**

4a. Growing on *Alnus*; at least some ascomata branching........ ***Stenocybe pullatula***
4b. Growing on *Betula* or *Rosa*; no ascomata branching **5**

5a. Growing on *Betula*; stalk paler than capitulum; capitulum:stalk ratio approximately 1:3 .... ***Phaeocalicium* aff. *tremulicola***
5b. Growing on *Rosa*; stalk concolorous with capitulum; capitulum:stalk ratio approximately 1:1 .... ***Phaeocalicium* sp. nov. 1**

6a. Primary thallus pale green, lime-green to yellow, farinose to granular **7**
6b. Primary thallus not apparent or squamulose........ **8**

7a. Stalks often >1mm tall and with yellowish-green pruina; capitula globose; growing on sheltered soil, roots and wood on tree bases in riparian and ravine habitats .... ***Chaenotheca furfuracea***
7b. Stalks typically <1 mm tall with light brown pruina; capitula lenticular (shaped like a lens when viewed from the side); growing on the bases of *Picea glauca*, sometimes intermingled with *Chaenotheca furfuracea* .... ***Chaenotheca stemonea***

8a. Primary thallus composed of grey-green waxy squamules; ascomata typically with white pruina .... ***Chaenotheca trichialis***
8b. Primary thallus immersed/invisible; capitula with yellow pruina .... ***Chaenotheca hispidula***

Figure 48. *Caliciopsis calicioides*, on *Populus balsamifera, UoA-CC-90.*

†***Caliciopsis calicioides*** (Fr.) Fitzp.

FIGURE 48.

Parkland epiphyte. This distinctive black calicioid has a central swelling that constitutes the ascogenous region; distally a long narrow beak forms through which the spores are released. It can be found in mature forests in the bark crevices of large-diameter *Populus balsamifera*. It is not clear why it is often excluded from treatments of calicioid lichens and fungi. It is undoubtedly more common than existing reports suggest. We are including it in part due to research suggesting it may be an indicator of healthy, mature forests (Jordal et al. 2014). See Jordal et al. (2014) for additional morphological and habitat images. Chemistry: not investigated. Molecular support: none found, one sequence in GenBank, no new sequences generated.

Specimen examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 148E, 53.587522, -113.640605, 2019, on trunk of *Populus balsamifera, D. Haughland & L. Hjartarson s.n. [UoA-CC-90]* (hb. Haughland); Edmonton, Urban Monitoring Site 163E, 53.6080134, -113.590864, 2019, on trunk of *Populus balsamifera*, *D. Haughland & L. Hjartarson* (unvouchered observation).

Chaenotheca furfuracea (L.) Tibell

FIGURE 49 A.

River valley terricole/basal epiphyte. This is a distinctive species that can be sighted from a distance due to its almost glowing, yellow-green thallus. The dust-like primary thallus produces relatively tall (0.5–1[–2] mm) yellow-pruinose stalks and globose capitula. It is by far the most common lichenized calicioid in Edmonton, and can be found reliably at the bases of *Picea* in river valley parks, where the bole and roots meet moist soil, in shaded nooks. The photobiont is *Stichococcus,* a small, filamentous,

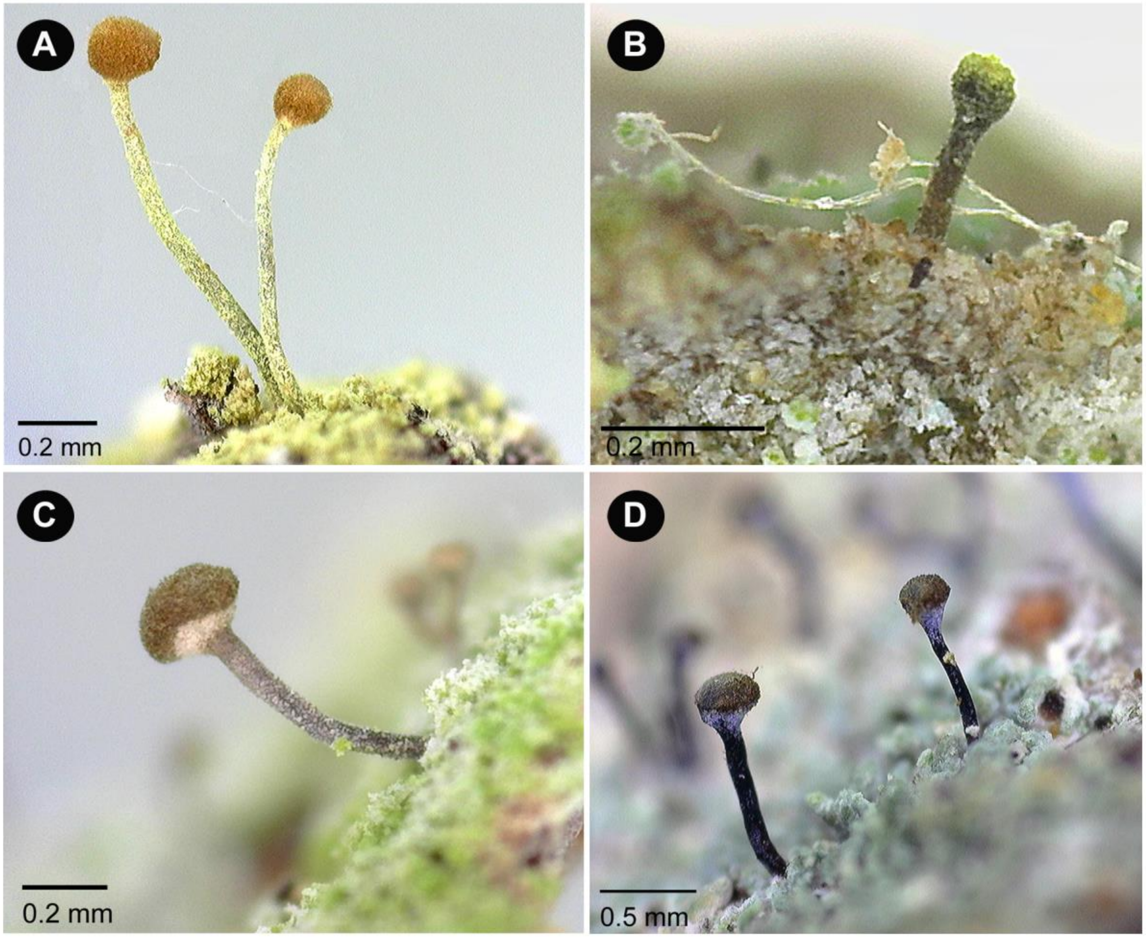

Figure 49. *Chaenotheca* of Edmonton. **A,** *C. furfuracea, Haughland 2020-11B*. **B,** *C. hispidula*, *Haughland 2020-102*. **C,** *C. stemonea*, *Haughland 2020-11A*. **D,** *C. trichialis, Haughland 2019-117*.

bacilliform green alga. Spores are spherical, yellow, to 3 µm in diameter. Care should be taken to check colonies for co-occurring *C. stemonea*, which has brown-grey pruina, lenticular capitula and a PD+ orange primary thallus. Chemistry: all spot tests negative, vulpinic acid, pulvinic acid, pulvinic dilactone (Tibell 1999). Molecular support: high species-level support albeit with limited sampling, reciprocally monophyletic and sister to *C. brachypoda* (Ach.) Tibell (Tibell et al. 2019). No new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502511, -113.601928, 2020, on bark on sheltered large roots of *Picea glauca* snag, *D. Haughland 2020-11B & C. Shier* (hb. Haughland); Edmonton, Patricia Ravine, 53.503283, -113.5932, 2020, on base of mostly decorticate stump, on roots and bark and soil, *D. Haughland 2020-40 & A. Hood* (hb. Haughland); Edmonton, Kinnaird Ravine, 53.558778, -113.462953, 2020, on base of *Picea glauca*, on roots and bark and soil, *D. Haughland 2020-26 & P. Williams* (hb. Haughland); Edmonton, Hawrelak Park, 53.52, -113.54, 2012, on sheltered soil at base of tree, *D. Haughland 2012-393* (hb. Haughland); Edmonton, Larch Sanctuary, 53.449813, -113.551919, 2020, on base of mature *Betula* tree, *D. Haughland* (unvouchered observation: NatureLynx record); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on decayed stump, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/17450/details).

Chaenotheca hispidula (Ach.) Zahlbr.

FIGURE 49 B.

River valley epiphyte. Apparently rare in Edmonton, this diminutive epiphyte is diagnosed by short ascomata (~0.5 mm), yellow pruina on the upper stalk and capitulum, an association with *Trentepohlia*, and globose spores 6–7 µm in diameter. Spore size should be checked to definitively exclude

C. olivaceorufa Vain., a similar species not yet detected in Alberta, with spores 3.0–4.5 µm in diameter (McMullin et al. 2018). Chemistry: all spot tests negative, vulpinic acid in pruina (Tibell 1999). Molecular support: not yet assessed at species-level, a single sequence basal to the *Chaenotheca* clade (Tibell 2001), no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Kinnaird Ravine, 53.558953, -113.459253, 2020, on bark of bole of *Picea glauca* snag, *D. Haughland 2020-102* (hb. Haughland).

Chaenotheca stemonea (Ach.) Müll. Arg.

FIGURE 49 C.

River valley epiphyte. This species may be uncommon or under-detected. It resembles *Chaenotheca furfuracea* but has shorter stalks that are brown-grey-pruinose (vs. yellow-green in *C. furfuracea*) and lenticular capita (vs. globose in *C. furfuracea*). As with *C. furfuracea*, the photobiont is *Stichococcus*, a filamentous, bacilliform green algae (Fig. 47A). Spores are spherical, yellow, to 3–4 µm in diameter. Chemistry: PD+ yellow to reddish, K-, KC-, C-, barbatic and obtusatic acid (Tibell 1999). Molecular support: two sequences in GenBank, not assessed at species-level, no new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502511, -113.601928, 2020, on bark on sheltered large roots of *Picea glauca* snag, *D. Haughland 2020-11A & C. Shier* (hb. Haughland).

Chaenotheca trichialis (Ach.) Th. Fr.

FIGURE 49 D.

River valley epiphyte. Rare in Edmonton, this species typically has a unique waxy, blue-green verrucose to squamulose thallus, producing shiny, black-stalked ascomata. The lower excipulum and sometimes the upper stalk may be white-pruinose. The photobiont is *Stichococcus* (Fig. 47A). Spores yellow, globose, up to 5.5 µm in diameter, slightly larger than indicated in the literature (Tibell 1999). Chemistry: all spot tests negative, two unidentified substances (Middelborg & Mattsson 1987). Molecular support: weak at species-level, paraphyletic with *Chaenotheca xyloxena* Nádv. (Tibell et al. 2019). No new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.50315, -113.602186, 2019, on bark on sheltered large roots of *Picea glauca* snag, *D. Haughland et al. 2019-117* (hb. Haughland); Edmonton, Kinnaird Ravine, 53.558953, -113.459253, 2020, on trunk of *Picea glauca* snag, *D. Haughland 2020-101* (hb. Haughland).

†***Phaeocalicium populneum*** Brond. ex Duby *s.l.*

FIGURE 50 A.

River valley and parkland epiphyte. Common on *Populus* across Alberta, from saplings to mature trees. This species is characterized by brown to black stalks bearing cupulate to lenticular capitula, periclinal hyphae forming the excipulum and uniseptate, brown spores with walls that range from smooth to minutely areolate in ornamentation at 1000x. Across Alberta, this species is highly variable in spore size, ascoma height and even capitulum shape, and may include multiple, undescribed species (Haughland et al, in prep.). Edmonton material: ascomata to 0.5–1.0 mm tall, black globose to lenticular capitulum, rarely branching. The spores are brown, uniseptate, septum pigmented and slightly constricted or wavy, spore wall smooth to faintly areolate ornamented, occasionally becoming 3-septate, 13–16 × 4.5–5.5 µm (only typical uniseptate spores measured). Chemistry: all Edmonton collections had purple or blackish pigments in the lower stalk that turned K+ aeruginose green, either in small patches or the entire lower stalk. Otherwise, the stalk and capitulum are red-brown in squash, swelling but K-. The collection from the rural Ardrossan Air Quality Monitoring Station was the exception, and it was both more robust (similar to much of Alberta material from non-urban settings) and K-. Substances detected by TLC: not investigated. The literature is mixed on chemistry; Tibell (1996, 1999) and Selva (2014) indicate K- while Aguirre-Hudson & Spooner (2019) and Nimis (2016) report K+green reaction in the stalk. Molecular support: additional molecular work is needed to determine if the urban phenotype is in response to growth in an urban environment or indicative of a different genotype. Species-level support for *Phaeocalicium populneum s.s.* has not been assessed phylogenetically, two sequences in GenBank, sequencing in progress with S. Selva and T. McMulllin.

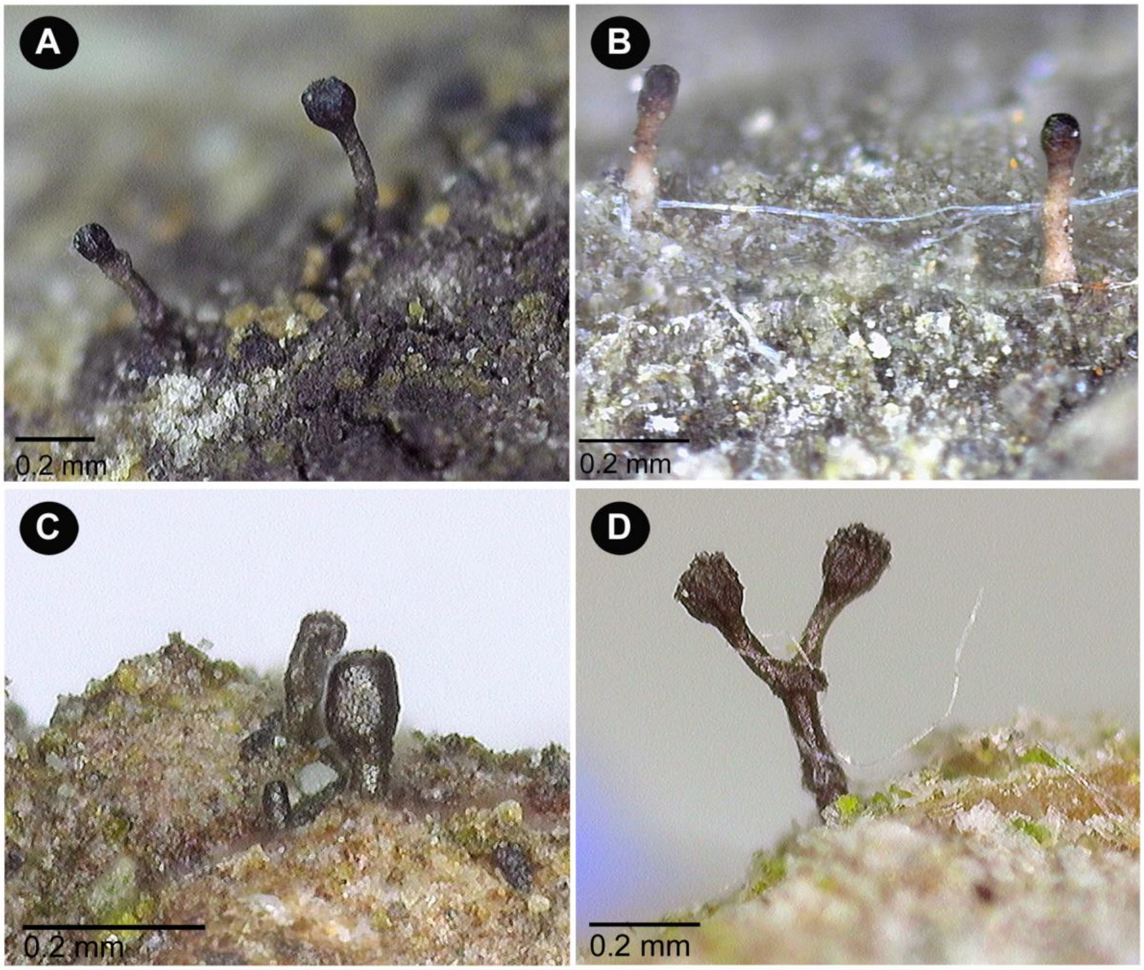

Figure 50. Non-lichenized calicioid fungi of Edmonton. **A,** *Phaeocalicium populneum s.l.*, *Haughland 2013-247*. **B,** *Phaeocalicium* aff. *tremulicola*, *Haughland 2013-192*. **C,** *Phaeocalicium sp. nov.* 1, *Haughland 2017-376*. **D,** *Stenocybe pullatula*, *Haughland 2020-15B*.

Representative specimens examined. – **CANADA. ALBERTA:** Ardrossan, Air Quality Monitoring Station, 53.55468, -113.143238, 2019, on trunk of *Populus balsamifera*, *D. Thauvette & J. Birch s.n. [UoA-CC-89]* (hb. Haughland); Edmonton, Whitemud Creek, 53.50, -113.56, 2013, on *Populus* branches, *D. Haughland et al. 2013-247* (hb. Haughland); Edmonton, Whitemud Creek, 53.501458, -113.560761, 2020, on *Populus balsamifera* dead branch, *D. Haughland 2020-62 & P. Williams* (hb. Haughland); Edmonton, Buena Vista Meadow off-leash park, 53.517138, -113.549195, 2020, on *Populus tremuloides* dead vertical branch, *D. Haughland 2020-92 & P. Williams* (hb. Haughland); Edmonton, Buena Vista Meadow off-leash park, 53.519725, -113.545738, 2020, on *Populus tremuloides* live horizontal branch, *D. Haughland 2020-93 & P. Williams* (hb. Haughland); Edmonton, Sir Wilfrid Laurier Park, 53.50834, -113.560926, 2019, on bark of large downed *Populus*, *D. Haughland 2019-115A & P. Williams* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on tree bark, *D.C. Lindsay s.n.* (PMAE-B77.24.170).

†Phaeocalicium* aff. *tremulicola*** (Norrlin ex Nyl.) Tibell

FIGURE 50 B.

River valley epiphyte. A single collection was made of a diminutive *Phaeocalicium* on live *Betula* twigs. It is closest to *Phaeocalicium tremulicola* (Norrlin ex Nyl.) Tibell anatomically, however, *P. tremulicola* has only been documented on *Populus tremula* (Tibell 1999) and *Hamamelis virginiana* (Selva 2014). Edmonton material: ascomata 0.3–0.4 mm tall, pale brown, with globose to obovate capitula. The stalks are pale pink-brown in squash to almost hyaline at the base with an outer hyaline layer, and the excipulum has an outer layer of thick-walled isodiametric cells. The spores are brown, smooth, broadly fusiform, with tips pointed to mucronate; most commonly they are uniseptate, occasionally becoming 3-septate, slightly constricted at the well-pigmented septa, 12–15 × 5–6 µm. Chemistry: not investigated. Molecular support: in progress, S. Selva has examined the material and noted "not *P. tremulicola*, possibly a new species" (S. Selva, pers. comm. 2020). No sequences of *P. tremulicola s.s.* in GenBank, sequencing with S. Selva and T. McMullin is in progress.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Whitemud Ravine, 53.50, -113.56, 2013, on live *Betula papyrifera* twig, *D. Haughland et al. 2013-192* (hb. Haughland).

†Phaeocalicium sp. nov*. 1,** ined. Haughland

FIGURE 50 C.

River valley and parkland epiphyte. This undescribed species was first found on dead *Rosa* branches in the Parkland Natural Region at an ABMI site. Searches by the senior author have found it to be common on relatively tall, dead (rarely live) *Rosa* branches in at least partially protected habitats in the river valley parks of Edmonton. Host *Rosa* that could be identified to species were *R. woodsii*. To date we do not know of any populations outside of Alberta, despite searches by the senior author in Saskatchewan, Yukon Territory, and the Northwest Territories in similar habitat. To our knowledge this is the first calicioid found on *Rosa*. We provide a basic description to alert others to this unique calicioid so that additional populations may be sought. Edmonton material: dark brown ascomata often growing near branch nodes, to 0.4 mm tall with the cupulate capitulum typically comprising ≥50% of the height. Development of the capitulum starts before stalk elongation. The stalk has an outer hyaline coat over isodiametric cells that continue upwards to form the outer excipulum, becoming stretched horizontally around upper edge of the capitulum. Asci are cylindrical, 75–88 µm long, spores brown, 10–15 × 4.5–6 µm, mostly uniseptate, some spores forming two additional septa even within the ascus, spore wall with faint, minute areolate ornamentation visible at 1000x. While most spores remain within the asci, loose spores are visible and may form a tall mazaedial mass in some stalks. Chemistry: not investigated. Molecular support: sequencing is in progress to confirm the phylogenetic placement of this species with T. McMullin and S. Selva.

Representative specimens examined. – **CANADA. ALBERTA:** Edmonton, Terwillegar Park, 53.4788, -113.6218, 2017, on dead standing stem of *Rosa* cf. *woodsii*, *D. Haughland 2017-375 & P. Williams* (hb. Haughland); Edmonton, Buena Vista Meadow, 53.521469, -113.548092, 2017, on dead standing stem of *Rosa woodsii*, *D. Haughland 2017-376* (hb. Haughland); Edmonton, Buena Vista Meadow, 53.521127, -113.548707, 2017, on live stem of *Rosa woodsii*, *D. Haughland 2017-377 & D. Thauvette* (hb. Haughland).

†***Stenocybe pullatula*** (Ach.) Stein

FIGURE 50 D.

River valley epiphyte. Common and variable calicioid fungus on *Alnus*, characterized by short ascomata (typically <0.6 mm tall but in some material in Alberta exceeding 1 mm), branching, with narrow, vertically striate capitula. Spores average 15–20 × 4.0–5.5 µm, brown, smooth to minutely ornamented, fusiform (with pointed tips), 1–3-septate, septa typically poorly pigmented but occasionally dark and constricted. Edmonton material fits within the range of variation observed across Alberta. Chemistry: all spot tests negative, no secondary metabolites detected (Tibell 1999). Molecular support: genus and species-level not assessed phylogenetically, three sequences in GenBank, a single sequence forms a highly supported branch sister to single sequence of *Phaeocalicium populneum* (Tibell & Vinuesa 2005).

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Whitemud Ravine, 53.491661, -113.55914, 2020, on bark of dead *Alnus* snag, *D. Haughland 2020-15B & P. Williams* (hb. Haughland); Edmonton, Whitemud Park, 53.50, -113.56, 2013, on *Alnu*s branches, *D. Haughland 2013-248 & S. Selva* (hb. Haughland); Edmonton, Whitemud Park, 53.501717, -113.560812, 2020, on *Alnu*s *incana* subsp. *tenuifolia* branches, *D. Haughland 2020-63 & P. Williams* (hb. Haughland).

GROUP 14. *CLADONIA*

Fifteen species. Key literature: Ahti & Stenroos 2013; Brodo et al. 2001; Goward 1999. A diverse genus of over 90 species in Alberta, *Cladonia* is underrepresented in Edmonton in both diversity and biomass. Given these are fairly detectable species, we suspect the dearth of *Cladonia* in our urban environment is real; while additional species are likely to be found (including perhaps *C. rei* Schaerer, Haughland et al. 2018), the depauperate flora documented to date is reminiscent of poor boreal sites. We employ a slight simplification of the morphogroup system of Goward (1999), while maintaining Goward's original groups to aid the user in working between the more inclusive keys to species of British Columbia (Goward 1999) and Alberta (Haughland, unpublished), and these species-limited keys. Spot tests are helpful for identification, particularly for novices learning to differentiate the pale yellow of usnic acid-producing species. This is a difficult group both morphologically and phylogenetically, with many species as currently circumscribed polyphyletic with similar species (e.g., Pino-Bodas et al. 2011, 2015; Stenroos et al. 2002, 2018). Expect future taxonomic revisions.

Key to the *Cladonia* Groups

1a. Podetia absent; thallus consisting entirely of primary squamules. In Edmonton, this group is composed of immature thalli that cannot be identified to species using morphology or chemistry .... Group A - *Cladonia* spp., not treated further
1b. Podetia present; primary thallus either crustose or squamulose or missing **2**

2a. Podetia richly branched (more than two times)..**Group B**
2b. Podetia unbranched to slightly branched (once or twice) **3**

3a. Some podetia tips opening by a gaping hole, look for in-rolled margins around the hole as confirmation that the hole developed as part of the podetium (vs. a broken podetium) ....**Group C**
3b. Podetia tips closed...**4**

4a. Podetia solid/compact throughout, longitudinally ribbed or fibrous AND esorediate AND cupless ....**Group D**
4b. Podetia not longitudinally ribbed or fibrous, stalk hollow and tubular, may be sorediate or cupped **5**

5a. Podetia distinctly cupped, cups typically symmetrical and wider than the stalk **6**
5b. Podetia wand-like to antler-like, typically either lacking cups, cups shallow and no wider than the stalk, or with sparse, irregular, oblique cups..**8**

6a. Cortex with a distinct yellowish cast (usnic acid present); apothecia red or less commonly beige to brown...Group E – None known from Edmonton at present, not treated further
6b. Cortex not distinctly yellowish (usnic acid absent or in low concentration); apothecia never red............**7**

7a. Podetia bearing at least some soredia (check upper portions) .... **Group F**
7b. Podetia lacking soredia.. **Group H**

8a. Podetia bearing soredia or corticate granules, or both (check upper portions) ....**Group I**
8b. Podetia lacking soredia and corticate granules (note: dorsiventral squamules and/or microsquamules may be present) .... **Group J**

Cladonia Group B: branched > 2 times

1a. Podetia lacking a cortex: podetial surface appressed-fibrous under the microscope (the "reindeer" lichens) ....*Cladonia arbuscula* **subsp.** ***mitis***
1b. Podetia corticate at least in part – matte or shiny, but fibrous hyphae not visible under the microscope .**2**

2a. Podetia tips and/or branch axils bearing flaring cups, these closed but sieve-like, doily-like, or lacerate OR basal portions of main podetia more or less distinctly flattened in cross-section; terminal portions of the supporting branches somewhat flattened or longitudinally lacerate, bearing abundant apothecia at the tips .... ***Cladonia multiformis***
2b. Podetia uncupped, terminal portions of branches with narrow openings or lacerations into the interior, these restricted to branch axils, not at all sieve-like; terminal portions of podetia in part lacking a cortex, often with soredia, corticate granules and/or detachable microsquamules, these sometimes extending downward into the middle or basal portions of the podetia ....***Cladonia scabriuscula***

Cladonia Group C: podetia tips with open axils or open cups

1a. Largest apical cups open and distinctly flaring; podetia in Edmonton stout, seldom branching; UV+ blue-white, PD- ....***Cladonia crispata* var. *crispata***
1b. Apices open but not flaring OR cups with seive-like perforations; podetia in Edmonton relatively tall, often branching; UV-, PD+ red to orange .... **Go to Group B Key couplet 2**

Cladonia Group D: podetia longitudinally ribbed or fibrous

1a. Apothecia beige or red; common on lignum and downed logs; podetia with a distinctly yellowish cast (usnic acid), K-, KC+ yellow **2**
1b. Apothecia dark brown; on soil, mossy rock or anthropogenic substrates; podetia grey, not at all yellowish, K+ yellow or red, KC- ....***Cladonia cariosa***

2a. Apothecia beige to pale brown ....***Cladonia botrytes***
2b. Apothecia red ....***Cladonia cristatella***

Cladonia Group F: podetia cupped, sorediate, grey, green or brown

1a. Podetia more green than grey, not melanotic (blackening); soredia fine or coarse; PD+ orange to red, UV-..**2**
1b. Podetia greyish-white to grey-green, often partially melanotic especially at the base; soredia granular; PD- or PD+ orange to red, UV+ purple to white; not yet found within Edmonton, but confirmed locations close to study boundary .... *Cladonia* spp. including *C. grayi* G. Merr. ex Sandst. & *C. merochlorophaea* Asahina see discussion under *Cladonia chlorophaea*

2a. Podetia with floury, fine soredia, >1 layer deep covering stalk; outer and inner cup, cups typically abruptly flaring with clear delimitation between cup and stalk .... ***Cladonia fimbriata***
2b. Podetia with granular, coarse soredia, typically patchy or sparse; cup flaring gradually from the podetium..***Cladonia chlorophaea***

Cladonia Group H: podetia cupped, esorediate

1a. Podetia commonly >1.5 cm tall, variable but often with relatively large, bulbous, brown apothecia on the margins of the cups, secondary squamules absent or limited to the stalk, inside of the cup smoothly corticate ....***Cladonia gracilis* subsp. *turbinata***
1b. Podetia typically <1.5 cm tall, squat, with peltate, pancake-like squamules inside the cup....................... ....***Cladonia pyxidata***

Cladonia Group I: sorediate podetia lacking regular cups

1a. Podetial soredia continuous, not at all borne in discrete patches; color consistent throughout podetium **2**
1b. Podetial soredia discontinuous, at least in part borne in discrete patches; podetia often mottled green and white **4**

2a. Podetia green, wand-like (tapered from bottom to top); primary squamules present and conspicuous; cortex of the podetium often intact and esorediate basally; PD+ orange to red ....***Cladonia coniocraea***
2b. Podetia pale mint-green to grey-green, often with swollen, club-shaped or antler-shaped tips; primary squamules various, but often small to absent; PD- or PD+ orange to red **3**

3a. Podetia pale minty-green, often slightly swollen or club-shaped at the very tips, occasionally branched near the terminus, often tipped with small red apothecia or pycnidia; PD-, UV- or UV+ faint white ....***Cladonia macilenta* var. *bacillaris***
3a. Podetia grey-green, typically sorediate over entire podetium, forming irregular, oblique cups or antler-like proliferations, apothecia brown and pycnidia black but both very rare; PD+ orange to red, UV-.............. ....***Cladonia subulata***

4a. Podetia <2 cm tall, variable from wand-like to terminating in small cups with narrow, pointed proliferations like a jester-cap; most common chemotype is PD-, UV+ faint white or UV-........ ***Cladonia rei***
4b. Podetia commonly >2.5 cm tall, most of the cortex intact with clearly delimited patchy soralia towards the tip; PD+ red to orange, UV- .... ***Cladonia cornuta* subsp. *cornuta***

Cladonia Group J: podetia uncupped, esorediate

1a. Apothecia beige to pale brown ....***Cladonia botrytes***
1b. Apothecia red ....***Cladonia cristatella***

Cladonia arbuscula* subsp. *mitis (Sandst.) Ruoss
(≡ *Cladonia mitis* Sandst., ≡ *Cladina mitis* (Sandst.) Mong.)

FIGURE 51 D.

River valley and ravine system xylicole. This is the most common reindeer lichen in Alberta, occurring on lignum, soil, and moss. In Edmonton it is rare and poorly developed, and has been found only on lignum. Primary thallus crustose, evanescent, forming ecorticate podetia to 12 cm tall that are densely branched. The podetia typically are yellowish-grey, with an almost transparent stereome at the base. The tips branch 3–4 times, and often form either brown apothecia or pycnidia. Chemistry: K-, KC+ yellow, C-, UV_{254}-, PD-. Substances detected by TLC: usnic acid, isousnic acid, ±rangiformic acid (trace). Molecular support: still incompletely understood at species-level (Ahti & Stenroos 2013), forming a monophyletic clade nested within *Cladonia arbuscula* (Wallr.) Flot. (Piercey-Normore et al. 2010).

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502711, -113.60241, 2020, lignicolous on downed log, *D. Haughland 2020-10B & C. Shier* (hb. Haughland); Edmonton, W of Whitemud Park, along Grandview Stairs, 53.502357, -113.552249, 2020, on lignum, *L. Hjartarson* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12334/details).

Cladonia botrytes (K. G. Hagen) Willd.

FIGURE 51 A.

River valley and ravine system xylicole. Primary thallus squamulose, developing pale yellow, esorediate podetia to 2(–3) cm tall that can be moderately branched in upper parts. The podetia always terminate in ochraceous to pale-brown apothecia. This is a common boreal species that may be tolerant of moderately polluted environments (Ahti & Stenroos 2013). Chemistry: K-, KC+ yellow, PD-, $UV_{254/365}$-. Secondary metabolites detected by TLC: usnic acid, barbatic acid. Molecular support: strong, multiple sequences cluster in a well-supported branch in the Clade “*Ochroleucae*” (Stenroos et al. 2018). No new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, on downed wood, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12143/details); Edmonton, MacKenzie Ravine, 53.529146, -113.558821, 2020, on downed log, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14205/details); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.101); Edmonton, MacKenzie Ravine, 1976, on rotten log, *D.C. Lindsay s.n.* (PMAE-B77.24.163); Edmonton, MacKenzie Ravine boardwalk, 53.528875, -113.558827, 2021, on decayed *Picea glauca* log, *D. Haughland 2021-8* (hb. Haughland).

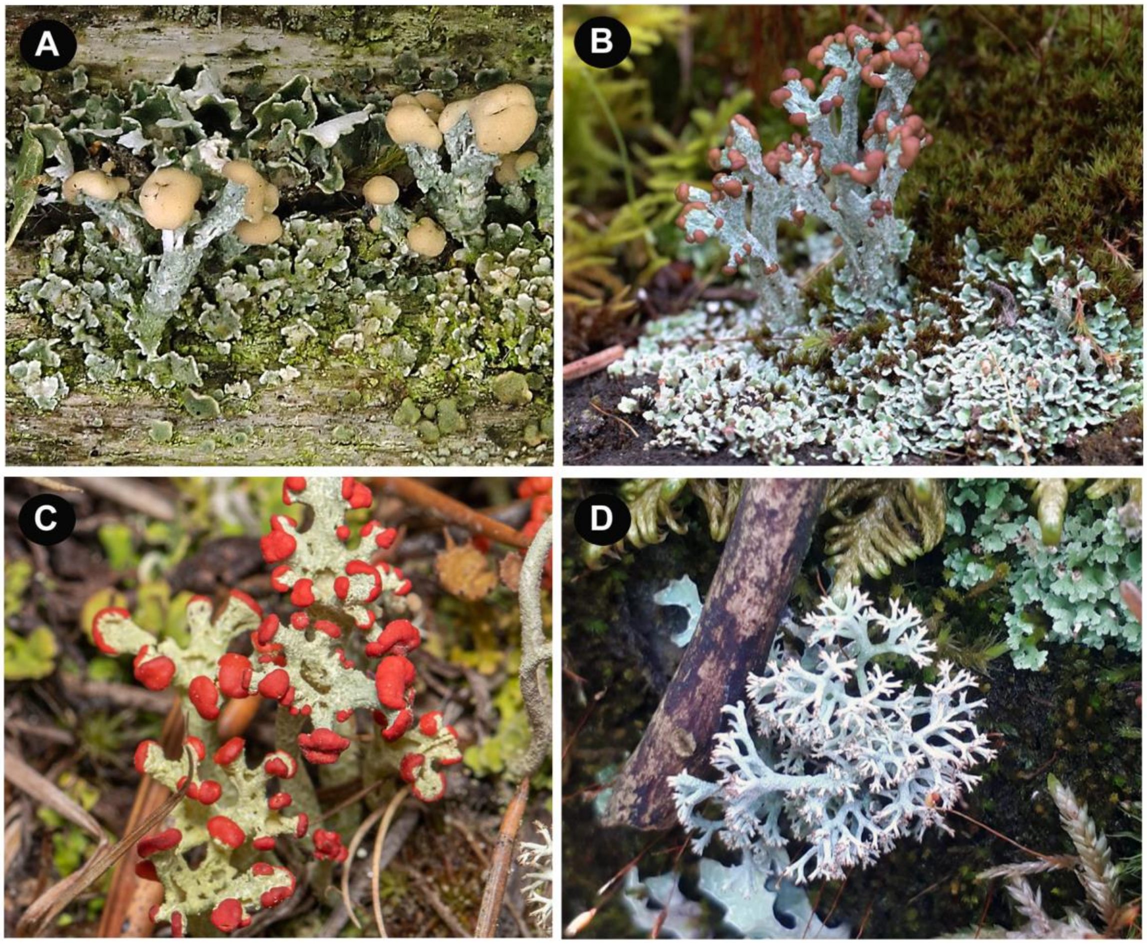

Figure 51. Fibrous and shrubby *Cladonia* of Edmonton. **A,** *C. botrytes,* growing on lignin of large log in river valley, *Haughland 2021-8.* **B,** *C. cariosa, Dueck* https://naturelynx.ca/sightings/9803/details. **C,** *C. cristatella,* Morinville region north of Edmonton, *Fielder* https://naturelynx.ca/sightings/15528/details. **D,** *C. arbuscula* subsp. *mitis, Hjartarson* https://naturelynx.ca/sightings/12334/details.

Cladonia cariosa (Ach.) Sprengel

FIGURE 51 B.

Apparently rare ravine terricole. Primary squamules tend to be small, to 2–3 mm across, convex (like clamshells), and persistent. When podetia are absent, confident identification without genetics is not possible because of overlapping chemistry with immature squamules of other *Cladonia*. Podetia to 3 cm tall, slender, made of solid, grey to grey-green, fissured cartilaginous strands, branching distally and always bearing brown apothecia. No vegetative propagules present. This species apparently can thrive in anthropogenically altered habitats, commonly growing on disturbed soil. Similar species include *Cladonia symphycarpa* (Flörke) Fr. and related, currently undescribed lineages (Lewis 2022: podetia may be similar, but primary squamules are larger and thicker, growing to 1 cm long, often reflexed when dry; chemistry may include psoromic or norstictic acids) and *C. acuminata* (Ach.) Norrlin (primary squamules similar but podetia wand-like, not fibrous, typically unbranched, lacking apothecia, chemistry atranorin ± norstictic, connorstictic acids). Chemistry: PD+ yellow, orange or red, K- or K+ dingy brown or yellow, KC-, UV-. Secondary metabolites detected by TLC: atranorin, ±fumarprotocetraric acid, protocetraric acid, rangiformic acid, and norrangiformic acid. Molecular support: a genotyping-by-sequencing study provides strong support for this species (Lewis 2022). Previous phylogenetic work using multiple loci left some phenotypically-similar lineages unresolved (Pino-Bodas et al. 2012).

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Mill Creek Ravine South, 53.509826, -113.463148, 2019, on landscaping fabric over rocks, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/9803/details); Edmonton, Mill Creek Ravine South, 53.511504, -113.465939, 2020, terricolous, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/13503/details); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-19 & S. Toni* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/17285/details).

Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel

FIGURE 52 A-B.

River valley and ravine system xylicole and epiphyte. Primary thallus squamulose, podetia to 4 cm tall, characterized by broad green to blue-green cups with granular soredia in the upper portion, subcontinuously corticate towards the base. Apothecia are fairly common, on short marginal proliferations. The *Cladonia chlorophaea* group generally requires chemistry to identify with certainty, although with experience color can discriminate this species from the more acid-tolerant and typically paler *C. grayi*. (with grayanic acid and ±fumarprotocetraric acid, PD+ orange or PD-, UV_{254}+ violet). and *C. merochlorophaea* (with merochlorophaeic acid, 4-O-methylcryptochlorophaeic acid, cryptochlorophaeic acid and ±fumarprotocetraric acid, PD+ orange or PD-, UV_{254}+ blue-white). Even with chemistry, identification remains challenging. Morphology intergrades with the trumpet-shaped, farinose-sorediate *C. fimbriata* and the esorediate *C. pyxidata*, and the chemistry of these three is identical. Chemistry: K- or K+ dingy brown, KC-, C-, PD+ orange, UV_{254}-. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: unresolved within the Clade "*Cladonia*", subclade "*Graciles*" (Stenroos et al. 2018), under further investigation (Ahti & Stenroos 2013). No new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.520733, -113.54158, 2020, on *Betula* base, *D. Haughland 2020-19A* (hb. Haughland); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.105); Edmonton, Whitemud Park, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.121); Edmonton, MacKenzie Ravine, 1976, on rotting log, *D.C. Lindsay s.n.* (PMAE-B77.24.186); Edmonton, MacKenzie Ravine, 53.52904, -113.5605, 2020, on stump on edge of mineral seep, *D. Haughland 2020-107* (hb. Haughland, NatureLynx record https://naturelynx.ca/sightings/14204/details).

Cladonia coniocraea (Flörke) Sprengel

FIGURE 53 A.

River valley and ravine system xylicole and epiphyte. A variable, wand-like *Cladonia* with a persistent primary thallus of green squamules. The podetia are 1–3 cm tall, mint-green to grey-green, unbranched and slender, often tapering to the tip, typically continuously sorediate except near the podetial base where the cortex remains intact. Apothecia are infrequent, brown, but may be found in very mature specimens that develop narrow cups at the podetial tips. This species can be separated from *C. subulata* by the latter's more continuous, often grey-brown soredia, typically evanescent primary squamules, and a proclivity to form antler-like branches or proliferations from cups. Unfortunately, intermediates exist, and chemistry does not distinguish them. Another species that may co-occur is *C. rei*, but in Alberta, *C. rei* and is a grassy-green color (vs. mint-green), and almost always lacks furmarprotocetraric acid, instead producing only homosekikaic acid ± sekikaic acid, (PD-, UV_{254}- or +dull white; Haughland et al. 2018). Chemistry: PD+ orange, UV_{254}-, K- or K+ dingy brown, C-, KC-. Substances detected by TLC: fumarprotocetraric acid, sometimes with traces of unknown compounds. Molecular support: strong species-level support within the *C. gracilis* group if synonymy with *C. ochrochlora* Flörke and *C. cornuta* subsp. *groenlandica* (E. Dahl) Ahti is accepted (Pino-Bodas et al. 2011, Stenroos et al. 2018). No new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton Hawrelak Park, 53.52, -113.54, 2017, on decaying wood under *Betula papyrifera*, *D. Haughland et al.* (unvouchered observation); Edmonton, Whitemud Ravine, 53.499008, -113.560730, 2020, on tree base, *D. Haughland & P. Williams s.n.* (unvouchered observation; NatureLynx record https://naturelynx.ca/sightings/12608/details); Edmonton, Whitemud Park, 53.503845, -113.554541, 2020, on moss over wood, *D. Haughland s.n.* (unvouchered observation; https://naturelynx.ca/sightings/13871/details); Edmonton, 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.104).

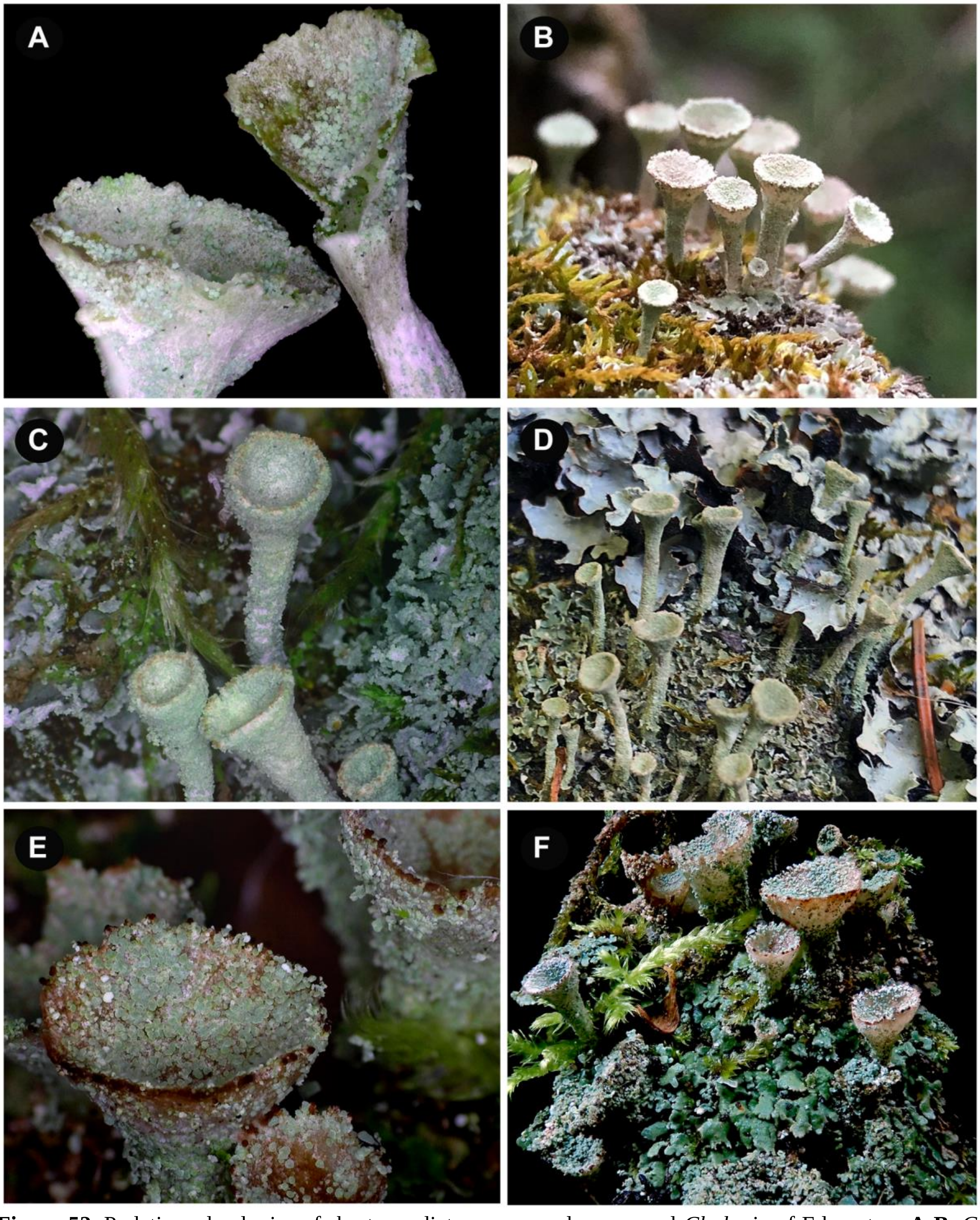

Figure 52. Podetia and colonies of short sorediate or squamulose cupped *Cladonia* of Edmonton. **A-B,** *C. chlorophaea,* growing on stump, with sparse, granular soredia, *Haughland 2020-107*. **C-D,** *C. fimbriata.* **C,** Cups with multiple layers of finer-grained soredia, *Haughland 2021-24.* **D,** Colony on base of *Betula*, *Haughland* https://naturelynx.ca/sightings/12605/details. **E-F,** *C. pyxidata,* growing on base of *Betula*, with peltate squamules in the cup, *Haughland 2020-19B.*

Figure 53. Wand-like *Cladonia* of Edmonton. **A,** *C. coniocraea*, *Haughland* https://naturelynx.ca/sightings/13871/details. **B,** *C. cornuta* subsp. *cornuta*, *Fielder* https://naturelynx.ca/sightings/16159/details. **C,** *C. macilenta* var. *bacillaris*, *Toni* https://naturelynx.ca/sightings/12140/details. **D,** *C. scabriuscula*, *Haughland* https://naturelynx.ca/sightings/10685/details. **E,** *C. subulata*, *Haughland 2021-15*.

Cladonia cornuta (L.) Hoffm. **subsp. *cornuta***

FIGURE 53 B.

River valley and ravine system terricole and xylicole. A common and often prolific wand-like *Cladonia* with a persistent to more often evanescent primary thallus. This species forms tall (to 8 cm) unbranched podetia with round patchy soralia in the upper third. Podetia vary from green to brown to spotted (shade-form?) due to a patchy algal layer. Chemistry: PD+ orange, UV_{254}-, K- or K+ dingy brown, C-, KC-. Substances detected by TLC: fumarprotocetraric acid, sometimes with traces of unknown compounds. Molecular support: good species-level support based on limited sequences within the Clade "*Cladonia*", subclade *"Graciles*" (Pino-Bodas et al. 2011, Stenroos et al. 2018). No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 2020, lignicolous on downed log, 53.502711, -113.60241, *D. Haughland & C. Shier s.n.* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14347/details); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.97); Edmonton, MacKenzie Ravine, 1976, on rotting log, *D.C. Lindsay s.n.* (PMAE-B77.24.184).

Cladonia crispata (Ach.) Flot. **var. *crispata***

FIGURE 54 A-B.

River valley and ravine system xylicole. Primary thallus squamulose, often with barrel-shaped pycnidia forming laminally on the squamules. The open-cupped podetia are 2–6 cm tall, esorediate, and often proliferate from the edges. Most diagnostic however are the UV+ open gaping funnels and cups, often with dentate, pycnidiate margins. Chemistry: K-, KC-, C-, UV_{254}+ white, PD-. Secondary metabolites detected by TLC: squamatic acid. Molecular support: species-level support low, polyphyletic as currently phenotypically delimited (Stenroos et al. 2018). No new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502711, -113.60241, 2020, lignicolous on downed log, *D. Haughland 2020-10C & C. Shier* (hb. Haughland); Edmonton, MacKenzie Ravine boardwalk, 53.528875, -113.558827, 2021, on decayed *Picea glauca* log, *D. Haughland 2021-4* (hb. Haughland).

Cladonia cristatella Tuck.

FIGURE 51 C.

Occasional river valley and ravine system xylicole. Common in the boreal on lignum or soil, forming predictable communities with *Cladonia arbuscula* subsp. *mitis*, *C. botrytes*, and *C. crispata* var. *crispata*. Primary thallus squamulose, often bearing barrel-shaped pycnidia with red pycnidial jelly visible at the ostiole. The pale-yellow podetia are uncupped and often sparsely branched, up to 2.5 cm tall, esorediate, with a continuous cortex. The bright red apothecia (or arrangement of apothecia sometimes giving the illusion of cups) combined with the lack of soredia or true cups are diagnostic. In other regions of Alberta, a rare species that may overlap morphologically is *C. bellidiflora* (Ach.) Schaerer, but that species is UV+ white due to the presence of squamatic acid. Chemistry: K-, KC+ yellow, PD-, $UV_{254/365}$- or $UV_{254/365}$ + pale yellow-white. Secondary metabolites detected by TLC: usnic acid, barbatic acid, ±4-O-demethylbarbatic acid, ±didymic acid, rhodocladonic acid in apothecia. Molecular support: not assessed at species-level, a single sequence forming a clade with either *C. metacorallifera* Asahina (Stenroos et al. 2002) or *C. camerunensis* Ahti & Flakus (Stenroos et al. 2018). No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502711, -113.60241, 2020, lignicolous on downed log, *D. Haughland & C. Shier* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/14346/details); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-as minor component in B77.24.101), *D.C. Lindsay s.n.* (PMAE-as minor component in B77.24.100).

Cladonia fimbriata (L.) Fr.

FIGURE 52 C-D.

Apparently rare river valley and ravine system xylicole. Primary thallus squamulose, persistent, producing podetia 0.5–3.0 cm tall. The bright-green to almost usnic-green podetia form abruptly flaring trumpet-shaped cups with margins that are entire to slightly dentate. The podetia are coated with farinose (floury), fine-grained soredia (see Fig. 43C). See *Cladonia chlorophaea* entry for similar species and how to discriminate them. An additional similar species recently detected in Alberta is *C. conista* (Nyl.) Robbins

(ABMI 2020). *Cladonia conista* is similar in shape, but it tends to be largely corticate with soredia only on the upper edge and inside of the cups; it also can be discriminated with TLC (but not with spot tests) as it contains the fatty acid bourgeanic acid in addition to fumarprotocetraric acid. Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: not assessed at species-level, a single sequence formed a clade with *C. subsquamosa* Kremp. in early analyses (Stenroos et al. 2002), while two sequences cluster with low support with *C. chlorophaea* (Stenroos et al. 2018). No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Hawrelak Park, Alberta, 53.52, -113.54, 2017, on decaying wood under *Betula papyrifera*, *D. Haughland et al. s.n.*(unvouchered observation); Edmonton, Emily Murphy Park, near LRT bridge and Kinsmen Sports Centre, 53.527, -113.51442, 2020, epixylic on decayed wooden bridge edge, *D. Haughland & P. Williams* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/13877/details); Edmonton, Whitemud Park, 53.49903, -113.560691, 2020, on tree base, *hanna1025* (unvouchered observation: iNaturalist record https://www.inaturalist.org/observations/59075224); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on decayed stump, *D. Haughland 2021-24* (hb. Haughland).

Cladonia gracilis* subsp. *turbinata (Ach.) Ahti

FIGURE 54 C-D.

River valley and ravine system terricole and xylicole. Primary thallus squamulose, evanescent or persisting, producing podetia 2–5 cm tall. The podetia are esorediate with a continuous, often hard, shiny cortex and are often secondarily squamulose (shade form). The podetia form well-developed closed cups, topped with pycnidia and/or large brown apothecia on marginal proliferations. This is one of the most common *Cladonia* species in Alberta, occurring in every natural region, typically on soil, moss, debris, or downed wood (ABMI 2020). The occasional perforate cup can be discriminated from *C. multiformis* by the rarity of perforations and the larger, bulbous apothecia that are common in this species. Other similar, PD+ orange species not known from Edmonton include *C. phyllophora* Hoffm. (more northern in distribution, outer cortex matte, dull and appearing fibrous), and *C. ecmocyna* (known only from the Rocky Mountains and Foothills in Alberta, grey to grey-green, often with pruina on the distal half of the podetia, lacking large apothecia, and K+ yellow due to atranorin). Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: unresolved within the Clade "*Cladonia*", subclade "*Graciles*", polyphyletic as currently morphologically circumscribed but separate from *C. ecmocyna* (Fontaine et al. 2010, Pino-Bodas et al. 2011, Stenroos et al. 2018). No new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502711, -113.60241, 2020, lignicolous on downed log, *D. Haughland 2020-10A & C. Shier* (hb. Haughland); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on soil, *D.C. Lindsay s.n.* (PMAE-B77.24.192), *D.C. Lindsay s.n.* (PMAE-B77.24.100).

Cladonia macilenta* var. *bacillaris (Ach.) Schaerer

FIGURE 53 C.

Ravine system xylicole. Another common *Cladonia* of Alberta forests, it is apparently rare within Edmonton. The primary squamules typically are persistent and variable in size and attachment to the substrate (appressed to ascending). Podetia 0.5–1.5 cm tall, pale greenish-grey to pale mint-green, unbranched to slightly-branched close to the blunt tips, covered in abundantly farinose soredia and commonly tipped with small, red apothecia. This species can be discriminated by chemistry if the red apothecia are lacking: *C. coniocraea* is PD+ orange, and *C. bacilliformis* (Nyl.) Sarnth. is KC+ yellow (usnic acid), both species have brown apothecia if fertile. Chemistry: there are two chemical variants of this species and the only one found in Alberta to date is *C. macilenta* var. *bacillaris*, K-, KC+ pinkish-gold, C-, UV_{254}- or dull/faint white, PD-. Secondary metabolites detected by TLC: barbatic acid, ±4-*O*-demethylbarbatic acid, ±didymic acid. Molecular support: unresolved as currently morphologically circumscribed, forming a highly supported clade with *C. floerkeana* (Fr.) Flörke (Stenroos et al. 2018). No new sequences generated.

Observation. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, on downed wood, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12140/details); Edmonton, Rainbow Valley, 1961, *G.W. Scotter s.n.* (ALTA); Edmonton, MacKenzie Ravine boardwalk, 53.528875, -113.558827, 2021, on decayed *Picea glauca* log, *D. Haughland 2021-9* (hb. Haughland).

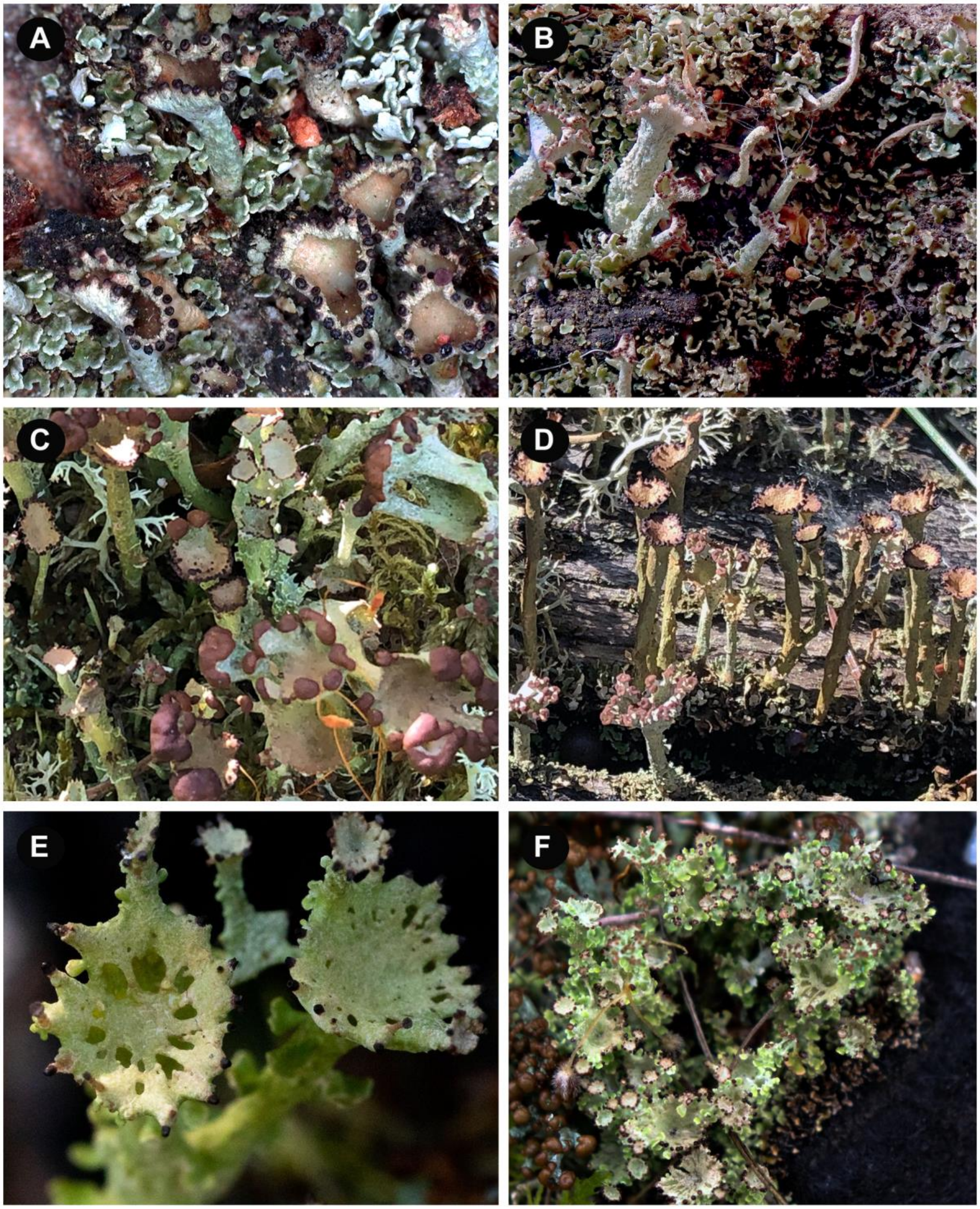

Figure 54. Podetia and colonies of cupped, esorediate *Cladonia* of Edmonton. **A-B,** *C. crispata* var. *crispata*, *Haughland 2021-4*. **C-D,** *C. gracilis* subsp. *turbinata,* with a few podetia of *C. crispata* var. *crispata*, *Haughland 2020-10A.* **E,** *C. multiformis* cups, *Fielder* https://naturelynx.ca/sightings/5231/details. **F,** *C. multiformis* colony, *Dueck* https://naturelynx.ca/sightings/14146/details.

Cladonia multiformis G. Merr.

FIGURE 54 E-F.

River valley and parkland terricole. A variable species that can have podetia that are either branched and fertile with flattened branches and longitudinal perforations, or cupped with sieve-like or doily-like perforations in the top and bottom of the cup. Both morphs are present in Edmonton and in Alberta. Similar in size and chemistry to *C. gracilis* subsp. *turbinata*, the regular perforations and small apothecia of *C. multiformis* help to discriminate it. *Cladonia crispata* var. *crispata* can also resemble this species, but *crispata* is PD- and UV+ white. Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Substances detected by TLC: fumarprotocetraric acid. Molecular support: unresolved and polyphyletic, in a complex with *C. farinacea* (Vain.) A. Evans, *C. furcata* (Hudson) Schrader, and *C. scabriuscula* (Pino-Bodas et al. 2015). No new sequences generated.

Specimen examined & observations. – **CANADA. ALBERTA:** Edmonton, 53.51078, -113.46508, 2019, on soil, *T.L. Dueck* (unvouchered observation: NatureLynx record https:// naturelynx.ca/sightings/14146/details); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on soil, *D.C. Lindsay s.n.* (PMAE-B77.24.107); Edmonton, River Loop Trail south of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-20 & S. Toni* (hb. Haughland).

Cladonia pyxidata (L.) Hoffm.

FIGURE 52 E-F.

River valley terricole and epiphyte. Characterized by short (to 3 cm), broadly cupped podetia arising from persistent, appressed, well-developed primary squamules. The podetia are esorediate, but the cups can be granular or patchy-corticate on the outside. A diagnostic feature is the peltate, pancake-like squamules found lining the inside of the cups. It can be difficult to distinguish from mature *Cladonia chlorophaea* especially as they grow intermingled on a variety of substrates within Edmonton and across Alberta—see the entry for that species for information on some similar species. Additional PD+ orange species to consider include *C. pocillum* (Ach.) O. J. Rich. and *C. magyarica* Vain., which are more common on soil in arid parts of the province. *Cladonia pocillum* has relatively thick primary squamules with a chalky, thick medulla. *Cladonia magyarica* tends to be more grey-green with less brown coloration, often has secondary squamules arising from the cup margins, and it is K+ yellow due to the presence of atranorin. Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: unresolved, sequences mapping to multiple branches throughout the Clade "*Cladonia*", subclade "*Graciles*" (Stenroos et al. 2018). No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.520733, -113.54158, 2020, on *Betula* base, *D. Haughland 2020-19B* (hb. Haughland); Edmonton, Patricia Ravine, 53.503638, -113.593736, 2020, on soil along roots of live, large *Picea glauca*, *D. Haughland & A. Hood* (unvouchered observation); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.191).

Cladonia scabriuscula (Delise) Nyl.

FIGURE 53 D.

Ravine system terricole and xylicole. Primary thallus not observed, forming distinctive podetia that are 3–9 cm tall, typically pale at base, green to whitish at top, mostly slender, with open axils and branching tips. The podetia are smoothly corticate except in the upper half to third where they become scabrose and patchily granular-sorediate. Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: unresolved and polyphyletic, in a complex with *C. farinacea*, *C. furcata*, and *C. multiformis* (Pino-Bodas et al. 2015, Stenroos et al. 2018). No new sequences generated.

Observation. – **CANADA. ALBERTA:** Edmonton, Larch Sanctuary, 53.447302, -113.550894, 2020, terricolous, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/10685/details); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on decayed stump, *D. Haughland 2021-23A* (hb. Haughland).

Cladonia subulata (L.) F. H. Wigg.

FIGURE 53 E.

Apparently rare ravine system terricole/xylicole. Primary squamules small to evanescent. Wand-like podetia grey-green to brownish-green, sometimes paler at base, to 5 cm tall locally, typically entirely sorediate. The podetia may be uniform in width and terminate in a blunt tip, form narrow cups, often with marginal proliferations, or branch in bifurcations that can resemble antlers. See *Cladonia. conocraea* entry for tips to discriminate similar species. Chemistry: K- or K+ dingy brown, KC-, C-, UV_{254}-, PD+ orange. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: monophyletic with strong support based on 3–15 sequences (Pino-Bodas et al. 2010, Stenroos et al. 2018).

Observation. – **CANADA. ALBERTA:** Edmonton, MacKenzie Ravine, by boardwalk, 53.52914, -113.5603, 2020, on *Picea glauca* snag, *D. Haughland 2020-110* (hb. Haughland); Edmonton, River Loop Trail S of Fort Edmonton, 53.500627, -113.576611, 2021, on trailside soil, *D. Haughland 2021-15 & S. Toni* (hb. Haughland).

GROUP 15. EPIPHYTIC FRUTICOSE LICHENS

Ten species. Key literature: Bird 1974; Brodo et al. 2001; Brodo 2016; Brodo & Hawksworth 1977; Clerc 2011; Halonen et al. 1998; Mark et al. 2016b; Wylie 1977. For *Bryoria*, we retain the ecological and morphological species concepts of Brodo and Hawksworth (1977) versus recent phylogenetic species concepts (Boluda et al. 2019, Velmala et al. 2014). Similarly, we use the morphospecies concepts of *Usnea* from Clerc (2011) for the few species documented in Edmonton rather than treat isidiate specimens historically called *U. substerilis* as synonymous with *U. lapponica* (as per Mark et al. 2016b, now called *U. perplexans*, Clerc 2016). We do not doubt the veracity of recent molecular work or nomenclatural corrections; rather we suspect that adopting taxonomic shifts here and in related work across the province would be more confusing than illuminating at this time, especially given the lack of resolution in studies to date. We provide limited spot test results as we seldom use them to help discriminate *Usnea* species; we have found them to be uninformative due to overlapping chemotypes or unreliable because of variable concentrations of metabolites. An additional epiphytic fruticose lichen reported which we could not confirm despite numerous attempts in the field and in the herbarium is *Pseudevernia consocians* (Whitemud Creek near ski slope, Edmonton, 1963, *A.W. Stewart 575* [ALTA]), Government of Alberta 2020). This species is more common in eastern North America but it has confirmed, disjunct populations as far west as Alberta (ABMI 2020).

1a. Thallus hair-like, brown .... ***Bryoria fuscescens***
1b. Thallus hair-like to shrub-like, greenish yellow **2**

2a. Thallus with a tough, elastic, cartilaginous central cord (stretch gently along axis to see cord) ... **3** ***Usnea***
2b. Thallus lacking a cord **6**

3a. Thallus lacking isidia, soralia present, eroding the branch when fully developed, with flaps of cortex around the soralia .... ***Usnea perplexans***
3b. Thallus isidiate, either individually from the branch in esorediate species or arising from larger soralia mixed with soredia (may be sparse so check soralia carefully) **4**

4a. Thallus elongate; branches growing relatively long and parallel to each other .... ***Usnea scabrata***
4b. Thallus shrubby; branches diverging from each other at wide angles **5**

5a. Soralia variable but wider than half the branch width, developing sparse to abundant isidia within the soralia; attachment point black; papillae present at base .... ***Usnea substerilis s.l.***
5b. Well-defined soralia lacking, instead developing punctiform isidia over the surface; attachment point typically pale; lacking papillae .... ***Usnea hirta***

6a. Thallus soft and pliable (cortex thin), dull, typically wrinkled; coarse soredia and/or isidia arising along the branches; medulla cottony .... ***Evernia mesomorpha***
6b. Thallus stiff (cortex thick), often shiny, smooth; if soralia present, in well-defined soralia rather than occurring throughtout the thallus; medulla dense to honey-comb-like .... **7** ***Ramalina***

7a. Soralia lacking, apothecia typically present **8**
7b. Soralia present along lobe edges or on lobe tips; apothecia not observed...**9**

8a. Thallus small (1–2 cm long), inflated and spiny, partially hollow and perforate, somewhat translucent .... ***Ramalina dilacerata***
8b. Thallus larger (to 3 cm long), flattened and solid, branches fan-shaped, imperforate...***Ramalina sinensis***

9a. Thallus inflated at least in part, with perforations into hollow branch interior; soredia present within hooded soralia or on tattered lobe tips..***Ramalina obtusata***
9b. Thallus solid, flattened; soralia variable but mostly discrete, marginal and terminal, becoming laminal on older tips... ***Ramalina pollinaria***

Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.
(= *Bryoria lanestris* (Ach.) Brodo & D. Hawksw.)

FIGURE 55 A.

River valley and ravine system epiphyte. Growing to 5–8 cm in length in Edmonton, *Bryoria fuscescens* is greyish-brown to dark-brown, and typically has abundant pale-green, fusiform soralia that are PD+ orange. An abundant epiphyte particularly on conifers in northern Alberta, this species is sparse locally. This is the only *Bryoria* documented to date in Edmonton. Chemistry: soralia PD+ orange, thallus PD-, all other spot tests negative. Secondary metabolites detected by TLC: fumarprotocetraric acid. Molecular support: high species-level support with recent reduction of two species to synonymy with *B. fuscescens* (Boluda et al. 2019): *B. vrangiana* (Gyelnik) Brodo & D. Hawksw. (morphologically distinguished by pseudocyphellae and more robust, regular branches), and *B. capillaris* (Ach.) Brodo & Hawksw. (distinguished by lack of soralia in North America and presence of alectorialic acid and barbatolic acid). Synonymy not adopted here. No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on live *Prunus* stems, *D. Haughland 2020-44 & A. Hood* (hb. Haughland); Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, epiphytic, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12139/details); Edmonton, Rio Park, 53.50320938, -113.592617, 2020, epiphytic, *L. Hjartarson* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12116/details); Edmonton, MacKenzie Ravine, 1976, *D.C. Lindsay s.n* (PMAE-B77.24.174); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on rotten wood, *D.C. Lindsay s.n.* (PMAE-B77.24.92); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513197, -113.53866, 2021, on *Picea* twigs, *D. Haughland 2021-33C* (hb. Haughland).

Evernia mesomorpha Nyl.

FIGURE 55 B.

Occasional river valley and ravine system and parkland epiphyte. One of the most common epiphytes in forested regions of Alberta, this species is rare in Edmonton outside of river valley parks. Thalli forming pale-green shrubby tufts of wrinkled branches bearing soredia and isidia along the ridges. The dull, wrinkled outer cortex and cottony medulla help separate this genus from *Usnea* (compact and often shiny cortex and elastic, cartilaginous central cord) and *Ramalina* (shiny cortex, often perforate or with linear pseudocyphellae, and a solid to honey-combed interior). No other *Evernia* species are found in Alberta's Boreal or Parkland Natural Regions (ABMI, unpub.. Chemistry: cortex KC+ yellow, medulla UV+ white, all other spot tests negative. Secondary metabolites detected by TLC: usnic acid (not detected at low concentrations), divaricatic acid,. Molecular support: The genus originally appeared polyphyletic (Crespo et al. 2010) or paraphyletic (Piercey-Normore 2006). In recent analyses, three species of *Evernia* formed a monophyletic clade (Divakar et al. 2017). More work is needed to ascertain whether the species is monophyletic as *E. mesomorpha* forms a clade with *E. esorediosa* (Müll. Arg.) Du Rietz in some analyses (Piercey-Normore 2006). No new sequences generated.

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 4, 53.443571, -113.461517, 2019, on trunk of *Ulmus americana, J. Birch & J. Wasyliw [UoA-CC-72]* (hb. Haughland); Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland 2020-47 & A. Hood* (hb. Haughland); Whitemud Park, Edmonton, 53.497703, -113.561303, 2020, epiphytic, *hanna1025* (unvouchered observation: iNaturalist record https://www.inatur-

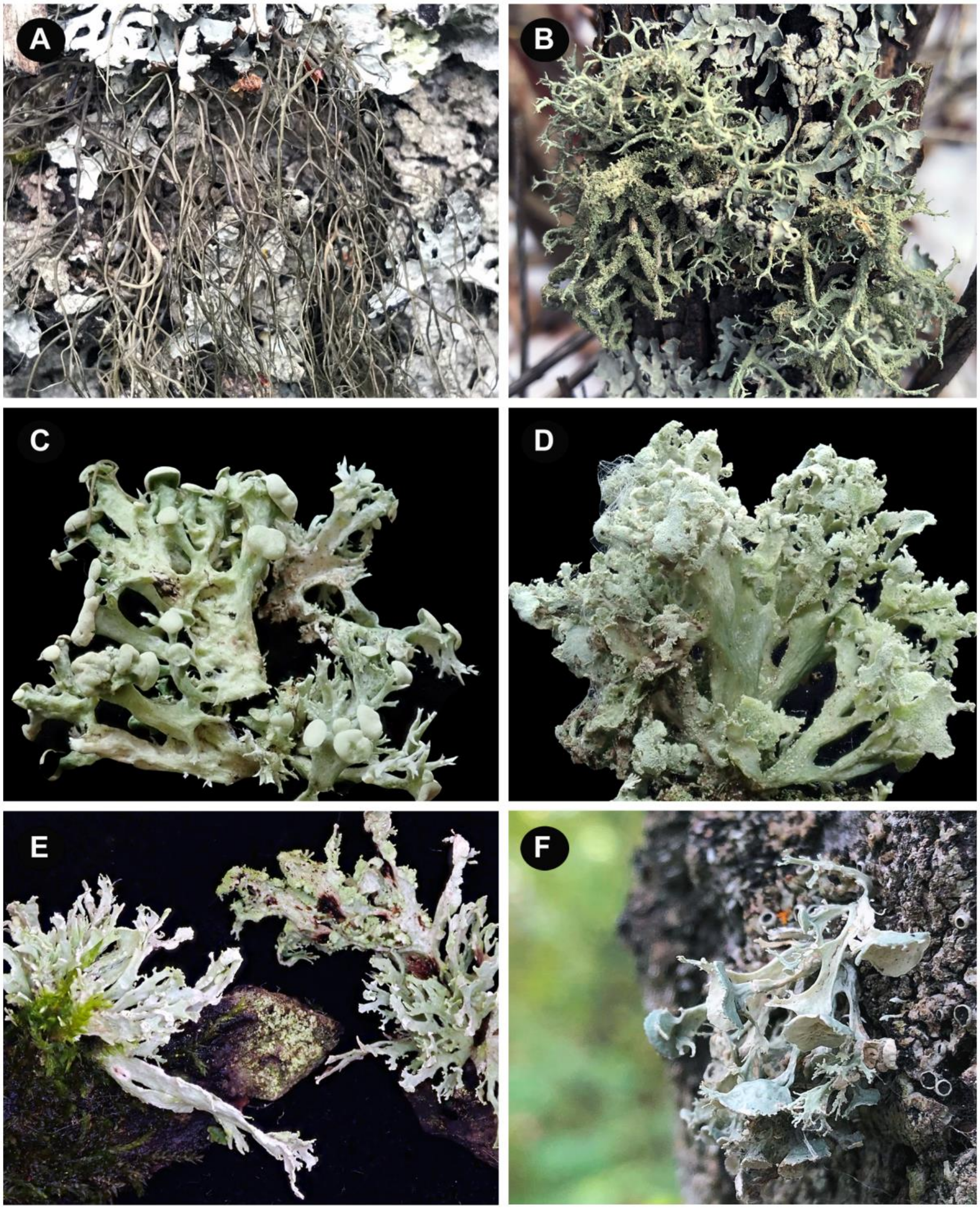

Figure 55. Epiphytic fruticose lichens of Edmonton plate 1. **A,** *Bryoria fuscescens, Toni* https://naturelynx.ca/sightings/12139/details. **B,** *Evernia mesomorpha*, Edmonton, Buena Vista, 2020, *Haughland* unvouchered observation. **C,** *Ramalina dilacerata,* wet thallus, *Haughland 2020-3*. **D,** *Ramalina obtusata,* wet thallus, *Haughland 2020-5.* **E,** *Ramalina pollinaria,* wet thallus, *Haughland 2020-14*. **F,** *Ramalina sinensis, Haughland* https://naturelynx.ca/sightings/14278/details.

-alist.org/observations/59078955); Edmonton, between Stony Plain Rd. and 100 Ave. at 148 St., 1976, on supports of wooden footbridge, *D.C. Lindsay s.n.* (PMAE-B77.24.141); Edmonton, MacKenzie Ravine, 1976, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.37); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.99).

Ramalina dilacerata (Hoffm.) Hoffm.

FIGURE 55 C.

River valley and ravine system epiphyte. A commonly overlooked but frequent boreal species characterized by small (1–2 cm) shrubby, tufted thalli. The cortex is shiny and semi-translucent and lacks the pseudocyphellae present in other species of the genus (e.g., *Ramalina sinensis*). Upon close examination, it is easily identified by its hollow, slightly inflated branches that develop characteristic punctures on the underside. Apothecia abundant, relatively large, with pale pinkish-yellow, lightly pruinose discs, forming near the ends of branches. No vegetative propagules. Chemistry: cortex KC+ yellow, medulla UV+ whitish, all other spot tests negative. Secondary metabolites detected by TLC: usnic acid (not detected at low concentrations), divaricatic acid. Molecular support: monophyletic with high support in an analysis of five sequences (Timsina et al. 2012). No new sequences generated.

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502937, -113.602263, 2020, stems of *Corylus cornuta*, *D. Haughland 2020-3 & C. Shier* (hb. Haughland); Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, epiphytic, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12144/details); Edmonton, MacKenzie Ravine, 1976, on rotting log, *D.C. Lindsay s.n.* (PMAE-as minor component in B77.24.41).

Ramalina obtusata (Arnold) Bitter

FIGURE 55 D.

Apparently rare river valley and ravine system epiphyte. A boreal species often found growing with *Ramalina pollinaria* elsewhere in Alberta. Characterized by yellowish-green, shrubby, shiny thalli, growing in tufts to 3 cm long. The branches usually are flattened near the attachment point, and become hollow and slightly inflated with open branch tips that terminate in tattered to hooded soralia. Distinguished from *R. pollinaria* by its inflated branches (vs. solid and flattened in *R. pollinaria*) and the terminal soralia (vs. marginal and terminal in *R. pollinaria*). Chemistry: cortex KC+ yellow, all other spot tests negative. Secondary metabolites detected by TLC: usnic acid (not detected at low concentrations), evernic acid and/or obtusatic acid (cannot differentiate solvents used herein). Molecular support: lacking, too few sequences available at present. Polyphyletic within *Ramalina* in a recent analysis including two sequences (Haughland, in prep.). No new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502787, -113.601791, 2020, on bark of dead *Picea glauca*, *D. Haughland 2020-5 & C. Shier* (hb. Haughland); Edmonton, Wolf Willow Creek, 53.502228, -113.60128, 2020, on *Salix*, *D. Haughland 2020-13A & C. Shier* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on bark of twig, *D.C. Lindsay s.n.* (PMAE-B77.24.173); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on *Betula papyrifera*, *D. Haughland 2021-22C* (hb. Haughland).

Ramalina pollinaria (Westr.) Ach.

FIGURE 55 E.

Occasional river valley and ravine system epiphyte. A common and variable boreal species. Thallus yellowish-green, shrubby, dull to slightly shiny, growing in tufts to 3 cm long. Branches usually flattened, solid throughout, slightly longitudinally striate. Soredia farinose, in delimited soralia along the lobe margins and in terminal, slightly labriform soralia. Apothecia not found. See *Ramalina obtusata* entry for points of distinction. Gasparyan et al. (2017) described *R. labiosorediata* Gasparyan, Sipman & Lücking as a segregate from *R. pollinaria* in North America. While *R. labiosorediata* has not been detected in Alberta, it is distinguished by relatively broad lobes that have few to no marginal soralia and well-developed terminal labriform soralia. Chemistry: cortex KC+ yellow, all other spot tests negative. Secondary metabolites detected by TLC: usnic acid (not detected at low concentrations), evernic acid and/or obtusatic acid (cannot differentiate in solvents used herein). Molecular support: high at species level. Recent analyses show that a sequence from Edmonton (isolate DLH12 from *Haughland 2020-13B*) and two collections from northern Canada form a highly supported, monophyletic clade with *R. pollinaria s.s.* from

Gasparyan et al. (2017), not with *R. labiosorediata*, evidence that both species occur in North America (Haughland et al. in prep.).

Representative specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Wolf Willow Creek, 53.502228, -113.60128, 2020, on *Salix*, *D. Haughland 2020-13B & C. Shier* (hb. Haughland); Edmonton, Whitemud Ravine, 53.495491, -113.55983, 2020, on deciduous tree bark, *D. Haughland 2020-14 & P. Williams* (hb. Haughland); Edmonton, Patricia Ravine, 53.503105, -113.592863, 2020, on bark of downed, intact *Betula papyrifer*a, *D. Haughland 2020-41 & A. Hood* (hb. Haughland); Edmonton, Kinnaird Ravine, 53.558953, -113.459253, 2020, on *Picea glauca* snag, *D. Haughland 2020-30 & P. Williams* (hb. Haughland); Edmonton, Patricia Ravine, 53.503448, -113.593252, 2020, epiphytic, *L. Hjartarson* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12095/details); Edmonton, Patricia Ravine, 53.502112, -113.592209, 2020, epiphytic, *S. Toni* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12450/details); Edmonton, Whitemud Creek Ravine, 53.495491, -113.559830, 2020, epiphytic, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12606/details); Edmonton, Whitemud Creek Ravine, 53.494633, -113.560377, 2020, epiphytic, *D. Haughland* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/12607/details); Edmonton, MacKenzie Ravine, 1976, on tree, *D.C. Lindsay s.n.* (PMAE-B77.24.26); Edmonton, Terwillegar Footbridge, 53.4797, -113.594315, 2021, on *Betula papyrifera*, *D. Haughland 2021-22B* (hb. Haughland); Edmonton, MacKenzie Ravine, by boardwalk, 53.52914, -113.5603, 2020, on *Picea glauca* snag, *D. Haughland 2020-109* (hb. Haughland).

Ramalina sinensis Jatta

FIGURE 55 F.

Rare tablelands epiphyte. This species is characterized by cartilaginous flattened lobes that tend to be deeply dissected, and at maturity terminate in large pinkish-yellow apothecia. The lobes attach at a single holdfast, and have long pseudocyphellae on one surface, developing between the cartilaginous ribs that run parallel to the branch in well-developed specimens. The single specimen collected in Edmonton resembled *Ramalina unifolia* J.W. Thomson (distinguished by a lack of dissection, forming thalli composed of a single, fan-like lobe that otherwise resemble *R. sinensis* (Thomson 1990)). Because we are uncertain about the validity of that species, we retain this sample within *R. sinensis*. Molecular support: mixed. An early-diverging species within *Ramalina* with at least three highly supported lineages (one from Alberta) within a deeper, monophyletic species-level clade; some authors suggest more research is needed to determine whether these branches should be split into separate species (Spjut et al. 2020, Timsina et al. 2012). In contrast, LaGreca et al. (2020) found that *R. sinensis* is paraphyletic with a strongly supported clade including two sequences of *R. unifolia*. More work is needed to determine if *R. unifolia* should be reduced to synonymy with *R. sinensis*. No new sequences generated.

Specimen examined. – **CANADA. ALBERTA:** Edmonton, Urban Monitoring Site 9, 53.453708, -113.527608, 2019, on trunk of *Fraxinus*, *D. Haughland & A. Stordock s.n. [UoA-CC-76]* (hb. Haughland); Edmonton, Urban Monitoring Site 77E, 53.501971, -113.348115, 2019, on trunk of *Populus*, 2019, *D. Thauvette & J. Birch* (unvouchered observation).

Usnea hirta (L.) Weber ex F. H. Wigg.

FIGURE 56 A.

River valley epiphyte. A species characteristic of northern coniferous forests in Alberta, this shrubby species typically is densely branched, forming compact tufts up to 5 cm long. The branches are ridged and/or foveolate, lack papillae or soredia, and have abundant punctiform isidia (arising singly from the branch). Some specimens have abundant fibrils, which resemble small, perpendicular side branches. The attachment point typically is pale, whereas the outer-most branch tips often are blackened. May be confused with *Usnea. scabrata*, but that species has a blackened attachment point and typically abundant, obvous papillae, especially near the base. Chemistry: PD-, K-, KC+ yellow, C-, UV-. Secondary metabolites detected by TLC: usnic acid. Molecular support: limited to date. Two sequences (both from Scotland) are monophyletic with strong support (Truong et al. 2013). No new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.519809, -113.540503, 2020, on *Betula* bark, *D. Haughland 2020-17* (hb. Haughland); Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland 2020-46 & A. Hood* (hb. Haughland); Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-as minor component in B77.24.96).

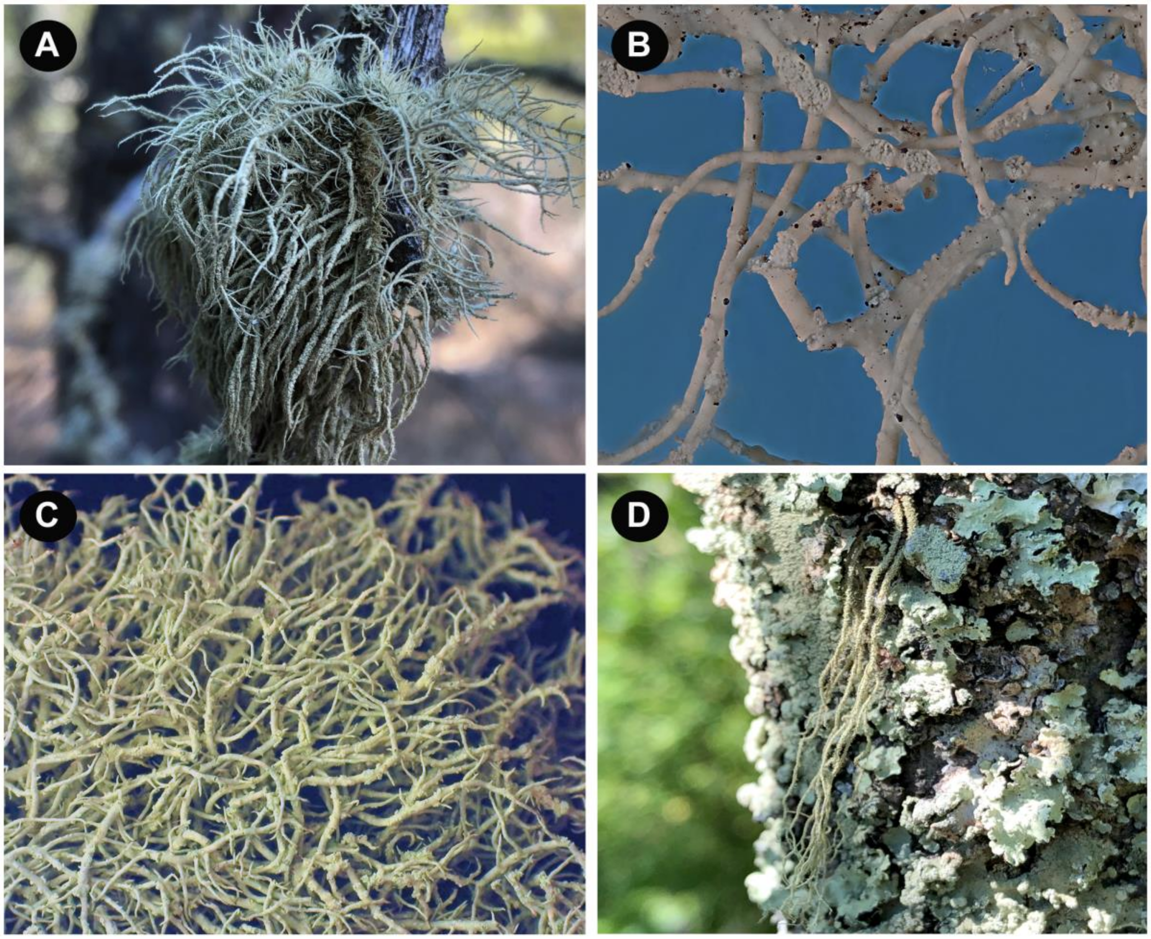

Figure 56. Epiphytic fruticose lichens of Edmonton plate 2: *Usnea*. **A,** *U. hirta*, Redwater Natural Area northeast of Edmonton, *Haughland* https://naturelynx.ca/sightings/15781/details. **B,** *U. perplexans*, closeup of excavate soralia, ca. 12 km NW of Zama City, ABMI Site 158, 59.23, -118.86, 2014, epiphytic, *D. Hogarth s.n.* [*ABMI Lichen # 577649*]. **C,** *U. substerilis*, *Haughland 2020-94.* **D,** *U. scabrata*, *Haughland* unvouchered observation.

Usnea perplexans Stirt.
(= *Usnea lapponica* Vain.)

FIGURE 56 B.

River valley epiphyte. Characterized by short, shrubby thalli up to 8 cm long, but typically shorter in the city. The branches can be round or dented and are densely papillate; the branches typically diverge but may grow parallel to each other in more luxurious morphs outside of Edmonton. It is best characterized by the development of deeply-excavate soralia that develop flaps of cortex around the soralia as the branch erodes, as well as the lack of isidia. The attachment point is typically black. Similar shrubby species include *Usnea substerilis* (with at least some isidia within the soralia, common) and *U. glabrescens* (Nyl. ex Vain.) Vain. (with round, excavate soralia that contain sparse isidia only when young; a well-developed, tree-like attachment point (resembling roots flaring from the base of a tree trunk and anchoring the thallus to the substrate; thick cortex and thin medulla in longitudinal section; and typically with norstictic acid, rare in Alberta). Chemistry: spot tests variable, not diagnostic. Secondary metabolites and chemotypes detected by TLC: usnic acid only (63%), usnic acid with salazinic acid (31%), usnic acid with barbatic acid (4%), or usnic acid with salazinic acid and barbatic acid (2%). These chemotypes agree with those documented elsewhere (e.g., Halonen et al. 1998), but recent phylogenetic analyses suggest that specimens with barbatic acid may belong to *U. wasmuthii* Räsänen (Mark et al. 2016b). Molecular support: weak at species-level. Clades in a multi-locus phylogeny do not correspond to traditionally circumscribed species. Because of the lack of resolution in a clade of *U. lapponica*, *U. substerilis*, *U. barbata* (L.) F.H. Wigg. and *U. intermedia*

(A. Massal.) Jatta, Mark et al. (2016b) placed *U. substerilis* in synonymy with this species. Synonymy not adopted at this time; no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, Hawrelak Trail off-leash park, 53.520721, -113.54155, 2020, on *Betula* bole, *D. Haughland 2020-22* (hb. Haughland); Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland 2020-45 & A. Hood* (hb. Haughland); Edmonton, MacKenzie Ravine, 1976, on tree, *D.C. Lindsay s.n.* (PMAE-B77.24.25); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513197, -113.53866, 2021, on *Picea* twigs, *D. Haughland 2021-33B* (hb. Haughland).

Usnea scabrata Nyl.
(? = *Usnea barbata* (L.) F. H. Wigg.)

FIGURE 56 C.

River valley epiphyte. Alberta's most common pendant *Usnea*. Characterized by relatively long branches that soon grow parallel to each other, typically branched very close to the base, with a narrowed, blackened attachment point and a relatively thin axis (axis: medulla ratio ≤1.5). Fibrils may be sparse or common. The branches are typically abundantly papillate, foveolate and ridged, with punctiform soralia giving rise to isidia. *Usnea dasopoga* differs in its relatively thick axis relative to the medulla, its broad attachment with numerous "root-like" extensions clasping the wood, and lack of foveoles. Chemistry: PD-, K-, KC+ yellow, C-, UV-. Secondary metabolites detected by TLC: usnic acid. An additional metabolite documented in this species elsewhere is salazinic acid (e.g., Clerc 2011). Molecular support: weak at species-level. Clades in a multi-locus phylogeny do not correspond to traditionally circumscribed species (Mark et al. 2016b).

Specimens examined & observations. – **CANADA. ALBERTA:** Edmonton, Patricia Ravine, 53.503216, -113.592645, 2020, on *Prunus* stems, *D. Haughland & A. Hood* (unvouchered observation); Edmonton, Mill Creek Ravine South, 53.508933, -113.461392, 2019, on deciduous trees, *T.L. Dueck* (unvouchered observation: NatureLynx record https://naturelynx.ca/sightings/9832/details); Edmonton, grassy park next to Saskatchewan Drive bordering river valley, 53.513197, -113.53866, 2021, on *Picea* twigs, *D. Haughland 2021-33A* (hb. Haughland).

Usnea substerilis Motyka *s.l.*

FIGURE 56 D.

River valley epiphyte. Another short, shrubby species similar to *Usnea perplexans*, *U. substerilis* traditionally is differentiated by soralia that vary from excavate to tuberculate but which seldom develop cortical flaps, and instead give rise to sparse to abundant isidia. Separated from the morphologically similar, rarer *U. subfloridana* Stirt. by chemistry (the latter with medulla UV+ white due to presence of squamatic acid in Alberta). Chemistry: spot tests variable, not diagnostic. Secondary metabolites and chemotypes detected by TLC: usnic acid only (40%), usnic acid with salazinic acid (35%), usnic acid with barbatic acid (9%), usnic acid with salazinic acid and barbatic acid (14%). These chemotypes agree with those documented elsewhere (e.g., Halonen et al. 1998), but recent phylogenetic analyses suggest that specimens with barbatic acid may belong to *U. wasmuthii* (Mark et al. 2016b). Molecular support: weak at species-level. Clades in a multi-locus phylogeny do not correspond to traditionally circumscribed species. Because of the lack of resolution in a clade of *U. lapponica*, *U. substerilis*, *U. barbata*, and *U. intermedia*, Mark et al. (2016b) placed *U. substerilis* in synonymy with *U. lapponica* (now *U. perplexans*). Synonymy not adopted at this time; no new sequences generated.

Specimens examined. – **CANADA. ALBERTA:** Edmonton, near Northland sandpit, 2 mi W and 1 mi S of 170 St. and 79 Ave., 1977, on wood, *D.C. Lindsay s.n.* (PMAE-B77.24.96); Edmonton, Buena Vista Meadow, 53.513721, -113.54878, 2020, on *Picea glauca* branch, *D. Haughland 2020-94 & P. Williams* (hb. Haughland).

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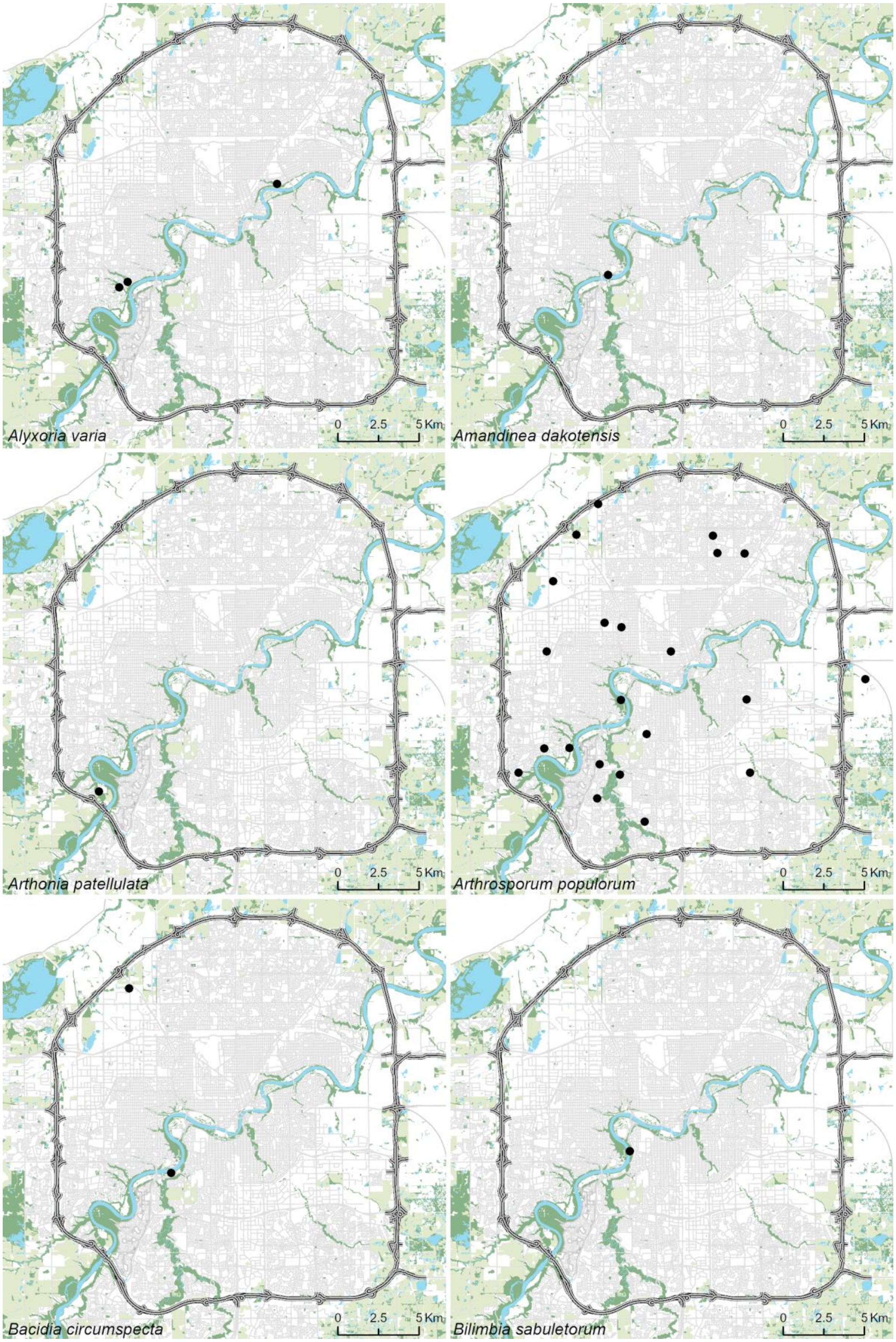
SUPPLEMENTARY APPENDICIES

Supplementary Appendix 1: Species List. – The complete species list, including species that we could not confirm, are included; in addition many traits for the lesser-known crustose species have been tabulated as well so the table can serve as an interactive key.
Deposited in Dryad: https://doi.org/10.5061/dryad.sqv9s4n6d

Supplementary Appendix 2: Sequence Voucher Table. – The complete list of 456 sequences used in this study, including the analyses each sequence was used in, the source of the sequence, voucher information including herbarium where those data were available, collection location, publication the sequence was first generated for, and GenBank numbers by genetic marker.
Deposited in Dryad: https://doi.org/10.5061/dryad.sqv9s4n6d

Supplementary Appendix 3: Species Distribution Maps. – Distribution maps for the confirmed historic and extant ocurrences of all the species within Edmonton and treated here are presented on the following pages. The maps are derived from the same basemap used in Figure 1. As most *Usnea* specimens were too poorly developed for species-level identification, open circles on the *Usnea* maps indicate genus-level records.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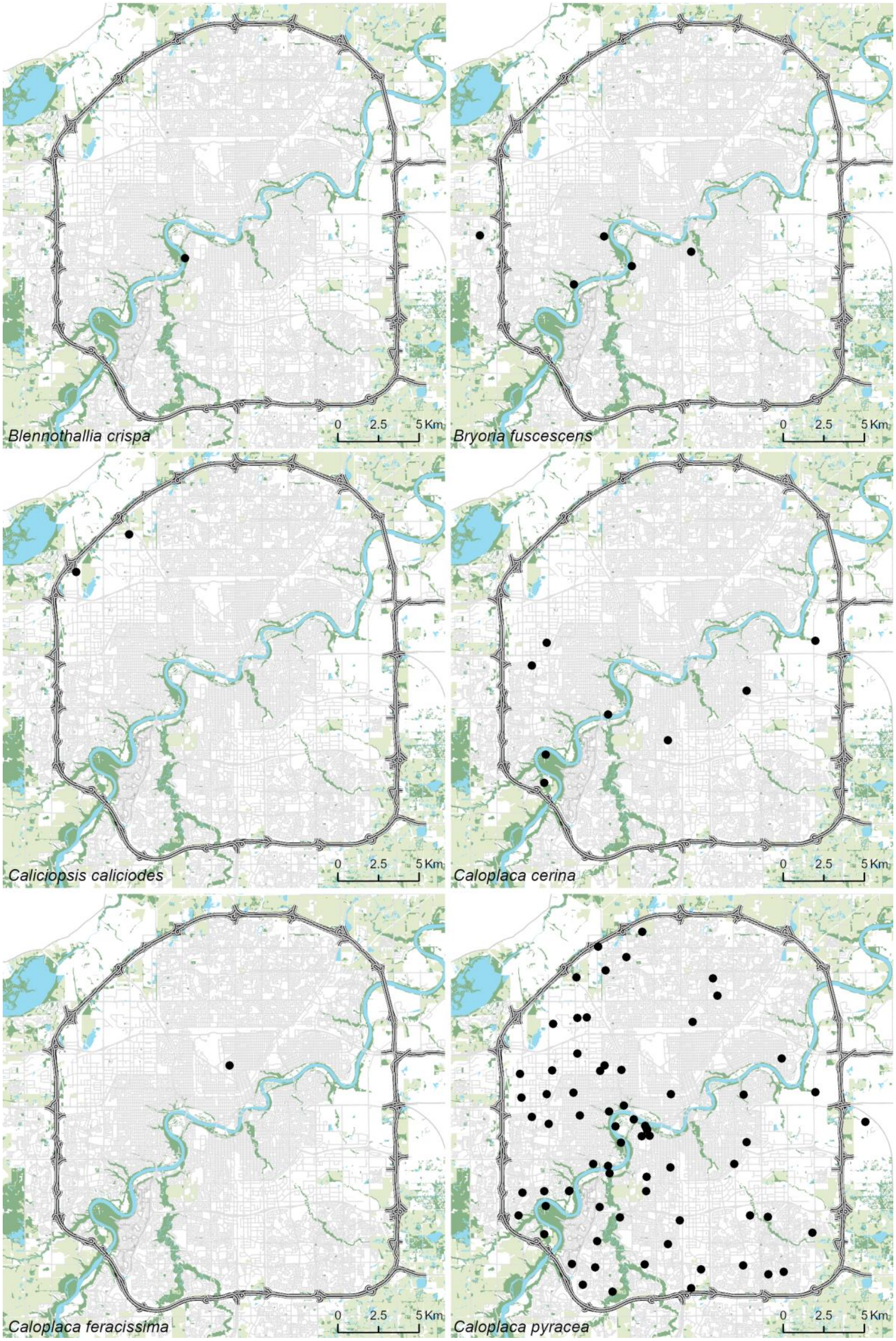
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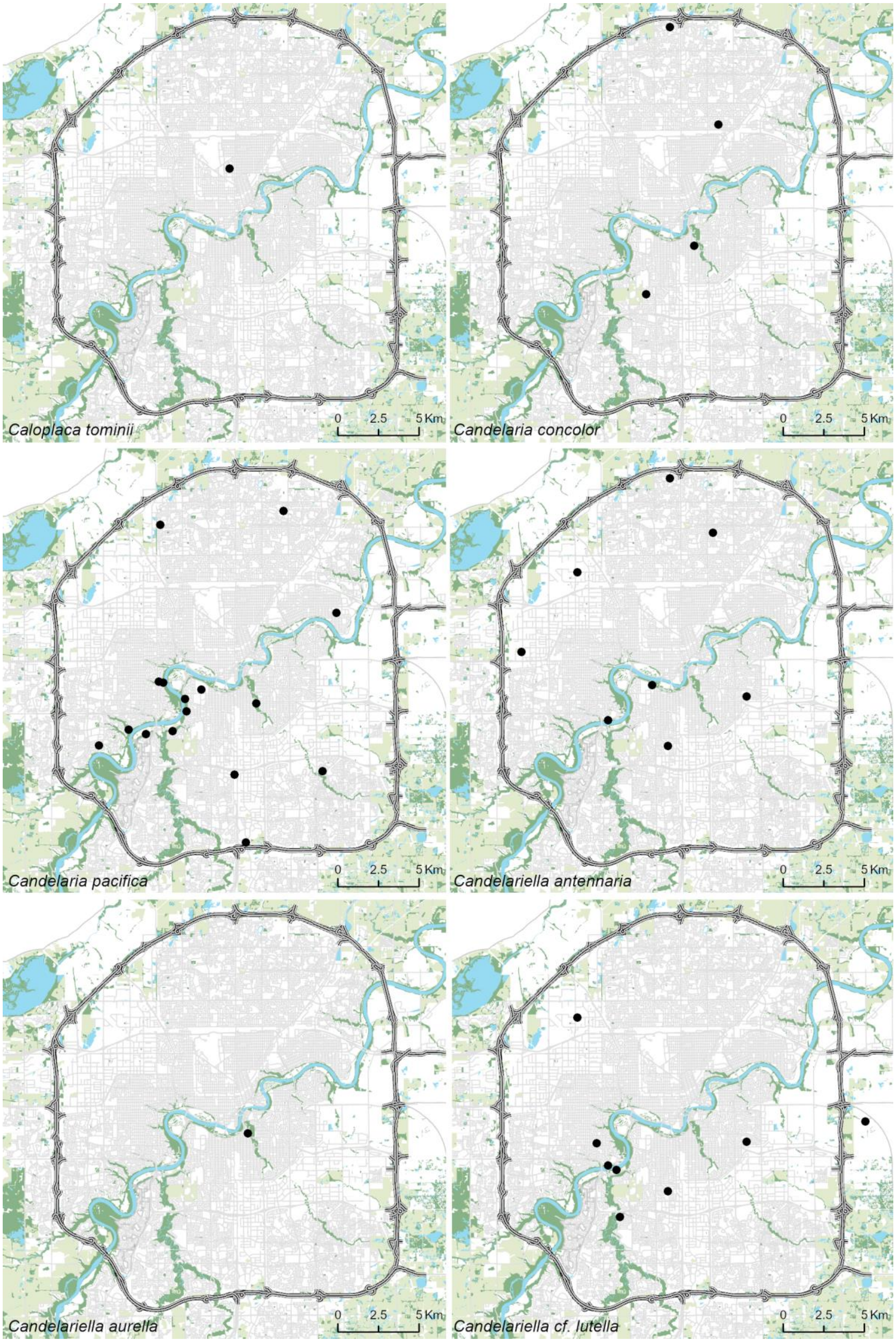
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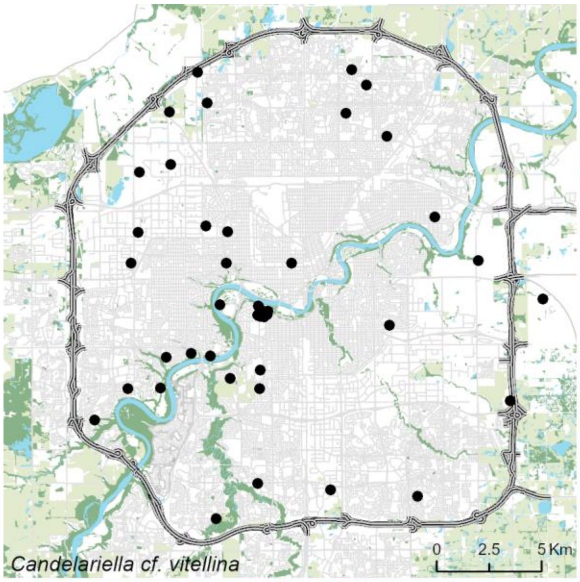
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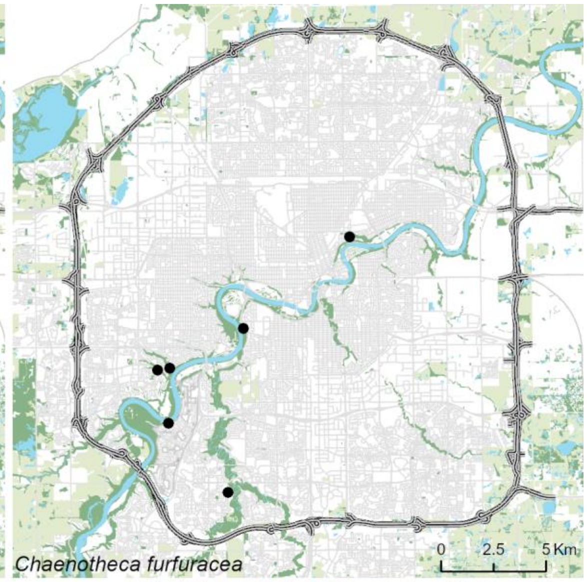
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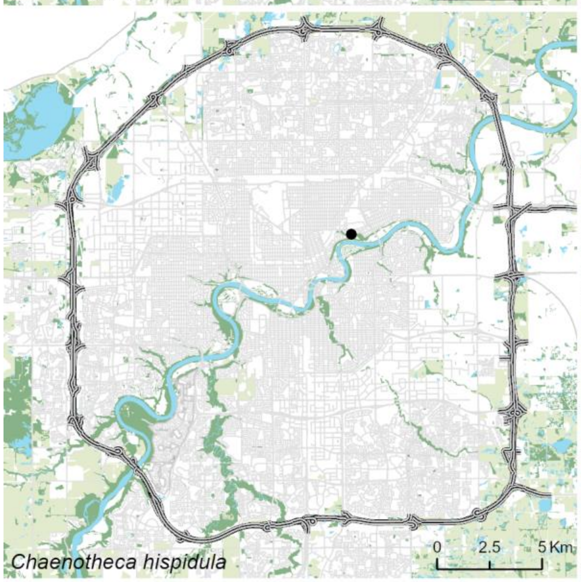
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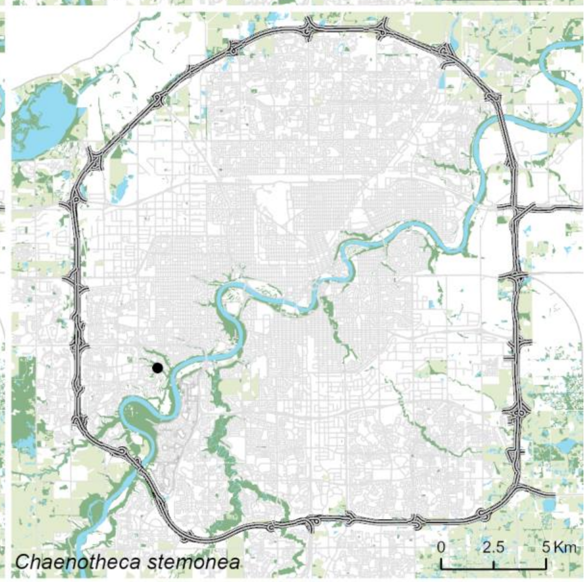
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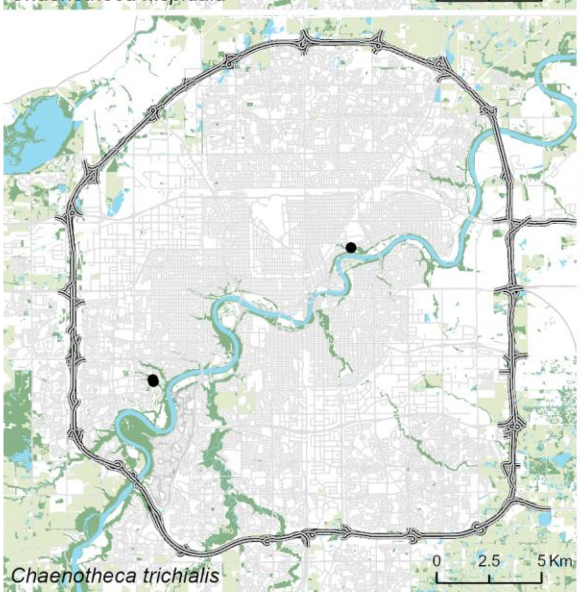
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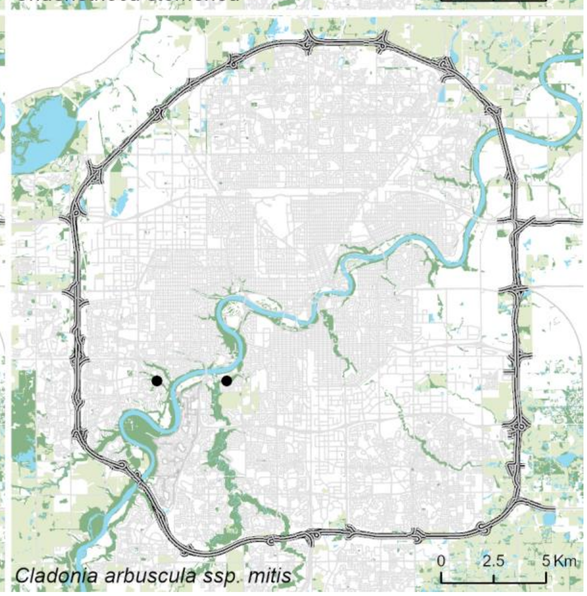
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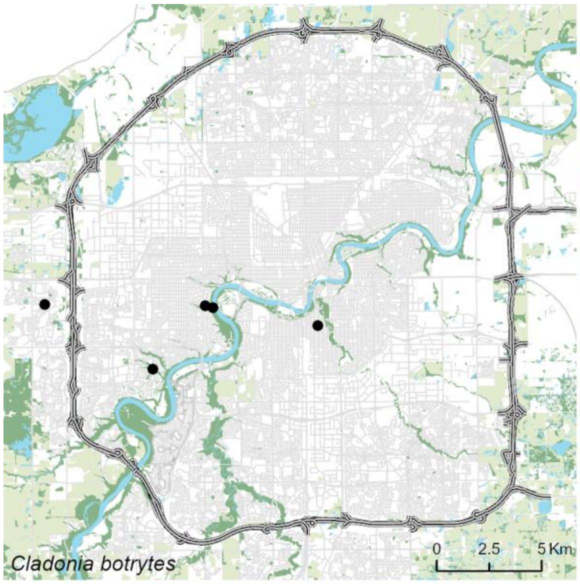
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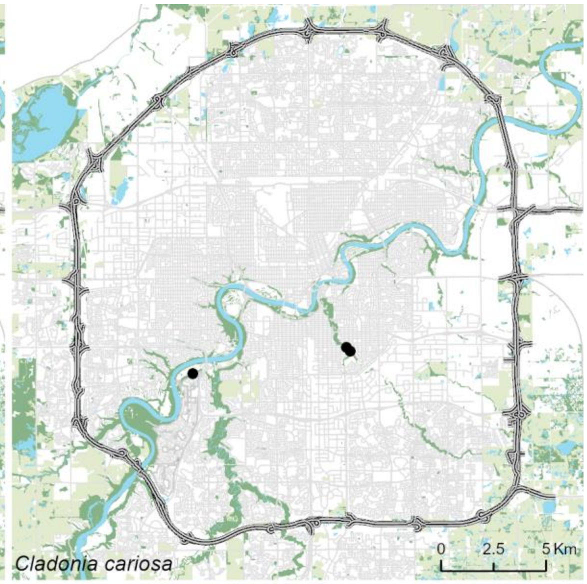
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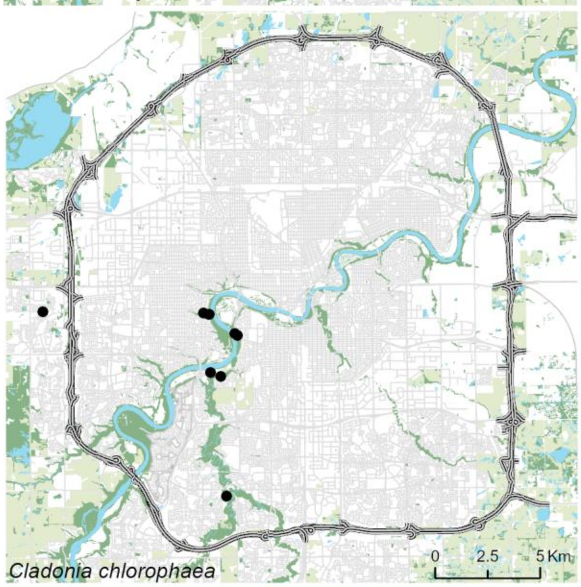
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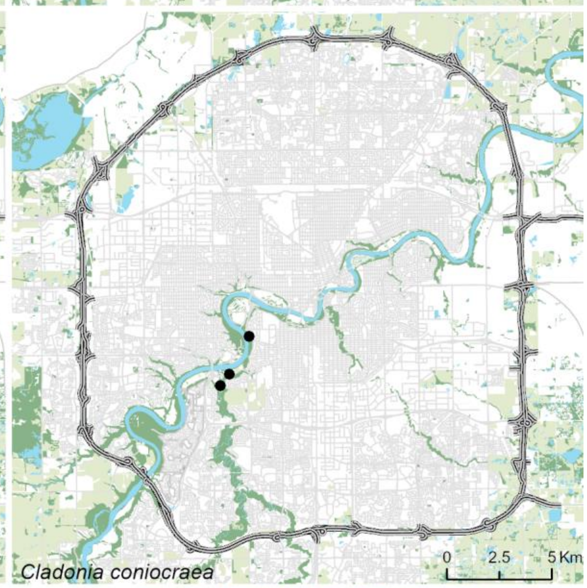
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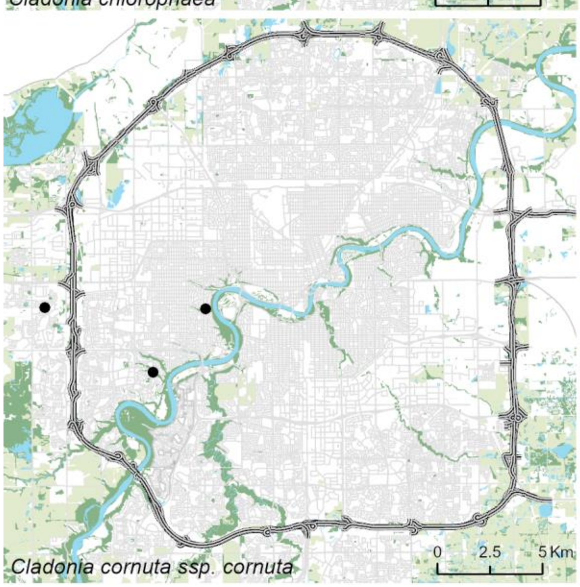
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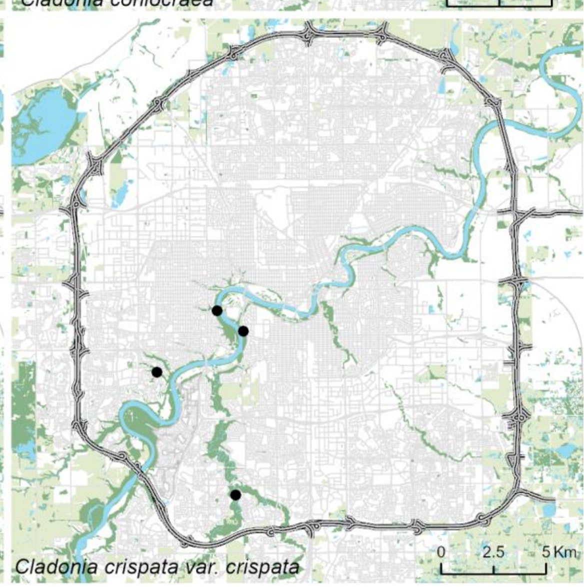
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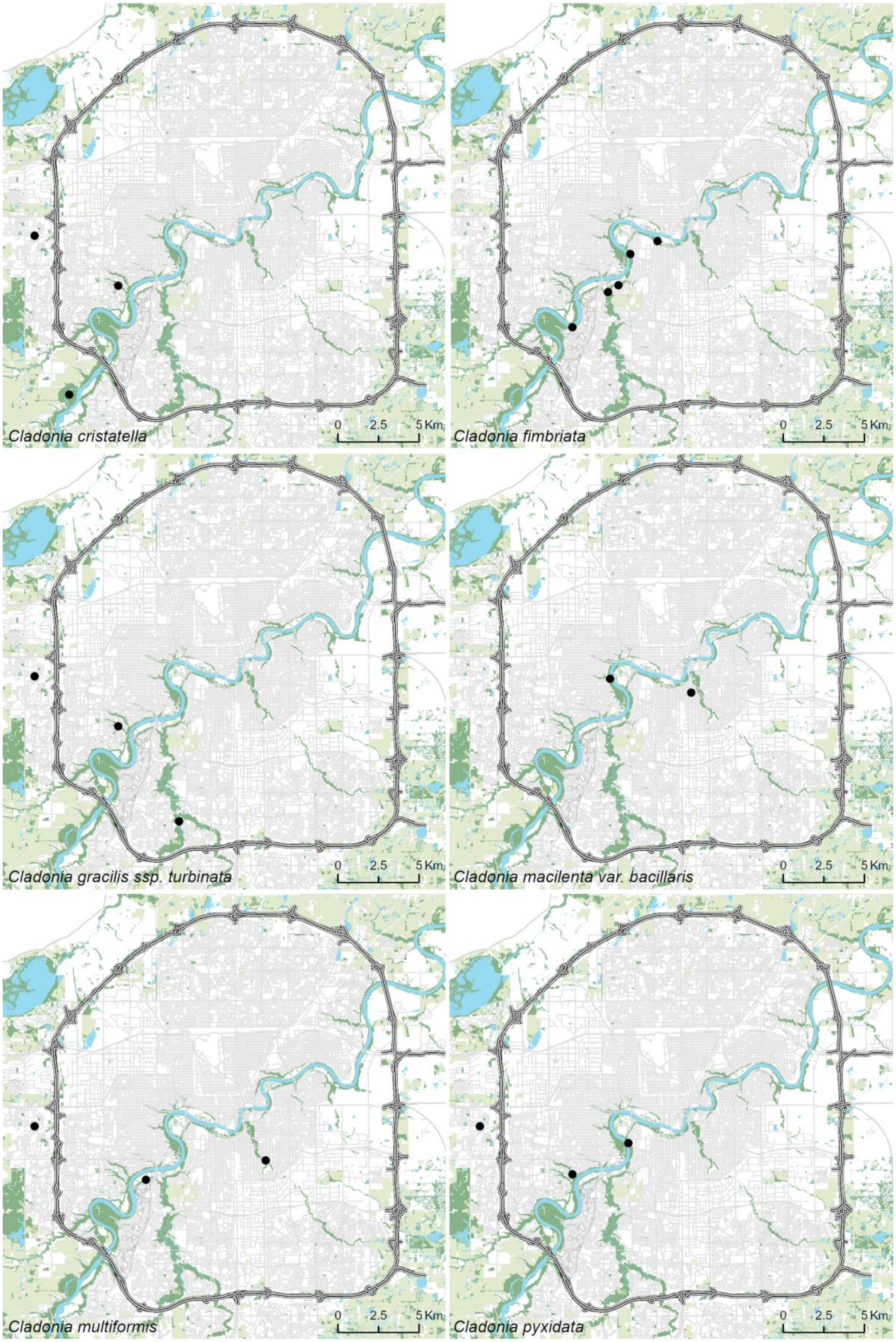
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Cladonia pyxidata
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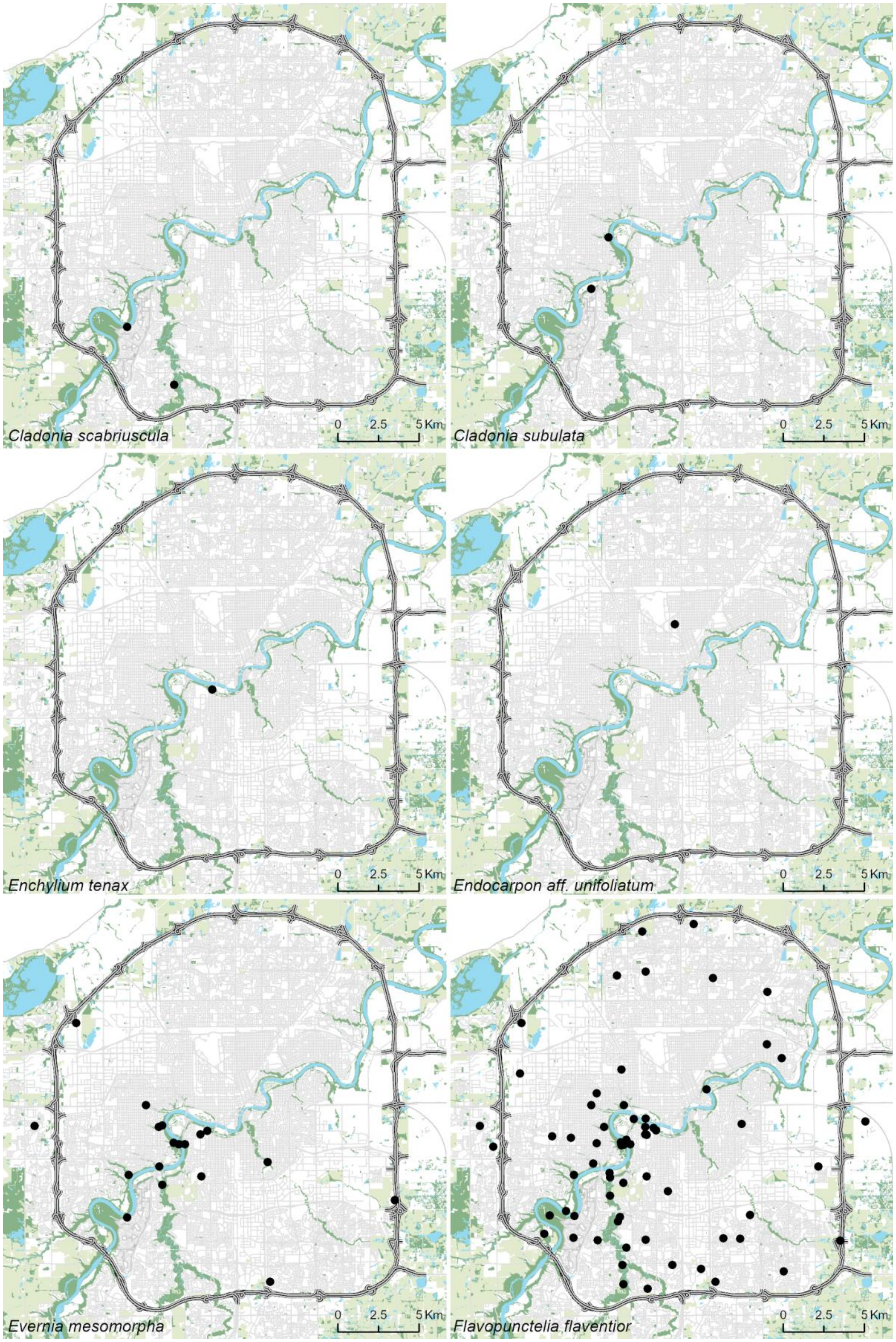
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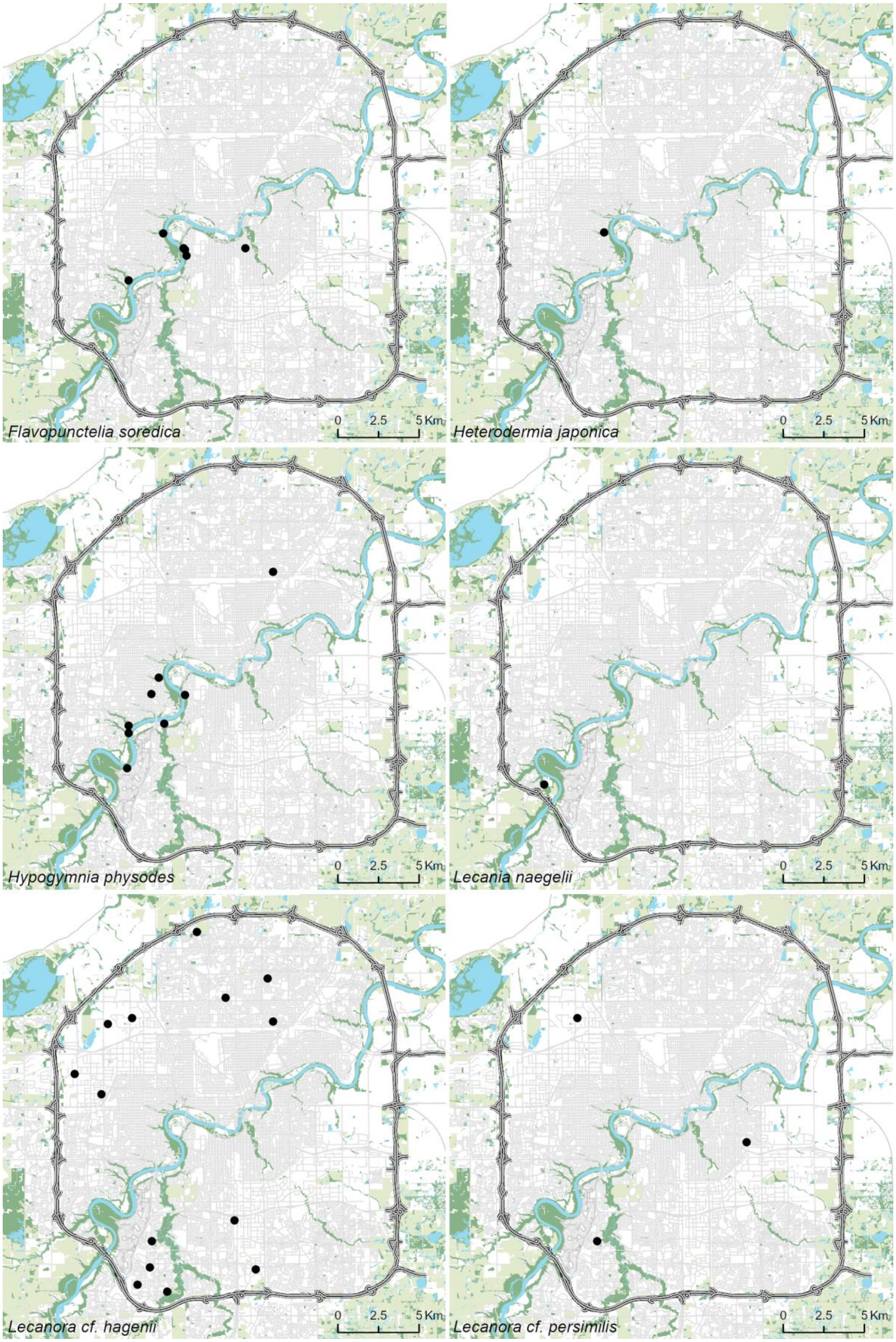
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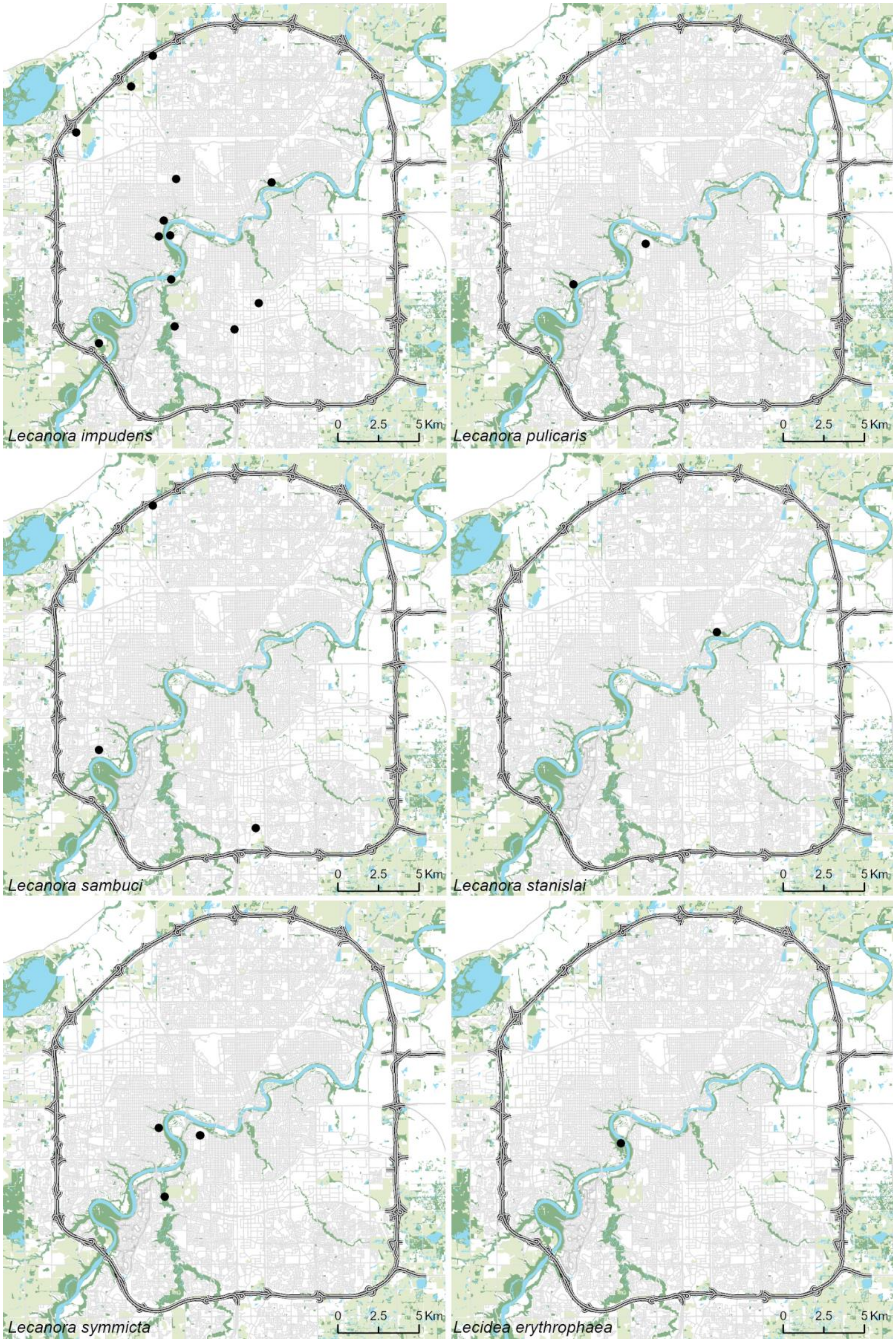
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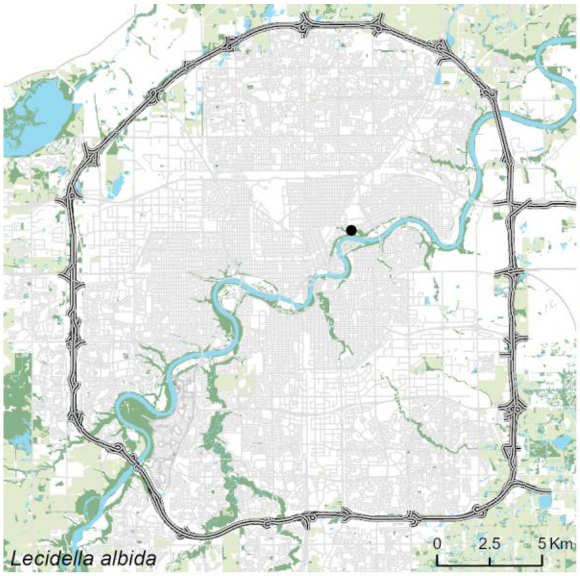
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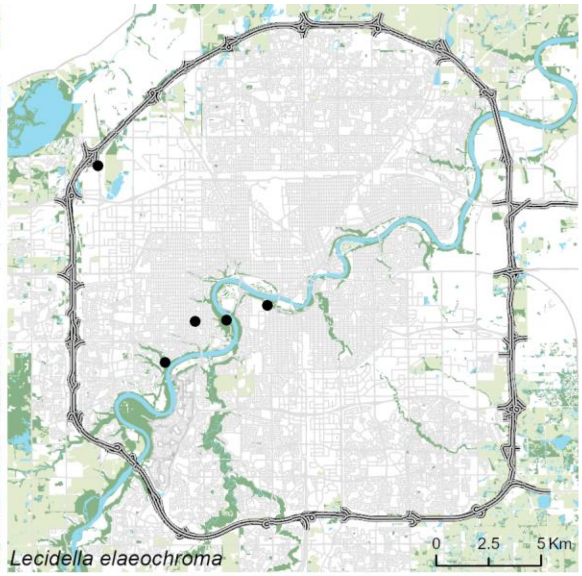
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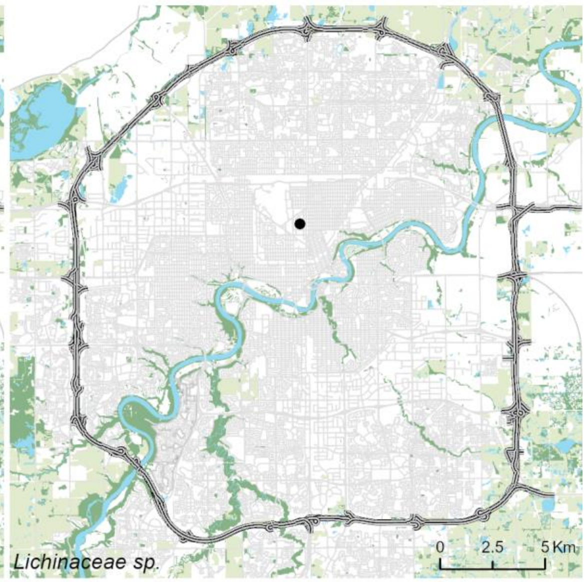
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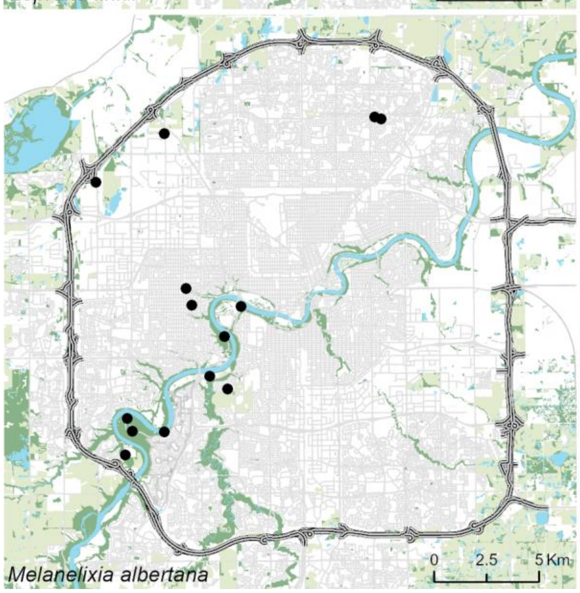
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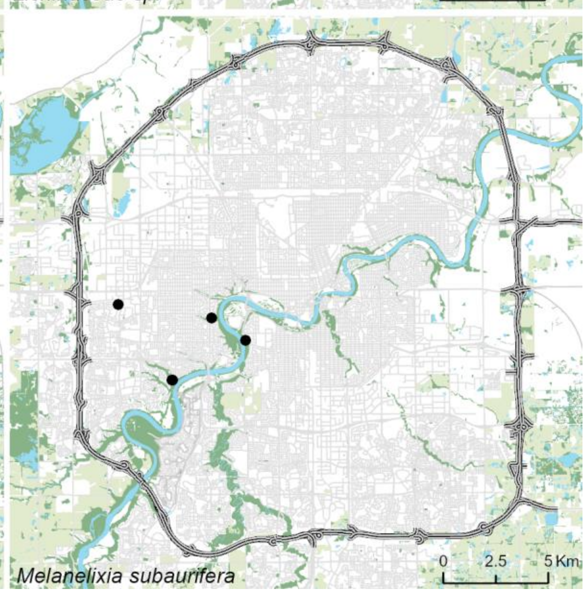
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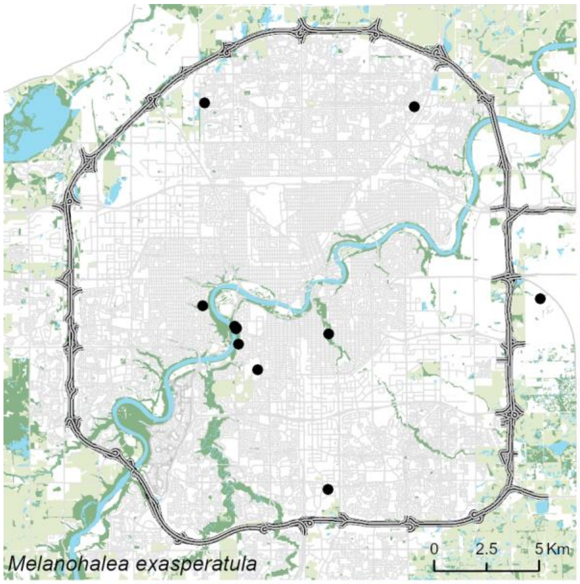
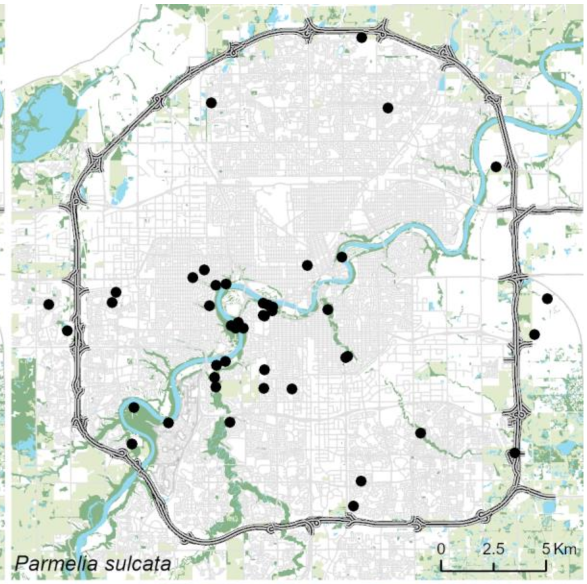
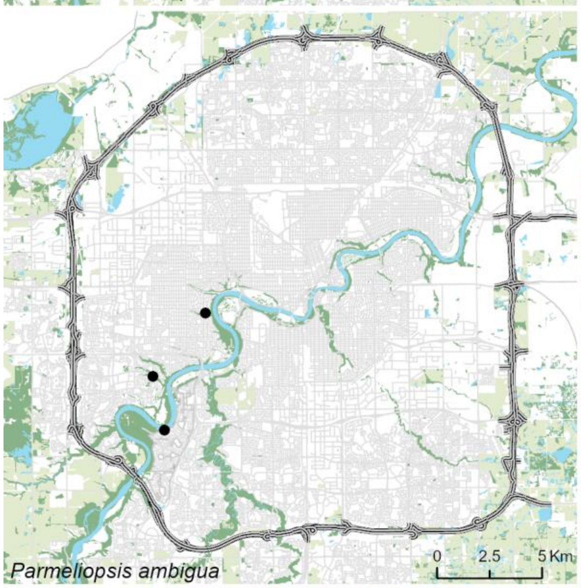

Melanohalea exasperatula
0 2.5 5 Km


Parmelia sulcata
0 2.5 5 Km


Parmeliopsis ambigua
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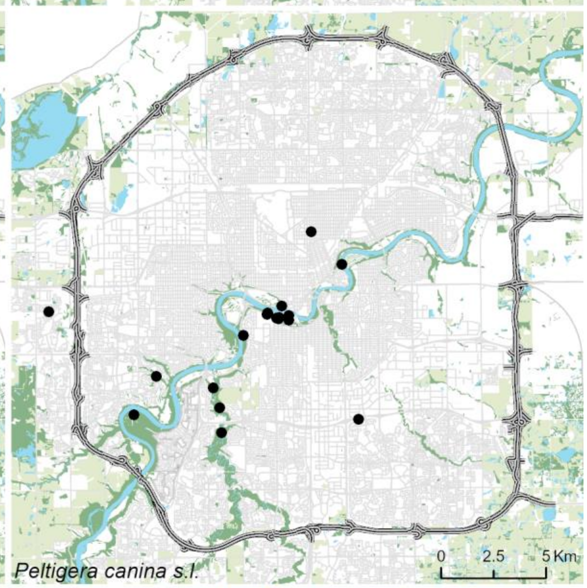
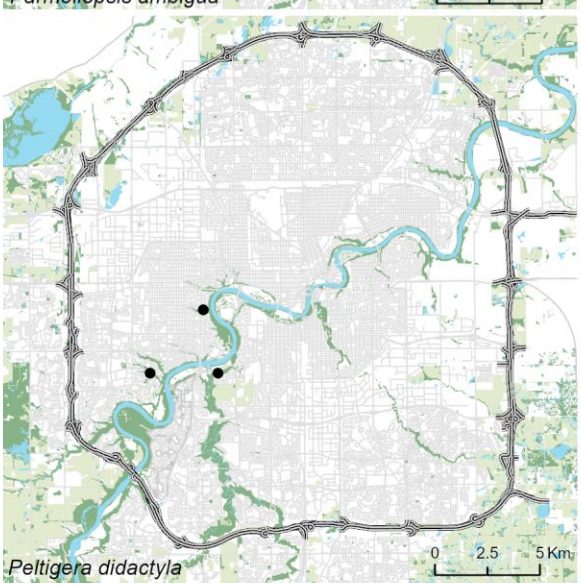

Peltigera canina s.l.
0 2.5 5 Km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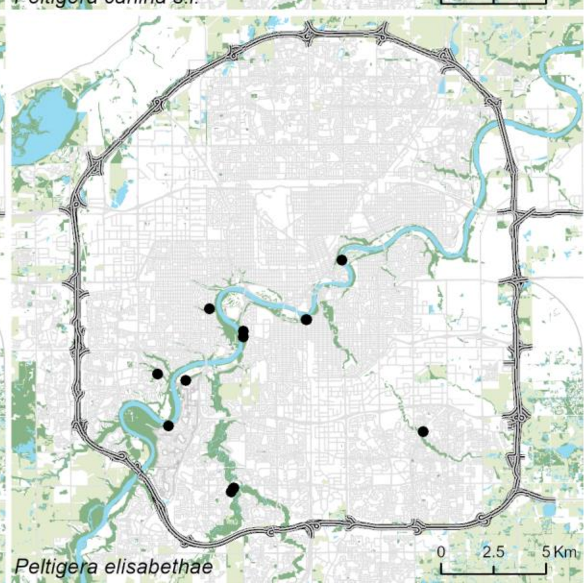
Peltigera elisabethae
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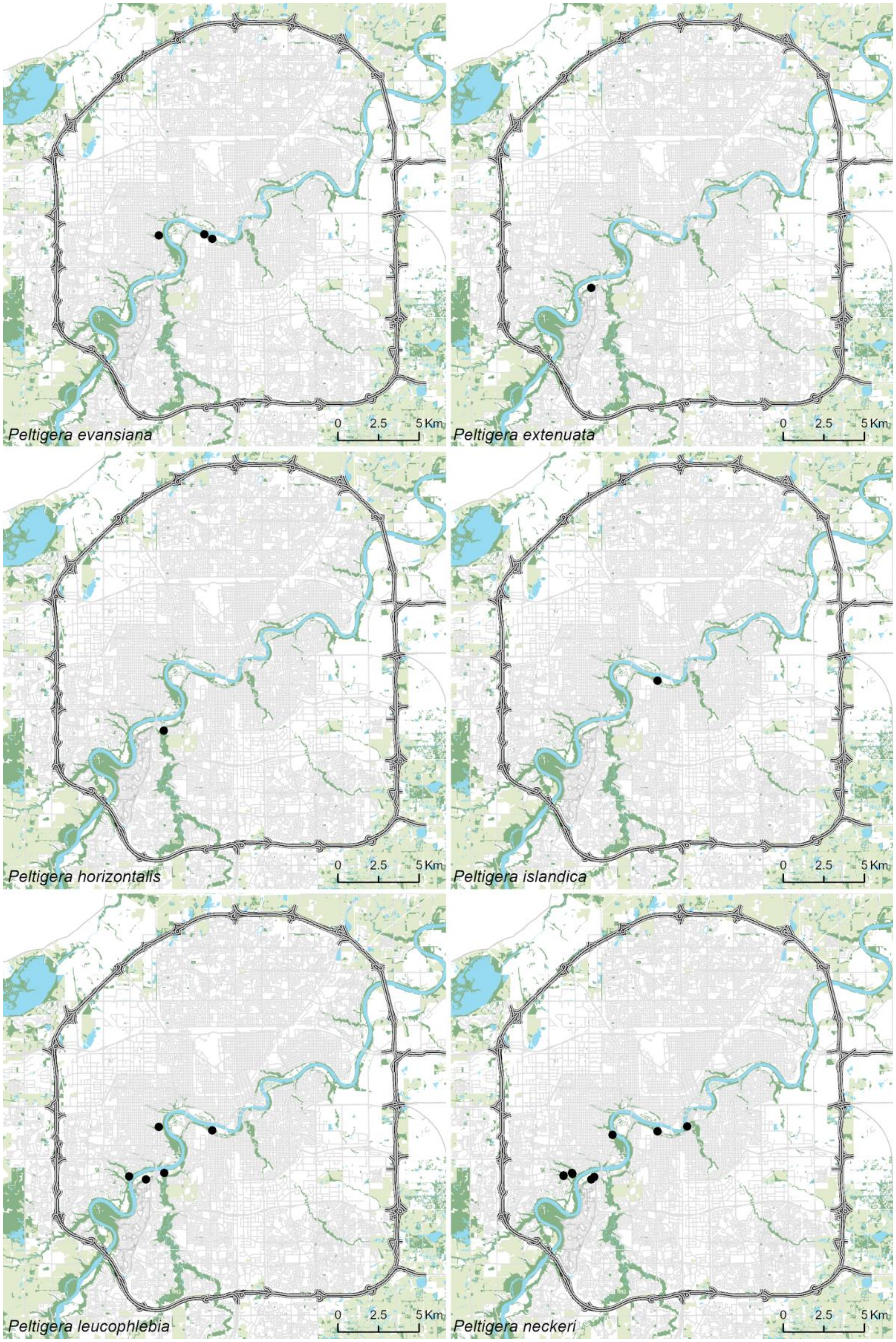
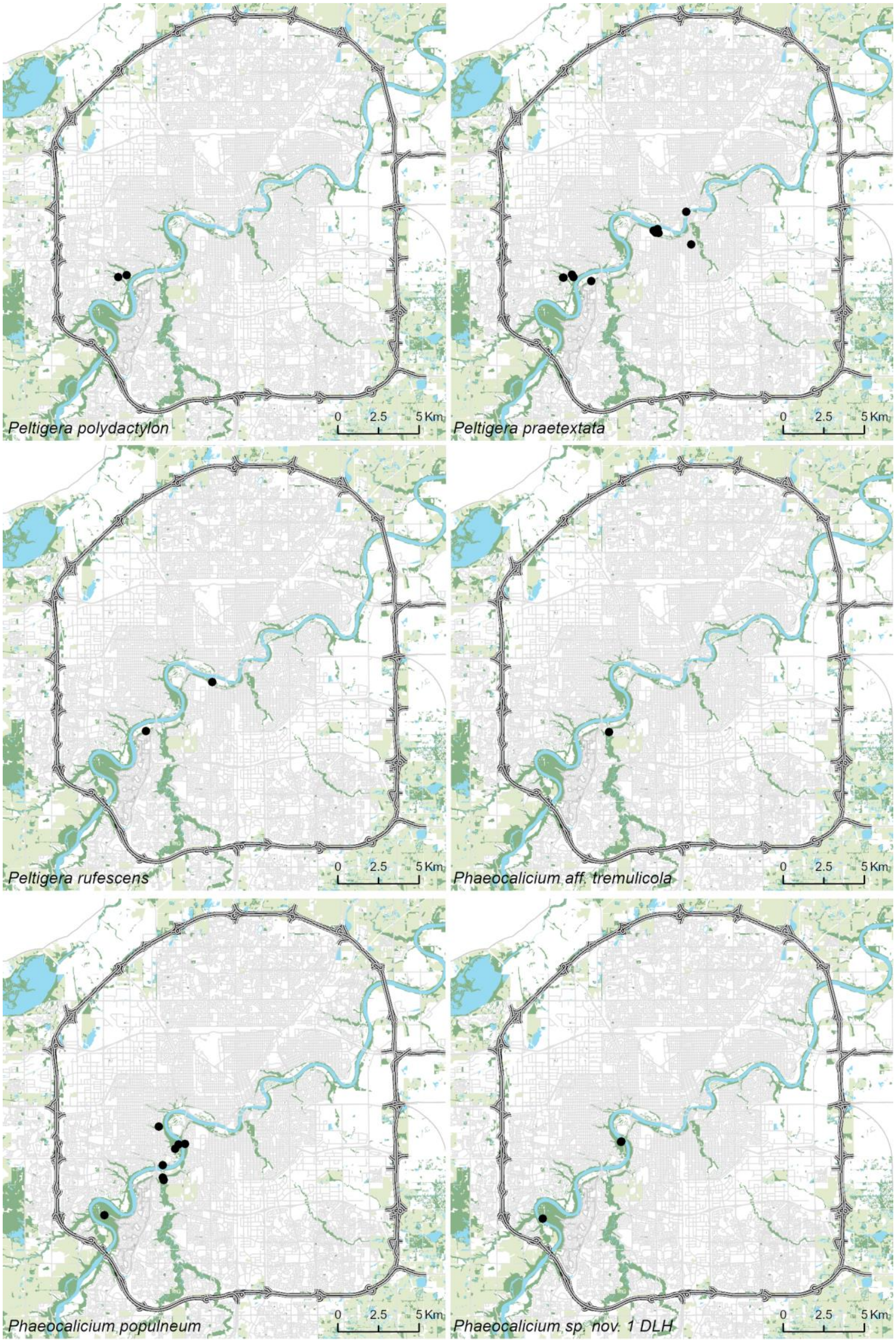
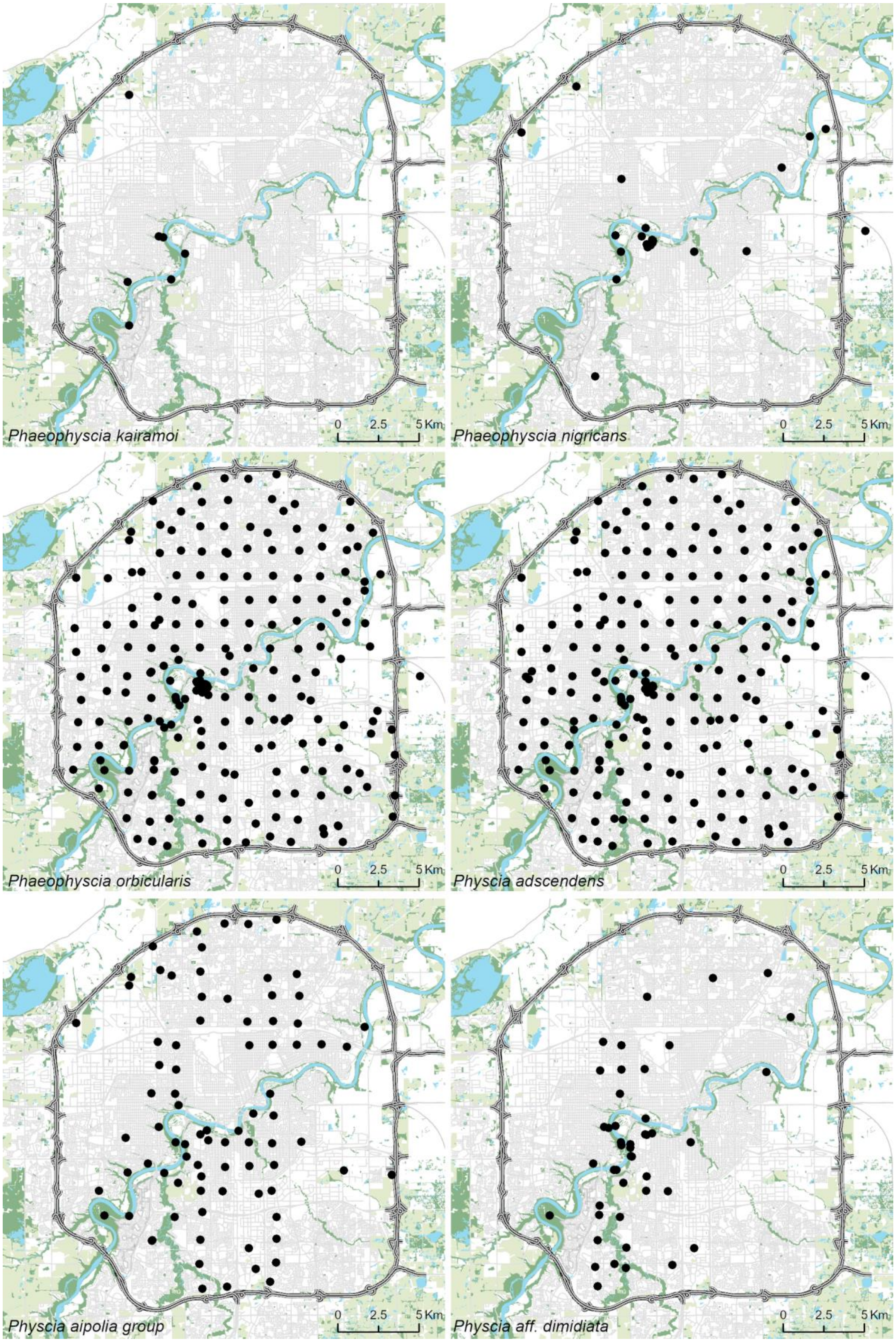

Peltigera evansiana
0 2.5 5 Km
Peltigera extenuata
0 2.5 5 Km
Peltigera horizontalis
0 2.5 5 Km
Peltigera islandica
0 2.5 5 Km
Peltigera leucophlebia
0 2.5 5 Km
Peltigera neckeri
0 2.5 5 Km


Peltigera polydactylon
0 2.5 5 Km
Peltigera praetextata
0 2.5 5 Km
Peltigera rufescens
0 2.5 5 Km
Phaeocalicium aff. tremulicola
0 2.5 5 Km
Phaeocalicium populneum
0 2.5 5 Km
Phaeocalicium sp. nov. 1 DLH
0 2.5 5 Km


Phaeophyscia kairamoi
0 2.5 5 Km
Phaeophyscia nigricans
0 2.5 5 Km
Phaeophyscia orbicularis
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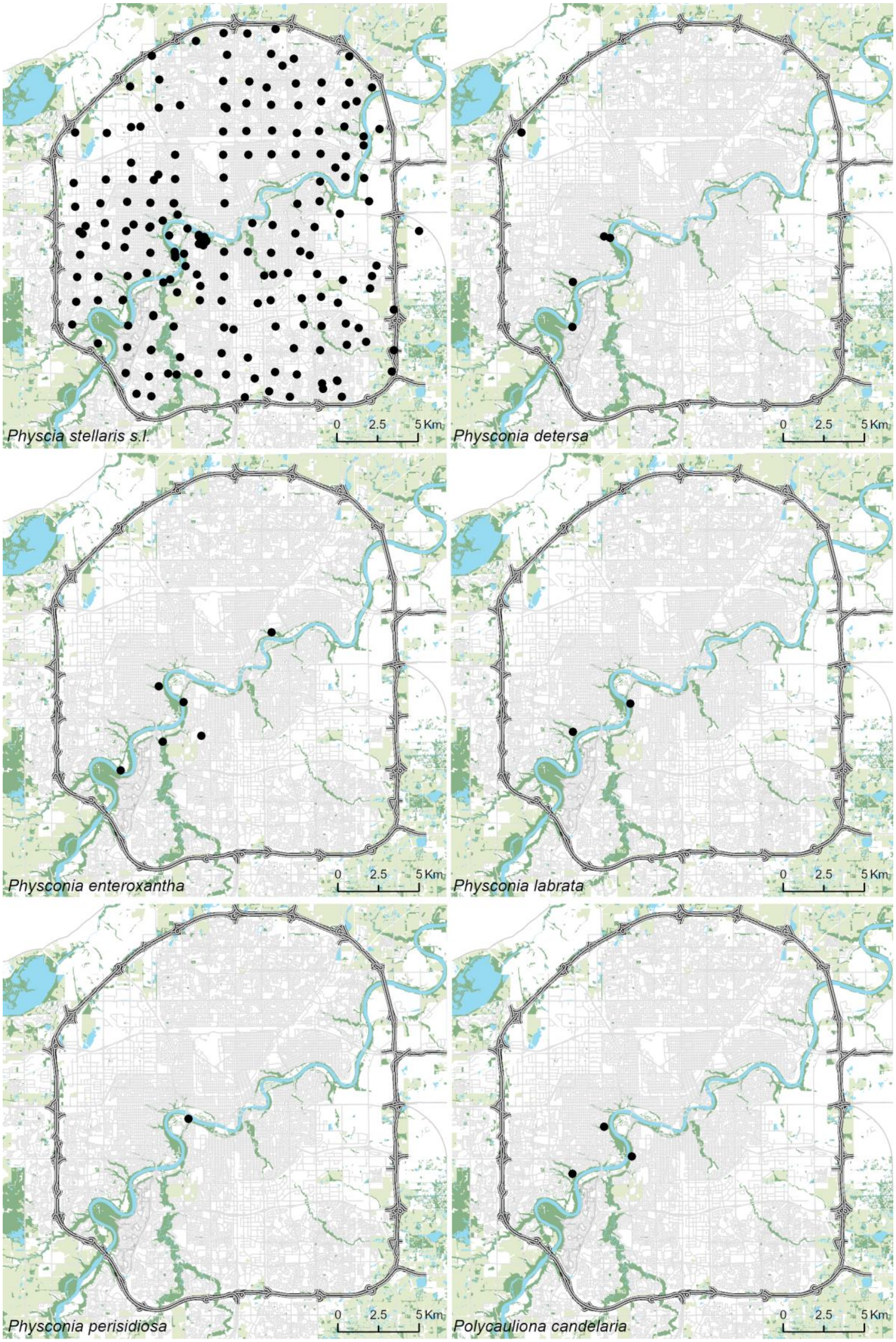
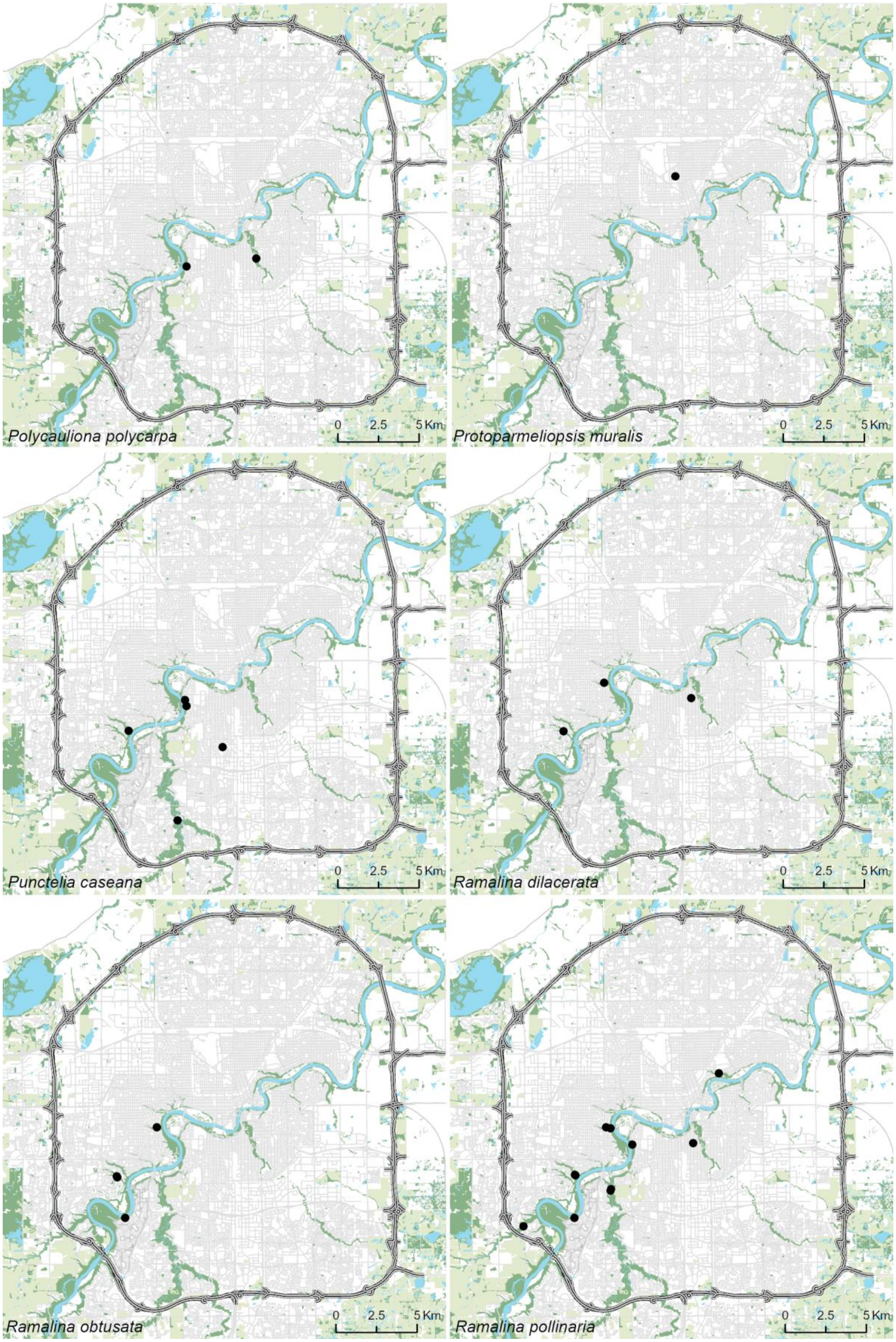
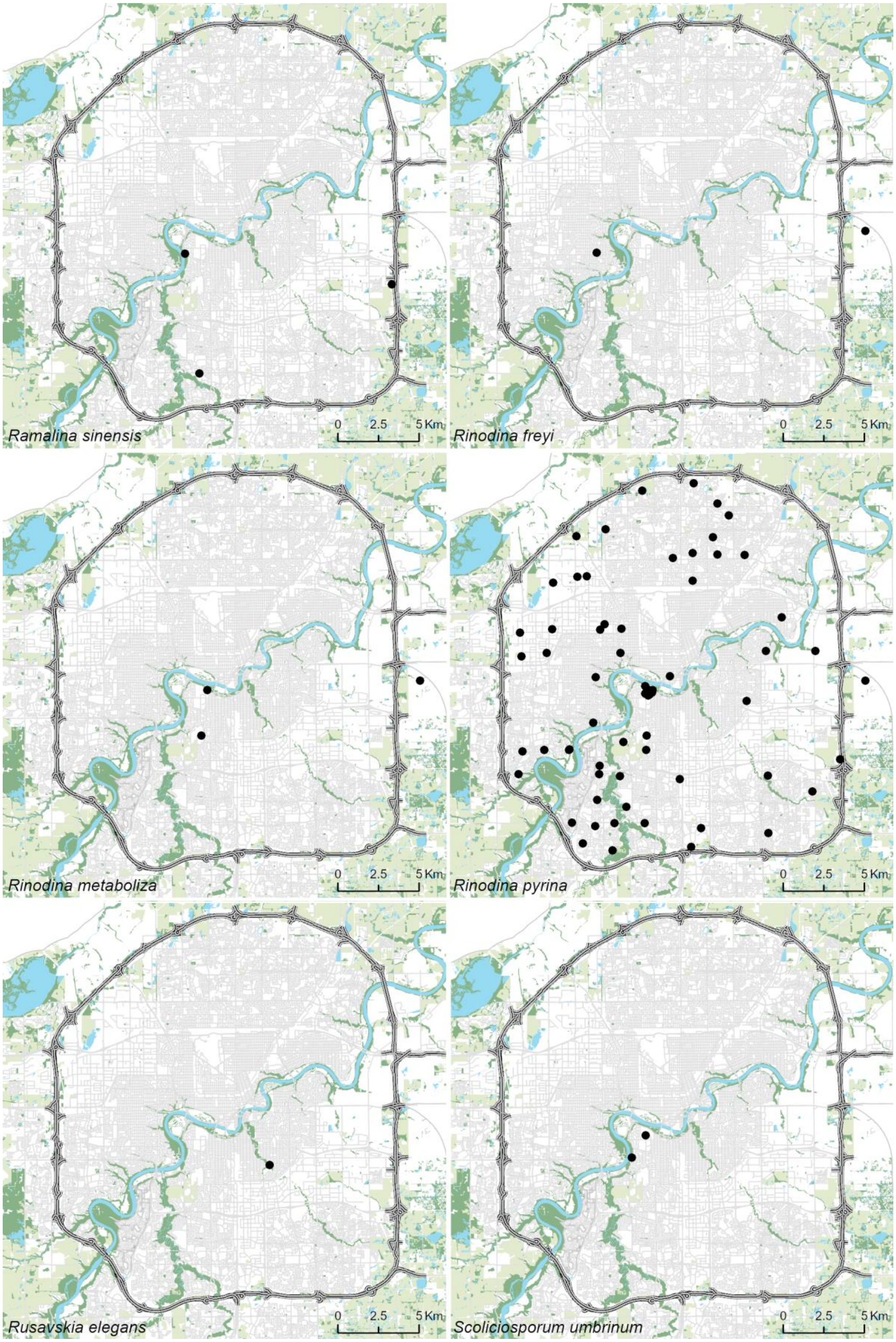
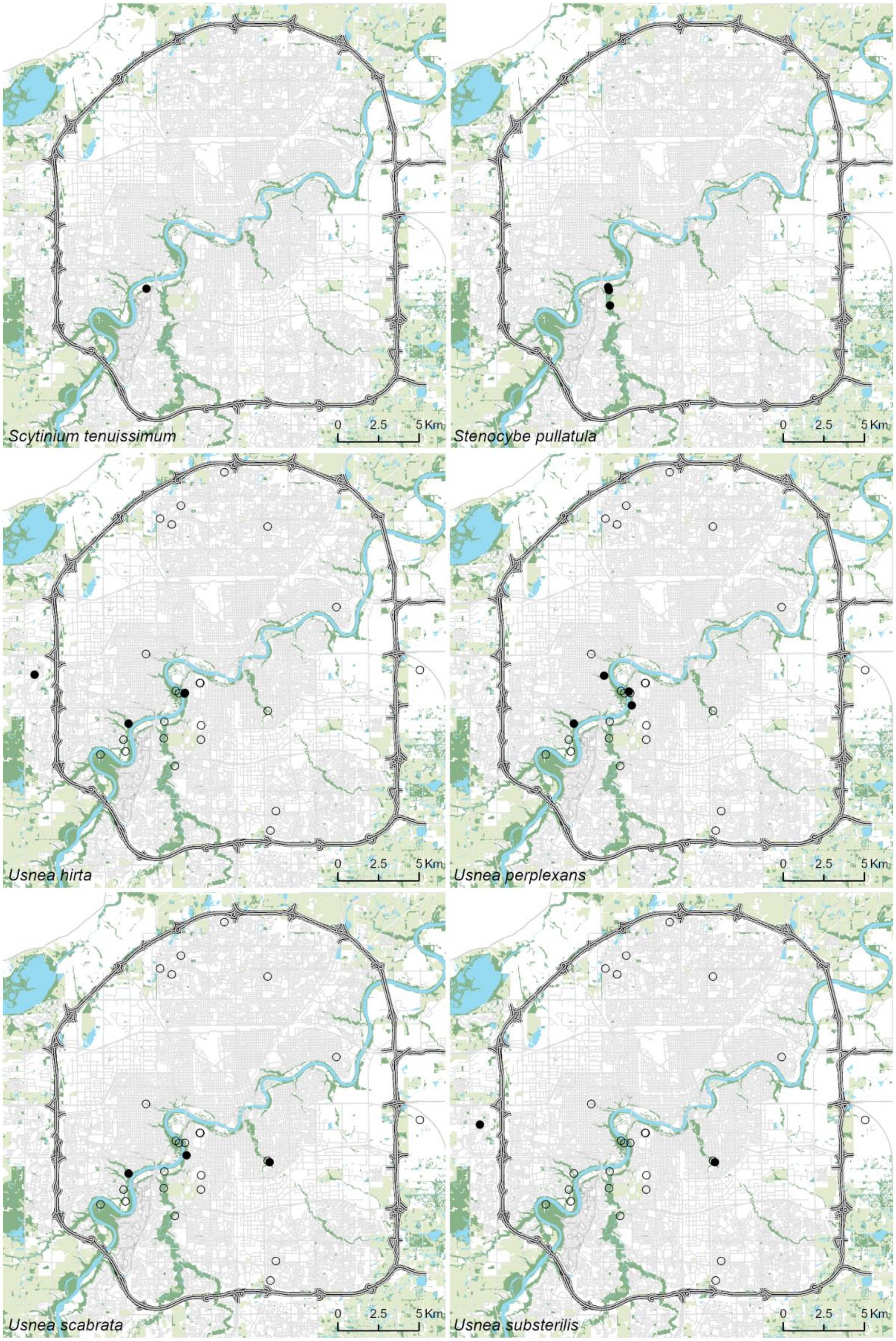
Physcia adscendens
0 2.5 5 Km
Physcia aipolia group
0 2.5 5 Km
Physcia aff. dimidiata
0 2.5 5 Km

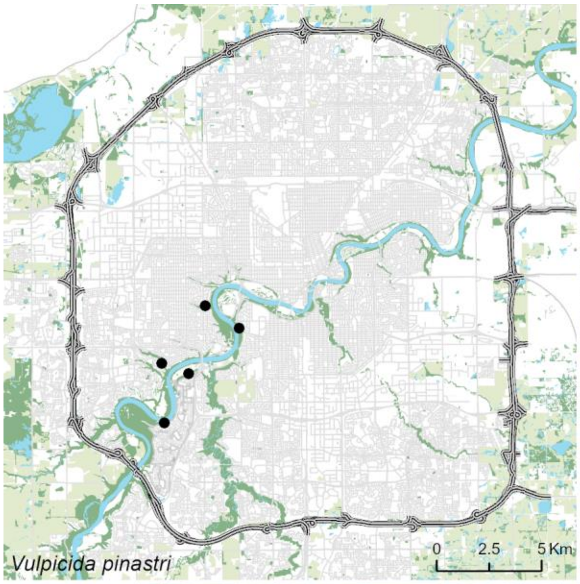

Physcia stellaris s.l.
0 2.5 5 Km
Physconia detersa
0 2.5 5 Km
Physconia enteroxantha
0 2.5 5 Km
Physconia labrata
0 2.5 5 Km
Physconia perisidiosa
0 2.5 5 Km
Polycauliona candelaria
0 2.5 5 Km

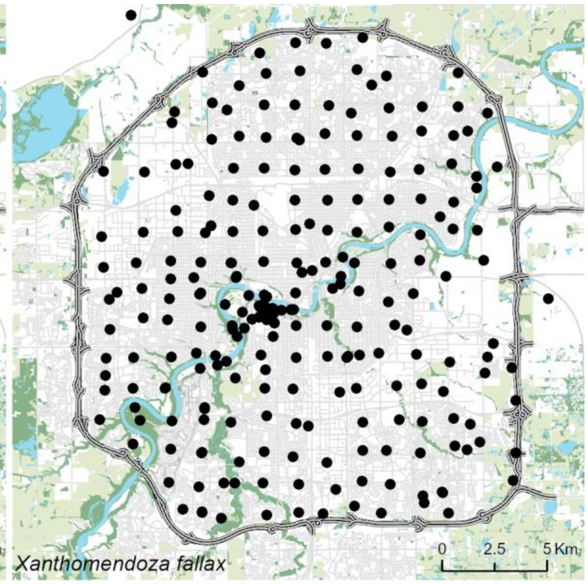


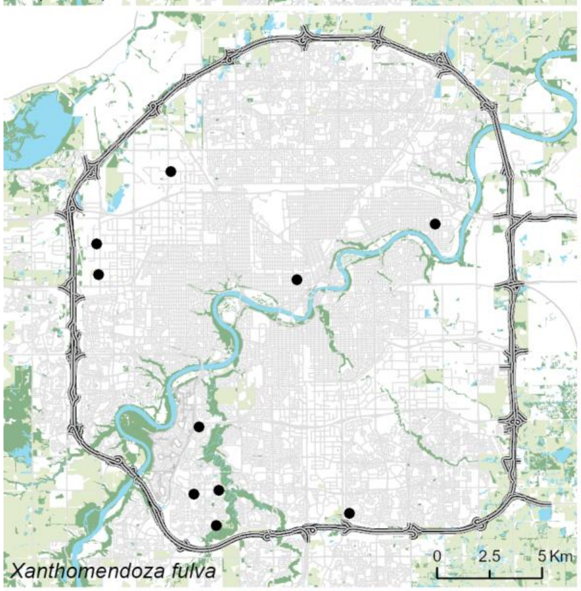
Polycauliona polycarpa
0 2.5 5 Km
Protoparmeliopsis muralis
0 2.5 5 Km
Punctelia caseana
0 2.5 5 Km
Ramalina dilacerata
0 2.5 5 Km
Ramalina obtusata
0 2.5 5 Km
Ramalina pollinaria
0 2.5 5 Km


Ramalina sinensis
0 2.5 5 Km
Rinodina freyi
0 2.5 5 Km
Rinodina metaboliza
0 2.5 5 Km
Rinodina pyrina
0 2.5 5 Km
Rusavskia elegans
0 2.5 5 Km
Scoliciosporum umbrinum
0 2.5 5 Km


Scytinium tenuissimum
0 2.5 5 Km
Stenocybe pullatula
0 2.5 5 Km
Usnea hirta
0 2.5 5 Km
Usnea perplexans
0 2.5 5 Km
Usnea scabrata
0 2.5 5 Km
Usnea substerilis
0 2.5 5 Km


0 2.5 5 Km
Vulpicida pinastri


0 2.5 5 Km
Xanthomendoza fallax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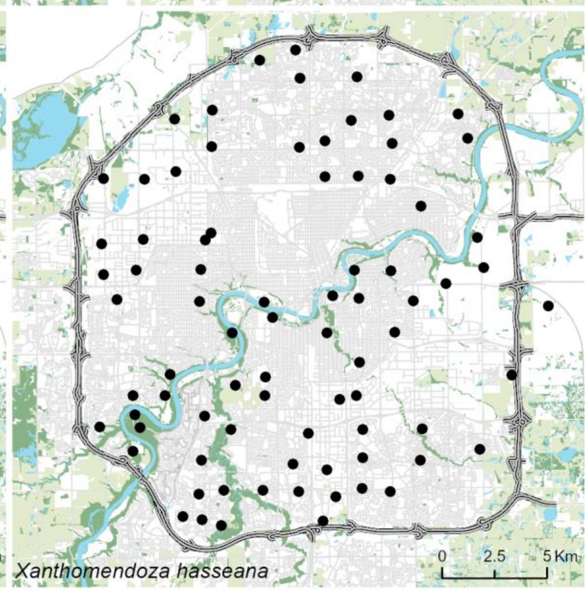
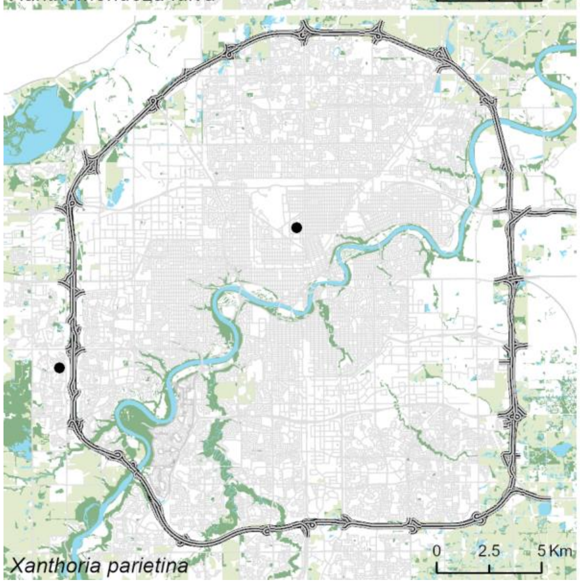
Xanthomendoza fulva


0 2.5 5 Km
Xanthomendoza hasseana


0 2.5 5 Km
Xanthoria parietina