Lichens and Allied Fungi of Rouge National Urban Park in the Greater Toronto Area, Ontario

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Cover Photograph: The Rouge River and Rouge River Valley in Rouge National Urban Park in the Greater Toronto Area of southern Ontario. Photograph © R. Troy McMullin.
Lichens and Allied Fungi of Rouge National Urban Park in the Greater Toronto Area, Ontario

R. Troy McMullin1,*, Claudia Cadranel2, Katherine H.I. Drotos3, Jose R. Maloles4, Juliana T. Skuza2, and Carl-Adam Wegenschimmel5

Abstract - Rouge National Urban Park is in the eastern region of the Greater Toronto Area (GTA) of southern Ontario. It was established in 2015 and is Canada’s first national urban park. To better understand the biodiversity in the park, we conducted a survey of the lichens and allied fungi and discovered 124 species in 69 genera. Three species are reported for the first time from Canada: Arthonia cf. granosa, Verrucaria dolosa, and V. phloeophila. Two additional species are reported for the first time in Ontario: Halecania sp. and Verrucaria praetermissa. Thirty-three species are new to the GTA. Four species have a provincial rank of S3 (vulnerable). Ten species are considered rare in Ontario. Most of the rare species occur in the narrow southern portion of the park that is heavily forested with deep ravines, flood plains, and old-growth forests. Our results show the importance of protected natural areas in urban landscapes for biodiversity, even for taxa that are sensitive to disturbance, such as species of lichens and their related fungi.

Introduction

Rouge National Urban Park (RNUP), in the eastern region of the Greater Toronto Area (GTA), is Canada’s first and only national urban park. Recorded human history in the park area dates back at least 10,000 years and includes the first farmers from Indigenous communities who started growing corn and other crops around 700 AD (PCA 2019, 2021). Increased human disturbances to the landscape as a result of the Euro-Canadian settlement and the proliferation of industrial agriculture, timber harvesting, and milling in the Rouge Valley dates back to the 18th century (PCA 2019, 2021). Disturbances intensified in the 20th century, and much of the Rouge Park landscape was further altered by housing developments, aggregate mineral extraction, the construction of service and transportation corridors, the introduction of numerous invasive alien plant species and feral animals, altered hydrological and fire regimes, unmanaged and increasing park visitation, dumping, and the creation of several unofficial trails through sensitive habitats, with most of these issues predating Parks Canada’s presence (PCA 2021). Despite these disturbances, the park still contains a rich biodiversity, including 971 species of vascular plants, 112 breeding birds, 24 mammals, and 19 herpetofauna (TRCA 2015). The 2013 Ontario BioBlitz (a 24-hour survey) also took place in the area that is now RNUP, and 54 lichen species were reported (McMullin et al. 2018).

Lichens are stable composite organisms that are comprised primarily of a mycobiont (fungus) and a photobiont (an alga, cyanobacterium, or both) (Brodo et al. 2001). Many lichen species are sensitive to disturbance and, consequently, are typically studied outside of urban centers in Canada, in less disturbed habitats where diversity tends to be higher (e.g., Bell-Doyon et al. 2021, Brodo et al. 2013, Paquette et al. 2019). A lichen study in three southern Ontario cities...
(Hamilton, Niagara Falls, and Owen Sound) confirmed this narrative and showed a negative
correlation between urbanization and lichen diversity (McMullin et al. 2016). One of the main
reasons for the lower diversity in urban areas is the presence of pollutants in the atmosphere and
precipitation, from which lichens obtain minerals and nutrients (Richardson 1975, Richardson
and Cameron 2004). They have a range of tolerances to air pollution and, as a result, sensitive
species have been used extensively to monitor air quality (Cameron et al. 2007, Henderson 2000,
Richardson 1992). Lichens are also used to monitor ecological integrity. Due to the narrow
environmental conditions required by particular species, they can be used as indicators of subtle

Despite the sensitivity of many species, natural environments in urban areas still provide
suitable habitat for many lichens (e.g., Allen and Howe 2016; Allen and Lendemer 2021; Mc-
Mullin et al. 2014; Tumur and Richardson 2017, 2019). For example, old-growth forests in deep
ravines, like those in the southern part of RNUP, could host relic populations in a landscape
where few old-growth forests remain (Bohdan 2014, Henry and Quinby 2010). The species
inhabiting old-growth forests can also become established in maturing stands nearby more easily
as dispersal limitations are reduced (e.g., Hilmo and Såstad 2001). In addition, the habitat
in urban parks is important for recolonization as air quality improves. Ontario’s air quality has
steadily improved since 1988 (Ministry of the Environment 2014). Therefore, lichens may re-
colonize suitable habitats in the GTA as they have done in the European cities of London and
Paris when air quality improved (Rose and Hawksworth 1981, Seaward and Letrouit-Galinou
1991). However, to track whether recolonization is occurring or to monitor increases or declines
in populations, baseline data are required. Knowing what species are present, where they are
located, and identifying which are rare or sensitive are also essential for developing management
strategies (Reid and Miller 1989, Powell et al. 2000).

The aim of our study is to document the lichen and allied fungi biota in RNUP. Our objec-
tives were to survey the major ecosystem types, examine as many meso- and micro-habitats as
possible, provide a summary of the lichen and allied fungi species discovered, and highlight rare
species and their location in the park. The results can help to illustrate the importance of natural
space in urban areas for biodiversity, even for taxa that are sensitive to disturbance such as spe-
cies of lichens and their related fungi.

**Methods**

**Study Area**

Parks Canada, an agency of the Government of Canada, began working towards the estab-
ishment of RNUP in 2011 with municipal and provincial governments, Indigenous partners,
and stakeholders (PCA 2019). The park was officially created in May 2015, and once it is fully
developed, it will cover 19546 acres (49.15 miles²) (PCA 2019), making it the largest protected
urban area in North America.

Rouge National Urban Park is located in the eastern portion of the GTA, Canada’s largest
metropolitan area (with 6,417,516 people), and overlaps the cities of Markham, Pickering,
Toronto, and the Township of Uxbridge (Fig. 1, PCA 2019, Statistics Canada 2017). The park
is centered on the Rouge River and its tributaries, but it also includes portions of the Duffins
Creek and Petticoat Creek watersheds (PCA 2021, TRCA 2015). It stretches north from Lake
Ontario about 14 miles to the Oak Ridges Moraine. This area has been exposed since the Late
Wisconsin glacier retreated about 12,000 years ago (Barnett et al. 1998). The bedrock in the
park is mostly shale (PCA 2019, Sharpe 1980). The ecosystems include forests, meadows,
ravines, and inland and coastal wetlands, along with small remnants of rare habitats such as
oak savannah and some of the northern-most remnants of Carolinian woodlands in Ontario.
(PCA 2021, TRCA 2015). The northern section of the park has scattered wetland and forested pockets with corridors intertwined, but it is mostly used for agriculture—approximately 50% of the total park area is actively farmed (PCA 2019). The southern section of the park is at the northern limit of the Carolinian Life Zone and it contains mature forested ravine complexes.

Figure 1. Rouge National Urban Park land cover and collection sites for all lichens and allied fungi. Red dots = rare species, which are defined in Table 2. Green dots = all other collection sites.
with steep valley slopes, bluffs, expansive floodplains, and the largest coastal wetland in Toronto, the Rouge Marsh (PCA 2019, 2021; TRCA 2015). The park is between 43.78974°N and -79.12129°W in the south, 43.99500°N and -79.19948°W in the north, 43.79476°N, -79.11678°W in the east, and 43.94834°N, -79.26816°W in the west. The mean annual temperature in the region is 48.92°F with a mean monthly low of 25.34°F in January and a high of 72.14°F in July, and the mean annual precipitation is 32.72 inches, with rainfall constituting 86% of the total (Government of Canada 2017). Most of the rain falls in May, August, and September, while most of the snow falls between December and March (Government of Canada 2017). The minimum and maximum elevations are 242.78 feet and 1082.68 feet above sea level (Ontario Ministry of Natural Resources and Forestry 2022). Air quality has been improving in Ontario in recent decades, and there has been considerable improvement since 2008, as well as fewer smog advisories (Government of Ontario 2014). Nitrogen oxides, sulphur dioxide, carbon monoxide, and fine particulate matter have decreased in concentration and emission by over 10% between 2006 and 2015, while ozone increased 3% (Government of Ontario 2015).

**Sampling**

Our survey of the lichens and allied fungi of RNUP was conducted from October 25–27, 2020. We also include the results from the Ontario BioBlitz on September 15, 2013. Using land cover maps, we selected a wide variety of natural habitat types to assess (Figs. 1 & 2, Table 1). Our survey methods followed Newmaster et al. (2005), who showed that examining large areas (referred to as floristic habitat sampling) captures cryptogam diversity more effectively than using smaller representative plots. Using floristic habitat sampling, we surveyed as many ecosystems in the park as possible. All observed restricted mesohabitats (e.g., streams, rock outcrops) were examined in each ecosystem. We attempted to assess as many microhabitats (e.g., snags, different tree species and rock types) as possible at each location. This method was described by Selva (2003) as an “intelligent meander.”

**Identification**

Our specimens were identified using light microscopy (compound and stereomicroscopes) and chemical spot tests with paraphenylenediamine in ethyl alcohol, 50% nitric acid, sodium hypochlorite, 10% and 20% potassium hydroxide, and Lugol’s iodine following Brodo et al. (2001). We further examined chemistry using a longwave ultraviolet light chamber (365 nm). Specimens that we could not reliably identify by morphology, spot tests, or ultraviolet light were analyzed for secondary metabolites using thin-layer chromatography (TLC) in solvents A, B’, and C following Culberson and Kristinsson (1970) and Orange et al. (2001). We captured images with a Leica DVM6 digital microscope (Figs. 3A, C; 4A, C, E). Maps were produced with ArcGIS v. 10.8.1 (Figs. 1; 2; 3B, D; 4B, D, F). Our specimens are housed at the Biodiversity Institute of Ontario Herbarium (OAC) at the University of Guelph and at the national herbarium at the Canadian Museum of Nature (CANL).

**Conservation Status**

Provincial conservation status ranks (S-ranks) are non-legal designations, which are set in Ontario by the Natural History Information Centre based on guidelines developed by NatureServe (2021). Species with distributions and frequencies that are well understood receive a rank between 1 and 5. Ranks are defined as follows: 1 = critically imperilled, 2 = imperilled, 3 = vulnerable, 4 = apparently secure, 5 = secure, NR = not ranked, U = unrankable (due to a lack of information), and ? = rank uncertain.
Figure 2. Major collection areas for lichens and allied fungi in Rouge National Urban Park. Roman numerals correspond with collections in the annotated species list and the habitat descriptions in Table 1.
Table 1. Site coordinates and habitat descriptions for localities examined. Roman numerals correspond with those in Figure 1 and the Annotated Species List.

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Ravine S of Hwy 401</td>
<td>43.79912</td>
<td>-79.12987</td>
<td>Mature and old-growth mixed-wood deciduous dominated forest in a river flood plain in a deep ravine. Tree cover includes American Beech, Eastern Hemlock, Maple, and Willow.</td>
</tr>
<tr>
<td>II</td>
<td>Trails between Glen Rouge Campground and Twyn Rivers Dr</td>
<td>43.80868</td>
<td>-79.14520</td>
<td>Mature American Beech, Eastern Hemlock, Sugar Maple, and Yellow Birch forest. Located atop a ravine.</td>
</tr>
<tr>
<td>III</td>
<td>Vista Trail</td>
<td>43.81425</td>
<td>-79.16157</td>
<td>Mature Sugar Maple/Red Oak forest on a ravine slope.</td>
</tr>
<tr>
<td>IV</td>
<td>Orchard Trail</td>
<td>43.81568</td>
<td>-79.15846</td>
<td>Mature American Beech, Eastern Hemlock, and Sugar Maple forest. Some patches of Freeman Maple/Green Ash Swamp. Also, some cultural woodlands with Manitoba Maple.</td>
</tr>
<tr>
<td>V</td>
<td>Rouge Valley Conservation Centre vicinity</td>
<td>43.81931,</td>
<td>-79.17069</td>
<td>Mature and young mixed-wood forest. Collections of exposed trees or trees at forest edge. Tree cover includes Maple, Russian Olive, Staghorn Sumac, White Ash, and White Pine.</td>
</tr>
<tr>
<td>VI</td>
<td>Cedar Trail and the Beare Wetlands Loop</td>
<td>43.82598</td>
<td>-79.17140</td>
<td>Wetlands with standing water and scattered trees. Most collections in the ravine between the two trails with mature mixed-wood forest that include American Beech, Eastern Hemlock, Eastern White Cedar, Maple, and Yellow Birch.</td>
</tr>
<tr>
<td>VII</td>
<td>Toronto Zoo – Canadian Domain</td>
<td>43.82175</td>
<td>-79.18433</td>
<td>Large scattered trees including Maple and Trembling Aspen.</td>
</tr>
<tr>
<td>X</td>
<td>Sewells Road and Old Finch Ave Vicinity</td>
<td>43.82761</td>
<td>-79.20059</td>
<td>Mature and old-growth mixed-wood forest in and atop a deep ravine. Tree cover includes Ironwood, Maple, and Oak.</td>
</tr>
<tr>
<td>XI</td>
<td>Woodlands Area</td>
<td>43.84600</td>
<td>-79.19386</td>
<td>Mature mixed-wood forests. Tree cover includes Ash, Black Maple, Eastern White Cedar, Red Oak, and Sugar Maple.</td>
</tr>
<tr>
<td>XII</td>
<td>Bob Hunter Memorial Park</td>
<td>43.85550</td>
<td>-79.21053</td>
<td>Mature mixed-wood deciduous dominated forest. Tree cover includes American Beech, Hawthorn, Ironwood, Maple, and Oak. Also, ornamental calcareous boulders and old exposed cedar fence posts.</td>
</tr>
<tr>
<td>XIV</td>
<td>Little Rouge Creek off Hwy 7</td>
<td>43.89002</td>
<td>-79.20454</td>
<td>Mature and old-growth American Beech/Sugar Maple forest on a ravine slope. Also, floodplain forest with Eastern White Cedar, Freeman Maple, Green Ash, and Yellow Birch. Located adjacent to Little Rouge River.</td>
</tr>
<tr>
<td>XV</td>
<td>Plug Hat Rd and Beare Rd</td>
<td>43.83147</td>
<td>-79.17113</td>
<td>Mature American Basswood, Black Cherry, Red Oak, Sugar Maple, and Trembling Aspen forest. Located along a small creek and adjacent to Little Rouge River.</td>
</tr>
</tbody>
</table>
Results

From 374 specimens, 124 species in 69 genera are reported. One hundred and twelve species are lichens and 12 are allied fungi, 2 of which are lichenicolous. Of the lichenized species, 65 (58%) are microlichens (crustose) and 47 (42%) are macrolichens (33 foliose, 14 fruticose). One hundred and eight (96%) species of lichens have green algae as their primary photobiont and 4 species (4%) have cyanobacteria as their primary photobiont. Seven species (6%) are calicioids (1 lichenized and 6 allied fungi).

Three species are reported for the first time from Canada: *Arthonia* cf, *granosa*, *Verrucaria dolosa*, and *V. phloeophila* (Figs. 3 & 4, Table 2). Two additional species are reported for the first time in Ontario: *Halecania* sp. and *Verrucaria praetermissa* (Figs. 3 & 4, Table 2). Thirty three species are reported for the first time from the Greater Toronto Area: *Agonimia* sp., *Anisomeridium polypori*, *Arthonia granosa*, *Aspicilia laevata*, *Bacidina chloroticula*, *B. egenula*, *Caloplaca microphyllina*, *Chaenotheca brunneola*, *Chaenothecopsis perforata*, *C. savonica*, *Cladonia ignatii*, *Halecania* sp., *Inoderma byssaceum*, *Ionaspis alba*, *Lecania crytella*, *Lecanora strobilina*, ...

![Figure 3. A–B, Reported for the first time from Canada. C–D, Reported for the first time from Ontario. A, Arthonia cf. granosa thallus and apothecia (Wegenschimmel 166, CANL). Inset showing the two-celled ascospores with equal sized cells. B, North American distribution of A. cf. granosa. C, Halecania sp. thallus and apothecia (McMullin 22418, CANL). D, North American distribution of Halecania sp. In maps, cyan dots = new records, red dots = previous collections.](image-url)
Lepraria caesiella, Multiclavula mucida, Physconia leucoleiptes, Placynthiella icmalea, Polyozosia dispersa, Punctelia bolliana, Ramalina intermedia, Rinodina tephraspis, Rapalospora viridis, Strigula stigmatella, Trapeliopsis flexuosa, Verrucaria dolosa, V. muralis, V. nigrescens, V. phloeophila, V. praetermissa, and Xanthomendoza weberi.

Ten species are considered rare in Ontario based on provincial ranks (S1-S3) or are non-ranked species with a small number of collections in the province (see Table 2 for additional details): Bacidina chloroticula, B. egenula, Halecania sp., Inoderma byssaceum, Phaeophyscia kairamoi, Verrucaria dolosa, V. praetermissa, V. phloeophila, Viridothelium virens, and Xanthomendoza weberi.

Table 2. Ten lichen and allied fungi species discovered in Rouge National Urban Park that are considered rare in Ontario based on provincial ranks (S1-S3) or are non-ranked species with a small number of collections in the province.

<table>
<thead>
<tr>
<th>Species</th>
<th>Provincial Rank</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacidina chloroticula</td>
<td>SNR</td>
<td>Three previous collections are known from Ontario - Brodo et al. 31686 (CANL), Macoun 2801 (CANL) (det. S. Ekman), and Wong et al. 2712 (CANL) (det. S. Ekman). The latter two collections were reported by Ekman (1996).</td>
</tr>
<tr>
<td>Bacidina egenula</td>
<td>SNR</td>
<td>Known from six previous collections in Ontario. Two from the Ottawa region (Brodo et al. 30406, CANL; Robitaille 149.4, CANL, det. S. Ekman; Ekman 1996), one from Guelph (McMullin 7101, OAC; McMullin et al. 2014), two from the Bruce Peninsula (Lay 08-0276, NY; Lewis 240, CANL; Brodo et al. 2013), and one from the Kingston area (McMullin 22427, CANL).</td>
</tr>
<tr>
<td>Halecania sp.</td>
<td>SNR</td>
<td>First known collection in ON and second known collection in Canada (Brodo et al. 2021).</td>
</tr>
<tr>
<td>Inoderma byssaceum</td>
<td>S3</td>
<td>-</td>
</tr>
<tr>
<td>Phaeophyscia kairamoi</td>
<td>S3</td>
<td>-</td>
</tr>
<tr>
<td>Verrucaria dolosa</td>
<td>SNR</td>
<td>Reported for the first time from Canada. Three previous collections are known: one from British Columbia (Björk s.n., Ways of Enlichenment- Lichen Photogallery — <a href="http://www.waysofenlichenment.net">www.waysofenlichenment.net</a>), and two from Ontario on the Bruce Peninsula (Brodo 32132, CANL) and in Algonquin Provincial Park (Brodo 33065B, CANL).</td>
</tr>
<tr>
<td>Verrucaria praetermissa</td>
<td>SNR</td>
<td>First known collection in Ontario.</td>
</tr>
<tr>
<td>Verrucaria phloeophila</td>
<td>SNR</td>
<td>First known collection in Canada.</td>
</tr>
<tr>
<td>Viridothelium virens</td>
<td>S3</td>
<td>-</td>
</tr>
<tr>
<td>Xanthomendoza weberi</td>
<td>S3</td>
<td>-</td>
</tr>
</tbody>
</table>
Annotated Species List

- The list is arranged alphabetically by genus and species.
- Species authors are cited following Brummitt and Powell (1992) or the 23rd edition of the North American Lichen Checklist (Esslinger 2019).
- Nomenclature follows the 23rd edition of the North American Lichen Checklist (Esslinger 2019). Any deviance from Esslinger’s list represents the opinion of the authors.
- Collection numbers follow the names of each collector.
- Collection numbers followed by (TLC) were analysed with thin-layer chromatography.
- Roman numerals correspond to collection sites in Table 1 and they are illustrated in Figure 2.
- Provincial conservation status ranks (S-ranks) are included for each species (S1-S5, SNR, or SU).
- † = non-lichenized fungi traditionally treated with lichens.
- * = reported for the first time from the Greater Toronto Area.
- ** = reported for the first time from Ontario.
- *** = reported for the first time from Canada.


*Agonimia spp. Corticolous on Acer x freemanii A.E. Murray (Freeman Maple) and Fagus grandifolia Ehrh. (American Beech). Bryicolous over tree bark, lignicolous on stump. Wegenschimmel 153 (IV), 155 (II), 224 (XIII), 308 (II), 314 (XV). SNR. Notes: These specimens do not appear to match any known species of Agonimia. Most of the collections are sterile with scattered roundish areoles that are strongly convex. One of those specimens, Wegenschimmel 272, was fertile and had the large (53–67 × 21–23 μm) heavily muriform ascospores characteristic of the genus. All of the specimens appear to be the same taxon except for two. Wegenschimmel 153 is sorediate, but no other known species in the genus is known to be sorediate, and Wegenschimmel 228 is sterile and has a granular thallus. It is possible that the latter two specimens belong to other genera, but we are placing them here due to their minute size, colour, and general gestalt that is consistent with other species of Agonimia.

Alyxia varia (Pers.) Ertz & Tehler — Corticolous on American Beech, Carya cordiformis (Wangen.) K.Koch (Bitternut Hickory), and Quercus macrocarpa Michx. (Bur Oak). McMullin 22385 (I), Wegenschimmel 158 (VIII), 226 (IX), 247 (IV), 255 (XIV), 269 (IX), 280 (XIII). S4.

Amandinea punctata (Hoffm.) Coppins & Scheid — Corticolous on Acer nigrum F.Michx. (Black Maple), A. Saccharum Marshall (Sugar Maple), and Freeman Maple. McMullin 12535 (XI), Wegenschimmel 258 (XIII), 299 (XV). S5.

*Anisomeridium polypori (Ellis & Everh.) M.E. Barr — Corticolous on Bur Oak, Fraxinus pennsylvanica Marshall (Green Ash), and Quercus rubra L. (Red Oak). McMullin 22382 (I). S4.


***‡Arthonia cf. granosa B. de Lesd. — Corticolous on Red Oak. Wegenschimmel 166 (IV). SNR. Notes: We have observed and collected this taxon frequently in southern Ontario. It is consistent with the description of A. granosa from Europe in lacking algae, making the host bark paler, having circular to ellipsoidal ascomata that are epruinose, ascospores that are 2-celled and 15–25 ×8–15 μm (see inset of Fig. 3A), an epispore that is KI-, and ascomatal gel that is I+ red and KI+ blue (Fig. 3A, Sundin 1999). However, European material is described with pycnidia present (Sundin 1999), which all specimens that we have seen lack. Therefore, it is being placed in A. cf. granosa for now, but further study may reveal the North American material to be a distinct species.

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**Arthonia radiata** (Pers.) Ach. — Corticolous on Ash and Freeman Maple. *McMullin 22387 (XIII), 22400 (I), Wegenschimmel 267 (IV).* S5.


**Arthroporus populorum** A. Massal. — Corticolous on Base of American Beech. *Wegenschimmel 189 (III).* SNR.

**Arthrosporum populorum** A. Massal. — Corticolous on Ash. *McMullin 22392 (XIII).* S1S2.


*Bacidia schweinitzii* (Fr. ex Tuck.) A. Schneid. — Corticolous on Bur Oak. *Wegenschimmel 191 (II).* S5.

*Bacidina chloroticula* (Nyl.) Vězda & Poelt — Corticolous on Base of American Beech. *Wegenschimmel 189 (III).* SNR.

*Bacidina egenula* (Nyl.) Vězda — Saxicolous on concrete. *McMullin 22424 (XII), Wegenschimmel 171 (I).* SNR.

*Bacidina sp.* — Saxicolous (non-calcareous). *Wegenschimmel 161 (XIII).* SNR. Notes: This taxon has minute apothecia ([0.2–]0.3–0.6–[0.7] mm in diameter) with pale brown pigmentation, a granular thallus, and acicular ascospores. It is inconspicuous in the field.

*Bilimbia sabuletorum* (Schreb.) Arnold — Bryicolous, corticolous on *Thuja occidentalis* L. (Eastern White Cedar). *McMullin 22362 (VI), Wegenschimmel 249 (XIII), 257 (XIV).* S5.


**Caloplaca microphyllina** (Tuck.) Hassel — Lignicolous on an old fence post. *McMullin 22363 (XII).* S5.


*Candelaria concolor* (Dicks.) Arnold — Corticolous on American Beech, *Fraxinus Americana* L. (White Ash), *Rhus typhina* L. (Staghorn Sumac), and Sugar Maple. *Maloles 23 (XV), McMullin 12545 (VII), 22367 (XIII), Wegenschimmel 209 (VIII), 220 (XIV), 224 (IX), 252 (XV).* S5.


*Catillaria nigroclavata* (Nyl.) J. Stein. — Corticolous on *Elaeagnus angustifolia* L. (Russian Olive), Freeman Maple, and a fallen conifer branch. *McMullin 12569 (V), 22416 (XIII), Wegenschimmel 214 (XIV).* S4S5.

**Chrysothrix caesia** (Flot.) Ertz & Tehler — Corticolous on Freeman Maple, Red Oak, Russian Olive, White Pine, Yellow Birch. *McMullin 12563 (V), Wegenschimmel 318 (XIII).* SNR. Notes: Ascospores 2-celled, 6–7 × 2.5–3 μm, light brown with a distinct septum. Stalk and capitulum lacking secondary compounds. Stalk <0.6 mm tall. Not associated with lichens or free-living algae.

*Chrysothrix caesia* (Flot.) Ertz & Tehler — Corticolous on Freeman Maple, Red Oak, Russian Olive, White Pine, Yellow Birch. *McMullin 12563 (V), Wegenschimmel 284 (IX), 284 (XV), 324 (XIII).* S5.

Graphis scripta (L.) Ach. — Corticolous on American Beech and Flavopunctelia soredica (Nyl.) Hale

Coenogonium pineti (Ach.) Lücking & Lumbsch — Lignicolous, bryicolous on a stump, and corticolous on Freeman Maple.

*Cresponea chloroconia (Tuck.) Egea & Torrente — Corticolous on Bur Oak.

Evernia mesomorpha Nyl. — Lignicolous on a log and corticolous on Yellow Birch.

*Dictyocatenulata alba Finley & E.F. Morris — Corticolous on Bur Oak and Yellow Birch.

Cladonia pyxidata (L.) Hoffm. — Lignicolous on a log.

Cladonia fimbriata (L.) Fr. — Lignicolous on a log and corticolous on Freeman Maple.

Cladonia incrassata Flörke — Bryicolous and lignicolous on a stump.

Cladonia pocillum (Ach.) O.J. Rich. — Lignicolous on a log.

Lecanora allophana f. sorediata Vain. — Corticolous on Maple and Oak. McMullin 22349\textsuperscript{TLC}, 22349\textsuperscript{TLC}

Lecanora adglutinata (Flörke) H. Mayrhofer & Poelt — Corticolous on Bur Oak and Yellow Birch.

*Lecania cyrtella (Ach.) Th. Fr. — Corticolous on Green Ash.

*Lecanora naegeli (Hepp) Diederich & van den Boom — Corticolous on American Basswood, American Beech, Freeman Maple, Sugar Maple, and Trembling Aspen. McMullin 12548 (VI), Wegenschimmel 227 (VIII), 264 (VIII), 271 (IV), 274 (IV), 282 (I), 320 (XV).

*Lecanora sorediata Vain. — Corticolous on Maple and Oak. McMullin 22349\textsuperscript{TLC}, 22349\textsuperscript{TLC}

*saxicolous (non-calcareous). McMullin 22418\textsuperscript{TLC} (VI), Wegenschimmel 159\textsuperscript{TLC} (XII), 192 (IV).

SNR. TLC: argopsin. Notes: the ascospores are 2-celled, hyaline, and 11.5–15 × 4–5 µm. Asci tips are Catillaria-type. On boulders in a creek valley. Although this taxon is undescribed, it is known from throughout eastern North America (e.g., Harris and Ladd 2005, Brodo et al. 2021). There is only one other record of this taxon in Canada, which is from Quebec (Fig. 3D, Brodo et al. 2021).

Hyperphyscia adglutinata (Flörke) H. Mayrhofer & Poelt — Corticolous on Bur Oak and a Juglans cinerea L. (Butternut) snag. Maloles 44 (II), McMullin 22564 (V), 22388 (XIII), Wegenschimmel 217 (XIV).

†Illosoriopsis christiansenii (B.L. Brady & D. Hawks.) D. Hawks. — Lichenicolous on Physcia adscendens and P. stellaris. Maloles 22 (XV), 29 (I), McMullin 22379 (XIII), Wegenschimmel 307 (XIV).


†Julella fallaciosa (Stüzenb. ex Arnold) R.C. Harris — Corticolous on Sugar Maple and White Birch. McMullin 12521 (IV), 22390 (XIII), Wegenschimmel 198 (IX), 219 (XIV).

Lecania croatica (Zahlbr.) Kotlov — Corticolous on American Beech, Prunus serotina Ehrh. (Black Cherry), Sugar Maple, and Ulmus Americana L. (White Elm). McMullin 22366 (XIII), 22386 (I), Wegenschimmel 221 (IX), 250 (VIII), 251 (XIII), 273 (III), 286 (XV), 293 (III), 312 (XV).

*Lecania cyrtella (Ach.) Th. Fr. — Corticolous on Green Ash. Wegenschimmel 160 (VIII). SNR.

Lecania alophana f. sorediata Vain. — Corticolous on Maple and Oak. McMullin 22349\textsuperscript{TLC}, 22349\textsuperscript{TLC} (XI). SNR. TLC: atranorin and two unknown fatty acids that char with sulphuric acid and heating.


*Lepraria caesiella* R.C. Harris — Lichenoicolous on *†Lepraria caesiella* R.C. Harris


Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on an Eastern White Cedar snag.


*Myricolecis dispersa* (Pers.) Śliva, Zhao Xin, & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple, Black Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on a rotting log (hardwood).

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple, Trembling Aspen.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

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Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.

Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawks., & Lumbsch — Corticolous on Sugar Maple.
Physcia aipolia (Ehrh. ex Humb.) Fürn. — Corticolous on Black Maple, a Butternut snag, Green Ash, and Sugar Maple. Maloles 34 (III), 71 (IX), McMullin 22347TLC (I), Wegenschimmel 253 (XIV), 281 (IV), 323 (XIV). S5. TLC: unknown fatty acids running below norstictic acid.

Physcia milleganra Degel. — Corticolous on Cherry, Freeman Maple, Sugar Maple, and White Ash. Maloles 18 (XV), 27 (I), McMullin 12565 (V), 22370 (XIII), Wegenschimmel 205 (VIII), 218 (XIV), 240 (IX), 242 (XIII), 287 (XV), 321 (XIII). S5.

Physcia stellaris (L.) Nyl. — Corticolous on Sugar Maple and White Ash. Maloles 12 (XV), McMullin 12562 (V), S5.

Physcilla chloantha (Ach.) Essl. — Corticolous on an Ash snag, Crataegus sp. (Hawthorn), Sugar Maple, and White Ash. McMullin 22396 (XII), 22410 (I), 22412 (XI), Wegenschimmel 254 (XIV), 277 (XV), 302 (II). S4?

Physcilla melanconra (Hue) Essl. — Corticolous on Sugar Maple and hardwood. McMullin 22355 (XI), 12543 (VII), Wegenschimmel 200 (IX), 206 (IV), 208 (VIII), 236 (IX), 292 (III), 306 (VIII). S4?


Placynthiella icmalea (Ach.) Coppins & P. James — Saxicolous (non-calcareous).

*Porpidia alboacaulescens (Wulfen) Hertel & Knoph — Saxicolous (non-calcareous). Wegenschimmel 175 (III). S4S5.


Protoparmeliopsis muralis (Schreb.) M. Choisy — Saxicolous. Wegenschimmel 180 (IX). S5.


*Ropalospora viridis (Tønsberg) Tønsberg — Corticolous on American Beech, Balsam Fir, and Maple. Maloles 33 (III), 48 (II), McMullin 22343 TLC (VIII), 22351 TLC (VIII), 22353 TLC (XI), Wegenschimmel 197 (II), 211 (VIII). S4, S5. TLC: perlatolic acid.

Sarcogynne hypophaea (Nyl.) Arnold — Saxicolous (non-calcareous). McMullin 12524 (IV), Wegenschimmel 225 (IX), 291 (III), 319 (XIII). SU.


*Strigula stigmatella (Ach.) R.C. Harris — Bryicolous and saxicolous. McMullin 22393 (VI), S4, S5.


*Trapeliopeps flexuosa (Fr.) Coppins & P. James — Lignicolous on old fence post. Wegenschimmel 172 (XIII). S4S5.

***Verrucaria dolosa Hepp — Saxicolous (non-calcareous). McMullin 22419 (VI), 22420 (VI), Wegenschimmel 185 (III), 186 (XIII), 199 (XIII), 300 (XV), 203 (XIV). SNR. Notes: Distinguished from similar species of Verrucaria on non-calcareous rocks by its thin thallus (25–50 μm thick) that is continuous (not forming areoles) and green to olive-brown ascospores that are 1-celled and 15–17.5 × 6.5–8.5 μm, and small (100–150–180] μm wide) semi-immersed to prominent perithecia with a colourless excipulum (Fig. 4A, Krzewicka 2012). Although this species is reported for the first time in Canada, it is common in RNUP.


***Verrucaria phloeophila Breuss** — Corticolous on Eastern White Cedar. *Wegenschimmel* 177 (XIV), 178 (XIII). SNR. Notes: This species is characterized by its corticolous substrate, an involucrellum that is indistinguishable from the dark exciple (see inset of Fig. 4C), a dark exciple throughout when perithecia are mature, and large ascospores (25–30 × 12–14 μm) (Fig. 4C, Lendemer and Breuss 2009).

**Verrucaria praetermissa** (Trevis.) Anzi — Saxicolous (non-calcareous). *Wegenschimmel* 173 (XIV), 241 (XIII). SNR. Notes: Distinguished from other *Verrucaria* species on non-calcareous rocks by a well-developed thallus with a grey-brown matt upper surface, a continuous black basal layer (see inset of Fig. 4E), immersed perithecia that are not in mounds on the thallus, and ascospores that are 18–23 × 7–13 μm (Fig. 4E, Krzewicka 2012).

**Viridothelium virens** (Tuck. ex Michen.) Lücking — Corticolous on American Beech. *Maloles* 36 (III), 54 (II), *McMullin* 22405 (I), Wegenschimmel 195 (IX), 303 (II). S3. Notes: specimens were all sterile.


Discussion

The lichen and allied fungi biota in RNUP includes a high number of rare species (10). The overall number of species discovered in the park (124) was surprisingly high as well, considering the urban landscape surrounding the park and the many previous and current disturbances. However, with no base-line data, it is impossible to know how this community of species compares to historical ones. Now that there is a base-line, management strategies for rare species can be developed and changes in populations can be monitored.

Comparisons to lichen communities in other areas in southern Ontario are also difficult to make because of different ecosystems, disturbances, and sizes (see Table 3 for comparisons). For example, the Carden Alvar Natural Area is the closest location (54.5 miles north) with a comparable lichen and allied fungus survey (199 species) (*McMullin* 2019). Nonetheless, that area is composed entirely of an alvar ecosystem that does not exist in RNUP. It is also a larger area (31810 acres vs 19546 acres in RNUP), is far from an urban center, and it lacks Carolinian forests and deep ravine ecosystems (*McMullin* 2019). The Arboretum at the University of Guelph in the City of Guelph is the next closest park (55.5 miles west), and the only other urban park that has been surveyed in the province (*McMullin* et al. 2014). It contains 104 species, but it is smaller (408 acres) and the bedrock is calcareous, which many lichen species are restricted to (*McMullin* et al. 2014, Lendemer and Harris 2008). Sandbanks Provincial Park is 94 miles east of RNUP and is the only other coastal park on the north shore of Lake Ontario that has been surveyed (it contained 128 species) (*McMullin* and Lewis 2014). However, the park is largely a dune ecosystem and it has calcareous rock outcrops, which are unlike any of the ecosystems at RNUP. There appears to be no comparable areas in Ontario that have been
surveyed for lichens and allied fungi, so the effects of the urbanization cannot be inferred by the communities in other areas.

Previous collections of lichens and allied fungi have been made in the GTA. McMullin et al. (2018) summarized all known collections, most of which were made during four bioblitzes in different watersheds within the GTA. They compiled all historical records with those made during the bioblitzes and reported 180 species. We discovered an additional 33 species that had not previously been reported and increase the number of known lichens and allied fungi in the GTA to 213.

The old forest stands in and around the deep ravines at the southern end of the park contained the greatest number of rare species (see Fig. 1). The steep slopes of the ravines likely prevented large scale timber harvesting in the past, and the lichen and allied fungus communities were preserved except for species that were negatively affected by air pollution.

Rouge National Urban Park is Canada’s only national urban park and, once fully developed, it will be the largest urban park in North America. The ecological integrity in the park has been affected considerably by past and current settlement and recreation activities. The park is surrounded by a dynamic urban environment, including residential, industrial, and commercial developments and infrastructure such as roads, highways, rail lines, hydro corridors, regional water mains, pipelines, and sewers that traverse all parts of the park and have the ability to greatly impact the ecological integrity of RNUP (PCA 2019, 2021). However, since the park was established in 2015, there have been at least 72 ecological restoration and farmland enhancement projects completed, in partnership with Toronto and Region Conservation Authority, Indigenous partners, and park farmers (PCA 2021). The results include the restoration of more than 173 acres of aquatic habitat, more than 67 acres of forest habitat, 5 acres of meadow habitat, and the planting of more than 126,000 native trees, perennials, shrubs and aquatic plants (PCA, 2021).

Based on these restoration projects and the improved air quality in the GTA in recent decades (Ministry of the Environment 2014), we expect the lichen and allied fungus biota to increase in the park. Future monitoring of the rare species is recommended. Our study shows that, despite their sensitivities, many lichens and their related fungi can colonize and persist in urban environments when suitable habitat is available.

Table 3. Survey results from studies of lichens and allied fungi in southern Ontario parks with similar search effort to that of the study in Rouge National Urban Park.

<table>
<thead>
<tr>
<th>Location</th>
<th>Approximate distance from RNUP (miles)</th>
<th>Area (acres)</th>
<th>Number of Species</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rouge Urban National Park</td>
<td>0</td>
<td>19546</td>
<td>124</td>
<td>-</td>
</tr>
<tr>
<td>Carden Alvar Natural Area</td>
<td>54.5</td>
<td>31810</td>
<td>199</td>
<td>McMullin 2019</td>
</tr>
<tr>
<td>Arboretum at the University of Guelph</td>
<td>55.5</td>
<td>408</td>
<td>104</td>
<td>McMullin et al. 2014</td>
</tr>
<tr>
<td>Copeland Forest Resource Management Area</td>
<td>57</td>
<td>4398</td>
<td>154</td>
<td>McMullin and Lendemer 2013</td>
</tr>
<tr>
<td>Awenda Provincial Park</td>
<td>80</td>
<td>7203</td>
<td>203</td>
<td>McMullin and Lendemer 2016</td>
</tr>
<tr>
<td>Sandbanks Provincial Park</td>
<td>94</td>
<td>3832</td>
<td>128</td>
<td>McMullin and Lewis 2014</td>
</tr>
<tr>
<td>Frontenac Provincial Park</td>
<td>138</td>
<td>12884</td>
<td>280</td>
<td>Lewis 2020</td>
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</table>
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Literature Cited


