# North American Fungi

**Volume 9, Number 5, Pages 1-16**
**Published August 28, 2014**

# The Arboretum at the University of Guelph, Ontario: An urban refuge for lichen biodiversity

**Richard Troy McMullin[1], Jose R. Maloles[1], Chris Earley[2], and Steven G. Newmaster[1]**

[1]Department of Integrative Biology, University of Guelph, 50 Stone Road East, Guelph, ON, N1G 2W1
[2]The Arboretum, University of Guelph, 50 Stone Road East, Guelph, ON, N1G 2W1

McMullin R. T., J. R. Maloles, C. Earley, and S. G. Newmaster. 2014. The Arboretum at the University of Guelph, Ontario: An urban refuge for lichen biodiversity. *North American Fungi* 9(5): 1-16.
http://dx.doi.org/10.2509/naf2014.009.005

**Corresponding author:** Troy McMullin rmcmulli@uoguelph.ca. Accepted for publication June 15, 2014.


**Abstract**: Southern Ontario is the most densely populated region in Canada and urbanization is extensive. As a result, a large number of natural areas have been set aside in the cities, such as parks and conservation areas. The value of these areas for conserving lichen biodiversity has not been investigated in Ontario. Therefore, between 2008 and 2014, we systematically examined the lichens and allied fungi in the Arboretum at the University of Guelph, a 165 hectare park and nature reserve centrally located in the City of Guelph, Ontario. One hundred and four species in 55 genera were recorded and several are considered rare. *Caloplaca soralifera* is recorded for the first time in Canada. Provincially, *Acarospora moenium* is recorded for the second time, *Bacidina egenula* and *Strangospora moriformis* are reported for the third time, and *Evernia prunastri* was collected for the second time in southern Ontario in over a century. An undescribed species of *Chaenotheca* with distinctive brown-orange pruina on the capitulum and mazaedium was also discovered along with nine species that have a provincial status rank of S1 (critically imperilled), S2 (imperilled), or S3 (vulnerable). The native old-growth forests contained the greatest number of lichen species, particularly the largest one, which borders the wetland in the Nature

Reserve. Investigations for lichens throughout Guelph revealed two species that were not found in the Arboretum. However, a substantial number of species were discovered in the park that were not found anywhere else in the city. Our results show that the Arboretum is a refuge for many lichen species within this urban landscape.

**Key words:** Conservation, biodiversity, sustainable management, phytogeography, *Acarospora moenium, Bacidina egenula*, *Caloplaca soralifera*, *Evernia prunastri*, *Strangospora moriformis*.

**Introduction:** To conserve biodiversity in a particular area, it is necessary to understand what species are present, where they are located, and which ones are rare or sensitive to environmental change. In Canada, some of this fundamental knowledge is lacking for lichens (Goward et al. 1998), making conservation strategies difficult to develop for them. Lichen conservation is also challenging because they are particularly sensitive to air pollution (Henderson 2000). Southern Ontario is Canada's most populated and developed area, and air pollution is present throughout the region (Bates & Sizto 1987, 1989), and is especially high in cities (Pengelly et al. 1985, Thurston et al. 1994, Luginaah et al. 2005). Therefore, a greater diversity of lichens occur outside of the cities, which is likely why lichens have almost exclusively been intensively studied in older, relatively undisturbed locations typically far from urban centres and sources of air pollution (McMullin & Lewis 2014; Brodo et al. 2013; McMullin & Lendemer 2013; Selva 2005; Matthes et al. 2000; Wong & Brodo 1992; Brodo 1988, Wong & Brodo 1973). Old-growth forests are examples of undisturbed habitats that are good locations to look for and conserve lichen diversity as they contain species that are not usually found in younger forests (McMullin 2008, Goward 1994, Lesica et al. 1991), but few old-growth forests remain in southern Ontario (Henry & Quinby 2010). Fragmented second-growth forests now dominate the natural landscape. The value of second-growth forests for lichen conservation in Ontario has recently been shown (McMullin & Lendemer 2013), but a knowledge gap remains about the ability of natural areas in urban settings to capture and conserve lichen diversity, particularly those with old-growth forests.

The purpose of our study was to examine an urban park or other natural area for lichen diversity. Our objectives were to: 1. select a location that contained a variety of habitats, including some old-growth forest, and was deeply embedded in an urban setting, 2. visit the area repeatedly until a thorough investigation was completed and new species were no longer discovered, and 3. identify any habitats rich with lichen species. Our results will provide the first comprehensive baseline data on lichen richness in an urban natural area in Ontario. Municipalities, conservation authorities, and private land owners can use these data to compare the lichen richness values of other similar properties and to help identify potential habitats and management strategies for lichen conservation in urban environments.

**Materials and Methods**: *Study Site:* The Arboretum at the University of Guelph is located at the east end of the main University of Guelph campus in the city of Guelph, which is in the southern part of Wellington County in southern Ontario (Figure 1). It is located at 43° 33' N latitude and 80° 13' W longitude, has a maximum elevation of 320 m, and an area of approximately 165 hectares (University of Guelph 2014). In January, the average rainfall is 17.6 mm and the average snowfall is 45.8 cm, while the mean temperature during this time is a maximum of -3.7°C and a minimum of -11.4°C. In July, the average rainfall is 88.5 mm and the mean temperature is a maximum of 25.9°C and a minimum of 13.5°C (Environment Canada 2012). Wellington County is underlain by Silurian

bedrock, and Guelph has grey-brown podzolic soils (Hoffman et al. 1963). A drumlin with a modest slope is located in the east end of the Arboretum (University of Guelph 2004). Water bodies include a small stream (Arboretum Stream), two treed wetlands (in the Nature Reserve and Wild Goose Woods), and three ponds that are larger than 1,000 $m^2$ (near Wild Goose Woods, in Victoria Woods, and north of College Street) (Figure 1). It is inhabited by a variety of species - the current species numbers are: 204 birds, 11 fish, 241 fungi, 1069 insects, 44 mammals, 247 plants and trees, 21 reptiles and amphibians (University of Guelph 2014). The Arboretum was established in the early 1970's, but some of the native forests are at least 200 years old (University of Guelph 2004).

*Sampling:* Between June 2008 and January 2014, 49 lichen collecting trips, ranging in time from 1-4 hours, were conducted in the Arboretum. Transects, spaced 35 m apart, were followed from the southwest to the northeast using a compass for the first 25 visits, and covered the entire area. The remaining 24 collecting trips were nonsystematic. We returned to lichen rich areas to examine them in more detail. Collecting in these areas continued until no additional species were discovered on three consecutive trips. Specimens collected were air dried for three days in open paper bags before being identified. Vouchers are deposited at the Biodiversity Institute of Ontario Herbarium (OAC) at the University of Guelph, Ontario and at the University of Maine at Fort Kent Herbarium (UMFK).

*Identification:* Lichen specimens were identified at the University of Guelph using stereo and compound microscopes, an ultraviolet light chamber, and chemical spot tests with Lugol's iodine, nitric acid, para-phenylenediamine in ethyl alcohol, 10% potassium hydroxide, and sodium hypochlorite, (Brodo et al. 2001; Smith et al. 2009). Thin-layer chromatography was used to identify specimens that could not be reliably confirmed by morphology or spot tests following Culberson and Kristinsson (1970) and Orange et al. (2001).

**Results:** On the first lichen collection trip to the Arboretum 25 species were discovered. During the second visit 11 additional species were located, and the third trip yielded 14 additional species. On the forth to forty-ninth collecting trip no more than seven additional species were collected on any one visit and no additional species were found on the final three assessments (Figure 2).

One hundred and four lichen and allied fungus species in 55 genera were discovered in the Arboretum. Thirty species (29%) are foliose, 14 (13%) are fruticose, and 60 (58%) are crustose, of which eight (8%) are calicioids (stubble lichens). The photobiont in 93 (89%) species is green algae (90 are chlorococcoid and three are *Trentepohlia*), three (3%) species have cyanobacteria, and eight (8%) contain no photobiont and are allied fungi traditionally treated with lichens.

Twenty-three lichens in the Arboretum are highly substrate specific and were only found growing on the one substrate that they had previously been known to grow on (Brodo et al. 2001, Smith et al. 2009): eight species were only on calcareous rock (*Acarospora moenium*, *Bacidina egenula*, *Caloplaca soralifera, Candelariella aurella*, *Porpidia speirea*, *Protoblastenia rupestris*, *Sarcogyne regularis, Verrucaria nigrescens*); six species were exclusively lignicolous (*Chaenotheca* sp., *C. xyloxena*, *Chaenothecopsis exilis*, *C.* sp., *Cyphelium tigillare, Mycocalicium subtile)*; four species only occurred on granitic rock (*Acarospora fuscata*, *Candelariella vitellina*, *Lecanora polytropa*, *Xanthoparmelia cumberlandia*); *Arthonia caudata* was only on *Pinus strobus*; *Arthrosporum populorum* was exclusive to *Populus*; *Phaeocalicium curtisii* was only on *Rhus typhina; Phaeocalicium polyporaeum* only

occurred on *polypores*; and *Sphinctrina anglica* was only on *Protoparmelia hypotremella*. Many lichen species are also habitat specific. In the Arboretum, 28 species occurred exclusively in the unmanaged native woodlands, of which 22 species were found only in the Nature Reserve, the largest of the three woodlands (Figure 1). Most of the species found in the Nature Reserve that were not found elsewhere in the park occurred in the old-growth forest bordering the wetland.

Many of the lichen species in the Arboretum are considered rare. *Caloplaca soralifera* is recorded for the first time in Canada. Provincially, *Acarospora moenium* is recorded for the second time, *Bacidina egenula* and *Strangospora moriformis* were collected for the third time, and *Evernia prunastri* was discovered in southern Ontario for the second time in the last 100 years. An undescribed species of *Chaenotheca* with distinctive brown-orange pruina on the capitulum and mazaedium was also discovered. Nine species (9%) have a provincial status rank, assigned by the Ontario Ministry of Natural Resources, of S1 (critically imperilled), S2 (imperilled), or S3 (vulnerable): *Anisomeridium polypori* (S2S3), *Arthrosporum populorum* (S1S2), *Catillaria nigroclavata* (S3), *Flavopunctelia soredica* (S2S3), *Phaeocalicium polyporaeum* (S2S3), *Phaeophyscia hirsuta* (S1S3), *Physciella chloantha* (S2S3), *Physconia enteroxantha* (S3), and *Sphinctrina anglica* (S3). Twenty three (23%) species do not have a provincial status rank (SNR).

*Annotated Species List*

- Lichen species collected in the Arboretum are listed below alphabetically by genus and species.
- Nomenclature mostly follows the 18th edition of the North American Lichen Checklist (Esslinger 2012). Any inconsistencies with Esslinger's list represent the opinions of the authors.
- Species authors are cited following Brummitt and Powell (1996).
- Substrates listed refer to the collections made in the Arboretum.
- Personal collection numbers following substrates belong to R.T. McMullin.
- Roman numerals following collection numbers correspond to the georeferenced localities in Table I.
- Frequencies following collection details refer to the number of observations in the Arboretum: 1 = very uncommon, 2-5 = uncommon, 5-15 = common, >15 = very common.
- Provincial S-ranks following frequencies are conservation status ranks assigned by the Natural Heritage Information Centre and are not legal determinations. Conservation status is designated by a number between 1 and 5: 1 = critically imperilled, 2 = imperilled, 3 = vulnerable, 4 = apparently secure, 5 = secure, H = historical, NR = 'not ranked' yet, U = 'unrankable' due to a lack of information, ? = rank uncertain (Ontario Ministry of Natural Resources 2012).
- All 'fence rail' substrates are *Thuja occidentalis* and are old and furrowed.
- Collections are housed at the University of Guelph Herbarium (OAC) unless otherwise stated.
- † = non-lichenized fungi traditionally treated with lichens.
- * = new to Canada.
- + = species that comprise the majority of the lichen biomass in the Arboretum.

***Acarospora fuscata* (Schrad.) Arnold:** On granitic rocks. *9291* (IV), *11837* (VI). Uncommon. S5.

***Acarospora moenium* (Vain.) Räsänen:** On calcareous rock. *9407* (VII). Very uncommon. SNR. *Notes* – The first Canadian report was in 2008 from the Bruce Peninsula (Brodo et al. 2013). The Arboretum collection is the second in Canada. A third collection was recently made at

Sandbanks Provincial Park (McMullin & Lewis 2013).

***Amandinea punctata* (Hoffm.) Coppins & Scheid.:** On *Acer saccharum*, a deciduous snag, a wooden bench, and a wooden telephone pole. *9308* (IV)*, 9312* (IV)*, 9597* (VIII), *11809* (X), *11843* (XIII). Very common. S5.

***Anisomeridium polypori* (Ellis & Everh.) M. E. Barr:** On *Betula alleghaniensis and Thuja occidentalis*. *9601* and *11830* (I). Uncommon. S2S3.

***Arthonia caesia* (Flot.) Körb.:** On *Acer* and a deciduous tree. *9309* and *9590* (IV), *11845* (XIII). Very common. S5. *Notes* – Recent preliminary molecular studies suggest that this species may belong in the genus *Chrysothrix* (Ertz & Tehler 2011).

***Arthonia caudata* Willey:** On a *Pinus strobus* branch. *9314* (IV). Very common. SNR.

***Arthrosporum populorum* A. Massal.:** On *Populus*. *9587* (XI). Uncommon. S1S2.

***Bacidina egenula* (Nyl.) Vězda:** On calcareous rock. *7101* (VII). Very uncommon. SNR. *Notes* – This is the third report of *B. egenula* in Ontario (McMullin & Lewis, 2013).

***Bilimbia sabuletorum* (Schreb.) Arnold:** On calcareous rock. *9212* (I). Uncommon. S5.

***Caloplaca arenaria* (Pers.) Müll. Arg.:** On rock. *11832* and *11872* (IV). Uncommon. S5.

***Caloplaca cerina* (Ehrh. *ex* Hedw.) Th. Fr.:** On a wooden bench. *11874* (VII). Very common. S5.

***Caloplaca feracissima* H. Magn.:** On cement. *9610* (VIII). Common. S5.

***Caloplaca flavovirescens* (Wulfen) Dalla Torre & Sarnth.:** On rock. *9297* (IV). Uncommon. S5.

***Caloplaca holocarpa* (Hoffm. *ex* Ach.) A. E. Wade:** On rock. *9293* (IV). Common. S5.

***Caloplaca microphyllina* (Tuck.) Hasse:** On a fence rail. *11850* (III). Very uncommon. S4.

***Caloplaca pyracea* (Ach.) Th. Fr.:** On *Populus*. *9586* (XI), *11870* (I), *11871* (VI). Common. S5. *Notes* – *Caloplaca pyracea* was included with *C. holocarpa* in the past (Arup 2009).

******Caloplaca soralifera* Vondrák & Hrouzek:** On calcareous rock. *11893* (I). Very uncommon. SNR.

**+*Candelaria concolor* (Dicks.) Stein.:** On *Acer*. *9294* (X), *11834* (IX). Very common. S5.

***Candelariella aurella* (Hoffm.) Zahlbr.:** On calcareous rock. *9299* (IV). Common. S5.

***Candelariella efflorescens* R.C. Harris & W.R. Buck:** On a fence rail. 9603 (VIII). Common. S5.

***Candelariella vitellina* (Hoffm.) Müll. Arg.:** On granitic rock. *9292* (IV). Uncommon. S5.

***Catillaria nigroclavata* (Nyl.) Schuler:** On *Picea*. *9292* (near X). Uncommon. S3.

******Chaenotheca* sp.:** On decorticated deciduous stumps. *7725*(II), *12810* (I). Uncommon. SNR. *Notes* – Apparently, an undescribed species. It was found in humid environments. The stalk is smooth and black, 0.3-0.5 mm × 0.05-0.10 mm. The capitulum and mazaedium are covered with an orange-brown pruina, which typically extends down approximately one third of the stalk. The pruina precipitates violet-red crystals with the addition of K. The mazaedium is brown, forming an areolate surface. The thallus is immersed. The photobiont is *Stichococcus*. The paraphyses are sparsely branched. Asci are cylindrical to clavate, 18-23 µm × 3.8-4.5 µm. Spores are globose and brown, ranging from 3.0-3.6 µm in diameter. It is similar in appearance to species of *Sclerophora*; however, the photobiont of that genus is *Trentepohlia*.

***Chaenotheca xyloxena* Nádv.:** On a decorticated stump. *11818* and *11819* (I). Uncommon. SNR.

†***Chaenothecopsis exilis* Tibell:** On a decorticated snag. *9451* (I) (UMFK). Very uncommon. SNR.

†***Chaenothecopsis* sp.:** On decorticated snags. *11827-11829* (I). Uncommon. SNR. *Notes* – This genus appears to have several undescribed species and requires an updated treatment. In a wet mount, the stalks are K- and $HNO_3$-. The spores are ellipsoid and 1-septate with a distinct septum. No specimens appear to be parasitic on

lichens nor are they associated with any algal colonies.

***Cladonia coniocraea* (Flörke) Spreng.:** On a *Thuja occidentalis* fence rail. *9605* (IX). Common. S5.

***Cladonia chlorophaea* (Flörke *ex* Sommerf.) Spreng.:** On a *Thuja occidentalis* fence rail. *11852* (III). Uncommon. S5.

***Cladonia cristatella* Tuck.:** On a wooden archway and a *Thuja occidentalis* fence rail. *11825* (XIII), *11864* (IV). Uncommon. S5.

***Cladonia fimbriata* (L.) Fr.:** On a log. *9589* (I). Uncommon. S5.

***Cladonia incrassata* Flörke:** On a moist heavily decomposed stump. *11822* (I). Uncommon. SNR.

***Cladonia macilenta* var. *bacillaris* (Genth) Schaer.:** On a stump and a fence rail. *11848* (VIII), *11861* (IV). Uncommon. S5.

***Cladonia macilenta* Hoffm.var. *macilenta*:** On a stump. *11862* (IV). Uncommon. S5.

***Cladonia ochrochlora* Flörke:** On a stump. *11886* (I). Very uncommon. SNR. *Notes* – Recent preliminary molecular work suggests that *C. ochlrochlora* may be conspecific with *C. coniocraea* (Pino-Bodas et al. 2011).

***Cladonia phyllophora* Hoffm.:** On a stump. *11869* (IV). Very uncommon. S5.

***Cladonia pyxidata* (L.) Hoffm.:** On a fence rail. *11851* (IV). Very uncommon. S5.

***Cladonia rei* Schaer.** On a fence rail. *11811* (IX). Common. S5.

***Cyphelium tigillare* (Ach.) Ach.:** On a wooden bench and wooden arch. *9310* (IX), *11868* (VII). Uncommon. S4.

***Evernia mesomorpha* Nyl.:** On a conifer snag and a wooden bench. *9606* (VIII), *9615* (I). Uncommon. S5.

***Evernia prunastri* (L.) Ach.:** On a telephone pole. *9604* (X). Uncommon. SH. *Notes* – Two immature thalli were observed on wooden benches and several well developed thalli were on a single telephone pole. This species was thought to have been extirpated in southern Ontario as it has not been reported in over a century (Wong and Brodo 1992), but it was collected again in 2008 on the Bruce Peninsula (Brodo et al. 2013), so ours is the second modern report in the region.

***Flavoparmelia caperata* (L.) Hale:** On *Acer*. *11820* (IX). Very common. S5.

***Flavopunctelia flaventior* (Stirt.) Hale:** On *Fraxinus*. *11816* (IX). Uncommon. S5.

***Flavopunctelia soredica* (Nyl.) Hale:** On a deciduous tree. *9319* (X). Uncommon. S2S3.

***Graphis scripta* (L.) Ach.:** On *Fagus grandifolia*. *11889* (I). Uncommon. S5.

***Hyperphyscia adglutinata* (Flörke) H. Mayrofer & Poelt:** On *Acer saccharum*. *11844* (X). Uncommon. S5.

***Hypocenomyce scalaris* (Ach. *ex* Lilj.) M. Choisy:** On a fence post. *9296* (III). Uncommon. S5.

†***Illosporiopsis christiansenii* (B.L. Brady & D. Hawksw.) D. Hawks.** On *Physcia stellaris*. *11833* (IX). Very common. SNR.

***Julella fallaciosa* (Arnold) R.C. Harris:** On *Acer saccharum*. *9596* (III). Very uncommon. SNR.

***Lecania croatica* (Zahlbr.) Kotlov:** On *Tilia*. *9211* (I). Very uncommon. SNR.

***Lecania naegelii* (Hepp) Diederich & v.d. Boom:** On *Fraxinus* and a deciduous snag. *9613* and *11847* (X). Very common. S2S4.

***Lecanora allophana* f. *sorediata* Schaer.:** On *Populus* and a deciduous snag. *11860* (I) *11867* (IV). Uncommon. SNR.

***Lecanora dispersa* (Pers. ) Sommerf.:** On calcareous rock. *9205* (VI). Uncommon. SNR.

***Lecanora hagenii* (Ach.) Ach.:** On a wooden bench. *11873* (VIII). Uncommon. S5?

***Lecanora hybocarpa* (Tuck.) Brodo:** On a deciduous tree and a wooden bench. *9318* (VIII), *11857* (I). Uncommon. S4S5.

***Lecanora polytropa* (Hoffm.) Rabenh.:** On granitic rock. *9215* (I). Very uncommon. S5.

***Lecanora sambuci* (Pers.) Nyl.:** On *Populus*. *9585* (XI).Uncommon. SNR.

***Lecanora symmicta* (Ach.) Ach.:** On *Crataegus*. *9602* (V). Uncommon. S5.

***Lecanora thysanophora* Harris:** On a deciduous tree. *11840* (I). Uncommon. S5.

***Lecidea* sp.:** On rock. *11891* (VI). Very uncommon. SNR. *Notes* – An immature specimen with no ascospores, an I+ blue medulla, poorly developed apothecia with lecideine margins and a black disk lacking pruina, and a grey continuous thallus with fine cracks forming areoles.

***Lecidella stigmatea* (Ach.) Hertel & Leuckert:** On calcareous rock. *9311* (IV). Uncommon. S5.

***Lepraria finkii* (B. de Lesd.) R.C. Harris:** On the base of *Thuja occidentalis*. *11807* (II). Common. S5.

***Lepraria neglecta* (Nyl.) Erichsen:** On *Thuja occidentalis*. *9591* (I). Uncommon. S4S5.

***Melanelixia subaurifera* (Nyl.) O. Blanco et al.:** On deciduous trees. *9289* (X), *9607* (IV), *11839* (XIII). Very common. S5.

***Micarea peliocarpa* (Anzi) Coppins & R. Sant.:** On a moist log. *9213* (I). Very uncommon. S4S5.

†***Mycocalicium subtile* (Pers.) Szatala:** On a decorticated snag. *11859* (I). Common. S4S5.

***Ochrolechia arborea* (Kreyer) Almb.:** On *Thuja occidentalis* and a conifer snag. *9598* and *11841* (I). Common. S4S5.

†**Ovicuculispora parmeliae (Berk. & Curt.) Etayo:** On *Physcia stellaris*. *13999* (IX). SNR.

**+*Parmelia sulcata* Taylor:** On *Acer* and a fence rail. *9200* (IX), *9316* (X). Very common. S5.

***Peltigera elisabethae* Gyeln.:** On a log with moss. *12496* (I). Very uncommon. S5.

***Peltigera polydactylon* (Neck.) Hoffm.:** On soil with moss. *11858* (XII). Very uncommon. S5.

***Peltigera praetextata* (Flörke *ex* Sommerf.) Zopf:** On soil. *11826* (XIII), *11884* (I). Uncommon. S5

†***Phaeocalicium curtisii* (Tuck.) Tibell:** On *Rhus typhina*. *11805* (X). Common. S5.

†***Phaeocalicium polyporaeum* (Nyl.) Tibell:** On a polypore (*Tricaptum*). *11806* (III). Uncommon. S2S3.

***Phaeophyscia adiastola* (Essl.) Essl.:** On *Acer*. *11836* (XIII), *11888* (I). Uncommon. S4.

***Phaeophyscia hirsuta* (Mereschk.) Essl.:** On *Populus* × *canescens*. *5010* and *9210* (VI). Uncommon. S1S3.

***Phaeophyscia orbicularis* (Neck.) Moberg:** On *Acer* and a wooden bench. *9300* (IX), *9317* (VIII). Common. S5.

***Phaeophyscia pusilloides* (Zahlbr.) Essl.:** On *Acer*, *Populus* × *canescens, Tilia*, and a deciduous snag. *9208, 11824*, and *11838* (I), *9209* (IV), *9295* and *11813* (X). Very common. S5.

***Phaeophyscia rubropulchra* (Degel.) Essl.:** On *Acer* and a deciduous tree. *11810* (IV), *11846* (XIII). Common. S5.

**+*Physcia adscendens* (Fr.) H. Olivier:** On *Populus x canescens*. *11842* (VI). Very common. S5.

***Physcia aipolia* (Ehrh. *ex* Humb.) Fürnr.:** On a deciduous tree. *9313* (IV). Very uncommon. S5.

**+*Physcia millegrana* Degel.:** On *Acer*. *9202* and *9593* (IV). Very common. S5.

**+*Physcia stellaris* (L.) Nyl.:** On *Quercus* and a deciduous snag. *9609* (IV), *11815* (V), *11854* (I). Very common. S5.

***Physciella chloantha* (Ach.) Essl.:** On *Populus* and a deciduous snag. *11880* (I), *11879* (XI). Uncommon. S2S3.

***Physciella melanchra* (Hue) Essl.:** On *Populus* × *canescens*. *11849* (VI). Uncommon. SU.

***Physconia detersa* (Nyl.) Poelt:** On *Acer*, *Crataegus*, and a fence rail. *11812* and *11853* (I), *11853* (III). Very common. S5.

***Physconia enteroxantha* (Nyl.) Poelt:** On *Populus* × *canescens*, *Prunus*, and *Tilia cordata*. *5009* and *9600* (VI), *9592* (IV), *9594* (III). Uncommon. S3.

***Porpidia speirea* (Ach.) Kremp.:** On calcareous rock. *9207* (I). Very uncommon. S4?

***Protoblastenia rupestris* (Scop.) J. Steiner:** On calcareous rock. *9204* and *9599* (VI), *11881* (XIII). Uncommon. S5.

***Protoparmelia hypotremella* Herk, Spier & V. Wirth:** On the dead and decorticated branches of *Thuja occidentalis*. *11876* and *11878* (I). Uncommon. SNR.

***Punctelia rudecta* (Ach.) Krog:** On *Thuja occidentalis* and a deciduous snag. *11823* and *11882* (I). Uncommon. S5.
***Rinodina destituta* (Nyl.) Zahlbr.:** On rock. *9217* (I). Very uncommon. SNR.
***Rinodina freyi* H. Magn.:** On a non-native *Quercus*. *9303* (V). Uncommon. SNR.
***Sarcogyne regularis* Körb.:** On calcareous rock. *9290* and *9307* (VI). Uncommon. S5.
***Scoliciosporum umbrinum* (Ach.) Arnold:** On *Quercus* and a deciduous snag. *11814* (V), *11856* (I). Common. S4.
†***Sphinctrina anglica* Nyl.:** On *Protoparmelia hypotremella*. *11875* and *11877* (I). Uncommon. S3.
***Strangospora moriformis* (Ach.) Stein.:** On a wooden bench. *11865* (VIII). Very uncommon. SNR. *Notes* – This is the third known Ontario collection.
***Trapeliopsis flexuosa* (Fr.) Coppins & P. James:** On a fence rail. *11885* (III). Uncommon. S4S5.
***Usnea hirta* (L.) F.H. Wigg.:** On a wooden telephone pole. *11831* (X). Very uncommon. S4S5.
***Verrucaria nigrescens* Pers.:** On calcareous rock. *9306* (VII). Uncommon. S5.
+***Xanthomendoza fallax* (Hepp *ex* Arnold) Søchting, Kärnefelt & S. Kondr.:** On *Acer* and a deciduous tree. *9203* (IX), *9298* (III). Very common. S5.
***Xanthomendoza ulophyllodes* (Räsänen) Søchting, Kärnefelt & S. Kondr.** On cement. *9301* (VI). Very uncommon. SNR.
***Xanthoparmelia cumberlandia* (Gyeln.) Hale:** On granitic rock. *9216* (on the roof of the Arboretum Centre). *11835* (I). Common. S5.
***Xanthoria parietina* (L.) Th. Fr.:** On *Acer* and a deciduous snag. *9315* (IV), *9588* (IX). Very common. SNR.
***Xanthoria polycarpa* (Hoffm.) Th. Fr. *ex* Rieber**: On *Larix laricina* and *Crataegus*. *11821* and *11887* (IX). Common. S4.

**Discussion:** The Arboretum is bordered on all sides by major roads and urban development. It is centrally located in the City of Guelph and heavily used for recreation by students at the University of Guelph and the general public. Yet it contains almost 20% of the known lichen species is southern Ontario (Wong & Brodo 1992, Selva 2005, Brodo et al. 2013, McMullin & Lendemer 2013, McMullin & Lewis 2013, McMullin & Lewis 2014), including several rare species. Throughout the last four years, investigations for lichens throughout Guelph have indicated that the Arboretum contains substantially more species than occur in the rest of the city. The negative effects of urbanization on lichens have been shown in several other cities, including Halifax (Cameron et al. 2007), New York (Brodo et al. 1966), and London (Rose & Hawksworth 1981). The Arboretum, however, appears to buffer some of the effects from the city and creates an island for lichen biodiversity in this urban landscape.

The Arboretum contains almost all known lichen species that occur in Guelph. During the investigations throughout the city two additional lichen species were discovered that were not located in the Arboretum, *Xanthoria elegans* (Link) Th. Fr. and *Multiclavula mucida* (Fr.) R. Petersen. *Xanthoria elegans* occurs on the cement walking bridge over the Speed River between Arthur Street and downtown. *Multiclavula mucida* was on a moist log along the Speed River near Herb Markle Park.

Prior to our study, nine lichen species were known from Guelph. *Xanthoria parietina* was recently reported from the Arboretum (Brodo et al. 2007), and the other eight species were historical records. The historical records were collected by John Macoun, Canada's first Dominion Botanist from 1881 to 1912, and Harold Hume, a student in the 1890's at the Ontario Agriculture College, which later became a part of the University of Guelph. Their collections were respectively deposited at the Canadian Museum of Nature Herbarium (CANL) in Gatineau and the Ada Hayden Herbarium at Iowa

State University (ISC) in Ames. Only two of the eight species that they collected were located again while conducting our assessment, *Flavoparmelia caperata* (1898 - *Macoun 733*! {CANL}, 1898 - *Hume* s.n. {ISC 25880}) and *Cladonia pyxidata* . (1899 - *Hume* s.n. {ISC 25467}). Six of the historically collected species were not found in the Arboretum or in Guelph during our assessment: *Cladonia furcata* (Huds.) Schrad. (1890 - *Hume* s.n. {ISC 25880}); *Lobaria pulmonaria* (L.) Hoffm. (1898 - *Macoun 1540*! {CANL}, 1898 - *Hume* s.n. {ISC 25467}); *Peltigera aphthosa* (L.) Willd. (1896 - *Hume* s.n. {ISC 24973}); *Peltigera leucophlebia* (Nyl.) Gyeln. (*Macoun 3942*! {CANL}); *Peltigera rufescens* (Weiss) Humb. (1898 - *Hume* s.n. {ISC 24984}); and *Parmotrema perlatum* (Huds.) M. Choisy ( 1948 - *Hume* s.n. {ISC 25881}). *Lobaria pulmonaria*, *P. aphthosa*, and *P. perlatum* are known to be sensitive to air pollution, particularly $SO_2$ (McCune & Geiser 2009), so their disappearance from the city is not surprising. The collection location of the eight historical records within Guelph is unknown; therefore, it is not certain if they were collected in the Arboretum. The number of lichens that have been reported from the City of Guelph is 112 in 58 genera, which includes historical and modern day collections. The number of species presently known to occur in the city is 106 in 56 genera.

While conducting our surveys in the Arboretum, we regularly encountered specimens that were poorly developed or immature. Since virtually all of the current habitats in the Arboretum have been available for many decades, we hypothesize that recently improved air quality may be the reason that new species are developing in the park given the sensitivity of some lichens to air pollution (Henderson 2000). Rose & Hawksworth (1981) showed that a decrease in London's air pollution corresponded with a recolonization of intolerant or sensitive lichen species over a 15 year period, which may also be occurring in Guelph. New legislation in Ontario has resulted in steadily improved air quality in the province since 1988 (Ministry of the Environment 2014), which corresponds well with the establishment of new species in the Arboretum. Guelph also benefits from improved air quality more than most areas in the province since air pollution is generally better moving in a northward and eastward direction across Ontario (Ministry of the Environment 2014). Therefore, we expect additional lichen species to colonize the Arboretum in the future and now that there is a baseline inventory changes can be monitored.

The Arboretum contained several rare species. *Caloplaca soralifera* was discovered for the first time in Canada. It was recently described from Europe (Vondrák & Hrouzek 2006), and more recently reported in North America, primarily from the mid-western United States (Wetmore 2009). The furthest east that Wetmore (2009) reported it from was Michigan. Our collection is now the eastern limit of its known range on the continent. *Caloplaca soralifera* is somewhat inconspicuous, particularly when sterile, so it has likely been overlooked in the past and is expected to have a broader distribution than is currently known. When sterile, *C. soralifera* is similar to *Caloplaca pratensis* Wetmore, but the latter has laminal instead of marginal soredia (Wetmore 2009). *Acarospora moenium* was collected for the second time in the province. It was first collected in Ontario on the Bruce Peninsula (Brodo et al. 2013) and after the Arboretum collection was made it was found again in the Copeland Forest (McMullin & Lendemer 2013) and Sandbanks Provincial Park (McMullin & Lewis 2014). *Acarospora moenium* is also inconspicuous and is expected to be more common in the province than was previously understood. *Strangospora moriformis* is recorded for the third time in the province. It was first collected in 2004 (*Lee 1730*) and 2005 (*Lee 1880*) in southeastern Ontario by Robert Lee. His collections are in a personal herbarium. *Bacidina egenula* was also reported for the third time in the province. It was first collected in the Ottawa area (Ekman 1996) and then again on the Bruce

Peninsula (Brodo et al. 2013). *Evernia prunastri* was thought to be extirpated in southern Ontario as it had not been collected in over a century, but it was recently reported from the Bruce Peninsula (Brodo et al. 2013) before it was discovered in the Arboretum. An undescribed species of *Chaenotheca* with distinctive brown-orange pruina on the capitulum and mazaedium was also discovered and will be described in a future article. Nine species have been assigned a rare rank by the provincial government and 23 species have no rank because too little is known about their distribution. Many of the species discovered, however, that are thought to be rare or that have a low status rank may have been overlooked in Ontario in the past because of the inconspicuous nature of some species and the small number of people studying lichens in the province.

The Arboretum is a refuge for lichen biodiversity in Guelph, but it is unknown if it is uniquely rich with lichens or if other urban parks or natural areas contain similar diversity. Further study is required to better understand the conservation value of such areas in larger cities, cities with more industry, and in cities where the general ecology of the region is different. What our results do show is that uncommon species can occur in urban environments, multiple substrates and habitats help to increase lichen diversity, old and undisturbed forests are rich with lichen species, and that multiple collection trips are required for a comprehensive assessment of the lichens in a particular area. Moreover, urban parks and conservation areas can be managed to promote and conserve lichen biodiversity.

**Acknowledgements:** We are grateful to: I. Brodo, S. Ekman, T. Esslinger, R. Harris, A. Launis, J. Lendemer, S. Selva, and L. Śliwa for identification assistance; F. Boerlin-Petzold, N. Daoust, L. Elias, B. Lacey, G. McMullin, J. McWilliams, N. Nadj, S. Rapai., L. Schram, and L. Tuohy for accompanying us on collecting trips over the years; and J. Lendemer and F. Rhoades for helpful comments on the manuscript.

**Literature cited**

Arup, U. 2009. The *Caloplaca holocarpa* group in the Nordic countries, except Iceland. Lichenologist 41:111–130. http://dx.doi.org/10.1017/S0024282909008135

Bates, D.V. & R. Sizto. 1987. Air pollution and hospital admissions in Southern Ontario: The acid summer haze effect. Environmental Research 43:317-331. http://dx.doi.org/10.1016/S0013-9351(87)80032-4

Bates, D.V. & R. Sizto. 1989. The Ontario air pollution study: Identification of the causative agent. Environmental Health Perspectives 79:69-72. http://dx.doi.org/10.1289/ehp.897969

Brodo, I.M. 1966. Lichen Growth and Cities: A Study on Long Island, New York. The Bryologist 69:427-449. http://dx.doi.org/10.2307/3240577

Brodo, I.M. 1988. Lichens of the Ottawa Region (Second edition). Ottawa Field-Naturalists' Club Special Publication No. 3:1-115.

Brodo, I.M., S.D. Sharnoff, & S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven, USA. 795 pp.

Brodo, I.M., C. Lewis, & B. Craig. 2007. *Xanthoria parietina*, a Coastal Lichen, Rediscovered in Ontario. Northeastern Naturalist 14:300-306. http://dx.doi.org/10.1656/1092-6194(2007)14[300:XPACLR]2.0.CO;2

Brodo, I.M., R.C. Harris, W. Buck, J.C. Lendemer, & C.J. Lewis. Lichens of the Bruce Peninsula, Ontario: Results from the 17th

Tuckerman Workshop, 18-22 Sept. 2008. Opuscula Philolichenum 12:198-232.

Brummitt, R.K. & C.E. Powell. 1996. Authors of Plant Names. Royal Botanical Gardens, Kew, Great Britain. 732 pp.

Cameron, R.P., T. Neily, & D.H.S. Richardson. 2007. Macrolichen Indicators of Air Quality for Nova Scotia. Northeastern Naturalist 14:1-14. http://dx.doi.org/10.1656/1092-6194(2007)14[1:MIOAQF]2.0.CO;2

Culberson, C.F. & H. Kristinsson. 1970. A standardized method for the identification of lichen products. Journal of Chromatography 46:85-93. http://dx.doi.org/10.1016/S0021-9673(00)83967-9

Ekman, S. 1996. The corticolous and lignicolous species of *Bacidia* and *Bacidina* in North America. Opera Botanica 127:1-148.

Environment Canada. 2012. National Climate Data and Information Archive. http://www.climate.weatheroffice.gc.ca/climate_normals/index_e.html . (Accessed: December 23, 2012.)

Esslinger, T.L. 2012. A cumulative checklist for the lichenforming, lichenicolous and allied fungi of the continental United States and Canada. North Dakota State University, Fargo, North Dakota. (First posted 1 December 1997; most recent version (#18) 13 December 2012). http://www.ndsu.edu/pubweb/~esslinge/chcklst/chcklst7.htm. (Accessed January 14, 2014)

Ertz, D. & A. Tehler. 2011. The phylogeny of Arthoniales (Pezizomycotina) inferred from nucLSU and RPB2 sequences. Fungal Diversity 49:47-71. http://dx.doi.org/10.1007/s13225-010-0080-y

Goward, T., 1994. Notes on old growth-dependent epiphytic macrolichens in inland British Columbia, Canada. Acta Botanica Fennica 150:31-38.

Goward, T., I.M. Brodo, & S.R. Clayden. 1998. Rare Lichens of Canada. A Review and Provisional Listing. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 74 pp.

Henderson A. 2000. Literature on air pollution and lichens XLIX. Lichenologist 32:89-102, Henry, M., & P. Quinby. 2010. Ontario's Old-Growth Forests. A Guidebook Complete with History, ecology and Maps. Fitzhenry and Whiteside Limited, Markham, Ontario. 232 pp. http://dx.doi.org/10.1017/S0024282900000086

Hoffman, D.Q, B.C. Matthews, & R.E. Wicklund. 1963. Soil Survey of Wellington County, Ontario. Canada Dept. of Agriculture, Research Branch. Ottawa, Canada. 69 pp.

Lesica, P., B. McCune, S.V. Cooper, & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69:1745-1755. http://dx.doi.org/10.1139/b91-222

Luginaah, I.N., K.Y. Fung, K.M. Gorey, G. Webster, & C. Wills. 2005. Association of ambient air pollution with respiratory hospitalization in a government-designated "area of concern": the case of Windsor, Ontario. Environmental Health Perspectives 113:290-296. http://dx.doi.org/10.1289/ehp.7300

Matthes, U., B.D. Ryan, & D.W. Larson. 2000. Community structure of epilithic lichens on the cliffs of the Niagara Escarpment, Ontario, Canada. Plant Ecology 148:233-244. http://dx.doi.org/10.1023/A:1009832507791

McCune, B. & L. Geiser. 2009. Macrolichens of the Pacific Northwest 2ed. Oregon State University Press, Corvallis, USA. 464 pp.

McMullin, R.T. & C.J. Lewis. 2013. New and interesting lichens from Ontario, Canada. Opuscula Philolichenum 12:6-16.

McMullin, R.T. & C.J. Lewis. 2014. The Unusual Lichens and Allied Fungi of Sandbanks Provincial Park, Ontario. Botany 92:85-92. http://dx.doi.org/10.1139/cjb-2013-0227

McMullin, R.T. & J.C. Lendemer. 2013. Lichen biodiversity and conservation status in the Copeland Forest Resources Management Area: A lichen-rich second-growth forest in southern Ontario. Canadian Field-Naturalist 127:240-254.

McMullin, R.T., P.N. Duinker, R.P. Cameron, D.H.S. Richardson, & I.M. Brodo. 2008. Lichens of coniferous old-growth forests of southwestern Nova Scotia, Canada; diversity and present status. Bryologist 111:620–637.

Ministry of the Environment. 2014. Air Quality Ontario. Toronto, Ontario. http://www.airqualityontario.com/ (Accessed January 14, 2014).

Orange, A., P.W. James, & F.J. White. 2001. Microchemical Methods for the Identification of Lichens. British Lichen Society, London, UK. 101 pp.

Pengelly, L.D., A.T. Kerigan, C.H. Goldsmith, & E.M. Inman. 1984. The Hamilton study: distribution of factors confounding the relationship between air quality and respiratory health. Journal of the Air Pollution Control Association 34:1039-1043. http://dx.doi.org/10.1080/00022470.1984.10465852

Rose, C.I. & D.L. Hawksworth. 1981. Lichen recolonization in London's cleaner air. Nature 289:289-292. http://dx.doi.org/10.1038/289289a0

Selva, S.B. 2005. Using calicioid lichens and fungi to assess ecological continuity of Four Forest Stands in the White Lakes region of southern Ontario. A report prepared for the Ontario Ministry of Natural Resources, Kemptville. 18 pp.

Smith, C.W., A. Aptroot, B.J. Coppins, A. Fletcher, O.L. Gilbert, P.W. James, & P.A. Wolseley (editors). 2009. Lichens of Great Britain and Ireland. Richmond Publishing, Slough, United Kingdom. 1046 pp.

Thurston, G.D., K. Ito, C.G. Hayes, D.V. Bates, & M. Lippmann. 1994. Respiratory hospital admissions and summertime haze air pollution in Toronto, Ontario: consideration of the role of acid aerosols. Environmental Research 65: 271-290. http://dx.doi.org/10.1006/enrs.1994.1036

University of Guelph. 2004. Arboretum Master Plan. University of Guelph, Guelph, Ontario. 76 pp.

University of Guelph. 2014. The Arboretum. University of Guelph, Guelph, Ontario. http://www.uoguelph.ca/arboretum/ . (Accessed January 14, 2014).

Vondrák, J. & P. Hrouzek. 2006. *Caloplaca soralifera*, a new species from Europe. Graphis Scripta 18:6-15.

Wetmore, C. M. 2009. New species of *Caloplaca* (Teloschistaceae) from North America. The Bryologist 112:379-386. http://dx.doi.org/10.1639/0007-2745-112.2.379

Wong, P.Y. & I.M. Brodo. 1973. Rock-inhabiting lichens of the Frontenac Axis, Ontario. Canadian Field-Naturalist 87:255-259.

Wong, P.Y. & I.M. Brodo. 1990. Significant records from the lichen flora of southern Ontario, Canada. The Bryologist 93:357-367. http://dx.doi.org/10.2307/3243528

Wong, P.Y. & I.M. Brodo. 1992. The lichens of southern Ontario. Syllogeus 69:1-79.

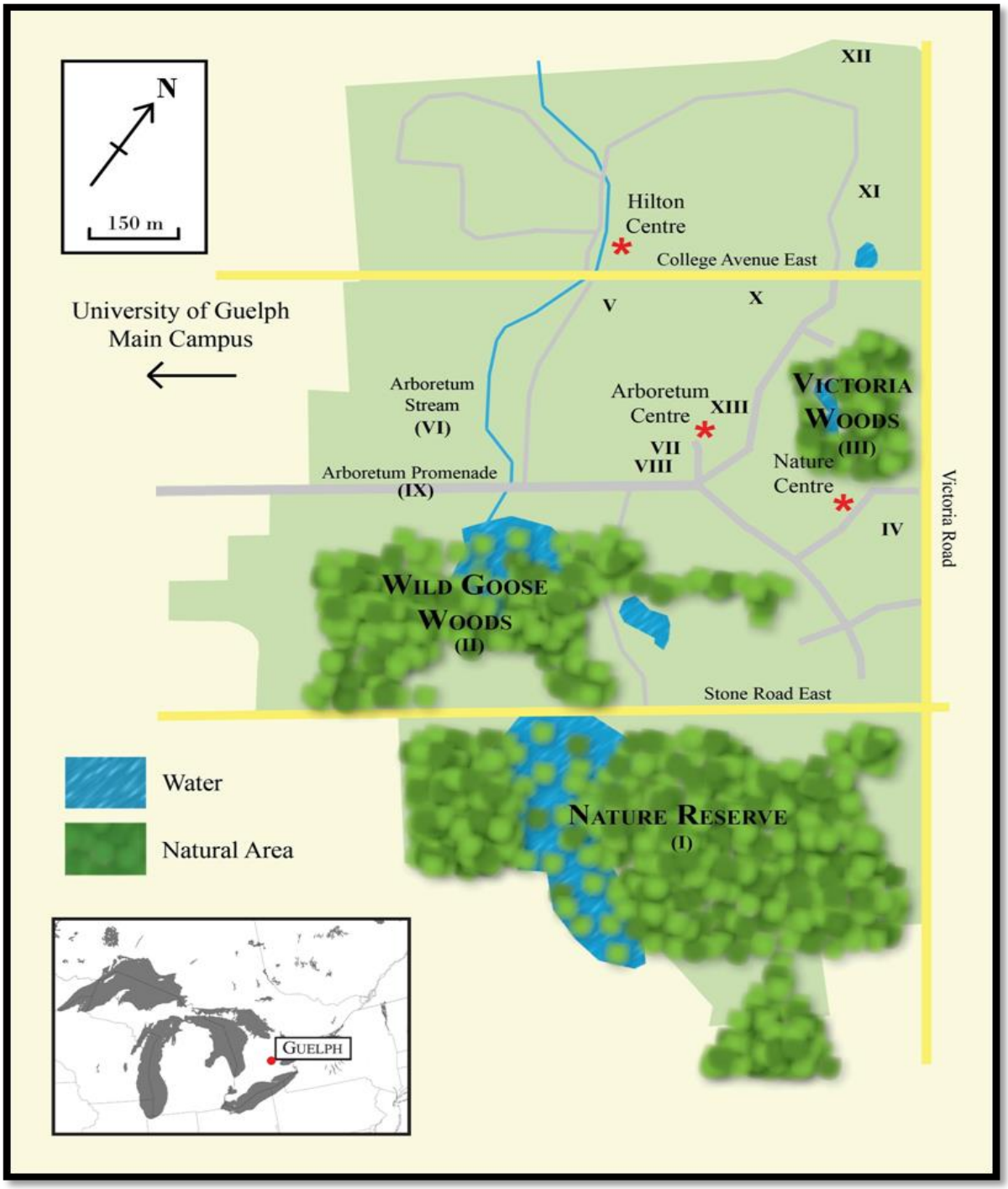


**Figure 1.** Location of the 13 major lichen collection sites in the Arboretum. Sites are georeferenced and described in Table 1. Natural areas are mature native woodlands.

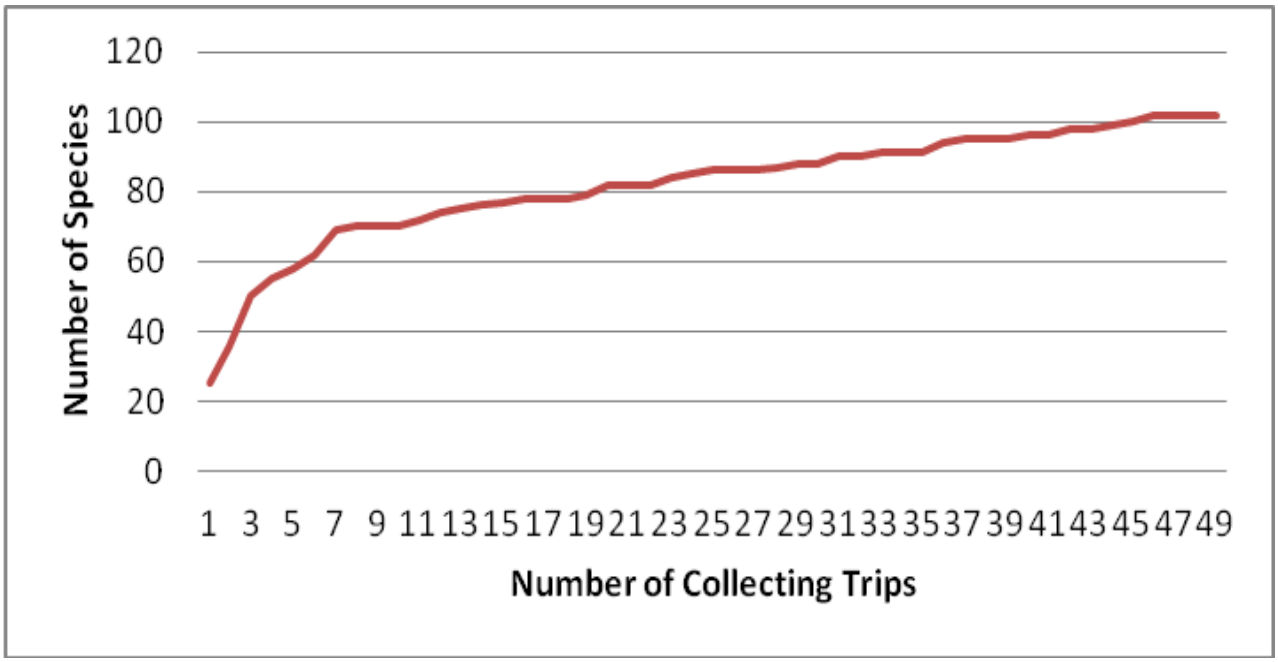


**Figure 2.** The cumulative number of lichen and allied fungi species discovered in the Arboretum during 49 collecting trips.

**Table 1.** Major lichen collection sites in the Arboretum. Site numbers are plotted on a map of the Arboretum in Figure 1.

| Number | Name | Latitude | Longitude | Description |
|---|---|---|---|---|
| I | Nature Reserve | 43.536074° | -80.206032° | A treed wetland with many standing snags bordered by an old-growth *Thuja occidentalis* forest, which is surrounded by a mature mixed-wood forest dominated by *Acer saccharum*, *Betula alleghaniensis*, *Fagus grandifolia*, *Fraxinus americana*, *Ostrya virginiana*, *Salix* spp., *Thuja occidentalis*, and *Tsuga canadensis*. |
| II | Wild Goose Woods | 43.536152° | -80.216739° | A mature mixed-wood forest dominated by *Acer x freemanii*, *Acer saccharum*, *Fraxinus americana*, *Populus tremuloides*, *Prunus serotina*, and *Fagus grandifolia*. The forest contains a treed wetland with a dense canopy cover. |
| III | Victoria Woods | 43.542871° | -80.213006° | A mature mixed-wood forest dominated by *Acer saccharum*, *Fagus grandifolia*, *Fraxinus americana*, and *Prunus serotina*. The forest surrounds an artificial pond. |
| IV | Gosling Wildlife Garden | 43.542082° | -80.21109° | Planted gardens with a variety of exposed trees and boulders. Tree cover contains ornamental and native species. The native trees include *Fraxinus quadrangulata*, *Pinus strobus*, *Ptelea trifoliata*, and *Quercus rubra*. |
| V | Disc Golf Course | 43.54088° | -80.219121° | A rich variety of planted trees that are mostly exposed. Tree varieties are native and ornamental and are coniferous and deciduous. |
| VI | Arboretum Stream | 43.538906° | -80.219274° | A slow moving stream that dries-up for part of the year. The stream is bordered by marsh plants or trees and small rocks. |
| VII | Japanese Garden | 43.540202° | -80.215453° | Ornamental trees and calcareous boulders with a small constructed fountain pond. |
| VIII | English Garden | 43.539993° | -80.215123° | A planted and manicured garden with a variety of partially shaded trees and benches. All trees are ornamental. |
| IX | Arboretum Promenade | 43.5385° | -80.216653° | Solitary deciduous trees in a manicured field with old *Thuja occidentalis* fences. Tree covered dominated by *Acer x freemanii*, *Pinus strobus*, and *Rhus typhina.* |
| X | Oak Grove | 43.543789° | -80.216382° | Planted mixed-wood forest that is partially shaded and dominated by *Quercus* and *Rhus typhina.* |
| XI | North of College 1 | 43.545966° | -80.217597° | Exposed trees in a non-manicured field dominated by *Populus deltoides* hybrids, *Populus* spp., *Salix* spp. and *Betula* spp. |
| XII | North of College 2 | 43.547553° | -80.21925° | Mixed-wood forest adjacent to the Cutten Fields Golf Course and Victoria Road. Tree cover is dominated by *Robinia pseudoacacia* with some *Acer negundo*, *Fraxinus* spp., and *Juglans nigra.* |
| XIII | Forest north of the Arboretum Centre | 43.541425° | -80.215259° | Planted mixed-wood forest between the Arboretum Centre and the main parking lot. Tree cover is dominated by *Acer saccharum*, *Betula papyrifera*, *Picea* sp., P*inus sylvestris*, and *Pinus strobus*. |