Diversity and conservation status of lichens and allied fungi in the Greater Toronto Area: results from four years of the Ontario BioBlitz

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Abstract
Bioblitzes are typically 24-hour biological surveys of a defined region carried out by taxonomic specialists, citizen scientists, and the general public. The largest in Canada is the Ontario BioBlitz, an annual event held in the Greater Toronto Area (GTA). Between 2013 and 2016, we examined the feasibility of including lichens and allied fungi in the Ontario BioBlitz. These taxa are often overlooked, understudied, and taxonomically difficult. We completed a bioblitz in each of the four major watersheds in the GTA and recorded 138 species in 72 genera which, combined with all previous collections, totals 180 species in 88 genera in the area. Thirteen of the species we collected are provincially ranked as S1 (critically imperilled), S2 (imperilled), or S3 (vulnerable). We collected *Lecanora carpinea* for the first time in Ontario. Our results provide a baseline list of GTA lichens that can be used for monitoring. This is one of the first detailed lichen surveys of a major North American urban area and it demonstrates that rapid bioblitz surveys are proficient in capturing lichen diversity despite their inconspicuous nature and the advanced microscopy and chemical analyses required for their identification.

Key words: Biogeography; biodiversity; conservation; citizen science; rare species; BioBlitz Canada

Introduction

Bioblitzes are biological surveys that are spatially defined and temporally limited, usually within a 24-hour period. The term bioblitz was introduced in 1996 by the United States National Park Service and popularized by Edward O. Wilson in 1999 (Shorthouse 2010). Bioblitzes are designed to document all living things in a particular area, and to include taxonomic specialists with the general public or citizen scientists in a meaningful and educational experience (Holden 2003; Scanlon *et al.* 2014). The value of a bioblitz to the understanding and conservation of biodiversity was described by Silvertown (2009) and Donnelly *et al.* (2014). Since 2003, at least 85 peer-reviewed articles mention the term bioblitz, with the vast majority lauding the method as a needed component for future biodiversity monitoring projects (Wheeler *et al.* 2012; Laforest *et al.* 2013; Telfer *et al.* 2015; Wei *et al.* 2016). Data gathered at a bioblitz are important for developing the biological knowledge of an area and they provide a baseline that can be used to monitor changes. For example, species have been discovered at bioblitzes that are new to science (Strongman and White 2011; Bird and Bamber 2013), represent major range extensions (McAlpine *et al.* 2012; Miller *et al.* 2012; Ridling *et al.* 2014; McMullin *et al.* 2015; Ratzlaff *et al.* 2016; Tucker and Rehan 2017; McMullin 2018), and have provided new information on the spread of invasive species (Miller 2016). In honour of the 2009 Saint Mary's University Bioblitz held in the Blue Mountain-Birch Cove Wilderness Area (Nova Scotia), a new species of fungus found in the stomach of a mayfly was named *Trifoliellum bioblitzii* (Strongman and White 2011).

The Ontario BioBlitz Program, led by the Royal Ontario Museum, has held six annual events since 2012 in the Greater Toronto Area (GTA). The GTA is the largest urban area in Canada with a population of almost 6.5 million (Statistics Canada 2017). Each major watershed in the GTA, delineated by ravine system and river complex, was surveyed. Approximately 3500 species have been identified including two species of spider that are new to Canada (*Myrmarachne formicaria* de Geer and *Pholcus opilionoides* Schrank) and over 40 species assessed by the Committee on the Status of Endangered Wildlife in Canada (Ontario BioBlitz 2017). Each event included between 200 and 300 taxonomic specialists, and an equal number of citizen scientists. To increase the scope of taxonomic expertise, the Ontario BioBlitz Program leverages partnerships among academic institutions (e.g., University of Toronto and the University of Guelph), non-government organizations (e.g., Ontario Nature), and governmental agencies (e.g., Canadian

Museum of Nature, Parks Canada, and the Toronto Zoo). All events include some component of public engagement, whether it is direct mentorship by taxonomic specialists or more general information provided at base camp by partner organizations. All data collected during the Ontario BioBlitz Program are made available on the iNaturalist Canada platform (www.inaturalist.ca) and, via Canadensys, to the Global Biodiversity Information Facility. Based on the number of volunteers and the number of species documented, the Ontario BioBlitz Program is one of the largest bioblitz initiatives in the world. The program includes taxonomic specialists in as many fields as possible, including those focussed on uncommonly studied groups such as lichens.

Lichens are composite organisms comprised primarily of a mycobiont (fungus) and photobiont (an alga or a cyanobacterium or both; McMullin and Anderson 2014). Unlike vascular plants, they lack a protective cuticle that allows them to acquire nutrients directly from the atmosphere and precipitation that washes over them (Richardson 1975; Richardson and Cameron 2004). As a result, airborne chemicals are also taken in by lichens, which have a range of tolerances, making it possible to correlate air quality with the presence of particular species (Richardson 1992; Cameron *et al.* 2007; McMullin *et al.* 2017). A study in three cities in southern Ontario showed that urbanization is negatively correlated with lichen diversity (McMullin *et al.* 2016). The GTA is the largest urbanized area in Canada, which has likely had a considerable impact on lichen diversity. Nevertheless, no baseline data exist for lichens, other than a small number of scattered historical collections (Wong and Brodo 1992), so changes cannot be ascertained. Bioblitzes are a way to quickly develop baseline data for a region. Once a baseline is established for lichens, it can be an efficient way to monitor air quality and the effects of urbanization on biodiversity.

Lichens and allied fungi, however, are often poorly represented at bioblitzes. They are typically overlooked because many species are minute and inconspicuous. Lichenology has also traditionally been an academic pursuit that limited the number of people with access to the resources and skills required for lichen identification. It was only recently that the first detailed identification guide with colour illustrations of North American lichens was published (Brodo *et al.* 2001), with more regional illustrated guides produced in the years that followed (e.g., Hinds and Hinds 2007; McCune and Geiser 2009; McMullin and Anderson 2014). Nonetheless, difficulty in locating smaller species plus the advanced microscopy and chemical analyses required for lichen identification (Brodo *et al.* 2001) continues to limit their inclusion in rapid surveys such as bioblitzes.

The aim of our study was to target lichens during the Ontario BioBlitz over four years in each of the four major watersheds in the GTA. Our objectives were to identify the areas most likely to contain a rich lichen biota, collect all species encountered, reliably identify specimens in a laboratory, deposit specimens in a public herbarium, and compare our findings with species that have been historically collected in the GTA. The results will provide the first baseline list of lichens in the GTA, one of the first detailed urban lichen surveys in North America, and demonstrate the ability of a 24-hour bioblitz to capture lichen diversity.

Study Area

The GTA is located in southern Ontario, Canada on the north shore of Lake Ontario (Figure 1). It covers 7127 km^2 and includes the City of Toronto surrounded by the four Regional Municipalities of Durham, York, Peel, and Halton. With a total human population of 6 417 516 (2016 figures), the GTA is the most populous region in Ontario (total population 13 448 494) and Canada (35 151 728; Statistics Canada 2017). Population densities range from 255.9 people/km^2 in the Durham region to 4334.4 people/km^2 in the City of Toronto (Statistics Canada 2017). The GTA is bordered by (from east to west) the Kawartha Lakes, Lake Simcoe, and the Niagara Escarpment. This area is sometimes referred to as the Greater Toronto Bioregion (Shoreline Regeneration Work Group 1991). Despite being a dense urban centre, it contains a number of conserved parks and natural areas as well as farmland, and overlaps with a portion of the Oak Ridges Moraine as part of the Greenbelt (Milne *et al.* 2006). Rouge National Urban Park for example, found at the intersection of the City of Toronto, York, and Durham, is one of the largest urban parks in the world, and aims to conserve both natural areas and agricultural lands. Of the 80 km^2 of parks within the City of Toronto, about 50% are naturalized areas (J. Weninger pers. comm. 2017). Within Toronto, there are 307 km of creeks and rivers, over 200 km of trails, and an estimated 10 million trees in the city core (Johnson 2012).

The Oak Ridges Moraine was exposed when the Late Wisconsin glacier retreated about 12 000 years ago (Barnett *et al.* 1998). The bedrock of the GTA however formed about 450 million years ago, and is comprised mainly of shale, dolomitic siltstone, and limestone. Outside of the densely urbanized zones, the soil is mostly clayey or sandy silt, and is often designated as till due to recent agricultural activities. In the most populous areas, the soil type varies widely, from gravel and sand to silty clay depending on location and proximity to large bodies of water (Sharpe 1980). The drainage and pH of the soil ranges broadly as well, and this variety leads to many different biological community types throughout the city (Smith *et al.* 2015). The mean annual temperature is 9.4°C with a mean monthly low of −3.7°C in January and a high of 22.3° in July. The mean annual precipitation is 831.1 mm, 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 Decem-

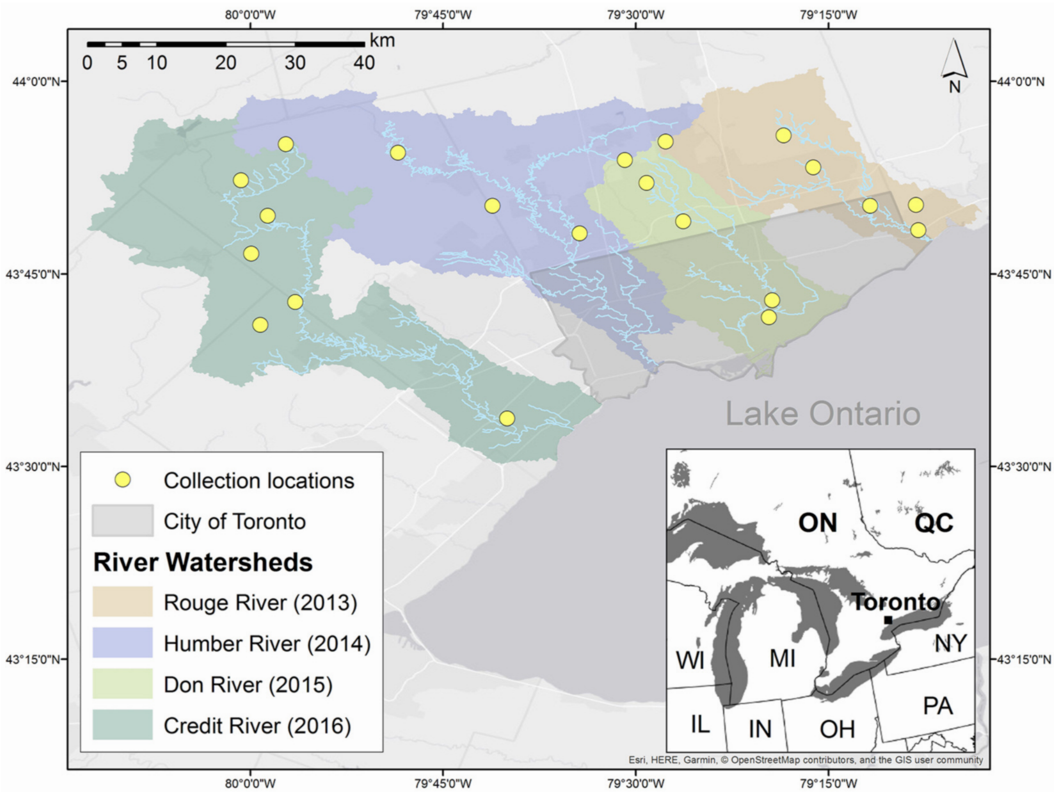

FIGURE 1. Lichen collection sites in the four watersheds surveyed in the Greater Toronto Area, Ontario, Canada.

ber and March (Government of Canada 2017). The province of Ontario has been improving air quality in recent decades, and there has been a 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 2015a). Some areas of the GTA with high vehicular traffic have poorer air quality than areas outside the city (Government of Ontario 2015a). Overall, air quality in the GTA is highly variable depending on proximity to highways, industrial sectors, and other point sources of pollution (Government of Ontario 2015a).

The southern edge of the GTA is Carolinian forest which is dominated by trees such as American Beech (*Fagus grandifolia* Ehrhart), hickory (*Carya* spp.), maple (*Acer* spp.), and oak (*Quercus* spp.). The tree communities in the GTA are also influenced by the Great Lakes-St. Lawrence forest to the north, which includes species such as Red Pine (*Pinus resinosa* Aiton), Eastern White Pine (*Pinus strobus* L.), and Yellow Birch (*Betula alleghaniensis* Britton; Government of Ontario 2015b; Smith *et al.* 2015). Prior to logging and urbanization, grasslands were present in the area. Today, the only remaining oak savannah grassland in the GTA is located in High Park in the west end of Toronto. The anthropogenic impacts on the land combined with the variety of soil types, slight changes in topography, and influences of the watersheds has meant that the GTA is a hotspot for biodiversity with many habitats and microhabitats supporting a wide range of wildlife (Smith *et al.* 2015).

Methods

Sampling and storage

We sampled each of the four major watersheds in the GTA over a 24-hour period in June, 2013 (Rouge River), 2014 (Humber River), 2015 (Don River), and 2016 (Credit River; Figure 1). The areas we visited were selected because they were among the least disturbed or developed in each watershed and they appeared to have a comparatively high diversity of ecosystems and habitat types, based on satellite images and ecosystem classification maps. To maximize the area covered, we split into two groups each year, one lead by R.T.M. and the other by K.D. Our sampling protocol followed the methods of Newmaster *et al.* (2005), who showed that examining large areas (referred to as floristic habitat sampling) captures cryptogam diversity more effectively than establishing smaller representative plots. Using floristic habitat sampling, we attempted to examine all distinct restricted mesohabitats in each area (e.g., streams, rock outcrops, cliffs, swamps) as well as many microhabitats (e.g., snags, tree bases, different rock types). This method was also used by Selva (1999, 2003) to sample lichens. He refers to it as an "intelligent meander" as it allows more time to be spent in areas that are likely to have a higher number of lichen species. We collected specimens on trees, wood, and soil with a knife and those on rock were collected with a 1.8 kg hammer and cold chisel. Our wet specimens were air dried for three days and then stored in acid free packets. All specimens were identified in the lichen laboratory at the Biodiversity Institute of Ontario in Guelph or the Canadian Museum of Nature in Ottawa.

Identification

We used standard microscopy and chemical spot tests to identify specimens following Brodo *et al.* (2001). We also used an ultraviolet light chamber to examine secondary metabolites. Using thin-layer chromatography, we further assessed chemical properties in solvents A, B′, and C (Culberson and Kristinsson 1970; Orange *et al.* 2001). We deposited our specimens at the Canadian Museum of Nature (CANL) and the Biodiversity Institute of Ontario Herbarium (OAC) at the University of Guelph (see Appendix S1 for collection and accession details).

Historical records

We obtained data on lichens and allied fungi previously collected in the GTA from various sources: Wong and Brodo (1990, 1992), a physical search of the national herbarium at the Canadian Museum of Nature, and an electronic search of five botanical databases (Canadensys, Canadian Museum of Nature, Consortium of North American Lichen Herbaria, Biodiversity Institute of Ontario, and the Global Biodiversity Information Facility). Reports of dubious species that we did not collect were borrowed and verified or revised, if they were available.

Conservation status

Ontario conservation status ranks (S-ranks) are nonlegal designations set by the Ontario Natural History Information Centre (NHIC) and are based on guidelines developed by NatureServe (NatureServe 2015). Species with distributions and frequencies that are believed to be well understood receive a rank between 1 and 5: 1 = critically imperilled, 2 = imperilled, 3 = vulnerable, 4 = apparently secure, 5 = secure. Other species receive one of the following designations: NR = not ranked, U = unrankable (due to a lack of information), ? = rank uncertain.

Results

We collected 138 lichen and allied fungus species in the GTA. These data, combined with all previous collections, total 180 species in 88 genera (see Annotated Species List). Ninety-five (51%) of these species are microlichens (crustose species that includes all allied fungi) and 85 (47%) are macrolichens (59 foliose and 26 fruticose). Green algae are the primary photobionts in 152 (84%) species, while 15 (8%) species have cyanobacteria as their primary photobiont, and 13 (7%) species are nonlichenized fungi traditionally treated with lichens. Four (2%) species are lichenicolous. Nine (5%) species are calicioids, six of which are nonlichenized, and one of which is lichenicolous, *Sphinctrina anglica* Nyl. *Lecanora carpinea* (L.) Vain. was collected for the first time in Ontario (McMullin 2018).

We located the highest number of lichens and allied fungi at the Forks of the Credit River Provincial Park (74 species), Glen Haffy Conservation Area (49 species), and the Belfountain Conservation Area (35 species; Figure 1).

Conservation status

One hundred and forty of the 180 species in the GTA have been assigned conservation ranks. Twenty-two species have a rank of S1 to S3—bolded species were collected during the bioblitzes and non-bolded are historical collections: S1. ***Acrocordia cavata* (Ach.) R.C. Harris** and *Gyalecta fagicola* (Hepp *ex* Arnold) Kremp.; S1S2. *Placidium lachneum*; S1S3. ***Melanelixia subargentifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch**, *Phaeophyscia hirsuta* (Mereschk.) Essl., and *Scytinium teretiusculum* (Wallr.) Otálora, P.M. Jørg. & Wedin; S2. *Bacidia laurocerasi* (Delise *ex* Duby) Zahlbr.; S2S3. ***Chaenothecopsis debilis* (Turner & Borrer *ex* Sm.) Tibell**, *Coenogonium luteum* (Dicks.) Kalb & Lücking, ***Flavopunctelia soredica* (Nyl.) Hale, *Gyalecta jenensis* (Batsch) Zahlbr.**, ***Lecania naegelii* (Hepp) Diederich & v.d. Boom**, ***Phaeocalicium polyporaeum* (Nyl.) Tibell**, *Phaeophyscia ciliata* (Hoffm.) Moberg, and ***Viridothelium virens* (Tuck. *ex* E. Michener) Lücking, M.P. Nelsen & Aptroot**; S3. *Anaptychia palmulata* (Michx.) Vain., ***Catillaria nigroclavata* (Nyl.) Schuler**, ***Coenogonium pineti* Lücking & Lumbsch**, ***Placidium squamulosum* (Ach.) Breuss**, and ***Sphinctrina anglica***; and S3S4. *Bacidia bagliettoana* (A. Massal. & De Not.) Jatta and ***Phaeophyscia kairamoi* (Vain.) Moberg**. The remainder of the species are either secure, apparently secure, possibly extripated or are not ranked: S4 = 26, S4S5 = 13, S5 = 78, S5? = 1, SU = 6, SH = 1, and SNR = 33. The S-ranks presented here may have changed during a recent update for Ontario lichens by the NHIC (available at: https://www.ontario.ca/page/get-natural-heritage-information). These updates were not available in time to include in the present manuscript.

Annotated Species List

The list is arranged alphabetically by genus and species. Species authors are cited following Brummitt and Powell (1996) or the 21st edition of the North American Lichen Checklist (Esslinger 2016). Nomenclature mostly follows the 21st edition of the North American Lichen Checklist (Esslinger 2016). Deviance from

Esslinger's list represents the opinion of the authors. Names in bold represent collections made during the watershed bioblitzes while those not in bold represent previous collections made in the GTA by different collectors. Non-lichenized fungi traditionally treated with lichens are preceded by a dagger (†). New provincial records are preceded by an asterisk (*). Substrates follow species names, followed by watershed acronyms (CR = Credit River, DR = Don River, HR = Humber River, RR = Rouge River), and provincial conservation status ranks (*S-ranks*).

***Acarospora fuscata* (Schrad.) Arnold** – Saxicolous on non-calcareous rock. CR, HR, RR. *S5*.

***Acarospora glaucocarpa* (Ach.) Körb.** – Saxicolous on calcareous rock. CR. *S4S5*.

***Acarospora moenium* (Vain.) Räsänen** – Saxicolous on calcareous boulders and concrete. DR, HR. *SNR*.

***Acrocordia cavata* (Ach.) R.C. Harris** – Corticolous on a deciduous snag and *Populus*. CR, DR. *S1*.

***Alyxoria varia* Pers.** – Corticolous on a deciduous snag, *Acer*, and *Fraxinus*. CR, HR. *S4*.

***Amandinea dakotensis* (H. Magn.) P. May & Sheard** – Corticolous on a deciduous snag. DR. *S4*.

***Amandinea punctata* (Hoffm.) Coppins & Scheid.** – Corticolous on *Acer nigrum* and *P. strobus*. Lignicolous on exposed wood and a *Thuja* fence. CR, DR, HR, RR. *S5*.

Anaptychia palmulata (Michx.) Vain. – Terricolous. *White 316* (CANL) (Wong and Brodo 1992). *S3*.

†*Arthonia caudata* Willey – Corticolous on *P. strobus*. CR, DR, HR, RR. *SNR*.

***Arthonia helvola* (Nyl.) Nyl.** – Corticolous on *B. alleghaniensis* and *Betula papyrifera*. CR, HR, RR. *SNR*.

***Arthonia radiata* (Pers.) Ach.** – Corticolous on *Acer*. CR. *S5*.

Arthothelium spectabile (Flot.) A. Massal. – Corticolous on *Acer saccharum*. (Wong and Brodo 1992). DR. *SU*.

***Aspicilia cinerea* (L.) Körb.** – Saxicolous on an exposed boulder. HR. S*4S5*.

Bacidia bagliettoana (A. Massal. & De Not.) Jatta – Terricolous. (Wong and Brodo 1992). *S3S4*.

Bacidia laurocerasi (Delise *ex* Duby) Zahlbr. – Corticolous on *Thuja occidentalis*. *Cain s.n.* (F). DR. *S2*.

***Bacidia rubella* (Hoffm.) A. Massal.** – Corticolous on *T. occidentalis*. HR. *S4*.

Bacidia schweinitzii (Fr. *ex* Tuck.) A.Schneid. – Corticolous. (Wong and Brodo 1992). HR. *S5*.

***Bacidia* sp.** – Corticolous on *A. saccharum*. HR. *SNR*.

Bacidia suffusa (Fr.) A.Schneid. – Corticolous. (Wong and Brodo 1992). *S4*.

***Bilimbia sabuletorum* (Schreb.) Arnold** – Bryicolous; corticolous on *T. occidentalis*; saxicolous. CR, HR. *S5*.

***Caloplaca arenaria* (Pers.) Müll. Arg.** – Saxicolous on non-calcareous rock. CR, HR. *S5*.

***Caloplaca cerina* (Ehrh. *ex* Hedw.) Th. Fr.** – Corticolous on *Fraxinus*, *Populus, Populus balsamifera*, and *Populus tremuloides*. CR, DR, HR. *S5*.

***Caloplaca feracissima* H. Magn.** – Saxicolous on calcareous rock and concrete. CR, DR, HR, RR. *S5*.

***Caloplaca flavovirescens* (Wulfen) Dalla Torre & Sarnth.** – Saxicolous on a calcareous boulder and a rock wall. CR. *S5*.

***Caloplaca holocarpa* (Hoffm. *ex* Ach.) A.E. Wade** – Saxicolous on a calcareous rock. CR, HR. *S5*.

***Caloplaca pyracea* (Ach.) Th. Fr.** – Corticolous on *Fraxinus*, *Populus, P. balsamifera, P. tremuloides*. CR, DR, HR, RR. *SNR*.

***Candelaria concolor* (Dicks.) Stein** – Corticolous on *Acer, A. saccharum*, a deciduous snag, and *Fraxinus americana*. CR, DR, HR, RR. *S5*.

***Candelariella aurella* (Hoffm.) Zahlbr.** – Saxicolous on calcareous rock and concrete. CR, DR, HR, RR. *S5*.

***Candelariella efflorescens* R.C. Harris & W.R. Buck** – Corticolous on *B. papyrifera*; lignicolous on an exposed fence and a *T. occidentalis* snag. CR, DR, RR. *S5*.

***Candelarie1lla vitellina* (Hoffm.) Müll. Arg.** – Saxicolous on non-calcareous rock. HR. *S5*.

***Catillaria nigroclavata* (Nyl.) Schuler** – Corticolous on *Elaeagnus angustifolia,* a fallen branch, *P. strobus,* and a snag. CR, DR, HR, RR. *S3*.

***Chaenotheca* sp.** – Lignicolous (stump). DR. *SNR*.

***Chaenotheca balsamconensis* J.L. Allen & McMullin** – Fungicolous on *Trichaptum abietinum*. CR. *SNR*.

†*Chaenothecopsis* sp. – Lignicolous on a snag. HR. *SNR*.

†*Chaenothecopsis debilis* (Turner & Borrer *ex* Sm.) Tibell – Lignicolous on a stump. CR. *S2S3*.

***Chrysothrix caesia* (Flot.) Körb.** – Corticolous on *A. saccharum, E. angustifolia, Fraxinus*, and *Quercus rubra*. CR, DR, HR, RR. *S5*.

Cladonia cariosa (Ach.) Spreng. – Terricolous. (Wong and Brodo 1992). *S5*.

***Cladonia cenotea* (Ach.) Schaer.** – Lignicolous on an old stump. HR. *S5*.

***Cladonia chlorophaea* (Flörke *ex* Sommerf.) Spreng.** – Corticolous; lignicolous on a log; saxicolous on a mossy rock. CR, HR, RR. *S5*.

***Cladonia coniocraea* (Flörke) Spreng.** – Lignicolous on a log. RR. *SU*.

Cladonia crispata **(Ach.) Flot.** – Lignicolous on a stump. HR. *S5*.

Cladonia cristatella **Tuck.** – Lignicolous on a log and a stump. HR, RR. *S5*.

Cladonia cryptochlorophaea **Asahina** – Saxicolous. HR. SU.

Cladonia decorticata **(Flörke) Spreng.** – Lignicolous on a log. *S4*.

Cladonia digitata **(L.) Hoffm.** – Lignicolous on a stump. HR. *S4S5*.

Cladonia fimbriata **(L.) Fr.** – Lignicolous on a log. CR. *S5*.

Cladonia furcata ssp. *furcata* (Huds.) Schrad. – Terricolous. (Wong and Brodo 1992). *S5*.

Cladonia gracilis ssp. *turbinata* (Ach.) Ahti – Terricolous. (Wong and Brodo 1992). CR. *S5*.

Cladonia humilis (With.) J.R. Laundon – Terricolous. (Wong and Brodo 1992). *S4*?

Cladonia incrassata **Flörke** – Lignicolous on a stump. HR. *S4*.

Cladonia macilenta **var.** ***bacillaris*** **(Genth) Schaer.** – Lignicolous on a log, a stump, and a *Thuja* fence. CR, HR, RR. *S5*.

Cladonia ochrochlora **Flörke** – Corticolous on the base of a tree; lignicolous on a stump; saxicolous on a mossy rock. CR, HR. *S5*.

Cladonia pocillum **(Ach.) Grognot –** Terricolous on thin soil over rock. CR, RR. *S4S5*.

Cladonia pyxidata **(L.) Hoffm. –** Lignicolous on a log. RR. *S5*.

Cladonia ramulosa (With.) J.R. Laundon – Corticolous on a *Pinus* stump. (Wong and Brodo 1992). *SNR*.

Cladonia rei **Schaer. –** Terricolous and on soil on a fence rail. CR, HR. *S5*.

Cladonia scabriuscula **(Delise) Nyl. –** Lignicolous on an old stump. HR. *S5*.

†***Clypeococcum hypocenomycis*** **D. Hawksw.** – Lichenicolous on *Hypocenomyce scalaris*. HR. *SNR*.

Coenogonium luteum (Dicks.) Kalb & Lücking – Corticolous on *Thuja*. (Wong and Brodo 1992). *S2S3*.

Coenogonium pineti **Lücking & Lumbsch** – Lignicolous on a charred stump and a log; terricolous. CR, RR. *S3*.

Cyphelium tigillare **(Ach.) Ach.** – Lignicolous on an old *Thuja* fence. CR. *S4*.

Dictyocatenulata alba **Finley & E.F. Morris** – Corticolous on *B. alleghaniensis* and a *B. papyrifera* snag. CR, HR, RR. *SNR*.

Dimelaena oreina **(Ach.) Norman** – Saxicolous on non-calcareous rock. HR. *S4*.

Diplotomma venustum **(Körb.) Körb.** – Saxicolous on a rock wall. CR. *SNR*.

Enchylium tenax (Sw.) – Terricolous. (Wong and Brodo 1992). *S4*.

Evernia mesomorpha **Nyl.** – Corticolous on a dead *Rhus typhina* branch, a deciduous snag, and *Larix laricina*. CR, HR. *S5*.

Flavoparmelia caperata **(L.) Hale –** Corticolous on *Acer, A. saccharum*, a fallen deciduous tree, an unknown ornamental tree, a snag, and *Ulmus*; lignicolous on fence rails. CR, DR, HR, RR. *S5*.

Flavopunctelia flaventior **(Stirt.) Hale** – Corticolous on *F. americana* and *Populus grandidentata*; lignicolous on a *Thuja* fence post. CR, DR, HR. *S5*.

Flavopunctelia soredica **(Nyl.) Hale** – Corticolous on a deciduous tree, *F. americana,* and on *Fraxinus*. CR, HR. *S2S3*.

Graphis scripta **(L.) Ach.** – Corticolous on *Acer*, *A. rubrum, A. saccharum,* and on *B. alleghaniensis*. CR, DR, HR. *S5*.

Gyalecta fagicola (Hepp *ex* Arnold) Kremp. – Corticolous on *Ulmus*. *Cain s.n.* (NY). CR. *S1*.

Gyalecta jenensis **(Batsch) Zahlbr.** – Saxicolous on calcareous rock. CR. *S2S3*.

Hyperphyscia adglutinata **(Flörke) H. Mayrh. & Poelt –** Corticolous on *Acer, A. saccharum*, *E. angustifolia,* and on *Quercus*. CR, DR, HR, RR. *S4*.

Hypocenomyce scalaris **(Ach.) M. Choisy** – Corticolous on *P. strobus*; lignicolous on a stump. DR, HR. *S5*.

Hypogymnia physodes **(L.) Nyl.** – Corticolous on a snag. HR. *S5*.

†***Illosporiopsis christiansenii*** **(B.L. Brady & D. Hawksw.) D. Hawksw.** – Lichenicolous on *Physcia*, and *Physcia millegrana*. CR, HR. *SNR*.

†***Julella fallaciosa*** **(Arnold) R.C. Harris** – Corticolous on *Acer, Acer saccharum*, *Betula,* and *B. papyrifera*. CR, DR, HR, RR. *SNR*.

Lecania croatica **(Zahlbr.) Kotlov** – Corticolous on *Acer, Acer rubrum, A. saccharum*, a deciduous tree, *F. grandifolia,* and *Tilia*. CR, DR, HR. *SNR*.

Lecania naegelii **(Hepp) Diederich & v.d. Boom** – Corticolous on *Fraxinus, F. americana*, and on *P. tremuloides*. DR, HR, RR. *S2S3*.

Lecanora albellula Nyl. – Corticolous. (Wong and Brodo 1992). *SNR*.

Lecanora allophana **f.** ***sorediata*** **Nyl.** – Corticolous on *P. tremuloides*. HR. *S5*.

****Lecanora carpinea*** **(L.) Vain.** SNR – Corticolous. DR. *SNR*.

Lecanora hybocarpa **(Tuck.) Brodo** – Corticolous on *A. rubrum* and a deciduous snag. CR, HR. *S4S5*.

***Lecanora polytropa* (Hoffm.) Rabenh.** – Saxicolous on non-calcareous rock. HR, RR. *S5*.

***Lecanora pulicaris* (Pers.) Ach.** – Corticolous on *P. strobus*. CR, HR. *S5*.

***Lecanora sambuci* (Pers.) Nyl.** – Corticolous on *Fraxinus, F. americana*, *Populus,* and *P. tremuloides*. CR, DR, HR, RR. *SNR*.

***Lecanora symmicta* (Ach.) Ach.** – Corticolous on *A. rubrum* and *P. strobus*; lignicolous on a *Thuja* fence rail. CR, DR, HR. *S5*.

***Lecanora thysanophora* Harris** – Corticolous on *Acer*, a deciduous snag, and *Q. rubra*. CR, DR, HR, RR. *S5*.

***Lecidella stigmatea* (Ach.) Hertel & Leuckert** – Saxicolous on concrete and a rock wall. CR, HR. *S5*.

***Lepraria finkii* (B. de Lesd.) R.C. Harris** – Corticolous on *Salix* and *T. occidentalis*; lignicolous on a log and a stump. CR, DR, HR, RR. *SNR*.

***Lepraria neglecta* (Nyl.) Erichsen** – Corticolous on *Tsuga canadensis*. HR. *S4S5*.

Leptogium byssinum (Hoffm.) Zwackh *ex* Nyl. – Terricolous on clay soil. (Wong and Brodo 1992). *SH*.

Lithothelium hyalosporum (Nyl.) Aptroot – Corticolous. (Wong and Brodo 1992). *S4*.

Lobaria quercizans Michx. – Corticolous. (Wong and Brodo 1992). CR. *S4S5*.

Megalaria laureri (Hepp *ex* Th. Fr.) Hafellner – Corticolous on *Fagus*. (Wong and Brodo 1992). *SNR*.

***Melanelixia subargentifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch** – Corticolous on *P. tremuloides*. HR. *S1S3*.

***Melanelixia subaurifera* (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch –** Corticolous on a dead *R. typhina* branch, *F. americana,* a snag, and *T. occidentalis*; lignicolous on a *Thuja* fence rail; saxicolous on exposed boulders. CR, DR, HR, RR. *S5*.

***Micarea prasina s. lat.* Fr.** – Corticolous on *T. occidentalis*. CR. *SNR*.

***Micarea peliocarpa* (Anzi) Coppins & R. Sant.** – Lignicolous on a stump. HR. *S4S5*.

***Montanelia sorediata* (Ach.) Goward & Ahti** – Saxicolous on an exposed boulder. HR. *S5*.

†***Mycocalicium subtile* (Pers.) Szatala** – Lignicolous on a decorticated stump and a snag. CR. *S4S5*.

***Myelochroa aurulenta* (Tuck.) Elix & Hale** – Corticolous on *Acer*. CR. *S5*.

***Myriolecis dispersa* (Pers.) Śliwa, Zhao Xin & Lumbsch** – Saxicolous on calcareous rock and concrete. DR, HR, RR. *SU*.

***Myriolecis hagenii* (Ach.) Ach.** – Lignicolous on a *Thuja* fence and a wooden sign post. CR, HR. *S5?*

***Myriolecis semipallida* H. Magn.** – Saxicolous on concrete. CR. *SNR*.

***Ochrolechia arborea* (Kreyer) Almb.** – Corticolous on a living fallen *T. occidentalis* and a snag. CR, HR, RR. *S4S5*.

†***Ovicuculispora parmeliae* (Berk. & Curt.) Etayo** – Lichenicolous on *Physcia* and *Physcia stellaris*. CR, DR. *SNR*.

***Parmelia sulcata* Taylor** – Corticolous on *A. saccharum, F. americana,* a snag, and *Ulmus*; lignicolous on a fence rail; saxicolous on exposed boulders. CR, DR, HR, RR. *S5*.

Peltigera canina (L.) Willd. – Corticolous on a rotting log. (Wong and Brodo 1992). HR. *S5*.

Peltigera didactyla (With.) Laundon – Terricolous. (Wong and Brodo 1992). *S5*.

Peltigera elisabethae Gyeln. – Terricolous. (Wong and Brodo 1992). HR. *S5*.

***Peltigera evansiana* Gyeln.** – Terricolous. CR. *S4S5*.

Peltigera horizontalis (Huds.) Baumg. – Terricolous. (Wong and Brodo 1992). HR. *S4S5*.

Peltigera lepidophora (Nyl. *ex* Vain.) Bitt. – Terricolous on sandy soil. (Wong and Brodo 1992). *S4*.

Peltigera leucophlebia (Nyl.) Gyeln. – Terricolous. (Wong and Brodo 1992). *S4*.

Peltigera neckeri Hepp *ex* Müll. Arg. – Terricolous (Wong and Brodo 1992). *S5*.

Peltigera neopolydactyla (Gyeln.) Gyeln. – Terricolous. (Wong and Brodo 1992). *S5*.

***Peltigera praetextata* (Flörke *ex* Sommerf.) Zopf** – Lignicolous on a moss-covered log; saxicolous on a mossy rock; terricolous on a moss-covered rock. CR, HR, RR. *S5*.

***Peltigera rufescens* (Weiss) Humb.** – Terricolous on well-drained soil. CR. *S5*.

***Pertusaria macounii* (Lamb) Dibben –** Corticolous on *F. grandifolia*. CR. *S4*.

†***Phaeocalicium curtisii* (Tuck.) Tibell** – Corticolous on *R. typhina*. CR, DR, HR. *S5*.

†***Phaeocalicium polyporaeum* (Nyl.) Tibell –** Fungicolous on *Trichaptum biforme*. DR. *S2S3*.

***Phaeophyscia adiastola* (Essl.) Essl.** – Bryicolous. CR. *S4*.

Phaeophyscia ciliata (Hoffm.) Moberg – Corticolous on *Populus*. *Darker 5609* (FH). *S2S3*.

Phaeophyscia hirsuta (Mereschk.) Essl. – Corticolous on *Salix*. (Wong and Brodo 1992). CR. *S1S3*.

Phaeophyscia kairamoi **(Vain.) Moberg** – Corticolous on *A. nigrum*. RR. *S3S4*.

Phaeophyscia orbicularis **(Neck.) Moberg** – Lignicolous on a picnic table; saxicolous on a boulder. DR, HR, RR. *S5*.

Phaeophyscia pusilloides **(Zahlbr.) Essl.** – Corticolous on *Acer, A. saccharum*, a deciduous snag, *Fraxinus*, and *Q. rubra*. CR, DR, HR, RR. *S5*.

Phaeophyscia rubropulchra **(Degel.) Essl. –** Corticolous on *A. saccharum, Crataegus*, and a snag. CR, DR, HR, RR. *S5*.

Physcia adscendens **(Fr.) H. Olivier –** Corticolous on *Acer, A. saccharum*, *Malus*, *P. strobus*, a snag, and *Ulmus*. CR, DR, HR, RR. *S5*.

Physcia aipolia **(Ehrh. *ex* Humb.) Fürnr.** – Corticolous on *A. nigrum,* a deciduous snag, *Fraxinus,* and *F. americana*. CR, DR, HR, RR. *S5*.

Physcia dubia **(Hoffm.) Lettau** – Saxicolous on a boulder. CR, HR. *S5*.

Physcia millegrana **Degel. –** Corticolous on *Acer, A. saccharum*, *Fraxinus, F. americana, Malus*, and *Tilia*. CR, DR, HR, RR. *S5*.

Physcia stellaris **(L.) Nyl.** – Corticolous on a deciduous snag, *F. americana, P. strobus,* and *Q. rubra*; lignicolous on a *Thuja* fence. CR, DR, HR, RR. *S5*.

Physciella chloantha **(Ach.) Essl.** – Corticolous on *Acer*, a deciduous snag, *Fraxinus*, and *Ulmus*. CR, DR, HR. *S4*.

Physciella melanchra **(Hue) Essl.** – Corticolous on *Acer* and *F. americana*. HR, RR. *S4*.

Physconia detersa **(Nyl.) Poelt** – Corticolous on *B. papyrifera* and a snag. CR, DR, HR, RR. *S5*.

Physconia enteroxantha **(Nyl.) Poelt** – Corticolous on *Acer, A. nigrum*, *Fraxinus, F. americana*, and *Ulmus*; saxicolous on boulders. CR, HR, RR. *S4*.

Placidium lachneum (Ach.) B. de Lesd. – Terricolous. (Wong and Brodo 1992). *S1S2*.

Placidium squamulosum **(Ach.) Breuss** – Terricolous. CR. *S3*.

Placynthium nigrum **(Huds.) Gray** – Saxicolous on shoreline rocks. CR. *S5*.

Polychidium muscicola (Sw.) Gray – Corticolous on old *Ulmus* log. *Cain 25418* (Det. Hale) (US). HR. *SNR*.

Porpidia crustulata **(Ach.) Hertel & Knoph** – Saxicolous. CR. *S5*.

Porpidia macrocarpa **(DC.) Hertel & A.J. Schwab** – Saxicolous. CR. *S4*.

Protoblastenia rupestris **(Scop.) J. Steiner** – Saxicolous on calcareous rock. CR, RR. *S5*.

Protoparmelia hypotremella **Herk, Spier & V. Wirth** – Corticolous on a dead branch. CR. *SNR*.

Protoparmeliopsis muralis **(Schreb.) Rabenh.** – Saxicolous on concrete. CR, HR. *S5*.

Pseudoschismatomma rufescens (Pers.) Ertz & Tehler – Corticolous on *Tilia*. *Cain 26826* (det. Harris) (NY). *SNR*.

Punctelia caseana Lendemer & Hodkinson – Corticolous*. Cain 27122* (det. Lendemer) (CANL). HR. *SNR*.

Punctelia rudecta **(Ach.) Krog** – Corticolous on *Acer*, *Crataegus*, a deciduous snag, *T. occidentalis,* and *Q. rubra*; saxicolous on boulders. CR, DR, HR, RR. *S5*.

Pyrenula pseudobufonia (Rehm) R.C. Harris – Corticolous on *Acer.* (CANL) (Wong and Brodo 1992). HR. *S4*.

Pyxine sorediata (Ach.) Mont. – Corticolous. (Wong and Brodo 1992). CR. *S5*.

Ramalina americana Hale – Corticolous on *Picea.* (Wong and Brodo 1992). CR. *S5*.

Ramalina obtusata (Arnold) Bitter – Corticolous on *Ulmus.* (Wong and Brodo 1992). HR. *S4?*

Rhizocarpon reductum **(Ach.) A. Massal.** – Saxicolous on a non-calcareous boulder. HR. *SNR*.

Rinodina freyi **H. Magn.** – Corticolous on *Q. rubra.* CR. *SNR*.

Sarcogyne hypophaea **(Nyl.) Arnold** – Saxicolous on non-calcareous rock. RR. *SNR*.

Sarcogyne regularis **Körb.** – Saxicolous on calcareous rock. CR, DR, HR, RR. *S5*.

†***Sarea resinae*** **(Fr.) Kuntze** – Resinicolous on *Picea* and *Picea glauca*. HR, RR. *SNR*.

Scoliciosporum chlorococcum **(Stenh.) Vězda** – Corticolous on *P. strobus* and on a fallen deciduous branch. CR, HR. *S5*.

Scoliciosporum umbrinum **(Ach.) Arnold** – Corticolous on *Q. rubra.* CR. *S4*.

Scytinium lichenoides **(L.) Otálora, P.M. Jørg. & Wedin** – Saxicolous. CR. *S5*.

Scytinium teretiusculum (Wallr.) Otálora, P.M. Jørg. & Wedin – Saxicolous. (Wong and Brodo 1992). *S1S3*.

†***Sphinctrina anglica*** **Nyl.** – Lichenicolous on *P. hypotremella.* CR. *S3*.

†***Stenocybe pullatula*** **(Ach.) Stein** – Corticolous on *Alnus*. CR. *SU*.

Thelocarpon superellum Nyl. – Terricolous. *Cain 25720* (TRTC) (Wong and Brodo 1992). *SNR*.

Trapelia placodioides **Coppins & P. James** – Saxicolous. CR, HR, RR. *S5*

Varicellaria velata (Tuner) Schmitt & Lumbsch – Corticolous on *Fagus*. (Wong and Brodo 1992). *S4*.

Variolaria trachythallina (Erichsen) Lendemer, Hodkinson & R.C. Harris – Corticolous. (Wong and Brodo 1992). *S4*.

***Verrucaria calkinsiana* Servít** – Saxicolous on calcareous rock. CR, DR. *S5*.

***Viridothelium virens* (Tuck. *ex* E. Michener) Lücking, M.P. Nelsen & Aptroot –** Corticolous on *F. grandifolia* and *Tilia*. DR. *S2S3*.

***Xanthomendoza fallax* (Hepp *ex* Arnold) Søchting, Kärnefelt & S. Kondr.** – Corticolous on *Acer, A. rubrum, Fraxinus, F. americana*, and *Ulmus*. CR, DR, HR, RR. *S5*.

***Xanthomendoza hasseana* (Räsänen) Søchting, Kärnefelt & S. Kondr.** – Corticolous on *Populus* snag. DR. *S5*.

***Xanthomendoza ulophyllodes* (Räsänen) Søchting, Kärnefelt & S. Kondr.** – Corticolous on *A. nigrum,* a fallen deciduous tree, a snag, and on *T. occidentalis.* DR, HR, RR. *S4*.

***Xanthoparmelia cumberlandia* (Gyeln.) Hale** – Saxicolous on non-calcareous rock. CR, HR, RR. *S5*.

***Xanthoparmelia plittii* (Gyeln.) Hale** – Saxicolous on non-calcareous rock. HR. *S4S5*.

Xanthoparmelia viriduloumbrina (Gyaln.) Lendemer – Saxicolous. (Wong and Brodo 1992). CR. *SU*.

***Xanthoria elegans* (Link) Th. Fr. –** Saxicolous on a non-calcareous rock. CR, DR, HR. *S5*.

***Xanthoria parietina* (L.) Th. Fr.** – Corticolous on *Acer* and *P. balsamifera*; lignicolous on a *Thuja* fence rail. CR, DR, HR. *SNR*.

***Xanthoria polycarpa* (Hoffm.) Rieber** – Corticolous on *Acer* and a fallen deciduous tree. CR, HR. *S4*.

Discussion

Our results from the four bioblitzes brings the total number of lichens and allied fungi known from the GTA to 180. This is a relatively large number of species compared to other studies in southern Ontario, such as the Arboretum at the University of Guelph (104 species; McMullin *et al.* 2014), Awenda Provincial Park (203 species; McMullin and Lendemer 2016), Copeland Forest Resources Management Area (154 species; McMullin and Lendemer 2013), and Sandbanks Provincial Park (128 species; McMullin and Lewis 2014). The major difference between these studies and the GTA bioblitzes is that they were comprehensive surveys without time restrictions. We expect to find additional species in unexamined habitats and localities in the GTA region. The GTA also differs by encompassing a much larger area than that examined by these previous studies, which could allow for a greater number of microhabitats that could be colonized by a greater number of species. However, the GTA is also affected more by air pollution, agriculture, and other industries such as historical timber harvesting that are known to have detrimental affects on lichen communities (Lesica *et al.* 1991; Henderson 2000; McMullin *et al.* 2013). Locations within the GTA that contained the greatest number of species were among the furthest from the city centre (e.g., Forks of the Credit Provincial Park and Glen Haffey Conservation Area). This pattern has been observed with lichens in four other Canadian cities (Halifax, Hamilton, Niagara, and Owen Sound; Cameron *et al.* 2007; McMullin *et al.* 2016). Despite the negative anthropogenic effects on lichen diversity, the GTA contains 37% of the 482 lichens reported in southern Ontario by Wong and Brodo (1992). This new baseline for the GTA can be used to monitor the impact of future environmental changes on lichen diversity.

Forty-two lichen species collected previously in the GTA were not collected during our study (see the Annotated Species List). We may not have examined the same microhabitats, or alternatively air pollution, habitat loss, or climate change may have caused their extirpation in the area. Targetted searches of the locations where these 42 species were collected (if they are known) would provide stronger evidence of their presence or absence in the area. Locations where species we collected are recorded to faciliate ongoing monitoring.

We discovered 13 species that are listed provincially as S1 (critically imperilled), S2 (imperilled), or S3 (vulnerable). Nine additional S1, S2, and S3 species were collected historically that we did not find. These results suggest that the GTA is ecologically important for lichens in Ontario. The most notable species we found does not have a rank because it is new to Ontario, *L. carpinea* (Figure 2; McMullin 2018). *Lecanora carpinea* is typically a western species in North America with small disjunct and scattered populations in the east, the largest of which is in the United States on the southwestern shore of Lake Superior (McMullin 2018). The only S1 ranked species that we discovered was *A. cavata*. This species may need to be reranked as it was also discovered during other recent surveys in southern Ontario (McMullin and Lewis 2014; McMullin and Lendemer 2016). Additional notable species that are rarely collected in the province and that have low ranks include *M. subargentifera* (S2S3), which has been previously collected five times (Wong and Brodo 1992; McMullin and Lewis 2013), *G. jenensis* (S2S3), which is known from four other sites (Brodo *et al.* 2013; Lewis and Brinker 2017), and *P. kairamoi* (S3 S4), which is known from three previous collections (McMullin *et al.* 2015). Although the bioblitzes were not comprehensive surveys, they revealed a surprising number of rare species as well as high overall richness.

Bioblitz projects can contribute to our understanding and, as a result the conservation, of lichens and other biota (Shorthouse 2010; Foster *et al.* 2013). The num-

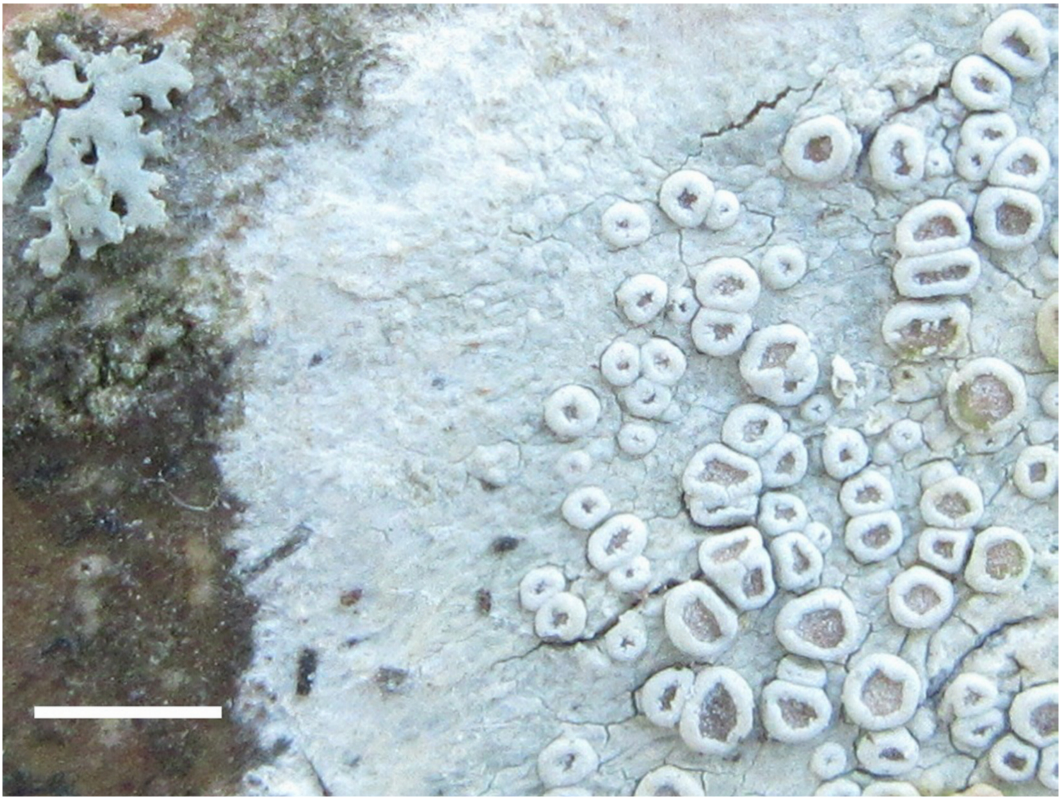

Figure 2. *Lecanora carpinea*, *McMullin 15729* (CANL), scale = 2.1 mm. A new record for Ontario. Photo: Troy McMullin.

ber of bioblitz projects globally has increased steadily since the term was introduced in 1996, and several countries now have their own national programs (Donnelly *et al.* 2014). National Geographic partnered with many United States-based environmental organizations to complete a 10-year bioblitz project in 2016 to celebrate the 100th anniversary of the United States National Parks Service. In the final year alone, more than 125 individual events occurred, with over 13 000 species recorded by some 6000 participants (www.nationalgeographic.org/bioblitz). Bioblitz projects that include non-scientists or other members of the general public lead to an increase in peoples' biodiversity knowledge (Pollock *et al.* 2015) and often encourages learning about the natural world (Bela *et al.* 2016), particularly for children (Himschoot 2017). Bioblitz events in or near large urban areas provide opportunities to teach people about the value of the urban biodiversity where they live (Wei *et al.* 2016). Technology is also an important driver of the success of the bioblitz movement; mobile applications and taxonomic identification software allow citizen scientists to crowd-source expertise. Online tools can have a positive impact on informal science learning (Scanlon *et al.* 2014; August *et al.* 2015) and can decentralize taxonomic expertise (Gardiner and Bachman 2016). High throughput DNA barcoding has also become more common at bioblitz events (Laforest *et al.* 2013; Telfer *et al.* 2015; Geiger *et al.* 2016) and has demonstrated that biodiversity surveys by non-experts can significantly increase overall species observations, especially when deliberately selecting diverse habitats.

Since 2012, the Ontario Bioblitz program has grown to be the largest and most robust (in terms of species documented and volunteers involved) bioblitz project in Canada. Although based in the GTA, the program has influenced province-wide action with many smaller communities adopting the program's core strategy of including taxonomic experts, citizen scientists, and general members of the public under one project delivery. The core strategy of the Ontario BioBlitz program was leveraged to propose a nation-wide bioblitz project to celebrate Canada's sesquicentennial in 2017. The project, titled BioBlitz Canada, was awarded $750K from the federal government to launch a series of bioblitz events across the country in 2017, including five flagship events in major urban areas (e.g., Halifax, Toronto, and Vancouver), 10 science-intensive events in ecosystems with taxonomic data gaps (e.g., Kluane National Park, Yukon and Big Trout Bay along the north shore of Lake Superior, Ontario), and 20 community-level bioblitz events in every province and territory (www.bioblitz canada.ca; Catling *et al.* 2017). The future of BioBlitz Canada rests with an advisory committee, which comprises 15 leading environmental groups and is currently facilitated by the Royal Ontario Museum.

The value of a bioblitz is multi-faceted and increasingly recognized in Canada, as it is in many other countries. The results from our study contribute to our understanding of this value. We show that, despite time restrictions, substantial scientific contributions can be made even with inconspicuous and understudied groups that are taxonomically difficult, such as lichens and allied fungi.

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SUPPLEMENTARY MATERIAL:

APPENDIX S1: Collection details of specimens examined.