

THE LICHEN-FORMING FUNGI IN THE HALIFAX PUBLIC GARDENS, NOVA SCOTIA

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ABSTRACT

Fifty-three lichens species belonging to 28 genera were recorded from the Halifax Public Gardens in Nova Scotia. A brief history of the gardens and of lichen recording in the city is presented, along with a commentary on the lichens found in this study. The results of this lichen survey are of particular interest as the lichen flora has not been previously documented and it provides a baseline for monitoring future changing patterns of pollution and climate. In addition, the Halifax Public Gardens are celebrating in 2017 the 150th anniversary of the opening of the gardens.

INTRODUCTION

The Halifax Public gardens are Victorian in style and date back to the formation of the Nova Scotia Horticultural Society in 1836 which established a garden that was eventually joined with the adjacent Public Gardens and officially opened in 1867 (Anon. 2016). The gardens are a rectangular block, 235m wide by 275m long and the total area is 6.4 ha which includes a small lake and outflow stream. The gardens are now looked after by staff of the Halifax Regional Municipality. In addition to the trees and other plants, there are winding paths, statues of Roman goddesses, a band stand, the Queen Victoria Diamond Jubilee fountain and decorative bird baths. The Gardens are surrounded by a wrought iron fence and very decorative main gates (McIvor, 2009). Many of the trees in the gardens are large and some are over 100 years old despite the impact

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of Hurricane Juan in 2003 which blew down many of the garden's larger trees (Anon. 2003). The gardens have busy roads on all four sides, with buildings opposite in the case of the east side (Lord Nelson Hotel and a high rise development under construction) and on the south side (apartment buildings and Sacred Heart School). To the west of the gardens is the Camp Hill Cemetery. To the north is an athletics field and the city greenhouse complex that supplies plants for the gardens.

Studies on the lichen communities in Nova Scotia were initiated by A.W. Mackay, the Principal of Pictou Academy, who focused on his local area. However he listed seven lichens that he observed in Halifax. i.e. *Cladonia furcata*, *C. uncialis*, *Lecidea spilita*, *Leptogium tremelloides*, *Peltigera aphthosa*, *Pertusaria leioplaca*, and *Umbilicaria muhlenbergii* (Mackay, 1881). Some seventy years later Mackenzie Lamb (1954) published an account of the lichens of Cape Breton Island and his study was extended by Selva (1999). Detailed studies on the lichen communities of the rest of Nova Scotia really began when Wolfgang Maass, in the early 1980s, turned his attention from mosses to lichens. He published a series of pioneering papers (see Richardson and Cameron 2016 for the list). Further research by Seaward *et al.* (1997), Cameron *et al.* (2010), McMullin *et al.* (2008), McMullin (2012) and Anderson (2014) have extended Maass's work.

Two lichen studies have focused on the city of Halifax. One was completed in 1968 by high school student and prodigy Philip Ward. He was interested in lichens and Lepidoptera, subsequently becoming a professor of entomology at the University of California Davis. His distribution maps provide the best historical data on the lichens of the city of Halifax (Ward 1968). He collected the alien species *Lecanora conizaeoides* on 23rd February, 1968, from Camphill Cemetery (Field notebook record). The species was identified for him by Irwin Brodo. One year later, he recorded this species as growing on a large old *Ulmus americana* in the Public Gardens, but did not list any other species from this site. There was one other study carried out in 1976, which examined the diversity and abundance of seven lichen species along main roads in Halifax in relation to traffic volume (Brawn and Ogden 1977). One of the seven lichens was also *Lecanora conizaeoides*. This lichen has subsequently been reported from St John's NL, Saint John NB and Halifax NS in eastern Canada and

from Vancouver BC and Victoria BC in the west as well from Boston Massachusetts, Seattle Washington, Portland Oregon and Illinois in the USA (LaGreca and Stutzman 2006). In Europe and particularly in the United Kingdom, *Lecanora conizaeoides* was widespread and extremely common on the trunks of trees in the 1960s. However, with the reduction of sulphur dioxide and levels of acid rain and the increase in nitrogen, ammonia, and dust, this lichen has become rare (Seaward, 1993) and replaced by members of the genus *Physcia* s.l, and *Xanthoria* s.l. Visually this has led to a change in colour of tree trunks from green-gray to silver and gold. Such a change may also take place in Halifax over the next few years because of a similar change in the lichen flora of trees. Lichens are particularly responsive to air pollution (Richardson 1992, McDermott 2016). Within the last decade there has been a drop in the levels of transboundary acid rain in Nova Scotia (CCME 2013), and there are more hybrid and fuel efficient vehicles in the city of Halifax as well as a change from oil to natural gas as the source of heating for many homes and commercial buildings. In addition, the Tufts Cove Generating Station is now able to operate on both oil and natural gas depending on fuel economics. Finally, new weather patterns and rising temperatures from climate change may also induce alterations in the lichen flora of the Halifax Public Gardens. The object of the present study was therefore to record the current lichen flora of the trees in the Halifax Public Gardens and to provide baseline data on the species and abundance of lichens in relation to the host trees. In addition, the results of this lichen survey are of particular interest as the Public Gardens celebrate the 150th anniversary of the opening of the first public garden in Halifax (Anon. 2016).

METHODS

The authors of this paper visited the Halifax Public Gardens to survey the lichens in November, 2016. One hundred and thirty trees were carefully examined from ground level to 2 m from the ground using hand lenses. The observed species were recorded and specimens of all but the easily identified lichens were collected. A georeference was recorded at each tree using a Garmin GPS and the data transferred to a computer with the help of Greg Baker at Saint Mary's University. The lichens were identified by

morphoanatomical observation, microscopic examination of the lichen ascospores, chemical spot tests and response to ultraviolet light. The following were valuable for identifying the collected species (Brodo *et al.* 2001, Brodo 2016, Hinds and Hinds 2007 and Smith *et al.* 2009). The nomenclature generally follows Esslinger (2016). Samples of the more interesting lichen species collected will be deposited in the Nova Scotia Museum of Natural History. A copy of the GPS data and lichens recorded on each tree will be given to the Halifax Public Gardens to lodge in their archives.

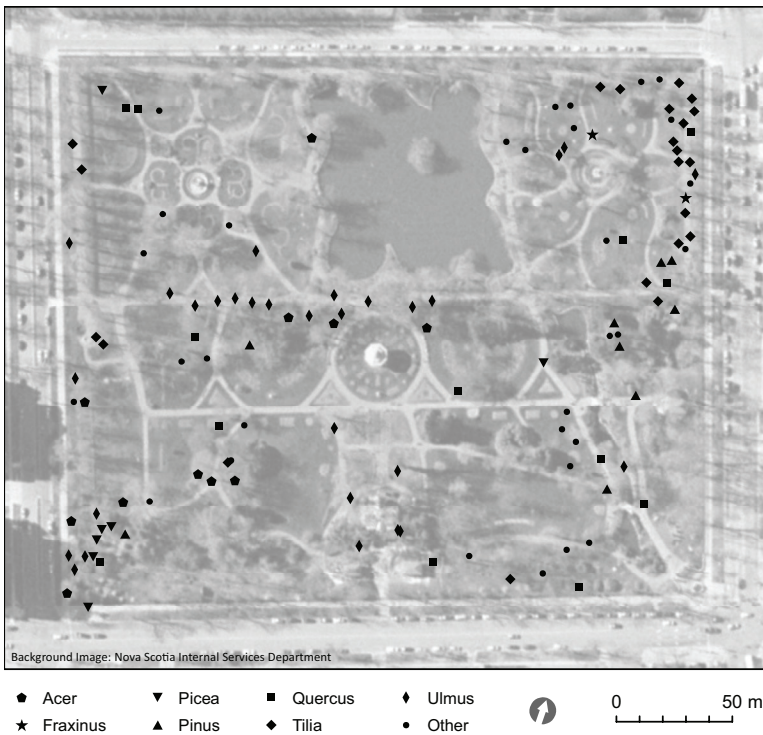


Fig 1 Map of the Halifax Public Gardens, Nova Scotia, showing the distribution of the trees examined for their lichen flora (Map constructed by Greg Baker, Saint Mary's University).

RESULTS AND DISCUSSION

Fifty three lichen species belonging to 28 genera were found growing on trunks of 26 different tree species in the Halifax Public Gardens (Table 1). The most frequently recorded genera were: *Cladonia* (6 species, 12% of the total number of species), *Lecanora* and *Physcia* (5 species, 10% of the total number of species respectively). Foliose lichens were the most common at 54%, while crustose and fruticose lichens made up 29% and 17% respectively. Thirty six percent of the species reproduce by ascospores and 64 % by vegetative propagules (isidia and soredia).

The distribution frequency of lichen species varies; *Parmelia squarrosa*, *P. sulcata*, *Physcia millegrana*, *Melanelixia subaurifera*, *Hypogymnia physodes* and *Usnea sp.* have high frequency and are widely distributed on deciduous and coniferous trees as shown in Table 2. Thus for example, *Candellaria* was found on six types of tree while *Parmelia sulcata* was found on nineteen different tree types.

In order to compare the lichen diversity between the different tree species, we calculated the Shannon–Wiener diversity index (Table 3). The number of lichen species and diversity differ between the tree species. *Ulmus*, *Quercus* and *Acer* had the highest diversity while coniferous genera such as *Pinus* had lower values. The low value for *Fraxinus* reflects the fact that only two trees in this genus were examined.

Lichens are a conspicuous component of the flora of Nova Scotia. They have intrigued at least a few people since Mackay (1882) gave his lecture to the Nova Scotian Institute of Science. He began with the words “Lichenology is the botanical field of romance, in it tales are told of beautiful blue and green algals under the tyrannous grasp and mastery of fungi which live upon them and cannot live without them”. The fifty three species of lichens found in the historic Public Gardens of Halifax contrast with the lichen flora of roadside trees in the Halifax peninsula, which comprises the core of the city. In this core area, Norway Maple and Red Maples are commonly planted trees and their trunks are covered by a limited number of lichens especially *Hypogymnia physodes*, *Parmelia sulcata* and *Parmelia squarrosa* that frequently exhibit white or pale pinkish patches caused by the parasitic *Nectria parmeliae* (Lawrey 2000). Occasional thalli of *Melanelixia subaurifera* and a few small tufts of *Usnea subfloridana* or *Bryoria* are to be found with abundant *Physcia millegrana* and sometimes

Table 1 Cont'd

	<i>Ulmus</i>	<i>Acer</i>	<i>Quercus</i>	<i>Tilia</i>	<i>Fraxinus</i>	<i>Picea</i>	<i>Pinus</i>	<i>Others</i>
<i>Lecanora thysanophora</i> R.C. Harris		+						+
<i>Lecidea albofuscescens</i> Nyl.	+							+
<i>Leparia caesiella</i> R.C. Harris	++	+	+	+		+		+
<i>Loxospora pustulata</i> (Brodo & W.L. Culb.) R.C. Harris								+
<i>Melanelixia glabratula</i> (Lamy) Sandler & Arup	+			+++	+	+	+	+++
<i>Melanelixia subaurifera</i> (Nyl.) O. Blanco <i>et al.</i>	++	++	++	+++				+
<i>Melanohalea exasperate</i> (De Not.) O. Blanco								+
<i>Mycoblastus caesius</i> (Coppins & P. James) Tonsberg.	+							+
<i>Ochrolechia androgyna</i> (Hoffm.) Arnold	+							+
<i>Ochrolechia arborea</i> (Kreyer) Almb.	+			+				+
<i>Parmelia squarrosa</i> Hale.	+++	+++	++	+++	+		+	++
<i>Parmelia sulcata</i> Taylor	+++	+++	+++	++	+		++	+++
<i>Phaeophyscia orbicularis</i> (Neck.) Moberg	+							+
<i>Phaeophyscia pusilloides</i> (Zahlbr.) Essl.	+	+	+	+	+			+
<i>Phaeophyscia rubropulchra</i> (Degel.) Essl.	++	+	+	+	+			+
<i>Physcia adscendens</i> (Fr.) H. Olivier	+++	+	+	++	+			+
<i>Physcia aioplia</i> (Ehrh. ex Humb.) Fühnr.								+
<i>Physcia millegrana</i> Degel.	+++	++	++	+++	++	+	+	+++
<i>Physcia stellaris</i> (L.) Nyl.				+				+
<i>Physconia detersa</i> (Nyl.) Poelt	+							+
<i>Platismatia glauca</i> (L.) W.L. Culb. & C.F. Culb.	+	+	++				+	+
<i>Punctelia rudecta</i> (Ach.) Krog	+		+					+
<i>Ramalina americana</i> Hale.								+
<i>Ramalina farinacea</i> (L.) Ach.	+							+
<i>Ramalina roesleri</i> (Hochst. ex Schaer.) Hue.	+		+					+
<i>Scoliosporium chlorococcum</i> (Graewe ex Stenh.) Vezda		+						+
<i>Usnea subfloridana</i> Stirt.	+++	+	++	+		+		+

Table 1 Cont'd

	<i>Ulmus</i>	<i>Acer</i>	<i>Quercus</i>	<i>Tilia</i>	<i>Fraxinus</i>	<i>Picea</i>	<i>Pinus</i>	<i>Others</i>
<i>Usnea dasopoga</i> (Ach.) Nyl.	+							
<i>Xanthoria parietina</i> (L.) Th.Fr								+
<i>Xanthoria polycarpa</i> (Hoffm.) Riebet	+		+					

The number of trees surveyed in each species of a given tree genus were as follows: *Acer* (*Acer platanoides* (3), *Acer pseudoplatanus* (2), *Acer platanoides* "Crimson King" (4), *Acer saccharinum* (1), *Acer pseudoplatanus f. aureovariegatum* (1)), *Fraxinus* (*Fraxinus excelsior* (2)), *Picea* (*Picea rubens* (1), *Picea pungens* (5), *Picea glauca* (1)), *Pinus* (*Pinus nigra* (3), *Pinus cembra* (1), *Pinus sylvestris* (2), *Pinus strobus* "Pendula" (3)), *Quercus* (*Quercus robur* (8), *Quercus rubra* (5)), *Tilia* (*Tilia europaea* (18), *Tilia americana* (2)), *Ulmus* (*Ulmus americana* "Princeston" (2), *Ulmus parvifolia* (1), *Ulmus glabra* (3), *Ulmus procera* (1)). The other tree category includes: *Aesculus hippocastanum* (6), *Abies alba* (1), *Aralia elata* (1), *Betula alleghaniensis* (1), *Castanea dentate* (2), *Cerasus* (2), *Cercidiphyllum japonicum* (2), *Crataegus monogyna* (1), *Cupressus* (1), *Fagus sylvatica* (3), *Ginkgo biloba* (2), *Juglas cinerea* (1), *Larix laricina* (1), *Liriodendron tulipifera* (2), *Malus sp.* (2), *Magnolia soulangeana* (1), *Phellodendron amurense* (1), *Platanus x acerifolia* (1), *Pyrus calleryana* (1).

Table 2 The number of different tree species on which each species of lichen was recorded in the Halifax Public Gardens.

Lichen species name	Number of tree genera on which the lichen was found	Lichen species name	Number of tree genera on which the lichen was found
<i>Amandinea punctate</i>	1	<i>Melanelixia glabratula</i>	1
<i>Bryoria furcellata</i>	1	<i>Melanelixia subaurifera</i>	20
<i>Bryoria trichodes</i>	1	<i>Melanohalae exasperata</i>	1
<i>Buellia disciformis</i>	2	<i>Mycoblastus caesius</i>	1
<i>Buellia stillingiana</i>	2	<i>Ochrolechia androgyna</i>	1
<i>Candelariella efflorescens</i>	6	<i>Ochrolechia arborea</i>	2
<i>Candelaria concolor</i>	1	<i>Parmelia squarrosa</i>	16
<i>Chysothrix caesia</i>	1	<i>Parmelia sulcata</i>	19
<i>Cladonia chlorophae</i>	4	<i>Phaeophyscia orbicularis</i>	1
<i>Cladonia coniocraea</i>	1	<i>Phaeophyscia pusilloides</i>	4
<i>Cladonia cristatella</i>	1	<i>Phaeophyscia rubropulchra</i>	9
<i>Cladonia fimbriata</i>	1	<i>Physcia adscendens</i>	13
<i>Cladonia ochrochlora</i>	14	<i>Physcia aipolia</i>	2
<i>Cladonia pyxidata</i>	1	<i>Physcia millegrana</i>	20
<i>Evernia mesomorpha</i>	8	<i>Physcia stellaris</i>	1
<i>Flavoparmelia caperata</i>	9	<i>Platismatia glauca</i>	6
<i>Flavopunctelia flaventior</i>	1	<i>Physconia deters</i>	2
<i>Hypogymnia physodes</i>	18	<i>Punctelia rupecta</i>	1
<i>Hypogymnia tubulosa</i>	1	<i>Ramalina americana</i>	1
<i>Lecanora cinereofusca</i>	1	<i>Ramalina farinacea</i>	1
<i>Lecanora conizaeoides</i>	13	<i>Ramalina roesleri</i>	3
<i>Lecanora hagenii</i>	2	<i>Scoliciosporum sp.</i>	1
<i>Lecanora symmicta</i>	12	<i>Usnea dasopoga</i>	1
<i>Lecanora thysanophora</i>	2	<i>Usnea subfloridana</i>	12
<i>Lecidea albofuscescens</i>	1	<i>Xanthoria parietina</i>	1
<i>Lepraria caesiella</i>	11	<i>Xanthoria polycarpa</i>	2
<i>Loxospora pustulata</i>	1		

Table 3 Lichen diversity assessment using the Shannon–Wiener diversity index in relation to the different tree types in the Halifax Public Gardens.

Name of Tree	Number of lichen species	Percentage (%)	Diversity Index
<i>Ulmus</i>	35	66.04	3.100
<i>Acer</i>	19	35.85	2.662
<i>Quercus</i>	26	49.06	2.904
<i>Tilia</i>	19	35.85	2.559
<i>Fraxinus</i>	7	13.21	1.889
<i>Picea</i>	12	22.64	2.223
<i>Pinus</i>	9	16.98	1.890
Others	30	56.60	2.904

patches of *Lepraria* or *Cladonia* on the lower parts of the tree trunks. The gray-coloured lichens on the trees in the Public Gardens are more diverse and include *Physconia detersa* that was found on Elm (*Ulmus* sp.) and Horse Chestnut (*Aesculus hippocastanum*).

Many of the trees in the Halifax Public Gardens and trees in the grounds of the adjacent Sacred Heart School are colonized by the alien lichen, *Lecanora conizaeoides*. It too is affected by another lichen parasitic fungus, *Athelia arachnoidea*, which is found affecting the lichen in the United Kingdom and other parts of Europe where this lichen is native (Gilbert 1988). *Lecanora conizaeoides* requires or thrives where there is at least some sulphur dioxide in the surrounding air and colonizes trees that have more acidic bark. Thus, in the Public Gardens, this lichen is found on elm but is even more common on coniferous trees upon which it is one of only a few species. *Lecanora conizaeoides* is easily identified by its greenish thallus, its pale greenish brown apothecia and its spot test reaction of Pd+Red using Steiners reagent. Brawn and Ogden (1977) recorded this lichen at seven of their 31 sampling sites noting that the lichen was plentiful to numerous at three sites, but they did not specify the locations within Halifax.

Another group of foliose lichens are yellowish green. *Flavoparmelia caperata* is a common species that forms large circular patches on old deciduous trees and is commonly seen in rural areas of Nova Scotia where it is often referred to as the 40 mile per hour lichen, being conspicuous enough to identify from a moving vehicle. While not common in Halifax, it was found in the public gardens along with the very much rarer *Flavopunctelia flaventior* which was discovered on Japanese Cherry (*Prunus* sp.).

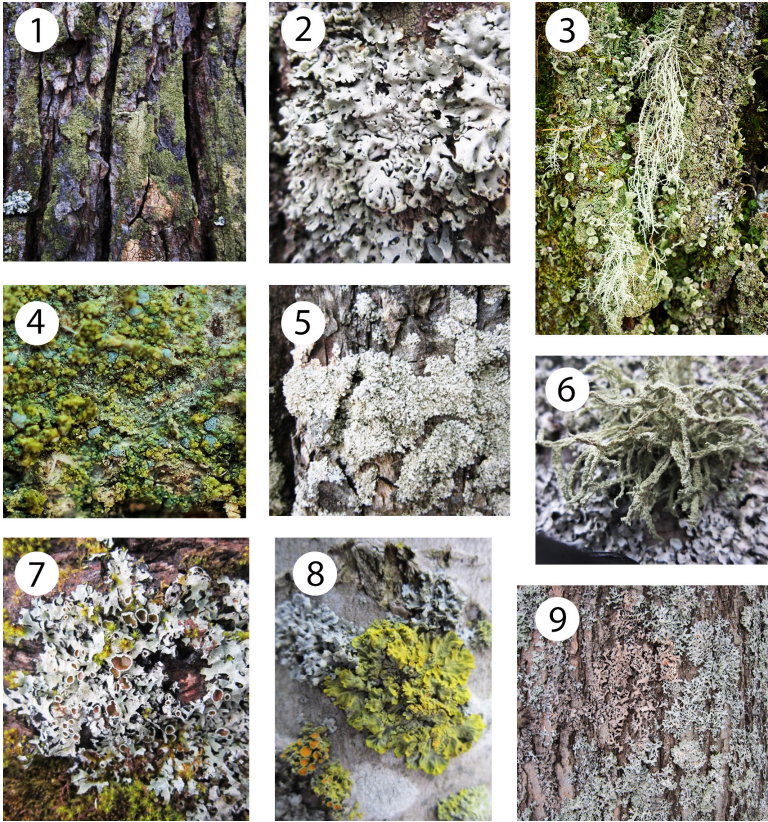
A conspicuous part of the lichen flora of Nova Scotia is provided by the lichens that are bright yellow to orange in colour. These include the genera *Candelaria* which is foliose and *Candelariella* which is crustose. Both are negative when spot tested with the KOH reagent. This reaction contrasts with the other common yellow-orange lichen, *Xanthoria*, which turns bright purple with this spot test. These lichens seem to thrive when there is an abundance of nutrient rich particulates. *Xanthoria* is generally associated with seashore rocks and eutrophicated habitats like farm buildings but the species *Xanthoria parietina* seems to be spreading throughout eastern North America based on observations and anecdotes (Allen 2016). It's not clear yet what impact this species will have on the existing lichen

communities. This readily identifiable lichen was only recorded twice by Ward (1968) in his Halifax study, both fairly close to the Northwest Arm, but today it is more common in the city and was recorded in our study of the Public Gardens.

A considerable number of crustose lichens were recorded in the Halifax Public Gardens. *Lecanora*, *Lepraria* and *Buellia* were common but there were also unusual or often easily overlooked lichens such as *Chrysothrix caesia*, *Loxospora pustulata* and *Scoliciosporum chlorococcum*. None of the crustose lichens proved to be new records for Nova Scotia (I. Brodo, *pers. comm.*).

In conclusion, the Halifax Public Gardens have a surprisingly rich lichen flora for a site that is in the centre of a large city. The reasons likely include the diversity of trees and the fact that some are over 100 years old. Secondly, interesting or unusual tree species planted in the gardens may have been imported from Europe or other parts of Canada and in the first instance brought with them *Lecanora conizaeoides* and its parasite. Indeed, lichens can even be imported on timber (Alstrup 1977). Whatever the sources of the interesting lichen flora, it is hoped that the present study will provide a baseline that will be of value for monitoring changes in the lichen flora of Halifax resulting from new patterns of weather or alterations in the levels of pollutants such as acid rain, sulphur dioxide or nutrient rich particulates.

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Some of the lichens in the Halifax Public Gardens:

1. *Lecanora conizaeoides* – Pollution Rim-lichen; 2. *Hypogymnia physodes* – Puffed Shield Lichen; 3. *Usnea* sp. – Beard Lichen and *Cladonia chlorophaea* – Mealy Pixie-cup; 4. *Chrysothrix caesia* – Dust Lichen; 5. *Physcia millegrana* – Mealy Rosette Lichen; 6. *Evernia mesomorpha* – Boreal Oakmoss Lichen; 7. *Parmelia squarrosa* – Bottlebrush Shield Lichen; 8. *Xanthoria parietina* – Maritime Sunburst Lichen (centre) and *Xanthoria polycarpa*– Pincushion Sunburst Lichen (Lower left); 9. *Parmelia sulcata* – Hammered Shield Lichen infected by the fungus *Nectria parmeliae* (pinkish in centre).

REFERENCES

- Allen, J.L.** (2016). The *Xanthoria* project. inaturalist.org/projects/maritime-sunburst-lichen-in-eastern-north-america.
- Alstrup, V.** (1977). Cryptogams on imported timber in west Greenland. *Lichenologist* 9:113-117.
- Anderson, F.** (2014). Macrolichens of Nova Scotia: a provisional checklist. Curatorial Report No. 101, Nova Scotia Museum of Natural History, Halifax. ojs.library.dal.ca/NSM/article/view/4762.
- Anon.** (2003). Hurricane Juan. en.wikipedia.org/wiki/Hurricane_Juan.
- Anon.** (2016). History of the Public Gardens, Halifax, Friends of the Public Gardens, Halifax. halifaxpublicgardens.ca/about/history-of-the-gardens/
- Brawn, K. & Ogden, J.G.** (1977). Lichen diversity and abundance as affected by traffic volume in an urban environment. *Urban Ecology* 2:235-244.
- Brodo, I.M.** (2016). Keys to Lichens of North America, Yale University Press, Newhaven.
- Brodo, I.M., Sharnoff, S.D., & Sharnoff, S.** (2001). Lichens of North America. Yale University Press, New Haven, 795 pp.
- Cameron, R.P., Anderson, F., & Maass, W.G.S.** (2010) Lichens of Scatarie Island wilderness area. *Proceedings of the Nova Scotian Institute of Science* 45:69-78.
- CCME.** (2013). Progress report on the Canada-wide acid rain strategy for post 2000. Canadian Council of Ministers of the Environment, Ottawa.
- Esslinger, T.L.** (2016). *A cumulative checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada*, version 21. ndsu.edu/pubweb/~esslinge/chcklst/chcklst7.htm.
- Gilbert, O.L.** (1988). Studies on the destruction of *Lecanora conizaeoides* by the Lichenicolous Fungus *Athelia arachnoide*. *Lichenologist* 20(2):183-190.
- Hinds, J.W. & Hinds, P.L.** (2007). The Macrolichens of New England. New York Botanical Garden Press, New York.
- LaGrecia, S. & Stutzman, B.W.** (2006). Distribution and ecology of *Lecanora conizaeoides* (Lecanoraceae) in eastern Massachusetts. *Bryologist* 109(3):335-347.
- Lawrey, J.D.** (2000). Chemical interactions between two lichen-degrading fungi, *Journal of Chemical Ecology* 26 (8):1821-1831.
- Mackay, A.H.** (1881). Lichens of Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 5(3):299-307.
- Mackenzie Lamb, I.** (1954). Lichens of Cape Breton Island, Nova Scotia. *Annual Report of the National Museum of Canada*, fiscal year 1952-53, pp. 239-313.

- McDermott, A.** (2016). Lichens are an early warning system for forest health. *Science News*, Society for Science and the Public, November 2016, pp. 1-8. sciencenews.org/article/lichens-are-early-warning-system-forest-health?
- McIvor, K.** (2009). Halifax Public Gardens – Cultural Asset Study – Victoria Jubilee Fountain, Halifax, 22 pp.
- McMullin, R.T.** (2012). New and interesting lichens to Kejimikujik National Park and National Historic Site, Nova Scotia, Canada. *Opuscula Philolichenum* 11:52-59.
- McMullin, R.T., Duinker, P.N., Cameron, R.P., Richardson, D.H.S., and Brodo, I.M.** (2008). Lichens of coniferous old-growth forests of southwestern Nova Scotia, Canada; diversity and present status. *The Bryologist* 111:620-637.
- Richardson, D.H.S.** (1992). Pollution Monitoring with Lichens. Richmond Publishing, Slough, (Naturalist Handbooks No.19), 76 pp.
- Richardson, D.H.S & Cameron, R.P.** (2016). Obituary: Wolfgang Siegfried Gunther Maass 1929–2016. *Symbiosis* 69:199-203.
- Seaward, M.R.D.** (1993). Lichens and sulphur dioxide pollution: field studies. *Environmental Reviews* 1:73-91.
- Seaward, M.R.D., Lynds, A. & Richardson, D.H.S.** (1997). Lichens of Beaver Brook, Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 41:90-92.
- Selva, B.** (1999). Survey of epiphytic lichens of late successional northern hardwood forests in northern Cape Breton Island. Report to Cape Breton Highlands National Park, Ingonish Beach and Parks Canada, Ottawa, 67 pp.
- Smith, C.W., Aptroot, A., Coppins, B.J., Fletcher, A., Gilbert, O.L., James, P.W & Wolseley, P.A.** (2009). *The Lichens of Great Britain and Ireland*. British Lichen Society, Natural History Museum, London.
- Ward, P.** (1968). Lichens and air pollution in Halifax. *Linnaea* 2:13-18.