Opuscula Philolichenum, **15**: 82-91. 2016.
**pdf effectively published online 23August2016 via (http://sweetgum.nybg.org/philolichenum/)*

Landfill Lichens: A checklist for Freshkills Park, Staten Island, New York

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ABSTRACT. – A checklist of the lichens discovered at Freshkills Park, Staten Island, after three days of surveying, is presented. In 1997 the Freshkills Municipal landfill was capped and the process to convert it to a park was begun. Seventeen species were found in the park, four of which are newly reported for the New York City metropolitan area. Comparison of our list to previous floras and checklists for New York City suggests that even the densely urbanized area of New York City likely hosts a surprisingly heterogeneous and diverse lichen flora.

KEYWORDS. – Urban ecology, restoration ecology, recolonization.

INTRODUCTION

Lichens are sensitive to air pollution, and systems of using lichens for air quality monitoring, such as those suggested by Hawksworth and Rose (1976), are in widespread use throughout the world (reviewed by: Conti & Cecchetti 2001, Nimis et al. 2002, Szczepaniak & Biziuk 2003), including northeastern North America (Will-Wolf et al. 2015) and the mid-Atlantic region of the United States (Brodo 1966, Will-Wolf et al. 2014). Urban areas generally have very poor air quality, and correspondingly low lichen diversity and abundance (Gries 1999). However, there is evidence that lichens are responding positively to recent improvements in urban air quality in developed countries. For example, in Paris eleven lichen species have recolonized the Jardin du Luxembourg in the past 100 years (Seaward & Letrouit-Galinou 1991). London has also seen considerable returns of lichen diversity and abundance (Davies et al. 2007, Rose & Hawksworth 1981, Larsen et al. 2007). In the United States, research on changes in urban lichen diversity are lacking for most cities, and urban lichen floras are both undertsudied and the focus of relatively few publications. Thus, many of the changes in urban lichen floras remain as unpublished observations by specialists.

New York City, one of the largest cities in the world, has had relatively little attention paid to its lichen flora when compared with cities like London, Paris and Rome (Larsen et al. 2007, Munzi et al. 2007, Seaward & Letrouit-Galinou 1991). Nonetheless it has had considerably more research attention than most urban areas in the United States. In 1823, 180 species were reported within a 50 mile radius of City Hall, along with a few species from upstate New York and Massachusetts (Halsey 1823). Almost a century later 300 species were reported within a 100 mile radius of city hall, with most of that diversity found in the Palisades of adjacent New Jersey (Woods 1914). In that report, fruticose species such as *Ramalina* and *Cladonia* were reported from Central Park, genera that are now absent from Manhattan (Allen & Howe, unpublished data). Long Island, which includes Brooklyn and Queens, two boroughs of New York City, has received considerably attention, with 279 documented species (Brodo 1968, 2004; Harris 1987; Harris et al. 1987). More recently, 19 species were reported from King and Queens Counties (Delendick 1994), and five species were reported from Highline Park, which is situated in densely urbanized lower Manhattan

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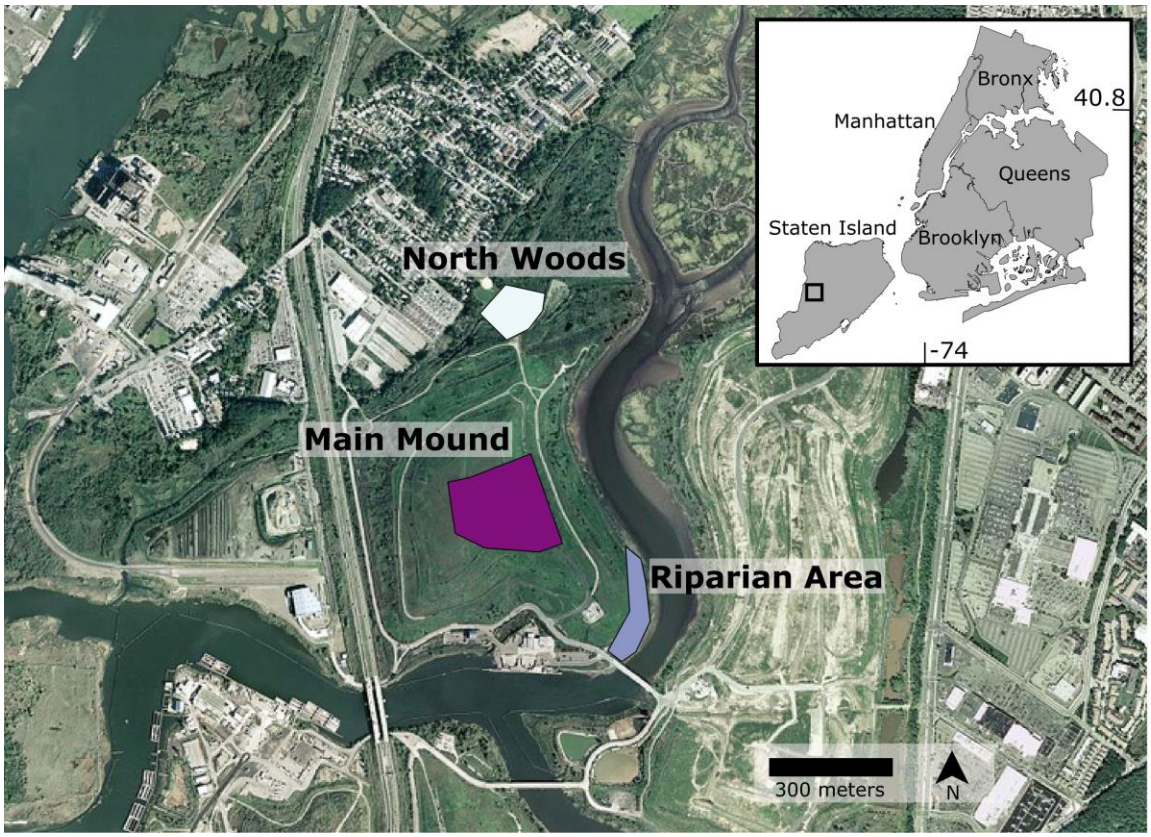

Figure 1. Map of lichen collecting areas at Freshkills Park, North Mound and inset with broader geographic context.

(Stalter 2004). Of the five boroughs, Staten Island has been the least studied, though it has the lowest population density and is now home to Freshkills Park, the largest park in New York City (see below).

Decommissioned (closed) landfills, with new vegetation cover and recently exposed rock substrates, are one example of a novel urban ecosystem type that has been shown to provide habitat for many taxa, including beetles (Do et al. 2014), herbaceous plants (Rahman et al. 2013), butterflies and birds (Camerini & Groppali 2014), and microbial communities that change as the landfill ages (Song et al. 2015). However, decomissioned landfills have not been well studied as habitat for lichens. While there have been studies of lichens near active landfills that show that the surrounding lichens accumulate heavy metals, and their communities simplify (Paoli et al. 2015), the present work presents the first study of lichen colonization of a decommissioned landfill. Freshkills Park, Staten Island, is an engineering and land reclamation marvel (Hirsh 2009). This 8.9 km^2 park covers what was once Fresh Kills Landfill which was opened in 1948 and had become the largest landfill in the world by 1955 (Hirsh 2009). It reached its peak operation in 1986–1987 when it received 26,000,000 kg of trash per day (Hirsh 2009). Two of the mounds ceased operating and were capped in 1997, and the last delivery to the landfill was in the west mound, where the debris from the World Trade Centers were deposited in 2001 (Hirsh 2009). One portion of the park is now open to the public on special days for recreation. Besides serving as a recreational resource, the large park in this highly developed region could also serve as an ecological resource. Increasing our knowledge of the biodiversity in the park is important to understanding its ecological impact on surrounding areas.

In August 2015 we lead groups of students from Macaulay Honors College of the City University of New York in Manhattan to search for lichens on the North Mound of Freshkills Park. Our lichen foray was part of the McCaulay Honors College Bioblitz, an activity that introduces first year students to field science. We were pleasantly surprised to discover a number of lichen species at the site, so we returned to the park after the Bioblitz to search for additional species. Here we present descriptions of the North Mound from a lichenological perspective, as well as a list of the species discovered throughout the park.

MATERIALS AND METHODS

We spent three days surveying the open portion of the park. Two days were during the Macaulay Honors College Bioblitz, 29-30 August 2015, and the third day the authors explored areas of the park in greater depth with the lead park scientist, Cait Fields.We surveyed the three main areas in the park (Fig. 1). At each site we searched all available substrates and collected a voucher specimen of every species that we found. Vouchers were deposited at The New York Botanical Garden Herbarium (NY). Lichens were identified following standard methods (Brodo et al. 2001) and taxonomy follows Esslinger (2015). Micrographs were taken using a Nikon SMZ1500 microscope fitted with a Nikon DS-Ri7 camera and maps were created in QGIS (QGIS 2016). Figures were prepared using Inkscape (inkscape.com). The following sites were surveyed:

1) *Main Mound*—The main mound is the actual capped landfill, which was covered in 1997. A thin layer of soil was added on top of the capping material, which is an impermeable layer of plastic. This area of the park is dominated by grasses, with scattered, young *Robinia pseudoacacia* (black locust) and *Populus deltoides* (cottonwood). No trees were planted in this area, so the few trees are all naturally occurring. The soils at this site are described as Kleinekill silt loam (USDA 2015).
2) *North Woods*—North of the mound there is a more densely wooded area. The small section of forest here is dominated by *R. pseudoacacia* with scattered *Prunus serotina* (black cherry). The soils are classified as Secaucus artifactual fine sandy loam with zero to three percent slopes (USDA, 2015)
3) *Riparian Zone*—There was a strip of wooded area along the eastern section of the mound bordering the tidal marsh. The dominant tree cover was *R. pseudoacacia*. The soils along the banks of the Main River were Kleinkill silt loam with 15–35% slopes (USDA 2015).

During the Macaulay Honors College Bioblitz, the student participants collected information on cover of crustose, foliose and fruticose lichens using the methodology from the Parks as Classrooms Great Smoky Mountains National Park Schoolyard Lichen Survey. Briefly, transparent sheets were printed with 100 one-centimeter diameter circles arranged in a 10 x 10 grid. Students chose a tree and at chest height on the north, south, east, and west faces of the tree they recorded how many of these circles included crustose, foliose, or fruticose lichens, and converted these values to percent cover. The cover on a total of 13 trees was recorded throughout the study area.

RESULTS

Seventeen species were discovered in Freshkills Park (Table 1; see the Appendix for annotated checklist). The most frequently observed and collected species were *Amandinea polyspora*, *Lecanora strobilina*, and *Physcia millegrana*. We found one calicioid species, *Phaeocalicium polyporaeum*, and a crust, *Verrucaria* cf. *elaeina*, growing on a brick. *Anisomeridium* sp., *Caloplaca subsoluta*, *Phaeophyscia adiastola*, *Physciella chloantha*, and *Verrucaria* cf. *elaeina* are newly reported for New York City.

Students who participated in the epiphyte tree cover survey as part of the Macaulay Honors College Bioblitz found that, on average, bark with lichens at Freshkills had 27% cover of epiphytes (though many trees had no epiphytes and were not included in the study). Most of this cover was from foliose lichens (83%), some was from mosses (11%), and a small proportion was from crustose lichens (5.5%). No fruticose lichens were located. The abundance of corticolous lichens was similar in the North Woods and Riparian Area, with 34.9% and 39.5% average foliose cover, and 2.2% and 2.7% average crustose cover, respectively. The lowest abundance of all lichens was found on the Main Mound with 0.2% average foliose cover and 0.05% average crustose cover.

DISCUSSION

The discovery of 17 species at Freshkills Park was very surprising given the young age of the park (<20 years old) since lichens are often slow to colonize an area (Lie et al. 2009), and its situation over a large landfill in a densely urbanized landscape, an area with very poor air quality. Most thalli of the species we observed were quite small and infrequent, and we suspect that some species on rocks were brought in

Species of Freshkills Park	Halsey 1823	Woods 1914	Brodo 1968; 2014	Delendick 1994	Stalter 2004
Amandinea milliaria	-	-	+	-	-
Amandinea polyspora	-	-	+	-	-
***Anisomeridium* sp.**	-	-	-	-	-
Caloplaca feracissima	-	-	+	+	-
Caloplaca subsoluta	-	-	-	-	-
Candelaria concolor	+	+	+	+	-
Flavoparmelia caperata	+	+	+	-	-
Lecanora dispersa	-	-	+	-	-
Lecanora strobilina	-	-	+	-	-
Leiomonis erratica	-	-	+	-	-
Phaeocalicium polyporaeum	-	-	+	-	-
Phaeophyscia adiastola	-	-	-	-	-
Phaeophyscia pusilloides	-	-	+	-	-
Phaeophyscia rubropulchra	-	-	+	-	-
Physcia millegrana	-	-	+	+	-
Physciella cloantha	-	-	-	-	-
Pyrrhospora varians	-	-	+	-	-
Verrucaria* cf. *elaeina	-	-	-	-	-

Table 1. List of species collected at Freshkills Park and comparison to previous floras in parts, or all, of the New York City Metropolitan Area (+ indicates presence in a list, - indicates absence from a list, names in bold-face type are new records for NYC).

with filling material (e.g., *Lecanora dispersa*). However, the corticolous species most likely dispersed to the study area from surrounding areas because the park is primarily maintained as a grassland and most trees have established naturally. This suggests that there are populations of all reported corticolous species occurring elsewhere within dispersal distance. Many of the collections for this flora were made from fallen trees and rotting logs, highlighting the importance of these substrates as habitat, which has been shown previously in many settings (Bunnell et al. 2008, Hauck et al. 2012).

The difference among species lists for lichens in the New York City metropolitan region is quite striking (Table 1). Unsurprisingly, historical lists (e.g., Halsey 1823, Woods 1914) reported many fruticose species, species associated with cyanobacteria, and other groups of lichens that are now quite rare throughout the region; none of these were not found at Freshkills Park. Additionally, the lichen flora of Long Island is much richer than the flora reported here, likely due to the much larger land area along with presence of older natural habitats (Brodo 1968, Harris 1987, Harris et al. 1987). Surprisingly, we found a number of species that have not been reported from the greater New York metropolitan area, suggesting that the heterogeneous, urbanized areas in and around New York City could host correspondingly distinct lichen floras. A thorough search of the region would likely uncover a surprisingly rich and distinctive lichen flora for such a densely populated and urbanized area, especially when special attention is paid to the crustose species, which represented 65% of the diversity at Freshkills Park. The surveys by the Macaulay Honors College students found that only 5.5% of the total epiphyte cover consisted of crustose lichens; the highest cover group, foliose lichens, consisted mainly of the very abundant *Physcia millegrana*.

Many of the species found at Freshkills are already described as city (or pollution) tolerant in other contexts. Nimis and Martellos (2008), in their ITALIC Information System on Italian Lichens database categorized several of the species we found as rather to highly tolerant of eutrophication in Italy, including

Candelaria concolor, *Lecanora dispersa*, and *Physciella chloantha*. Nimis and Martellos also included several species of *Caloplaca* and *Verrucaria* in the eutrophication-tolerant group, although not the species that we found at Freshkills. In surveys after landfill enlargement in central Italy, Paoli et al. (2012), found several of the Freskhills lichens in their study: *Candelaria concolor*, *Lecanora strobilina*, and *Physciella chloantha*. One of the lichens we found on rock, *Leimonis erratica,* was also one of the most abundant lichens on the mountainsides of Palmerton, Pennsylvania, near the former location of a zinc smelter (Howe & Lendemer 2010). *Candelaria concolor, Phaeophyscia rubropulchra, Phaeophyscia pusilloides, Physcia millegrana,* and *Physciella cloantha* are listed by Will-Wolf et al. (2015) as lichens of the northeastern United States that are tolerant to acidic air pollution.

Flavoparmelia caperata presents an interesting case of a lichen that may be tolerant of some, but not all urban conditions. It was the most common lichen near in the landfill studied by Paoli et al (2015), and though present in those marginal habitats near the landfill, it did not thrive there, as measured by indicators of photosynthetic activity and secondary compound production. Additionally, Brodo (1961) found that *F. caperata* was relatively pollution intolerant, as transplants of the species died within four months of establishment in Brooklyn. Will-Wolf (2015) also ranked *F. caperata* as a relatively intolerant species, and it is rarely found in Philadelphia (Howe, unpublished data).

Some of the species we found are not frequently reported from cities; these include *Amandinea milliaria, Anisomeridium* sp., *Phaeocalicium polyporaeum, Phaeophyscia adiastola*, *Pyrrhospora varians*, and *Verrucaria elaeina.* The first four of these are crustose species that are easily overlooked and may actually be more widespread in cities. The discovery of a *Phaeocalicium* species, which grows as stubble on a polypore fungus, might not be considered surprising because the host organism, *Trichaptum biforme* (Fr.) Ryvarden is widespread in North America (Hutchinson, 1987), and this species has previously been reported from urban parks (McMullin et al. 2014). *Phaeophyscia adiastola* is common in the northeastern United States (Hinds & Hinds 2007), but has not been reported in the other earlier studies of the New York Region because most studies were conducted previous to 1977, when the species was described (Esslinger 1977). The absence of some commonly reported urban lichens is also notable. *Parmelia sulcata* (L.) Ach. has been reported from many urban settings (reviewed by Conti & Cecchetti 2001), and it, along with *Hypogymnia physodes* (L.) Nyl., demonstrate high tolerance for atmospheric SO_2 (Prescott et al. 2015). The lichens listed by Will-Wolf et al. (2015) as tolerant of air pollution included *P. sulcata* along with several other lichens we did not find, including *Physconia leucoleptes* (Tuck.) Essl., *Xanthomendoza fallax* Søchting et al., and *Flavopunctelia flaventior* (Stirt.) Hale.

Our work provides baseline data for the lichen diversity at Freshkills Park, and is the first we know of specifically devoted to reporting on lichens at a decommissioned landfill. It is also the first to document the lichen flora specifically of Staten Island. At the time of the survey only a portion of the park was open, as much of it is still transitioning from being a landfill. Once the entire park is complete, a thorough search of all four mounds would certainly be warranted. Many of the specimens from this study were from *Prunus* and *Robinia* trees, but as tree diversity increases in the future, the corresponding epiphytic diversity will likely also increase. Repeated visits to the park in the coming decades will likely yield interesting results because more trees are being planted at the park as part of the Million Trees NYC program (Zalensky et al. 2014). As those trees mature, they will provide substrates for a wider variety of lichens (Lie et al. 2009), especially as the woody vegetation expands over the capped mounds, perhaps through bird dispersal (Robinson & Handel 1993). The tidal marsh will likely also prove to be valuable lichen habitat, as lichen species richness increases with more air moisture (Coffey & Fahrig 2012). As large and small-scale environmental change continues in densely urbanized landscapes across eastern North America, tracking the associated lichen flora will provide important insights into how lichens are both negatively and positively impacted by anthropogenic change.

ACKNOWLEDGEMENTS

We are grateful for the help of Cait Fields facilitating field work at Freshkills Park, Kelly O'Donnell and Lisa Brundage for organizing the Macaulay Honors College Bioblitz, and James Lendemer and Dick Harris for their help with species identification. The comments of the reviewers, I. Brodo and R.T. McMullin, were helpful in improving the manuscript. We also thank the students who joined the lichen team of the Macaulay Honors College Bioblitz. The funding for the Macaulay Honors College 2015 Freshkills Bioblitz was provided by the National Environmental Education Foundation and by Toyota Motor Sales USA, Inc. The first author is supported by The National Science Foundation Graduate Research Fellowship and the second author is supported as a Graduate Assistant at Rutgers, the State University of New Jersey.

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APPENDIX – ANNOTATED CHECKLIST OF FRESHKILLS LICHENS

The checklist presented below is arranged alphabetically by genus and species. Voucher specimens deposited at NY are cited for each species, and for each voucher specimen the locality data are provided. Many of the most common species are illustrated in two plates following the checklist. The four sites visited for the survey are indicated in the list using abbreviated codes as follows:

NM – U.S.A. NEW YORK. RICHMOND CO.: Freshkills Park, north end of North mound, 0.68 km E of intersection of Pearl Harbor Memorial Expressway and Victory Blvd.

PL – U.S.A. NEW YORK. RICHMOND CO.: Freshkills Park, north end of North Mound in forest behind Schmul Playground, 98 Pearson St., Staten Island.

SE – U.S.A. NEW YORK. RICHMOND CO.: Freshkills Park, southeast end of North mound, 1.56 km SE of intersection of Pearl Harbor Memorial Expressway and Victory Blvd.; Freshkills Park, southeast end of North Mound, north of bridge, on west side of river, along trail at base of mound.

Amandinea milliaria (Tuck.) P.F. May & Sheard

Specimens examined – **NM**, on *Acer*, 26.x.2015, *J.L. Allen 4480* (NY), on *Robinia pseudoacacia*, *J.L. Allen 4482* (NY).

Amandinea polyspora (Willey) E. Lay & P.F. May

Specimens examined – **NM**, on *Prunus serotina, J.L. Allen 4486* (NY); **PL**, on *Prunus, N.M. Howe 378* (NY), *N.M. Howe 382* (NY), *N.M. Howe 436* (NY).

Anisomeridium sp.

Specimen examined – **PL**, on rock, *N.M. Howe 376* (NY).

NOTE. – Specimen too poorly developed to identify to species.

Caloplaca feracissima H. Magn.

Specimen examined – **NM**, on rock, *J.L. Allen 4414* (NY).

Caloplaca subsoluta (Nyl.) Zahlbr.

Specimen examined – **NM**, on rock, *J.L. Allen 4413* (NY).

Candelaria concolor (Dicks.) Arnold

Specimen examined – **NM**, on *Robinia pseudoacacia, J.L. Allen 4411* (NY).

Flavoparmelia caperata (L.) Hale

Specimen examined – **NM**, on *Prunus serotina, J.L. Allen 4484* (NY).

Lecanora dispersa (Pers.) Sommerf.

Specimen examined – **NM**, on rock, *J.L. Allen 4415* (NY).

Lecanora strobilina Ach.

Specimens examined – **SE** on *Prunus, J.L. Allen 4491* (NY); **PL**, on *Prunus, N.M. Howe 377* (NY), *N.M. Howe 381* (NY), *N.M. Howe 437* (NY).

Leiomonis erratica (Körb.) R.C. Harris & Lendemer

Specimens examined – **SE,** on rock fill, *J.L. Allen 4416* (NY), *N.M. Howe 383* (NY), *N.M. Howe 384* (NY).

Phaeocalicium polyporaeum (Nyl.) Tibell

Specimens examined – **NM**, on *Trichaptum biforme, J.L. Allen 4485* (NY); **PL**, on *Trichaptum biforme, N.L. Howe 380* (NY).

Phaeophyscia adiastola (Essl.) Essl.

Specimen examined –**SE**, on fallen branch, *J.L. Allen 4490* (NY).

Phaeophyscia pusilloides (Zahlbr.) Essl.

Specimen examined – **NM**, on *Robinia pseudoacacia, J.L. Allen 4412* (NY).

Phaeophyscia rubropulchra (Degel.) Moberg

Specimens examined – **NM**, on *Robinia pseudoacacia, J.L. Allen 4409* (NY); **PL**, on *Prunus, N.M. Howe 437* (NY).

Physcia millegrana Degel.

Specimens examined – **NM**, on *Robinia pseudoacacia, J.L. Allen 4410* (NY); **SE**, on *Pinus, J.L. Allen 4489* (NY), *N.M. Howe 438* (NY).

Physciella chloantha (Ach.) Essl.

Specimen examined – **SE**, on *Robinia pseudoacacia, J.L. Allen 4488* (NY).

Pyrrhospora varians (Ach.) R.C. Harris

Specimens examined – **NM**, on *Robinia pseudoacacia, J.L. Allen 4483* (NY); **PL**, on *Prunus, N.M. Howe 379* (NY).

Verrucaria cf. *elaeina* Borrer

Specimen examined – **NM**, on brick, *J.L. Allen 4481* (NY).

NOTE. – This specimen was identified by R.C. Harris and though this specimen is most similar to *V. elaeina* it doesn not exactly fit the current circumscription of this species (Orange 2000). However, there is no described species to which it is seems to be more similar.

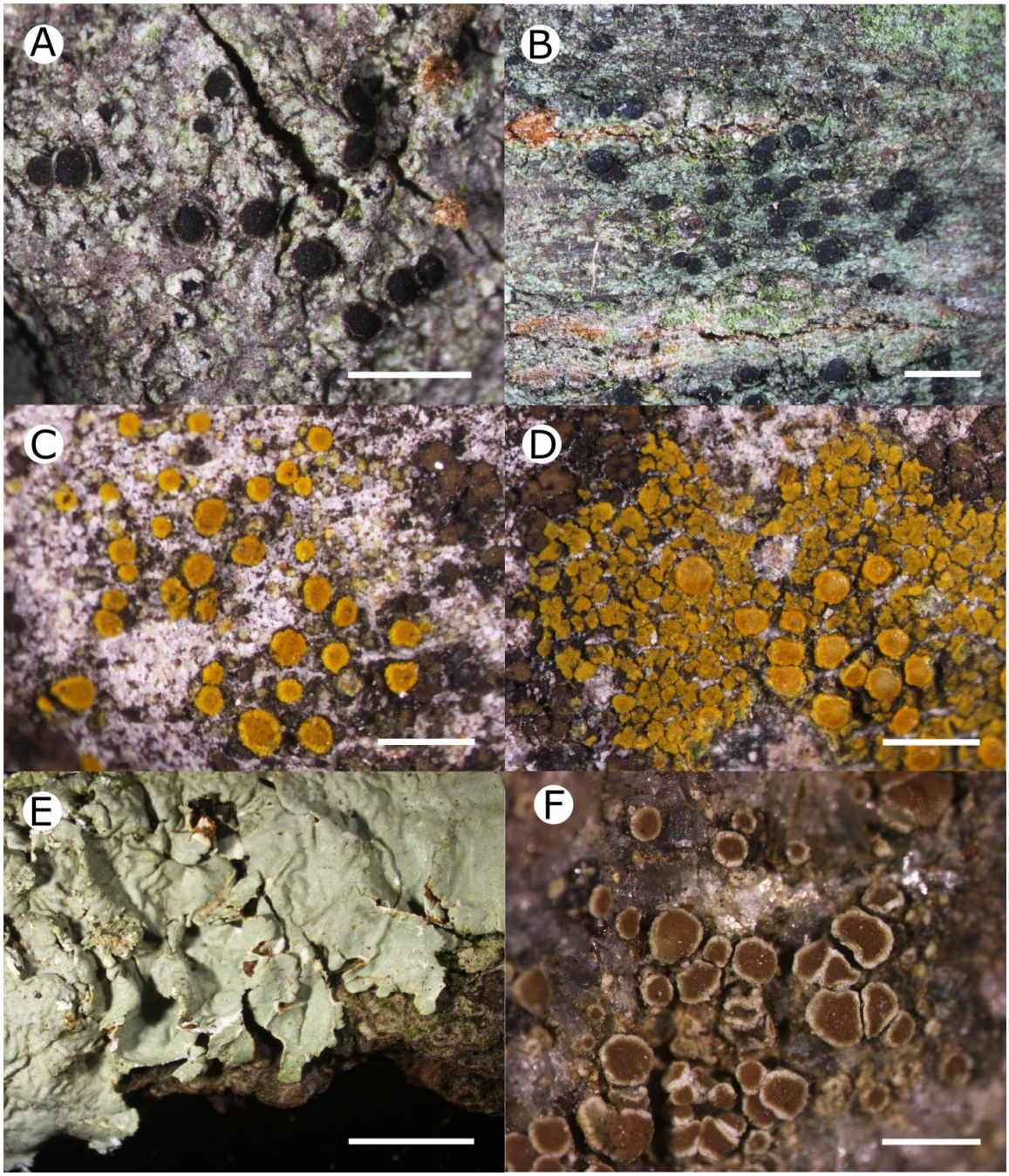

Figure 2. Selected lichens of Freshkills Park, (scale = 1mm unless otherwise noted). A. *Amandinea milliaria* (*Allen 4482*, NY). B. *Amandinea polyspora* (*Allen 4486*, NY). C. *Caloplaca feracissima* (*Allen 4413*, NY). D. *Caloplaca subsoluta* (*Allen 4414*, NY). E. *Flavoparmelia caperata* (*Allen 4484*, NY) (scale = 5mm). F. *Lecanora dispersa* (*Allen 4415*, NY).

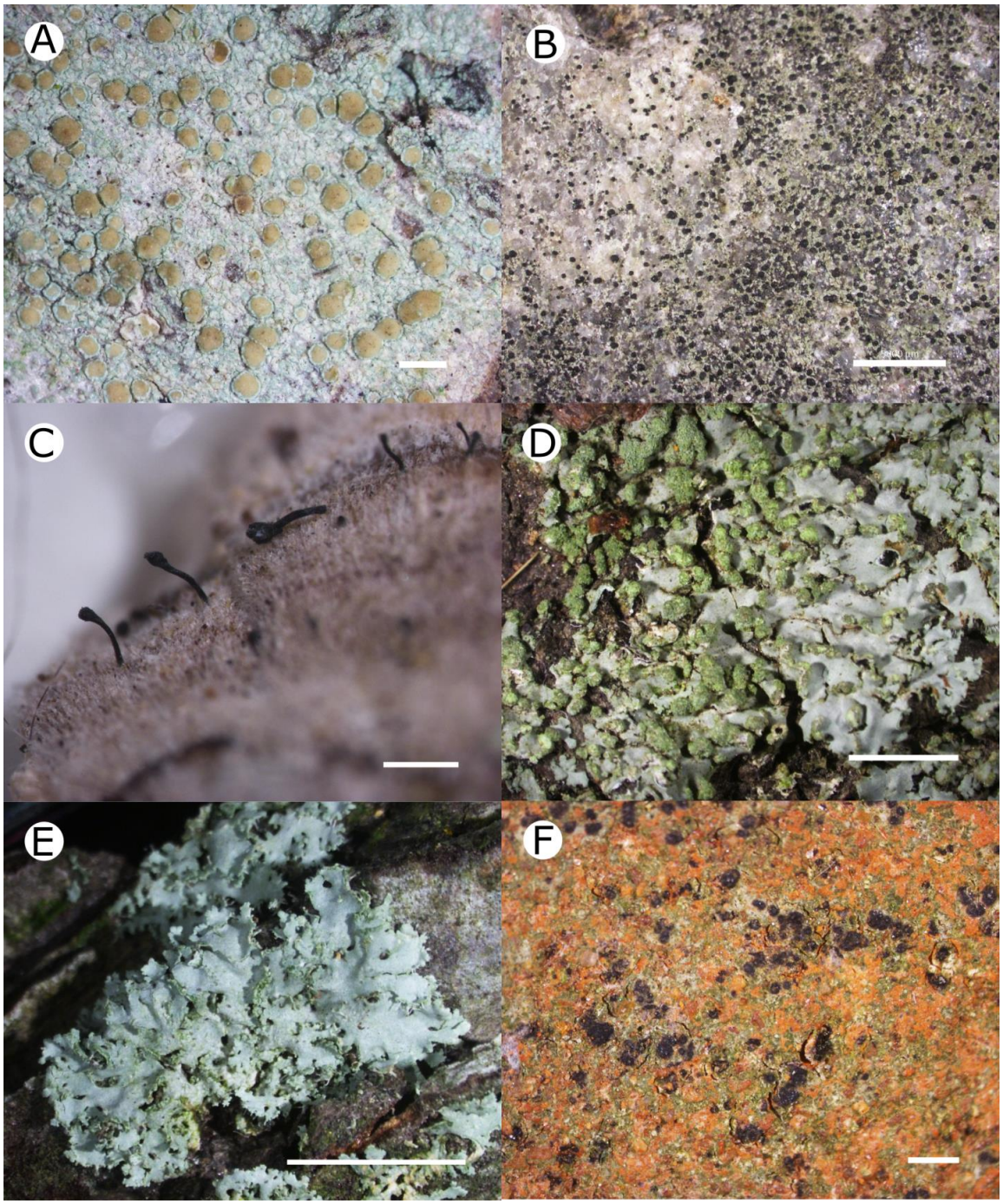

Figure 3. Selected lichens of Freshkills Park, (scale = 1mm unless otherwise noted). A. *Lecanora strobilina* (*Allen 4491*, NY). B. *Leimonis erratica*, (*Allen 4416*, NY) (scale = 5mm). C. *Phaeocalicium polyporaeum* (*Allen 4490*, NY). D. *Phaeophyscia adiastola* (*Allen 4490*, NY) (scale = 5mm). E. *Physcia millegrana* (*Allen 4489*, NY) (scale = 5mm). F. *Verrucaria* cf. *elaeina* (*Allen 4481*, NY).