Lichens of six vernal pools in Acadia National Park, Maine, USA

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Abstract. **Whereas lichen-habitat relations have been well-documented globally, literature on lichens of vernal pools is scant. We surveyed six vernal pools at Acadia National Park on Mount Desert Island, Maine, USA for their lichen diversity. Sixty-seven species were identified, including seven species that are new reports for Acadia National Park: *Fuscidea arboricola, Hypogymnia incurvoides, Lepraria finkii*, *Phaeographis inusta, Ropalospora viridis, Usnea flammea,* and *Violella fucata.* Five species are considered uncommon or only locally common in New England: *Everniastrum catawbiense*, *Hypogymnia krogiae*, *Pseudevernia cladonia*, *Usnea flammea*, and *Usnea merrillii.* This work represents the first survey of lichens from vernal pools in Acadia National Park and strongly suggests that previous efforts at documenting species at the Park have underestimated its species diversity. More work should be conducted to determine whether a unique assemblage of lichens occurs in association with this unique habitat type.**

Key words. **Biogeography, edaphic islands, lichen ecology, vernal pools, wetlands.**

INTRODUCTION

Vernal pools are short-lived wetlands driven by seasonal fluxes in precipitation (Cutko & Rawinski 2008). The ephemeral hydroperiod associated with vernal pools creates a challenging environment, often contributing to the assembly of unique communities of plants and animals, including many rare and endangered plant species (Barbour et al. 2005; Calhoun & deMaynadier 2008; Deil 2005; Gerhardt & Collinge 2003). As seasonal wetlands, vernal pools are inundated from rain or snowmelt in the early spring and exhibit an extended period of drought during the late summer and fall (Keeley & Zedler 1998). In addition to their seasonal shifts in water availability, vernal pools are also characterized by low nutrient availability and fluctuating levels of pH, dissolved oxygen and carbon dioxide, and salinity (Keeley & Zedler 1998; Tiner et al. 2002). These fluctuating conditions create a physiologically stressful environment, requiring specialized life histories and unique adaptations (Baskin 1994; Deil 2005; Stone 1990).

In northeastern North America, early snow melts and heavy rains inundate woodland vernal pools in spring (Cormier et al. 2013; Leonard et al. 2012). The pools dry out in the summer, and unlike vernal pools in Mediterranean climates that fill once each year (late autumn to late winter; Keeley & Zedler 1998), vernal pools in the northeast may fill several times during the year when heavy rains occur in the autumn, winter, and spring (Schneider & Frost 1996; Zedler 2003).

Lichens associated with vernal pools have to deal with fluctuating moisture and associated stressors, including large seasonal shifts in thallus saturation (Larson 1979), ranging from supersaturated conditions when pools are inundated to desiccated conditions when pools are dry. These stressors have the potential to impose strong ecological selection on species (Kershaw 1985), thereby affecting lichen community composition in vernal pools. *Leptogium rivulare* (Ach.) Mont, also historically known from Vermont and Illinois, is a vernal pool-associated lichen that is threatened in Canada (COSEWIC 2011), known only from one site in Manitoba and five sites in eastern Ontario (Consortium of North American Lichen Herbaria 2013). The species is largely found on bark of *Fraxinus nigra* (black ash) trees found in and around the pools. In New England, macrolichen species richness and diversity have been fairly well documented (e.g., Anderson et al. 1995; Dibble et al. 2009; Hinds 1995; Hinds & Hinds 2007). In Acadia National Park (ANP) on Mount Desert Island, Maine, extensive research has characterized lichen diversity and communities (Bennett et al. 2005; Cleavett et al. 2009; Selva 1994; Sullivan 1996; Wetmore 1984). Despite the large body of work on the lichens of ANP, no mention of vernal pool-associated lichens occurs in the literature. In fact, we were able to find only a handful of studies (e.g. Björk 2011; Björk & Dunwiddie 2004) documenting lichens found in vernal pools for *any* part of North America. Björk & Dunwiddie (2004) mention only six lichens (all saxicolous on cobbles), whereas Björk (2011), although reporting 132 lichen taxa, mentioned that “macrolichens are abundant only on trees and shrubs (mostly *Bryoria fremontii, Letharia columbiana* and *Letharia vulpina*), and are relatively species-rich on rocks, while all soil and epiphytic habitats are poor in species” and concluded that “The low abundance and diversity of soil-dwelling bryophytes, lichens, and cyanobacteria means that cryptogamic crusts currently are not a significant component of the ecosystem.”

The objective of this study was to generate a checklist of the lichens in six vernal pools of ANP to preliminarily assess whether these ephemeral pools may harbor new species previously not reported for Acadia National Park.

Materials and Methods

We surveyed lichens from six vernal pools in ANP, located on Mount Desert Island (MDI) in Hancock County, Maine, USA (44°34’9”N, 68°34’94”W; Fig. 1). Mount Desert Island is ca.

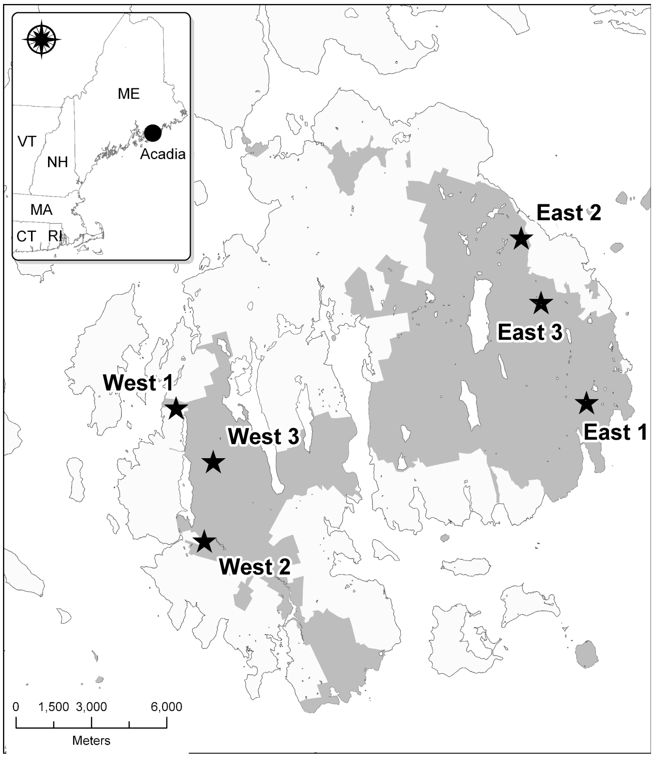

Figure 1. Locations of the six vernal pools sampled in Acadia National Park.

28,100 ha^2 and is characterized by distinct and fairly predictable seasonal weather patterns including cold winters, mild summers, and wet springs and autumns (National Park Service 2012). Annually, MDI receives approximately 140 cm of rainfall and 155 cm of snowfall (National Park Service 2012; Neilsen & Kahl 2007). With the majority of precipitation occurring during autumn through spring, vernal pools are flooded during the colder months and dry out during the hotter and drier summer (National Park Service 2012; Tiner et al. 2002).

The six vernal pools selected for the current study were the same as those studied by Ciccotelli et al. (2011). All six pools were similar in size and canopy cover, but differed in the composition of vascular plants found in each pool. At each pool, five transects were established between April 21 and 24, 2008 (Ciccotelli et al. 2011) and were re-established between May 16 and 19, 2012 (current study). Transect lines radiated at 72° intervals from the deepest part of the pool and extended to the spring high water mark of each pool following the methods described by Ciccotelli et al. (2011). In both 2008 and 2012, square quadrats measuring 2 m on each side (4 m^2) were established at 3-meter intervals along each transect starting at the deepest point of the pool and continuing to the edge of the pool. Within each quadrat, lichen specimens were collected from hardwoods, conifers, decaying wood, moss, rock and soil substrates. For trees and other substrates extending above the elevation of the spring high water mark, lichens were collected from within 0.5 m above the elevation of the spring high water mark; this was intended to capture lichen species that may have been affected by increased humidity above the pools or by water wicked up the trunk by mosses or other absorptive organic matter.

Lichens were identified using Brodo et al. (2001), Gowan and Brodo (1988), Hinds and Hinds (2007), and Wetmore (2005). Nomenclature follows Esslinger (2013) for lichens and the International Plant Names Index (2013) for plants. Voucher specimens were deposited at the Herbarium of College of the Atlantic (HCOA).

Results

Sixty-seven lichen species were identified from the six vernal pools we examined (Table 1). Of the 67 species identified, 16 were foliose (23.9%), 24 were fruticose (35.8%), 25 were crustose (37.3%), and two were leprose (~3%; Table 2). *Cladonia*, *Lecanora*, and *Usnea* were the most well-represented genera in the six pools. Fourteen *Cladonia* species were found in the vernal pools compared to seven each of *Lecanora* and *Usnea*. Five species of macrolichens found in the pools are listed as rare or occasional in Maine: *Everniastrum catawbiense*, *Hypogymnia krogiae*, *Pseudevernia cladonia*, *Usnea flammea*, *Usnea merrillii* (Hinds & Hinds 2007). Seven species of lichen found in the pools were previously undocumented in ANP: *Fuscidea arboricola*, *Hypogymnia incurvoides, Lepraria finkii, Phaeographis inusta, Ropalospora viridis*, *Usnea flammea*, and *Violella fucata*; of these, six were found only in one of the six pools (Table 1). *Usnea flammea* was the only new record for ANP also listed as uncommon in Maine by Hinds and Hinds (2007). Only three lichen species (approximately 4% of total vernal pool flora documented here)—*Buellia disciformis*, *Graphis scripta*, and *Hypogymnia physodes*—were found in all six pools we surveyed. Twenty-nine species (approximately 43% of total vernal pool flora documented here) of the lichens collected were found in only one each of the six pools.

Table 1 (following two pages). Sixty-seven lichen species collected from six vernal pools in Acadia National Park (ANP), Maine. Species documented in the study are compared with ANP's lichen inventory based on Cleavitt et al. (2009), Sullivan (1996), and Wetmore (1984). * = Rare or occasional lichens based on Hinds and Hinds (2007). The seven lichen species documented for the first time from ANP are in bold font. Substrate abbreviations are as follows: SW= Softwood, HW= Hardwood, DW= Decaying wood. Common softwood species encountered within the pools were *Picea rubens* Sarg., *Larix laricina* (Du Roi) K. Koch. Common hardwood species encountered were *Acer rubrum* L., *Ilex verticillata* A. Gray, *Betula papyrifera* Marshall, and *Vaccinium corymbosum* L. Pools are labeled based on their locations on Mount Desert Island (E, East; W, West; Figure 1). Nomenclature follows Esslinger (2013) and International Plant Names Index (2013).

Species	Substrate	E1	E2	E3	W1	W2	W3
Bryoria furcellata (Fr.) Brodo & D. Hawksw.	SW	–	–	–	–	–	X
Buellia disciformis (Fr.) Mudd	HW	X	X	X	X	X	X
B. erubescens Arnold	HW	–	–	X	X	–	–
Cladonia caespiticia (Pers.) Flörke	Soil	–	–	–	–	X	–
C. chlorophaea (Flörke ex Sommerf.) Spreng.	DW	X	X	–	X	–	X
C. coniocraea (Flörke) Spreng.	Soil	–	–	–	–	X	–
C. cristatella Tuck.	DW	–	–	–	–	X	–
C. digitata (L.) Hoffm.	Humus	X	–	–	–	–	X
C. macilenta Hoffm.	HW	–	–	–	–	–	X
C. maxima (Asah.) Ahti	Humus	–	–	–	–	X	–
C. ochrochlora Flörke	Soil	–	–	X	X	–	–
C. parasitica (Hoffm.) Hoffm.	Soil	–	–	–	–	X	–
C. ramulosa (With.) J. R. Laundon	Moss	–	–	–	X	–	–
C. scabriuscula (Delise) Nyl.	Soil	–	–	–	–	X	–
C. squamosa Hoffm.	HW	–	–	–	X	X	X
C. stygia (Fr.) Ruoss	Humus	–	–	–	–	–	X
Evernia mesomorpha Nyl.	HW	X	X	–	–	–	–
**Everniastrum catawbiense* (Degel.) Hale ex Sipman	SW	–	–	–	–	X	–
Flavoparmelia caperata (L.) Hale	HW	–	–	X	X	–	–
Fuscidea arboricola Coppins & Tønsberg	HW	–	X	–	–	–	–
Graphis scripta (L.) Ach.	HW	X	X	X	X	X	X
Hypogymnia incurvoides Rass.	HW	X	X	–	–	–	–
**H. krogiae* Ohlsson	SW	–	–	–	–	X	X
H. physodes (L.) Nyl.	HW, SW	X	X	X	X	X	X
H. tubulosa (Schaer.) Hav.	SW	–	–	X	X	X	–
Imshaugia aleurites (Ach.) S. L. F.Mey.	HW	–	–	–	–	X	–
Julella fallaciosa (Stizenb. ex Arnold) R. C. Harris	HW	–	–	X	–	–	–
Lasallia papulosa (Ach.) Llano	Rock	–	–	X	–	–	–
Lecanora allophana Nyl.	HW	–	–	X	–	–	–
L. caesiorubella Ach.	HW, SW	–	–	X	X	X	X
L. chlarotera Nyl.	HW	–	–	X	–	–	–
L. cinereofusca H. Magn.	HW	–	X	X	–	–	–
L. hybocarpa (Tuck.) Brodo	HW	X	X	X	–	–	–

L. pulicaris (Pers.) Ach.	HW	–	–	X	–	X	–
L. subrugosa Nyl.	HW	–	–	–	–	X	–
L. symmicta (Ach.) Ach.	HW	–	–	–	X	X	–
L. thysanophora R. C. Harris	HW	–	–	–	X	–	–
Lepraria lobificans Nyl.	HW	–	–	–	–	X	–
L. finkii (de Lesd.) R. C. Harris	HW	–	–	–	–	X	–
Loxospora ochrophaea (Tuck.) R. C. Harris	HW	–	–	–	X	X	X
L. elatina (Flot.) A. Massal.	HW, SW	–	–	–	X	X	X
Melanelixia subaurifera (Nyl.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	HW	X	X	–		–	–
Mycoblastus affinis (Schaer.) T. Schauer	HW	–	–	–	X	–	–
Ochrolechia arborea (Kreyer) Almb.	HW	X	–	X	X	–	–
Parmelia squarrosa Hale	HW, SW	X	X	X	X	X	X
P. sulcata Taylor	SW	–	–	–	X	–	–
Parmeliopsis hyperopta (Ach.) Arnold	HW	–	–	X	–	–	–
Pertusaria amara (Ach.) Nyl.	HW	X	–	X	–	X	–
P. multipunctoides Dibben	HW	–	–	–	–	–	X
P. ophthalmiza (Nyl.) Nyl.	HW, SW	X	X	–	–	X	–
Phaeographis inusta (Ach.) Müll. Arg.	HW	–	X	–	X	X	–
Platismatia glauca (L.) W. L. Culb. & C. F. Culb.	HW	–	–	–	X	X	X
P. tuckermanii (Oakes) W. L. Culb. & C. F. Culb.	SW	–	–	X	X	X	X
**Pseudevernia cladonia* (Tuck.) Hale & W. L.Culb.	SW	–	–	–	–	X	–
P. consocians (Vain.) Hale & W. L.Culb.	SW	–	–	–	–	–	X
Punctelia rudecta (Ach.) Krog	HW	–	–	X	X	–	X
Pyrrhospora varians (Ach.) R. C. Harris	HW	–	X	X	–	–	–
Ropalospora viridis (Tønsberg) Tønsberg	HW	–	–	X	–	–	–
Tuckermannopsis americana (Sprengel) Hale	HW	X	–	–	–	X	–
Usnea filipendula Stirt.	SW	–	–	X	X	X	X
****U. flammea*** Stirt.	SW	–	–	–	–	–	X
U. hirta (L.) F. H. Wigg.	SW	–	–	–	–	X	–
**U. merrillii* Motyka	SW, HW	–	–	–	–	X	–
U. subgracilis Vain	SW	–	–	–	–	X	–
U. subfloridana Stirt.	HW	X	X	X	–	X	–
U. subrubicunda P. Clerc	SW	–	–	X	X	X	X
Violella fucata (Stirt.) T. Sprib.	HW	–	–	–	–	–	X

DISCUSSION

Approximately 440 lichen species are known from ANP (Consortium of North American Lichen Herbaria 2013), the fifth highest number of lichen species listed among 144 U.S. National Parks included in the study by Bennett et al. (2005). The high diversity of lichens at ANP may result from the Park's proximity to the coast, its topographic heterogeneity, and management practices minimizing tree harvest (Cleavitt et al. 2009; Harris et al. 2012), but is more likely due to the fact that, unlike most other US National Parks, ANP has been the subject of numerous studies examining its lichen biota (Cleavitt et al. 2009, Sullivan 1996, Wetmore 1984). Despite the large body of work on the lichens of ANP, we were unable to find studies documenting lichens from vernal pools in ANP. Our study documented approximately 16% of the total lichen flora of ANP from approximately 2,156 m^2 of vernal pools, representing less than 1% of the total area of ANP. Although we were unable to find other reports documenting lichen diversity on a per meter basis for ANP, our results strongly suggest that previous efforts to quantify lichens at ANP (Bennett et al. 2005; Cleavett et al. 2009; Selva 1994; Sullivan 1996; Wetmore 1984), have only provided, at best, a partial list for species diversity at the Park. The lichen taxa reported from ANP are divided almost equally between macro- (foliose and fruticose) and micro- (crustose) lichens, whereas in most comprehensive inventories macrolichens constitute only around one third of the total lichen biota (Spribille et al. 2010). By this measure, it could be expected that a further 200 microlichens await discovery in ANP – and this assumes that the macrolichen biota is fully known. The same can be said for other regions of North America, particularly National Parks, where, even after extensive study previously, new records have been documented in more recent surveys (Knudsen et al. 2013; Lendemer et al. 2010, 2013; Spribille et al. 2010), suggesting that previous estimates of completeness of lichen checklists for National Parks have been seriously exaggerated.

The majority of species we found are common throughout ANP and northeastern North America (Anderson & Neily 2012; Gowan & Brodo 1988; Hinds & Hinds 2007; Richardson et al. 2009; Sullivan 1996). However, five lichen species found in the vernal pools are listed as uncommon in Maine (Hinds & Hinds 2007) and seven lichens are new reports for ANP, including five lichens (*Fuscidea arboricola*, *Lepraria finkii, Ropalospora viridis*, *Usnea flammea*, and *Violella fucata*) that were restricted to a single pool. It is unclear whether these new reports were previously uncollected or are the result of recent changes in the taxonomy of these and closely related species. It may be that a re-examination of previously collected material (e.g., collections by Sullivan 1996 or Cleavitt et al. 2009) will prove to include some of the seven additions reported here.

We did not observe any strong patterns of zonation in the six pools studied, which may be an indication of large variation in hydroperiod from year to year (Mitchell 2005). However, we also didn't explicitly explore the effects of zonation in the current study so have to be cautious about this conclusion. A more detailed study examining differences in water depth along sampling transects, as well as variations in hydroperiod from year to year, is needed to determine the presence of zonation among lichens found in the vernal pools. Of the 67 species we identified, 12 species (18%) were found on soil, rock, humus, decaying wood, or moss substrates within one or more of the pools, and as such, were assumed to be directly influenced by pool hydrology. The other species (82%) were found on hardwood or softwood tree trunks rooted within the pools. Many of these lichens probably never experience inundation for extended periods nor are directly influenced by seasonal changes in hydrology. Work on the epiphytic macrolichen populations of riparian areas in the Pacific Northwest (McCune et al. 2002) concluded that the occurrence of rare or threatened species was related to stream size, which they further related to the increase occurrence of hardwoods as opposed to conifers. However, lichens in vernal pools may be influenced by high humidity levels near the pool surface during much of the year. Additional research is needed to demonstrate whether the lichens we collected from the vernal pools represent a lichen community distinct from that of the surrounding forest or are exclusively associated with the pools of any given region.

Except for the new records for ANP and those listed as rare or occasional by Hinds and Hinds (2007), the species we collected are generally of little special interest, as they are both regionally-common and ecologically broadly-tolerant. However, several species are at the northeastern edge of their range in North America (e.g., *Pertusaria consocians*, *Phaeographis inusta*, *Usnea flammea*), but others have reported these species from the region (Anderson & Neily 2012; Gowan & Brodo 1988; Hinds & Hinds 2007; Richardson et al. 2009). Interestingly, cyanolichens are conspicuously absent from our list, even though hardwoods such as *Acer rubrum*, which generally host these species, were found in at least some of the vernal pools we studied.

The study of lichen species found in vernal pools will help better evaluate how abiotic factors such as fluctuating water regimes, pH, and ionic concentrationsmay influence community assembly and will provide a baseline for additional research exploring lichens found in similarly stressed environments, including those found in other wetland types in the region. In light of recent conservation setbacks (Oscarson & Calhoun 2007; Zedler 2003), state and federal efforts to restore and manage vernal pools are limited. Conservation efforts have become weakened due to U.S. Supreme Court decisions (Oscarson & Calhoun 2007; Zedler 2003), leaving approximately 29% of vernal pools in the United States unprotected under government regulation. Although this is a preliminary study of lichens of vernal pools, results generated from this study, including the documentation of regionally uncommon species and seven new records for ANP, will be helpful for continuing conservation efforts related to vernal pools in northeastern North America. Additionally, the study stresses the importance of continuing field surveys even in the 'well-studied' National Parks, with a particular emphasis on specialized habitats that are often under-explored.

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