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Introduction

The southern Rocky Mountains and adjacent prairies of Colorado represent a biological mosaic of environments typical of many montane areas of North America, especially western North America. Boulder County alone ranges in elevation from ca. 5,000 ft. to 14,000 ft., traversing one of the greatest elevational gradients of any single county in North America and hosting a range of habitats including mixed grass prairies with tallgrass relicts, submontane forested foothills, and alpine environments above treeline. Among these dominant vegetation zones are patches of rarer habitat such as geological outcroppings of sandstone or shale, eastern woodland relict forests, and fens. This book is documentation of a sandstone outcropping within the city limits of Boulder. The lichen biota of White Rocks represents an assemblage of species from the High Plains and mesas of Colorado, as well as from mid- to low-elevation montane habitats throughout the Rocky Mountains. As such, many species in this Field Guide are encountered commonly throughout central and western North America. There exist several additional Fox Hills outcrops in Colorado and neighboring states as well as sandstone outcrops of other geological time periods. The present guide will be especially useful in helping to identify the lichen constituents of those formations. Importantly, this guide treats fully the diverse crustose lichen biota in addition to the more conspicuous macrolichens.

White Rocks represents an ~100-acre ecologically important protected area within Boulder. Its biological significance is attributable in part to its geological history, climatological history, and degree of preservation but also to the fact that it is a biodiversity reservoir within a sea of agriculture and urban development (i.e., the Boulder-Denver-Longmont urban triangle). White Rocks is a rare and fragile outcropping of sandstone that rises directly above the northern margin of Boulder Creek. The outcrop itself consists of a large one- to two-tier sandstone shelf with horizontal and vertical exposed surfaces. It is approximately two-thirds of a mile in length oriented in an east-west manner. This outcropping is flanked by a more minor, adjacent sandstone exposure directly to the east, which is approximately one-half of a mile in length. White Rocks belongs to the Fox Hills Laramie Formation, dating to ca. 67 million years before present. The sandstone at

White Rocks is, as the name implies, very white in color and is composed primarily of quartz with small amounts of montmorillinite clay. The sandstone is extremely fragile and susceptible to weathering by foot travel or natural phenomena such as strong rains or high winds, but its erosion is slowed substantially by "case hardening" of the rock, which derives from hardened clay strengthened by biotic crusts—primarily lichens.

Despite the relatively small geographical size of White Rocks, the preserve is known to harbor numerous common as well as rare vascular plants and animals (Byars 1936; Weber 1949; Clark, Crawford, and Jennings 2001). This relates to the high microhabitat diversity represented at White Rocks, which is attributable to small-scale variation in relative humidity and available water, exposure to wind and sun, mineral content, aspect and steepness of slopes, and the biotic environment itself. White Rocks similarly hosts a community of common lichens (seen throughout the High Plains and Rocky Mountains) as well as rare lichens that are un- or underrepresented in Boulder County or much of Colorado. The latter builds upon prior discoveries of rare or unusual lichens present at other sandstone outcrops in North America (Skorepa 1973; Showman 1987).

Several species at White Rocks warrant conservation protection. A few may even deserve protection under the federal Endangered Species Act (ESA). However, at present, lichens are more or less excluded from federal conservation measures (only two species are currently protected by the ESA). Rare lichens at White Rocks do, however, receive local protection through the Open Space and Mountain Parks (OSMP) conservation practices. To protect the many sensitive natural resources that occur at this site, including federally regulated bird nesting habitat, White Rocks can be accessed only through permitted research and scheduled educational tours and is otherwise closed to the public(additional information on public access is available on the OSMP website www.bouldercolorado.gov/osmp).

Although a history exists of research and general interest in White Rocks Open Space, no inventory or assessment of lichens of this unique outcropping has been conducted. Thus, the primary objective of this project was to conduct a comprehensive inventory of the lichens of White Rocks. This inventory builds baseline information about the biodiversity of this important preserve as well as similar sandstone formations across western North America, enables long-term conservation planning and resource management in a data-driven manner, facilitates future lichen taxonomic and ecological research, and improves our capacity to educate the public about the importance of lichens in urban environments.

Finally, while the total lichen biota of Colorado is expected to be particularly rich given the mosaic of environments and sharp elevational and climatological gradients, a comprehensive account of Colorado lichens is lacking. Shushan and Anderson (1969) presented a lichen checklist for the state, but this list represents a small fraction of the state's total lichen biodiversity, is based entirely on literature reports, and is outdated taxonomically. The manuscript from which this Field Guide draws (Tripp 2015) is based on new field collections and adds to a list of important regional inventories in western North America that, together, will help scientists stitch together a better understanding of lichenology of the Great American West. Most immediately, this Field Guide and associated publication provide the initial steps toward a revision of the lichen biota of Colorado. Readers should refer to Tripp (2015) for more extensive information and background on White Rocks, as well as Tripp and Lendemer (2015) for descriptions of two new species from the site.

Why Lichens?

Every component of an ecosystem functions in some way vital to that ecosystem (Braun 1950). Lichens are for the most part Ascomycete fungi (the "mycobiont") with an obligate symbiotic relationship with one or more green algae or cyanobacterium (the "photobiont"). Lichens are among the most diverse and ecologically important obligate symbioses and represent important components of terrestrial ecosystems worldwide (Hawksworth 1991; Brodo et al. 2001; Cornelissen et al. 2007). In some regions of the world, lichens (together with bryophytes) contribute more to the total biotic diversity than do vascular plants (Kantvilas 1990; Jarman and Kantvilas 1995). In the relatively arid state of Colorado, the ratio of flowering plant species to lichens probably ranges between ~3 to 1 and ~3 to 2, indicating the importance of lichens to the total biota of the state. However, unlike the ±3,000 species of flowering plants in Colorado, we have only the most rudimentary knowledge of the identity, let alone ecology, of the ±1,000 to 2,000 species of Colorado lichens. Yet the pace of new species description of North American lichens far exceeds the pace of description of new plants—despite the fact that major, large-scale plant floristic projects that would seem to correlate with new species discovery exist or have been recently completed (e.g., Flora of North America Editorial Committee 1993; Jepson Flora Project 2016; Conquista et al. 2013; Weakley 2015) whereas large-scale efforts in lichenology are few (Nash et al. 2002, 2004, and 2007 represents one of the few modern lichen floras in North America).

Just like plants and animals, lichens grow and respire; just like plants, lichens also photosynthesize because of the presence of the photobiont. In addition, lichens with a cyanobacterial photobiont and/or specialized lineages of endolichenic bacteria contribute to the "fixation" of nitrogen—that is, the process by which atmospheric nitrogen is converted into a form usable by living organisms. At White Rocks, only two genera of lichens harbor cyanobacteria: *Enchylium* and *Lichinella*. Elsewhere in Boulder County, cyanolichens include *Leptogium*, *Lobaria*, *Nephroma*, *Peltigera*, and, if you are really lucky, *Sticta*. Genomic investigation of bacterial communities of lichens is in its infancy, but it is likely that other nitrogen-fixing prokaryotes in addition to cyanobacteria are far more prevalent in lichens than previously recognized (Kane, Tripp, Lendemer, and McCain, in progress).

Lichens that grow on rock also influence nutrient distribution in their environments in another manner: as primary decomposers of parent rock material into what will ultimately become soil. The lichen mycobiont manufactures and secretes various chemicals that aid fungal hyphae in the penetration of rock surfaces. Once below the surface, hyphae grow among the crystalline structures and between rock cleavage lines, further fracturing the parent material. As lichens grow and decompose, they also trap fine soil particles among their surfaces, encouraging saprophytic fungi and bacterial growth, further adding to the process of soil formation. Lichens that grow on trees influence local distribution of nutrients by trapping airborne nutrients including water, thereby helping to maintain relative humidity as well as providing shelter for microorganisms. Whether their presence is detrimental to living substrates (e.g., trees) is a question unanswered. On the whole, however, it is widely appreciated that healthy ecosystems have ample lichen cover, and unhealthy ecosystems lack lichen cover. A stop along a forest bordering northern stretches of Interstate 95 will demonstrate the latter. A hike at 13,000 feet in Rocky Mountain National Park will demonstrate the former.

Beyond their roles in ecosystem nutrient cycling, lichens also function prominently in many food webs. In Colorado, lichens figure substantially in the diets of both large- and small-bodied animals ranging from elk to moose, deer, squirrels, birds, snails, mites, and insects (Sharnoff 1994; Pettersson et al. 1995). In boreal ecozones, lichens serve as primary food sources for mountain goats, and caribou cannot live without them. Lichens are also used by numerous animals in nest construction (Ladd 1998) or medicinally in some human societies (Wei et al. 1982). In fact, lichens manufacture hundreds of secondary compounds not known elsewhere in nature and whose ecological functions are at best minimally understood. This chemical diversity has (perhaps unsurprisingly) been exploited by lichenologists as a source of taxonomic information: thin layer chromatography (TLC) to determine lichen secondary chemistry is necessary to identify at least a third of all North American species with confidence.

Finally, lichen abundance and species richness have long been appreciated as indicators of the richness of other taxa, habitat quality, and air quality of a particular region (De Wit 1983; Nilsson et al. 1995; Bergamini et al. 2007; Tripp and Lendemer 2012; Lendemer et al. 2013). Nordén and colleagues (2007) found a significant correlation between temperate and deciduous forest lichen, bryophyte, and wood fungi diversity and the number of rare, Red Listed species in these groups. In the southeastern United States, McCune and colleagues (1997) found lower lichen diversity and abundance in areas of higher air pollution. Great Smoky Mountains National Park, which contains some of the most extensive tracts of old growth forest remaining in eastern North America, is lichenologically the most diverse park in the United States and contains upward of half of all species present in eastern North America (Tripp and Lendemer 2012; Lendemer et al. 2013). For the most part, relatively common species have been used as forest indicators (McCune et al. 1998). However, recent studies are also bringing new recognition to the rarer component of the lichen biota, and inventories have indicated that occurrence of rare plants and animals correlates to occurrence of rare lichens (Lendemer et al. 2013).

Lichen Biology: The Basics

The traditional concept of the lichen symbiosis has been that the mycobiont and photobiont form a mutualist relationship, with the fungus providing a protected environment in which the photobiont can thrive and the photobiont supplying nutritional products of photosynthesis to feed the fungus. More recent perspectives suggest this traditional view may not be accurate, with one or both of the partners functioning parasitically at times (reviewed in Richardson 1999). Recent research has also demonstrated that the lichen symbiosis itself is far more complex than previously understood, with the discovery of multiple photobiont genotypes in a single organism (Muggia et al. 2013), as well as additional partners including endolichenic fungi or bacteria, whose functions are for the most part still under investigation (Arnold et al. 2009; Spribille et al. 2016).

The vegetative or non-sexual portion of the lichen body is termed a thallus (plural: thalli) and consists generally of four layers. The upper and lower layers comprise the cortex and are composed of densely packed fungal hyphae. The upper cortex is where many accessory pigments that give lichens their color reside. Just underneath the upper cortex is the photobiont layer, which varies from light to dark green to orange to blue, depending on photobiont type (e.g., coccoid green alga, *Trentepohlia*, a cyanobacterium). The layer below the photobiont is termed the medulla; it is usually bright white in cross section (but can be brightly pigmented in some species, such as in *Vulpicia pinastri*, which is common in Boulder

County and has a bright yellow medulla) and consists of loosely arranged fungal hyphae. Below the medulla, the lower cortex (where present, see below) is generally white, gray, brown, or black in color.

Lichen upper cortices are modified or ornamented in myriad ways. Specialized features include cyphellae and pseudocyphellae, maculae, perforations, cilia, and pruina. Pruina is a whitish coating on the upper surfaces of some lichens, giving an appearance of powdered sugar. Pruina is very common among species at White Rocks and can often be seen on surfaces of apothecia (e.g., *Diplotomma venusta*) and/or on surfaces of thalli (e.g., *Psora tuckermanii*). Degree of pruinosity can vary to such an extent even over a single thallus as to completely obscure the true color of the upper cortex by giving the lichen the appearance of a white color (as in *Acarospora strigata*: dark brown when epruinose but bright white when pruinose). Lichen lower cortices are differentiated by color, texture, and presence of attachment structures such as rhizines, which anchor lichens to their substrate and are typical of many foliose lichens.

Not all lichens have differentiated upper and lower cortices, and not all lichens have both cortices. First, by definition, most fruticose lichens (see growth form information below) have only one type of cortex, that is, an upper cortex is non-differentiable from a lower cortex. We have only one fruticose lichen at White Rocks: *Lichinella stipatula*, which is microfruticose. Second, by definition, crustose lichens lack a lower cortex. The majority of the lichen biota at White Rocks is crustose (e.g., *Caloplaca trachyphylla*, *Lepraria finkii*, *Acarospora* spp.). Finally, most foliose lichens have well-differentiated upper and lower cortices, but a small number of foliose lichens are characterized by having "ecorticate" lower surfaces (like crustose species), such as species in the genus *Peltigera* and *Heterodermia* (not present at White Rocks but commonly encountered elsewhere in Boulder County).

Lichen Reproduction

Lichens reproduce sexually and/or asexually. Most commonly, a given species reproduces primarily through one but not both means, that is, a species is either sexual or asexual (Tripp 2016); however, asexual species are on occasion encountered with sexual reproductive structures (see below). At White Rocks, *Psora tuckermanii* is almost always found with sexual reproductive structures, whereas *Verrucaria furfuracea* is always found with asexual reproductive structures. Just like all other Ascomycete fungi, the basic unit of sexual reproduction in lichens is the ascoma. Lichen ascoma (plural: ascomata) occur primarily in two forms: disc-shaped apothecia and flask-shaped perithecia. Inside the ascomata are sacs that contain the products of meiosis: ascospores. Spores are released from either the open discs of an apothecium (as in *Candelariella rosulans*) or from a pore-like opening at the top of a perithecium (as in *Staurothele areolata*). Because sexual reproduction involves only the fungus and not the alga, dispersed fungal ascospores must encounter a non-lichens-compatible alga (or steal an alga from a different lichen, which surely happens with some frequency) to give rise to a new thallus. Lichen apothecia, the most common type of reproductive structure, are extremely diverse morphologically. They can occur with or without thalline margins, and when present, these are sometimes ornamented. Thalline margins are typically described as lecideine if they lack algae and are carbonized or black in color (as in *Lecidea hoganii*) or lecanorine if algae are present and margins are the same color as the thallus (as in *Lecanora muralis*). Apothecia may be concave at maturity (*Xanthoparmelia coloradoensis*), convex (*Lecidella carpathica*), flat (*Candelariella clarkiae*), lirellate or lip-like (this modification not present at White Rocks), or raised on stalks or podetia (this modification also not present at White Rocks but characteristic of the diverse and widespread genus *Cladonia*). Sexual reproductive structures can range from comprising nearly the entire visible lichen (*Lecanora flowersiana*) to being scattered across the thallus (*Caloplaca sideritis*) to being rare (*Caloplaca decipiens*) or completely unknown (*Lepraria finkii*) for a given species. Finally, sexual ascospores are extremely important in lichen identification. They range from hyaline to brown at maturity and simple to transversely sepatate to muriform. A given sexually reproducing species generally has a diagnostic number of ascospores per ascus. The most typical number is eight spores per ascus, reflecting meiosis followed by a single mitosis event, but severe reductions in the number of spores per ascus are possible (as in one spore/ascus in *Rhizocarpon disporum*), as are additional mitotic events to yield many more spores per ascus (as in *Acarospora*, with thirty-two to hundreds of tiny spores/ascus). Sexually reproducing crustose lichens almost always need to be sectioned by hand and studied under a compound microscope to identify species with confidence.

Asexual reproduction in lichens occurs primarily through modifications of the thallus into specialized lichen propagules. Unlike sexual reproduction, asexual propagules generally disperse the fungus and the alga together as a unit, the exceptions being structures termed pycnidia that house asexual, fungal-only conidia (pycnidia can be seen as tiny black dots on the surface of one of the lobes in the uppermost portion of the photo of *Xanthoparmelia coloradoensis*). The most common asexual reproductive structures are termed soredia (rounded masses of hyphae surrounding one or a few algal cells, as in *Caloplaca decipiens*), isidia (columnar versions of soredia, as in *Xanthoparmelia lavicola*), and phyllidia (micro-lobules that break off of the main thallus, not present at White Rocks). Soredia usually develop in regions of the thallus known as soralia. Fragments of the lichen thallus may also break away and disperse to yield a new lichen thallus.

Growth Forms

Most lichens can be broadly characterized as having one of four major growth forms: foliose, fruticose, crustose, or squamulose (note, however, that similarity in growth form does not convey shared evolutionary relationship). A much smaller number of lichens defy placement into one of these four primary categories and are best described using more specific terms such as "leprose" (as in *Lepraria*) or "filamentous" (this form not present at White Rocks, but species in the genus *Coenogonium* are good examples). Of the four major growth forms, foliose lichens most readily exemplify the four-layered, stratified thallus described above. Foliose species are the large and readily visible lichens that come to mind when one conjures an image of macrolichens covering their substrates via flattened, "leaf-like" thalli. Various aspects of both macro- and micromorphology as well as chemistry aid in the identification of foliose lichens. For example, in Colorado, the widespread species *Parmelia saxatilis* and *Parmelia sulcata* are characterized by the network of pseudocyphellae on their upper cortices. The diverse and primarily eastern North American genus *Parmotrema* is characterized largely by the presence of cilia scattered about the margins of the thallus lobes. The most common foliose lichens at White Rocks and indeed in much of western North America are species of the genus *Xanthoparmelia*. Other genera including *Montanelia*, *Umbilicaria*, *Punctelia*, *Physcia*, and *Physciella* are common foliose lichens in the Front Range of Colorado.

Fruticose lichens are generally the most three-dimensional of the four major growth forms. They almost always have indistinguishable upper and lower cortices and are often (but not always) cylindrical or sub-cylindrical in cross section. Fruticose lichens adhere to substrates through a single or a few holdfast structures and are often seen dangling from trees and rocks. The most common fruticose lichens in Boulder County are species of *Usnea* and, at higher elevations, species of *Cetraria* and *Bryoria*. At lower elevations of White Rocks, we have only one fruticose species, *Lichinella stipatula*, considered to be "dwarf fruticose" because of its diminutive size. One of the most species-rich lichen genera in the world (and a genus of fruticose lichens), *Cladonia*, occurs at both high and low elevations in Colorado but is conspicuously absent from White Rocks. Some genera such as *Aspicilia* contain both fruticose species and species with other growth forms (mostly crustose in *Aspicilia*). Fruticose lichens together with foliose species comprise a taxonomically artificial group typically referred to as "macrolichens."

Crustose lichens are by far the most understudied of the four growth forms, even though they constitute over half of total lichen diversity in most areas worldwide. At White Rocks, over 70 percent of the total lichen diversity (41 of 58 species) is crustose. This percentage probably applies to much of Colorado as well as throughout western North

America, where crustose species are the rule rather than the exception. Crustose lichens are characterized by their lack of a lower cortex; instead of having rhizines or other attachment structures, their lower cortices are in direct contact with the substrate. Thus, crustose lichens cannot easily be removed from substrates and, as such, pieces of bark, rock, or soil serving as the lichen substrate must be removed together with the lichen for further laboratory study and museum accessioning. Many crustose species are large and seen easily with the naked eye (*Acarospora stapfiana*, *Caloplaca saxicola*); an equal number are minute and require magnification to discern even the most general aspects of morphology (*Polysporina simplex*, *Rinodina venostana*). This added challenge has contributed to less overall knowledge of crustose lichens compared with that of North American macrolichens. *Lecanora*, *Lecidea*, *Lecidella*, *Verrucaria*, and *Acarospora* are among the most diverse and important genera of crustose lichens in western North America, including at White Rocks; they can be found abundantly on rock and, to a much lesser degree, on other substrates.

The squamulose growth form is intermediate between foliose and crustose growth forms. Squamulose species are characterized as having miniature and often overlapping lobes or lobules. Because of the small size of these lobes, they superficially resemble (and are often discussed together with) crustose lichens. The squamulose growth form is very common in western North America and appears to be correlated with growth on soil or loose rock substrates. Examples of squamulose genera at White Rocks include *Endocarpon*, *Psora*, *Placidium*, and one species of *Lichinella* (*L. nigritella*).

Substrates

Lichens occur on a tremendous variety of substrates ranging from the bark of living plants (corticolous) to rock (saxicolous), soil (terricolous), decomposing wood (lignicolous), and leaf surfaces (foliicolous). Rarer substrates include tree resin (resinicolous), rotting metal (metalicolous), and the exterior surfaces of animals such as tortoises (zooicolous). Saxicolous lichens can generally be sorted into calcareous-loving and non-calcareous-loving species, that is, species that grow on limestone or other calcium-rich rock versus species that grow on silicaceous rock such as granite or sandstone. A given species of corticolous lichen will typically grow on either acid bark (mostly conifers) or more basic to neutral bark (mostly hardwoods). Hardwoods almost always host more diverse lichen communities than conifers. Lichens that occupy decaying or non-living wood such as old stumps, fence posts, or signs are mostly specific to these types of substrates; that is, they typically do not also occur on living wood. In arid portions of western North America, saxicolous followed by terricolous and lignicolous substrates are the most important growing surfaces for lichens.

Additional Remarks

Ecological functions of lichens include contributions to biogeochemical cycling, biomass production, pollutant sequestration, decomposition, soil formation, and habitat or nutrition sources for an untold diversity of organisms (Szczepaniak and Biziuk 2003; Cornelissen et al. 2007; Bobbink et al. 2010). This functional diversity coupled with impressive ecological amplitude contributes prominently to the conspicuous diversity and abundance of lichens across the globe, even in extreme environments where few other organisms occur (Lutzoni and Miadlikowska 2009). Yet the diversity and ecological relevance of lichens have gone unnoticed by a great number of natural history enthusiasts, in part because of a lack of inclusion of lichen biology in science curricula in North America. It is hoped that the present contribution will help remedy this problem by providing an accessible, user-friendly guide to educators, conservationists, and land managers as well as lichenologists. Above, the reader is equipped with basic information on lichen morphology, reproduction, and ecology to enable a general understanding and appreciation of the species represented in this Field Guide.

About the Guide

The above text is intended to provide only the most basic introduction to lichen biology. For a much more comprehensive, general overview of lichen biology, readers are encouraged to read the excellent introductory chapters of Brodo and colleagues (2001) as well as introductory pages in Nash and colleagues (2002, 2008).

The following species pages are intended to capture fully all currently known lichens present at White Rocks. Thus, all fifty-six known species are included, as is a dichotomous key to assist with their identification. For each species in the Field Guide, a general description is provided, which is intended to serve the primary purpose of conveying easy-to-recognize features of a given lichen as well as distinguishing it among close relatives, either at White Rocks or in the surrounding area. Additional information regarding ecology, substrate, and distribution and a primary literature reference to further information about the species are provided. Spot tests refer to standard chemical reagent assays (Brodo et al. 2001). Some use of technical terminology was necessary in preparing the text, and as such, a truncated glossary to a small selection of lichenological terms used in this book can be found in the back of this guide.

All collections were photographed in the field by the author (except where noted) using a Nikon D7100 digital SLR with a 105 mm 1:1 macrolens and ring flash. The primary set of voucher specimens has been deposited at the University of Colorado Museum of Natural History (COLO Herbarium), and duplicates are deposited elsewhere, primarily the New York Botanical Garden (NY Herbarium). Photographs of all species included in this Field Guide derive from the White Rocks field setting without exception, despite the fact that in several instances I have on hand better-quality images for a given species. The rationale for doing this is that the primary purpose of this Field Guide is to facilitate future research, conservation, and management of the White Rocks lichen biota, and providing photographs of species in essentially a raw, unedited state conveys as much of the general lighting and site-specific features of a species as possible. Thus, the degree of thallus pruinosity of *Acarospora strigata* at

White Rocks is depicted, rather than pruinosity typical of the species as it occurs elsewhere.

This Field Guide is somewhat unique among professional or amateur field guides in that photographs of all species are in all cases tied to a physical museum (herbarium) voucher specimen, thus enabling future researchers to confirm or re-investigate the identification of a given voucher specimen at any point in time. This guide utilizes modern taxonomies of species arrangements, largely following that of Esslinger's (2015) North American Lichen Checklist, with rare exception. A translucent box superimposed on each photograph depicts the museum voucher(s) upon which the photograph was made. The number refers to my herbarium collection numbers. Credit to the photographer(s) is provided in each translucent box (following the voucher), which is important in any case but especially in lichenology given that in some cases it takes thirty bad photographs before one decent photograph is made.

The present study serves as the first documentation of the lichen biota of a rare sandstone formation in Boulder, Colorado. Eighty-two collections yielded 57 total species (see the appendix for a list of species with taxonomic authorities). Somewhat remarkably, there have been very few lichen inventories of sandstone formations across North America. By far the most relevant to the present study was that of Anderson (1962), who inventoried the Dakota sandstone formation of northern Colorado. In that study, Anderson documented 130 species over a stretch of ca. sixty-five miles, ranging from Boulder northward along the Front Range of the Rocky Mountains (width of band not reported in the publication but likely not more than fifteen to thirty miles wide). The White Rocks formation supports just under half of the total number of species in Anderson's study but occupies only 100 acres versus ca. 832,000 acres (65 × 20 miles, or 1,300 mi^2), highlighting the ecological significance of White Rocks Open Space. Moreover, the White Rocks lichen biota contains at least two (i.e., *Candelariella clarkiae*, *Lecidea hoganii*) and as many as four species new to science (Tripp and Lendemer 2015; Tripp 2015), as well as one newly confirmed report for the United States (*Rinodina venostana*; Tripp 2015). My hope is that this Field Guide improves management practices at

White Rocks and other urban open spaces and helps educate staff as well as the public about the importance of lichens in our environments.

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FIGURE 1.1. Incoming storm over the city of Boulder, as seen from White Rocks (August 2014). Photo by Dina Clark.