

LICHENS AND THEIR DISTRIBUTION IN LEWIS AND CLARK CAVERNS
STATE PARK

by
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A thesis submitted in partial fulfillment
of the requirements for the degree

of
Master of Science
in
Biological Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2004

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April 2004

ACKNOWLEDGMENTS

Funding for this project was provided by the Department of Ecology, Montana State University and the Big Sky Institute.

I would like to thank Dr. Sharon Eversman, my advisor, for taking me under her wing and introducing me to the exciting field of lichen ecology. Sharon also provided me with some fantastic opportunities that have helped shape my career goals. Her assistance throughout my project was much appreciated. In addition, I would like to thank Dr. Cathy Cripps and Dr. Matt Lavin, also on my committee, for their knowledge shared with me in and out of the classroom. The Big Sky Institute has additionally provided me with some great opportunities as a graduate student and I appreciate their alliance.

A special thank you is sent to my Grandpa Seaman who always encouraged me to follow my dreams and pursue more knowledge. His influence in my life and support for my education will never be forgotten.

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ABSTRACT

Lichens are unique organisms composed of two to three different organisms living together in a symbiotic relationship. They occur in most terrestrial habitats and perform many valuable roles in an ecosystem. Many species of lichen are sensitive to airborne pollutants, making them good biological indicators of air quality. A high diversity of lichens can indicate a relatively stable environment. In this study, an exhaustive inventory of the lichen species in Lewis and Clark Caverns State Park, Jefferson County, Montana, was done by collecting from all substrates in 22 different sites. The distribution of species among seven vegetation types, frequency of growth forms, and substrate inhabitance are presented. One-hundred-sixty-four species were identified in the park. Crustose species were the most common (45%), while 40% were foliose, 5% were fruticose, 7% were squamulose and 3% were *Cladonia* species. Forty-six per cent occurred on rock, 32% on bark or wood 12% on moss, litter or other and 10% on soil. The greatest diversity of species was found in the mountain mahogany grasslands with 88 species collected. The smallest number of species was found in the willow grassland with only 20 species collected. The large diversity of lichens present in Lewis and Clark Caverns State Park suggests that the parks resources are relatively undisturbed. In comparison with other pristine sites in Montana and Wyoming, Lewis and Clark Caverns State Park has the most species in common with Yellowstone National Park, having 123 shared species, and shares the highest similarity index (Jaccard's Similarity Index) with Grand Teton National Park (36% IS_j). In addition, our study extended the known range of distribution for *Thyrea confusa*, which has not been previously reported in Montana.

INTRODUCTION

Biology of LichensSymbiosis

Lichens are symbiotic associations involving fungi (mycobiont) and one or more photosynthesizing partners (photobiont), either green algae and/or cyanobacteria, which together form a distinct thallus (Ahmadjian 1993). Approximately 85 per cent of lichen-forming fungi associate only with green algae (Tscheramak-Woess 1988). Over 50 per cent of these involve the genus *Trebouxia*, which is rarely found free living (Ahmadjian 1993, Tscheramak-Woess 1988). Other common photobiont genera are listed in Table 1 (Ahmadjian 1993, Hawksworth and Hill 1984). Ten per cent of lichens include only cyanobacteria, and another three to four percent associate simultaneously with both kinds of photobionts (Tscheramak-Woess 1988). Those fungi that associate with cyanobacteria are also supplied with nitrogen through the process of nitrogen fixation by the cyanobacterium. Common lichen genera containing nitrogen-fixing cyanobacteria include *Collema*, *Leptogium*, *Lobaria*, *Nephroma*, *Peltigera*, *Pseudocyphellaria*, and *Sticta* (Tscheramak-Woess 1988). Common genera of lichen-associated cyanobacteria are listed in Table 1. *Nostoc* is the most common cyanobacterium of lichens and is also very common in free-living situations.

Table 1. Common Genera of Lichen Photobionts

Green Algae	Cyanobacteria
<i>Chlorella</i>	<i>Calothrix</i>
<i>Chlorosarcina</i>	<i>Gloeocapsa</i>
<i>Coccomyxa</i>	<i>Nostoc</i>
<i>Leptosira</i>	<i>Scytonema</i>
<i>Myrmecia</i>	<i>Stigonema</i>
<i>Phycopeltis</i>	
<i>Trebouxia</i>	
<i>Trentepohlia</i>	
<i>Trochiscia</i>	

The unique lichen partnership is most commonly thought to be a mutualistic relationship; however, some suspect the fungi of controlled parasitism (Ahmadjian and Jacobs 1981). From the mutualistic point of view, it has been observed that not only does the fungus provide a safe microenvironment for the photobiont and facilitate gas and water exchange (Honegger 1994), but that some transfer of mineral nutrients from the fungus to the photobiont may also occur (Clark et al. 1999, Clark 2001, Clark et al. 2001). Clark et al. (2001) and Clark (2001) have found nutrient partitioning between the fungus and photobiont, and in finding this they presume the fungus to be a mediator of necessary elements to the photobiont. Elements such as calcium, chlorine, phosphorus and sulfur were found to occur in the highest concentrations near the algal layer (Clark et al. 1999). The nutrient gradients established by the mycobiont may be promoting a more efficient state for photosynthesis of the algae, thus allowing optimal energy gain with the fewest number of photobiont cells (Clark 2001). More specifically a band of calcium oxalate crystals has been found to occur in several lichen thalli just below the algal layer and is thought to perform several functions for the photobiont, including the release of

water vapor at elevated temperatures and the regulation of light by acting as a radiation reflector (Clark 2001). Aside from these findings, possibly the strongest argument for a mutualistic relationship lies in the fact that the association allows both partners to increase their range of distribution.

On the other hand, Ahmadjian and Jacobs (1981) suggest the lichen association is a controlled parasitism of the photobiont by the fungus. In a study of the relationship between the fungus and algae of *Cladonia cristatella*, Ahmadjian and Jacobs (1981) observed between 57 and 65 per cent of the algal cells being penetrated by fungal haustoria. They also found dead algal cells, presumed to be killed by the fungal haustoria. It was suggested that possibly a balance is maintained in the lichen association by abundant reproduction of the algal cells, suggesting that the relationship is actually a balanced or controlled parasitism. Ahmadjian (1993) compares the lichen association to that of humans and cattle. Even though we take good care of our cattle, we do so only in a controlled manner for our own benefit. We control their food and water, their population size and even their distribution, much like the fungus controls its own food source. With this interpretation, we can view the care given to the photosynthetic partner by the fungus as a form of agriculture that the mycobiont uses in order to distribute itself over a wider range of ecological habitats, while supplying itself with carbohydrates.

Four common growth forms of lichen include: 1) crustose lichens, which are intimately attached to their substrate and are usually the major growth form in dry areas; 2) squamulose lichens, which are shingled and scaly, and found on soils and rocks of all kinds of areas; 3) foliose lichens, which are leafy and found on many substrates in dry to

moist areas; and 4) fruticose lichens, which are shrubby and found in greater abundance in moister areas (Brodo et al. 2001). Only about 22 per cent of lichens are of the more complex foliose or fruticose types (Honegger 1994). The lichen thallus is primarily composed of fungal tissue, 80 to 93 per cent, and only seven to 20 per cent algal cells (James and Henssen 1976). The general structure of a foliose lichen thallus includes a thin layer of upper fungal cortex that serves to protect the photosynthesizing algae. A thin layer of algae lies below the cortex where it gets sufficient light for photosynthesis when the cortex is wetted and becomes translucent (Jahns 1973). The medulla is a loose layer of fungal hyphae located below the algal layer, and serves as a region for food storage, gas exchange and water holding. Below this layer is the lower fungal cortex which may have extending structures (rhizines) for holding onto the substrate. Crustose species have no lower cortex.

The lichen thallus is formed as a result of compatible partnering between a mycobiont and photobiont. The fact that without the photobiont, no lichen thallus is formed by the mycobiont suggests the strong role the photobiont plays in initiating this morphological change (James and Henssen 1976). Ahmadjian et al. (1980), showed that several species of related photobionts can initiate lichen formation with the same mycobiont. They found that the mycobiont of *Cladonia cristatella* formed lichen thalli with 12 photobionts other than its regular partner. Therefore, the morphological stimulus is provided by the photobiont, but the fungal genome is responsible for determining the morphological and chemical characteristics, hence the species. Lichen-forming fungi have been found to form associations with incompatible photobionts. These associations

can result in a type of “pre-thallus” structure that may serve as a hold-over for the mycobiont until a compatible photobiont partner is found (Beck et al. 1998). A similar situation of photobiont switching also occurs in the life cycle of the parasitic lichen-forming fungi, *Diploschistes muscorum* (Friedl 1987). In the first part of *Diploschistes muscorum*'s lichenized life, it forms an association with *Trebouxia irregularis*, the photobiont of the lichen genus *Cladonia*, which it parasitizes by stealing the algae and eventually destroying the thallus. However, at maturity, *Diploschistes muscorum* exchanges this photobiont for *Trebouxia showmanii*, which is the preferred photobiont. Beck et al. (1998) suggest that the exchange of photobionts is more common in sexually reproducing lichens than in vegetatively reproducing ones, due to the difficulty in finding compatible photobiont partners. Complex interactions such as these provide more opportunity for compatible partnering, and may relate to the tremendous success of the lichen association.

Almost 15,000 different fungal species, or 25 percent of fungi, can form lichens by associating with one or more of about 100 different species of algae and cyanobacteria (Honegger 1994, Nash 1996) to create the estimated 13,500 (Hawksworth and Hill 1984) to 20,000 different species of lichens (Vitt et al. 1988). The fungal phylum Ascomycota contains 98 per cent of the lichen-forming fungi, with about half of 28,000 Ascomycota species being lichen-forming (Hawksworth and Hill 1984, Honegger 1994). Five orders within the Ascomycota consist of only lichen-forming fungi: Graphidales, Gyalectales, Peltigerales, Pertusariales and Teloschistales (Hawksworth and Hill 1984). The phylum Basidiomycota has a few lichen forming species, but only three genera of Basidiomycota

are known to be lichen-forming in North America: *Dictyonema*, *Multiclavula*, and *Omphalina* (Brodo et al. 2001). The asexual stages in the phylum Ascomycota are placed in a special group known as the “deuteromycetes.” They too include some lichen forming genera: *Lepraria*, *Leproaulon*, *Racodium*, and *Thamnolia* (Nash 1996). Since lichen-forming fungi arise in different fungal groups, it is clear that the evolution of this fungal lifestyle has occurred several times (Gargas et al. 1995).

Distribution

The distribution of lichens is global, ranging from the polar regions of the Arctic and Antarctic to the equatorial tropical regions (Hale 1983). From the tidal zones to the peaks of mountains, they can be found on almost any natural surface such as rock, soil, bark, and bone (Brodo et al. 2001). Man-made surfaces such as cement, brick, cloth, paint, leather, rubber, glass and metal are also suitable substrates for some lichens (Brightman and Seaward 1977). Their ability to photosynthesize, absorb minerals from the air, and tolerate drought and high temperatures has made them successful colonizers of many habitats (Longton 1992). Larson (1987) has estimated that lichens are the dominant cover on eight per cent of terrestrial earth, which would include harsh Arctic/Antarctic, alpine and desert ecosystems where little else can grow.

The distribution of this large number of lichen species across the globe is determined by several factors such as temperature, moisture, solar radiation and altitude (Krog 1987); the pH, water holding capacity, and stability of the substrate (Hale 1983); and the pollution and the geological and climatic history of the region (Brodo et al. 2001). Some lichens are widely distributed across the globe, being less particular about

substrate types, or air quality, whereas other lichens may only be found on a particular type of rock, or in pristine environments, or in relatively isolated climate regions. For example, *Xanthoria elegans* is a very widespread species that occurs on rock, bark or wood in high nutrient areas, whereas *Lecanora dispersa* also has a wide distribution in North America, but is restricted to calcareous rocks (Brodo et al. 2001). The distribution of the genus *Himantormia* is very restricted and is known only from Antarctica (Lamb, 1961). Moisture and humidity are very beneficial for abundant lichen growth since they allow the upper fungal cortex to become translucent and the algae to photosynthesize. Cool weather between 15 and 20° C is optimal for maximum mycobiont growth (Hale 1983). Paterson et al. (1983) found that moisture was the limiting factor for lichen growth and that the highest net photosynthesis occurred on a rainy summer day for the genus *Cetraria*. Looking at these two criteria, moisture and temperature, some generalizations can be made about the distribution of lichen diversity and lichen growth forms. Generally, there is a higher lichen diversity in moist, cool areas, compared to hot, dry environments. Also, moister environments are more favorable for fruticose lichens, which have a more exposed three-dimensional structure than either crustose or foliose types, making them highly susceptible to drying out. An example of these generalizations is evident when comparing the lichen composition and diversity across the Continental Divide, where the climate on the western side is moister due to the maritime influence of the Pacific Ocean, and drier on the eastern side due to the continental climate of the plains and the rain shadow of the Rocky Mountains. A summary study of the macrolichen distribution in Montana, including Yellowstone and

Glacier National Parks, reports that west of the Continental Divide there was a 13 per cent higher lichen diversity and 26 per cent more fruticose lichens than east of the divide (Eversman 2004).

Ecological Roles of Lichens

Trophic Interactions, Dispersal and Nutrient Cycling

Lichens are most noted for their pioneering abilities in harsh ecosystems where little else can grow. They perform many valuable roles in the ecosystem by: 1) physically and chemically breaking down rock to create soil for subsequent plant communities, including other forms of lichens (Longton 1992); 2) trapping wind-blown silt, spores and seeds (Syers and Iskandar 1973); 3) holding moisture in the forest canopy or near the soil; 4) and releasing important nutrients, such as potassium, phosphorus, sulfur and nitrogen into the substrate upon death and decay (Jacks 1965, Smith 1982, Ugolini and Edmonds 1983).

Many animals benefit from the presence of lichens in an ecosystem as well. Several ungulates eat lichens as a high carbohydrate food source on occasion, while others actually depend on lichens for winter survival (Brodo et al. 2001). The winter diet of caribou (*Rangifer tarandus*) may consist of more than 60 per cent lichen, primarily from the genus *Cladina*, but also from the genera *Alectoria*, *Evernia*, and *Usnea* (Crittenden 2000, Longton 1992). Lichens are important food sources for other animals such as rodents, weevils (Order: Coleoptera), snails (Molluska) and arthropods (Arthropoda) (Baur et al. 2000, Brodo et al. 2001, Chown and Klok 2001). Brodo et al.

(2001) report that 80 to 93 per cent of the diet of the northern flying squirrel (*Glaucomys volans*) is made up of *Bryoria* and *Usnea* in winter and spring. Other studies have shown lichen to be an important diet component of the flying squirrel, *Glaucomys sabrinus*, in Southeast Alaska and West Virginia (Mitchell 2001, Pyare et al. 2002). Fruticose lichens are common forage materials, where foliose lichens are more often habitat for invertebrates, but may be consumed as well (Chown and Klok 2001, Eversman 1994). Some protozoans and insects find shelter under lichens (Longton 1992), while other organisms, like the lepidopteran caterpillar (Order: Lepidoptera), have adapted an appearance that mimics that of a lichen in order to reduce predation (Brodo et al. 2001, Seaward 1988). Even more amazing are the tropical forest weevils (Gressitt et al. 1965) and the lacewing larvae (Order: Neuroptera) that attach pieces of lichen to their backs as camouflage (Brodo et al. 2001). Birds are also well known users of lichens for nest materials; Richardson and Young (1977) estimated that at least 45 species of North American birds use lichens as nesting material. In addition, lichens may benefit from consumption by animals. Meier et al. (2002) discovered that the fecal pellets of lichenivorous mites (*Acari*) contained viable fungal spores and algal cells, which suggests they may function as vegetative dispersers of lichens into new areas. This can be important in areas where either component is rare outside of the partnership.

While lichens play critical roles in the food web, they can also affect the persistence of other species, and ultimately the health of the forest. For example, in the Pacific Northwest, flying squirrels consume lichen as their primary winter food. In turn, the endangered spotted owl preys on the flying squirrel as one of two or three primary

foods (McCune and Geiser 1997). During the summer months, the flying squirrels eat underground-fruited fungi as their primary food source and spread the fungal spores throughout the forest in their droppings. These spores germinate and develop mycorrhizal associations with tree roots, which benefit the trees by connecting to their root mass and effectively increasing root surface area; this enables the trees to obtain more mineral nutrients, such as phosphates, and increase their water uptake (Campbell et al. 1999). This food web scenario illustrates the importance of lichens as a primary food source for flying squirrels, and how lichens indirectly have an additional effect on the health and survival of the endangered spotted owl, the mycorrhizal fungi, the trees in the forest and animals that inhabit those trees, including the squirrels and owls. Similar situations have been observed in the east as well, involving the West Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*), lichens, and mycorrhizal fungi as reported by Mitchell (2001). She found that lichen elements were found in 40 per cent of the spring scat samples and 23 per cent of the fall scat samples of the flying squirrel. About 50 per cent of both the spring and fall scat samples also contained fragments of mycorrhizal fungi. Allen (1991) suggests that “mycorrhizal symbiosis is such an integral part of communities that it regulates the functioning of these communities,” again emphasizing the importance of the relationship between squirrels (and other animals), lichens, mycorrhizal fungi, and the health of the forests.

The mineral and hydrological cycles of an ecosystem can be greatly influenced by lichens. Lichens with nitrogen fixing cyanobacteria leach nitrogen into the soil during periods of high rainfall, or upon their death and decay. The amount of nitrogen supplied

can be significant in areas with a large biomass of nitrogen fixing species (Pike 1978). Denison (1973) suggested that *Lobaria oregana* was the main source of nitrogen input in the moist Douglas fir forests of Oregon. Forman and Dowden (1977) found that *Peltigera aphthosa* and *P. canina* contributed 0.04-3.3 kg N per hectare per year in a *Pseudotsuga* and *Picea* forest of New Mexico. Kallio (1974) estimated nitrogen inputs of *Stereocaulon paschale* and *Nephroma arcticum* to be between 10 and 40 kg N per hectare per year in a *Pinus* and *Betula* forest in Sweden. However, researchers of the nitrogen fixing capabilities of lichens are finding that predictive modeling is problematic due to the many factors that influence nitrogen fixation, and suggest that estimates are likely not very accurate (Crittenden and Kershaw 1978). Aside from nitrogen, other atmospheric nutrients are absorbed from air, rain, dew, fog, and gases, and also leached into the soil. Management plans in the Pacific Northwest now encourage the retention of mature lichen covered trees in the logging process to intercept the fog and help regulate the humidity and temperature of the forest canopy (Rosentreter 1995). Lichens living on soil help control erosion and runoff by sending their rhizines into the soil, holding particles together and also keeping absorbed moisture in and near the soils surface.

Lichens as Bioindicators of Air Quality

Since lichens absorb most of their nutrients from the air and rainwater, and lack any waxy covering or stomatal control of gas exchange, they can consequently accumulate high levels of air borne pollutants (Brodo et al. 2001, Nash 1996). High concentrations of sulfur dioxide (SO₂), nitrogen oxides (NO_x) and ozone (O₃) gases, as

well as fluorides and acid precipitations, are known to cause injury and even mortality to lichens, liverworts, mosses and cyanobacteria. Such high levels of pollutants are most often found around point sources, such as fossil-fuel fired steam electric plants, metal smelters, gas purification plants, aluminum production plants, cement plants, chemical plants, and pulp mills (Belnap et al. 1993). Lichens have different tolerances to specific pollutants, and as a result, certain species can be used as biological indicators of air quality (Brodo et al. 2001, Nash 1996). The three-dimensional structure of fruticose lichens, with a higher surface area to absorb airborne materials, makes them particularly sensitive to air pollutants. Mat-forming fruticose lichens of the open arctic areas are particularly susceptible to intercepting pollutants, both as precipitation and particulates, due to their open exposure with little or no over story (Crittenden 2000). The analysis of these lichen structures can reveal morphological and anatomical deformations, as well as provide information on specific pollutants, such as the levels of accumulated heavy metals (Hale 1983, Nash 1996). The trapping efficiencies of lichens can be measured to provide a correlation between the amount of deposited metals from bulk precipitation collectors and that found in the thallus of a lichen. These correlations can then be used to monitor metal deposition within a known area as well as to provide retrospective fallout rates (Nash et al. 1993).

Lichen inventories are a valuable method for monitoring air quality. By surveying the composition of a lichen community in an urban area and comparing its composition and structure with that of a more pristine habitat or historical records of the same region, one can determine which sensitive lichens are present or absent. A recent

study in Buenos Aires City, Argentina, discovered that four species reported in an earlier study (1984) no longer exist in the city, likely due to increased pollution (Scutari et al. 2001). The increased surface area of fruticose lichens and the fact that lichens only photosynthesize when their bodies are moist, makes them favor moist locations and also allows for more absorptive processes to take place throughout the year, resulting in their high sensitivity. In the Buenos Aires Study, two of the four lichens no longer present were fruticose (Scutari et al. 2001)

Interestingly, recent lichen research in Europe and the United States has focused on the apparent increase in epiphytic lichen diversity on pollution-caused forest dieback trees as compared to that of healthy trees (Bastien et al. 1998, Hauck 2003, Hauck et al. 2001, Hauck et al. 2002, Hauck and Runge 1999, Schmull et al. 2002). Some of these studies suggest that the loss of foliage due to pollution results in reduced pollution intake by the tree and therefore a decreased concentration of pollutants in the stem and bark, providing a less toxic substrate for the lichens (Hauck et al. 2001, Hauck and Runge 1999). Schmull et al. (2002) found that there was greater lichen diversity on dead trees than on living, and also that the mean concentration of NO_3^- in the stem was lowest in dead trees. They suggest that possibly the lichens are absorbing some of the pollutants in the bark and effectively lowering the pollution concentration in the bark and stem.

Another study suggests that the increase in light availability due to loss of foliage may be responsible for the increase in lichen diversity (Bastien et al 1998). Hauck et al. (2002) also found that some lichen species were more tolerant of higher concentrations of NH_4^+ , NO_3^- , PO_3^- , and SO_3^{2-} in stemflow than were others. The foliose species *Hypogymnia*

physodes was more frequent on dieback trees, whereas the crustose species *Lecanora conizaeoides* was more common on healthy trees with a higher stemflow concentration of pollutants. Studies such as these are important for determining which elements of pollution contribute to changes in lichen abundance and community structure as well as for determining the relative sensitivities of different species so that other polluted areas can be diagnosed based on their lichen composition.

LICHENS IN LEWIS AND CLARK CAVERNS STATE PARK

In 1991, The National Park Service, Air Quality Division and the USDA Forest Service met in Denver, Colorado with federal land managers, regulatory experts, and researchers specializing in the study of lichens for a workshop to review the knowledge, methods, and usefulness of lichens as bioindicators of air quality (Huckaby 1993). Previous to this, few lichen inventories had been done regionally. The assessment of baseline information is important for understanding the ecology and the resources available for the development of a biomonitoring study (Nash et al. 1993). McCune inventoried lichens in the Swan Valley (1982) and those with oceanic affinities in the Bitterroot Mountains (1984). Eversman (1982) had inventoried the lichens in Custer National Forest in Southwest Montana. Since then there have been several lichen inventories of state and federal lands in the west: Yellowstone National Park (Eversman 1994, 2002), Glacier National Park (Debolt and McCune 1993), and Teton National Park (Eversman 1998). In Montana, Schubloom (1995) surveyed the Anaconda-Pintler and Gates of the Mountains Wilderness areas and the Elkhorn Mountains. Similar programs for state parks are rare. Eversman (1996) initiated lichen inventories in the state parks of Montana at Headwaters State Park, Gallatin County, Montana. The present study at Lewis and Clark Caverns State Park (Lewis and Clark CSP), Jefferson County, is a continuation of the effort to obtain baseline data for the state of Montana. There have been no complete botanical inventories of Lewis and Clark CSP, making my study the first in contributing to the baseline flora information of the park.

Objectives

The three primary objective of my study were to: 1) complete an inventory of the lichens in the park; 2) determine the distribution of the lichen communities related to vegetation types; and 3) characterize lichens according to substrate and growth form.

Study Area

Lewis and Clark Caverns State Park is located at 45°52'N and 111°85'W in the London Hills area of Jefferson County, Montana, north of the Jefferson River and east of the Continental Divide. The park is 123 hectares and has elevations ranging from 1280 to 1797 m with an annual precipitation of 21 to 38 cm, mostly falling between the months of May and July (Garcogian 2001). Geologically the park is diverse, with calcareous Madison limestone composing the caverns and extending in a broad strip from Cave Mountain to the southwestern part of the park. Three Forks Shale (noncalcareous) exists in a narrow band south of Cave Mountain with Jefferson Dolomite (calcareous) occurring in a pear-shaped section to its east. The mostly noncalcareous Belt Arkose (LaHood conglomerate) dominates the landform in the eastern and western parts of the park. Much of the substrate along the road side is recent alluvium and gravel (Perry 1946). The type of rock substrate is important to note due to lichen substrate specificity. Vegetation in the park varies from dry grasslands to moist stream banks. Seven vegetation types (Mueggler and Stewart 1980, Pfister et al. 1977) were identified in the park and are presented in order of driest to the most moist: 1) Exposed rock above 1584 meters with dwarfed mountain mahogany (*Cercocarpus ledifolius* Nutt.) and small forbs ;

2) dry grassland meadows of Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass (*Pseudoroegneria spicata* Pursh) with forbs and exposed rocks between 1295 and 1420 meters; 3) mountain mahogany grasslands between 1400 and 1520 meters with mountain mahogany, Rocky Mountain juniper (*Juniperus scopulorum* Sarg.), few limber pine (*Pinus flexilis* James) and bluebunch wheatgrass, consisting of rocky terrain, grasses and forbs; 4) Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) grasslands with bluebunch wheatgrass and occasional limber pine and Rocky Mountain juniper, occurring between 1490 and 1600 meters; 5) a willow (*Salix*) grassland at one site in the park located around an intermittent pond with rock scree surrounding it (1304 meters elevation); 6) deciduous cottonwood (*Populus balsamifera* L.) communities with aspen (*Populus tremuloides* Michx.), chokecherry (*Prunus virginiana* L.), and water birch (*Betula occidentalis* Hook.) occurring along small streams between 1343 and 1500 meters; 7) moist Douglas fir forests on north and west facing canyon slopes with moss understory and moist soils between 1450 and 1706 meters (Appendix C).

Methods

Between June, 2001, and October, 2003, I collected lichen samples from 22 sites among the various vegetation types within the park (Figure 1). The site sizes ranged from five to 50 meters square and were determined by either vegetation boundaries, or in more expansive locations, by the area needed to collect all lichens present (Nash et al. 1993). Sufficient time was spent at each site to adequately collect from all substrates including rock, wood, soil, moss, bark, bone, litter and other lichens. After collection, the

lichens were brought into the lab and identified following standard morphological and chemical techniques (Culberson 1972; McCune and Goward 1995; McCune and Geiser 1997; Thomson 1984, 1997; St. Clair 1999). Nomenclature for lichens followed Esslinger (1997), and vascular plants followed Dorn (1984) and Lavin and Seibert (2001). Voucher specimens are in the Montana State University Herbarium (MONT). Jaccard's Index of Similarity (IS_j) (Mueller-Dombois and Ellenberg 1974) was used to compare the similarity of lichen species composition among the seven vegetation types within the park, as well as the similarity of lichen flora between Lewis and Clark CSP and seven other pristine areas of Montana, and Wyoming. This index divides the number of common species between two locations by the number of dissimilar species in both locations and then multiplies by 100 to get a percent.

Results and Discussion

General Distribution

A total of 164 species of lichens in 65 genera was identified from Lewis and Clark CSP, including one species not previously recorded in Montana, *Thyrea confusa* (Table 2). Crustose lichens were the most prevalent growth form collected in the park, with 73 species, 45% of the total, identified (Figure 2). *Aspicilia*, *Caloplaca*, *Candelariella* and *Lecanora* were the most common crustose genera (Table 2, Figure 2). Sixty-six foliose species (40% of the total) were identified, with the major foliose genera being *Peltigera*, *Physcia*, *Melanelia*, *Xanthoparmelia* and *Xanthoria* (Table 2, Figure 2). Twelve squamulose lichens (7% of the total) were identified, with four species in the

genus *Psora* (Table 2, Figure 2). Nine fruticose lichens (5% of the total) belonged to five genera, *Bryoria*, *Evernia*, *Letharia*, *Nodobryoria* and *Usnea* (Table 2, Figure 2). Five *Cladonia* species (3% of the total) were present, with *Cladonia fimbriata* occurring in 13 of the 22 sites (Table 2, Figure 2).

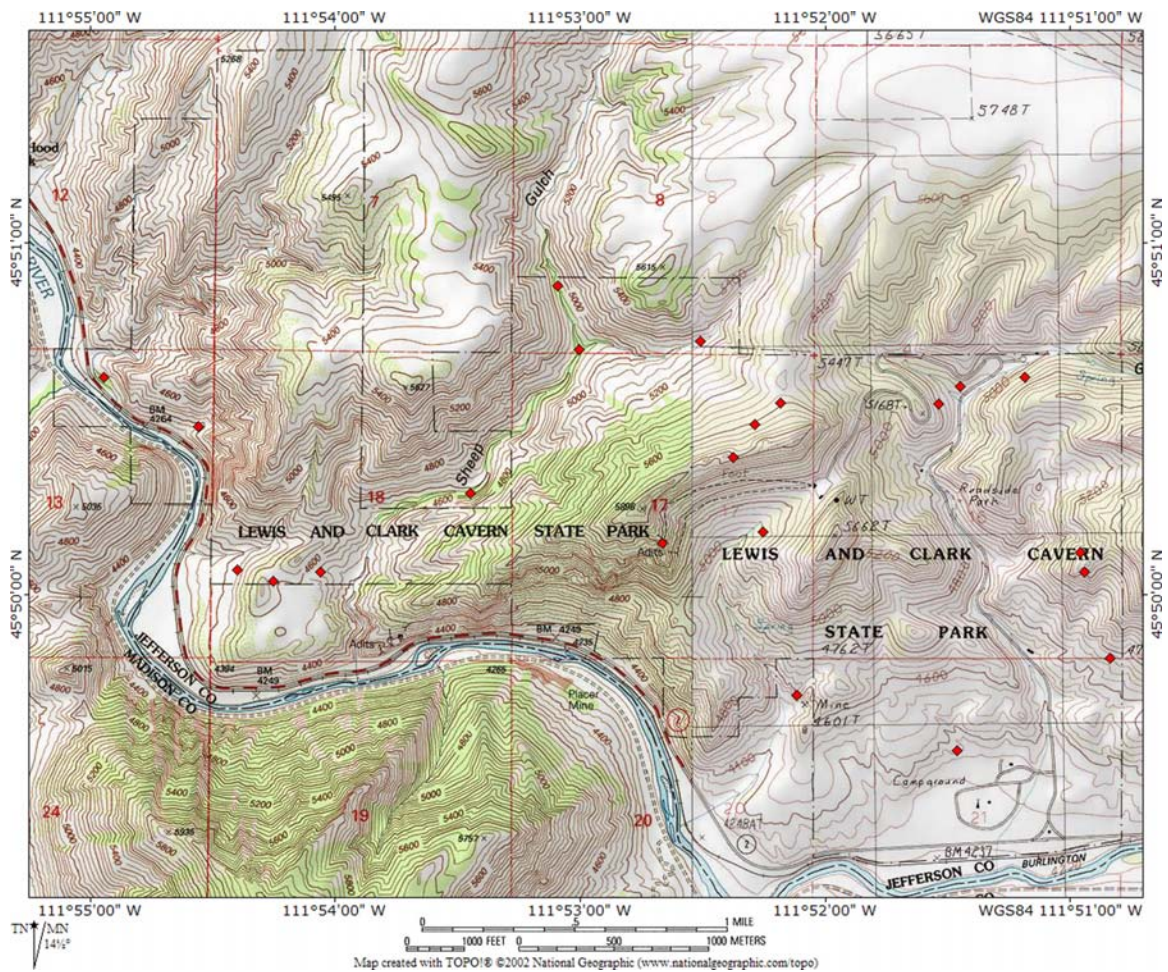


Figure 1. Twenty-two sites where lichens were collected in Lewis and Clark Caverns State Park between June, 2001 and October, 2003 are indicated by diamonds (◆)

Table 2. A list of 164 lichen species in 65 genera from Lewis and Clark Caverns State Park. The columns give the number of sites in each vegetation type in which each species occurred. Sites are arranged in order from driest to most moist. Roc = exposed rock. Gras = dry grasslands. Mt.m = mountain mahogany grasslands. Df/gr = Douglas fir grasslands. Wil = Willow grassland. Cotw = deciduous cottonwood community. Df/fr =moist Douglas fir forest. Tot = total number of sites the species was found in. Lichen growth forms are: cr = crustose; fo = foliose; fr = fruticose; sq = squamulose. Substrates are: r = rock; b = bark; dw = dead wood; m = moss; l = litter; s = soil; m-r = mossy rock; n = bone; and o-l = other lichen. A (+) next to the substrate rock, (r), represents a positive hydrochloric acid reaction (calcareous rock); a (-) represents a negative reaction. Species nomenclature follows Esslinger (1997) (Appendix B).

Type of vegetation			Ro	Gra	Mt.	Df/g	Wi	Cot	Df/f	To
No. sites in each veg.type			c	s	m	r	l	w	r	t
	for		3	4	3	3	1	3	5	22
Species	m	substrate								
ACAROSPORA										
<i>glaucocarpa</i>	sq	r+	1						1	2
<i>heppii</i>	cr	r+			1					1
<i>strigata</i>	cr	r+/-	1	2	2	1				6
<i>veronensis</i>	sq	r+/-	1		2			1		4
ANISOMERIDIUM										
<i>carinthiacum</i>	cr	r+			1					1
ARTHONIA										
<i>lapidicola</i>	cr	r+							1	1
ASPICILIA										
<i>caesiocinerea</i>	cr	r+/-	2	3		2		1	2	10
<i>calcareea</i> group	cr	r+/-	1	1	1	1				4
<i>cinerea</i>	cr	r-/dw	1	1	3	3		2	3	13
<i>contorta</i>	cr	r+/-	2	4	2	1		1		10
<i>desertorum</i> group	cr	r-			1					1
BRYORIA										
<i>fremontii</i>	fr	b				1				1
<i>fuscescens</i>	fr	b							2	2
BUELLIA										
cf. <i>elegans</i>	cr	m	1							1
<i>punctata</i>	cr	b				1				1
CALOPLACA										
<i>arenaria</i>	cr	r-						2	1	3
<i>citrina</i>	cr	r-,dw,n		2	1					3
<i>decipiens</i>	cr	r+	1							1
<i>epithallina</i>	cr	r+		2						2
<i>jungermanniae</i>	cr	s				1				1
<i>fraudans</i>	cr	r-	1	3	2	1		1	1	9
<i>holocarpa</i> group	cr	r+		1						1
<i>Saxicola</i>	fo	r+/-	1	1	1			1		4

Table 2. Continued.

CANDELARIA										
<i>concolor</i>	fo	b					1	1		2
CANDELARIELLA										
<i>athallina</i>	cr	r+	1	2		1				4
<i>aurella</i>	cr	r+,dw,b		4	2	1	1	1	2	11
<i>dispersa</i>	cr	r+	1		1					2
<i>lutella</i>	cr	dw			1					1
<i>rosulans</i>	cr	r-,dw	1	1	2	1		2	1	8
<i>terrigena</i>	cr	s,m	2	3	1					6
<i>vitellina</i>	cr	r-,dw			1	1			1	3
<i>xanthostigma</i>	cr	b,dw	1		1					2
CATAPYRENIUM										
<i>cf. globosum</i>	sq	r-		2						2
CLADONIA										
<i>cariosa</i>	sq/fr	s				1				1
<i>chlorophaea</i>	sq/fr	dw,l,m,m-r		1		1		2	2	6
<i>fimbriata</i>	sq/fr	dw,l,m,s,b			2	3		3	5	13
<i>Pocillum</i>	sq/fr	m,s,m-r			1	1		1	1	4
<i>pyxidata</i>	sq/fr	m,s,m-r		1		2		1	1	5
COLLEMA										
<i>Crispum</i>	fo	r+,s	1	2	1					4
<i>fuscovirens</i>	fo	r+	1							1
<i>tenax</i>	fo	r+/-	2	1						3
CYPYELIUM										
<i>pinicola</i>	cr	dw				1			1	2
DERMATOCARPON										
<i>Miniatum</i>	fo	r+/-	3	1						4
<i>Reticulatum</i>	fo	r-							1	1
DIMELAENA										
<i>oreina</i>	cr	r-	1	1	1	1		1	2	7
DIPLOSCHISTES										
<i>Muscorum</i>	cr	dw,m,s		1	1			2	2	6
<i>scruposus</i>	cr	r-		1					2	3
DIPILOTOMMA										
<i>Alboatrum</i>	cr	dw				1				1
ENDOCARPON										
<i>Pusillum</i>	sq	r-	1						1	2
EVERNIA										
<i>prunastri</i>	fr	b							1	1
FLAVOPUNCTELIA										
<i>soredica</i>	fo	b					1			1
FULGENSIA										
<i>Desertorum</i>	fo	s	1	1						2
HYPOCENOMYCE										
<i>scalaris</i>	sq	b							1	1
HYPOGYMNIA										

Table 2. Continued.

OCHROLECHIA										
<i>upsaliensis</i>	cr	dw,m,s		1		2			4	7
PARMELIA										
<i>hygrophila</i>	fo	r-,b,m-r				1		2	4	7
<i>saxatilis</i>	fo	r-							1	1
<i>sulcata</i>	fo	r-,dw,b	1			2		1	2	6
PARMELIOPSIS										
<i>ambigua</i>	fo	b							2	2
PELTIGERA										
<i>canina</i>	fo	m				1			2	3
<i>didactyla</i>	fo	m,s				1		1	2	4
<i>neckeri</i>	fo	m							1	1
<i>polydactyla</i>	fo	m				1			1	2
<i>ponojensis</i>	fo	m,l			1			1	3	5
<i>rufescens</i>	fo	m,s,l	1	1	2				4	8
PHAEOPHYSCIA										
<i>constipata</i>	fo	r+	2							2
<i>hirsuta</i>	fo	b			1					1
<i>orbicularis</i>	fo	r-,m-r	2	1						3
<i>sciastra</i>	fo	r+/-	2				1		3	6
PHYSCIA										
<i>adscendens</i>	fo	r-,dw,b		1	2	3	1	3	3	13
<i>biziana</i>	fo	r-,b	1		2					3
<i>caesia</i>	fo	r+/-,b	1	2	3	3	1	3	5	18
<i>dimidiata</i>	fo	r-,dw,b	2		1	2		2	2	9
<i>dubia</i>	fo	r-,dw,b	1	1	1	1	1	2	3	10
<i>phaea</i>	fo	r-						1	1	2
<i>stellaris</i>	fo	dw,b			1	1		1	1	4
PHYSCIELLA										
<i>chloantha</i>	fo	r+	1							1
PHYSCONIA										
<i>enteroxantha</i>	fo	r-,dw						2		2
<i>isidiigera</i>	fo	dw,b,m	1		1			1	1	4
<i>muscigena</i>	fo	m,s,l		1	1	1			3	6
PLACIDIUM										
<i>squamulosum</i>	sq	s	1	2						3
PLACYNTHIELLA										
<i>uliginosa</i>	cr	dw				1				1
PLATISMATIA										
<i>glauca</i>	fo	r-,dw,b					1		4	5
PLEOPSISIDIUM										
<i>chlorophanum</i>	cr	r-	1		1				1	3
POLYSPORINA										
<i>urceolata</i>	cr	r+	1							1
PROTOPARMELIA										
<i>badia</i>	cr	r-				1				1

Table 2. Continued.

PSORA										
<i>cerebriformis</i>	sq	r-,s		1						1
<i>decipiens</i>	sq	s		2						2
<i>icterica</i>	sq	s		1						1
<i>tuckermanii</i>	sq	r+/-,s,m	2	3	2	1			2	10
PUNCTELIA										
<i>subrudecta</i>	fo	b			1			1		2
PYRRHOSPORA										
<i>elabens</i>	cr	b,dw			1					1
RHIZOCARPON										
<i>disporum</i>	cr	r-,b		1	1			1	2	5
<i>geographicum</i>	cr	r-							1	1
RHIZOPLACA										
<i>chrysoleuca</i>	fo	r-,dw,b	1	1	2	2	1	2	3	12
<i>melanophthalma</i>	fo	r-,dw,b	1	2	3	3	1	2	4	16
<i>subdiscrepens</i>	cr	r-							1	1
RIMULARIA										
<i>insularis</i>	cr	r-				1				1
RINODINA										
<i>bischoffii</i>	cr	r+	1	2						3
SARCOGYNE										
<i>regularis</i>	cr	r+		1						1
SPORASTATIA										
<i>testudinea</i>	cr	r+/-	1		1					2
STAUROTHELE										
<i>areolata</i>	cr	r+		1						1
<i>drumondii</i>	cr	r+		2	1				1	4
<i>fissa</i>	cr	r+		1						1
THYREA										
<i>confusa</i>	fo	r+	1							1
TONINIA										
<i>sedifolia</i>	sq	s	1	1	1					3
TRAPELIOPSIS										
<i>flexuosa</i>	cr	dw			1				1	2
TUCKERMANNOPSIS										
<i>chlorophylla</i>	fo	b				1			5	6
UMBILICARIA										
<i>hyperborea</i>	fo	r-	1		1	1		3	2	8
<i>krascheninnikovii</i>	fo	r-				1				1
<i>phaea</i>	fo	r	1		2				1	4
<i>torrefacta</i>	fo	r-		1	1	1		2	2	7
<i>virginis</i>	fo	r-	1			1				2
USNEA										
<i>hirta</i>	fr	dw,b					1	1	2	4
<i>lapponica</i>	fr	b				1	1			2
<i>substerilis</i>	fr	b			1	2		2	3	8

Table 2. Continued.

<i>VERRUCARIA</i>										
<i>Inficiens</i>	cr	r+	1							1
<i>nigrescens</i>	cr	r+		1				1		2
<i>XANTHOPARMELIA</i>										
<i>coloradoensis</i>	fo	r-,s,l				1		1		2
<i>mexicana</i>	fo	r-,dw,b	1	2	3	1	1	2	2	12
<i>Plittii</i>	fo	r+/-	1	1	1	1		2	1	7
<i>subdecepiens</i>	fo	r-			1	1	1	2		5
<i>wyomingica</i>	fo	s,l		2	1	1			1	5
<i>XANTHORIA</i>										
<i>Elegans</i>	fo	r+/-	2	3	2	2	1	3	2	15
<i>Fallax</i>	fo	b			1		1			2
<i>Fulva</i>	fo	r-,dw,b		1	1	1	1	3	2	9
<i>polycarpa</i>	fo	b	1		2	1				4
<i>sorediata</i>	fo	dw,b	1			1				2

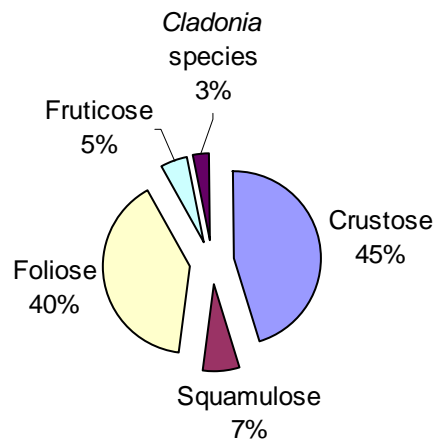


Figure 2. Distribution of lichen growth forms collected in Lewis and Clark Caverns State Park.

The foliose species *Melanelia elegantula*, *Physcia caesia*, *Rhizoplaca melanophthalma* and *Xanthoria elegans* were the most widespread in the park, found at 19, 18, 16 and 15 sites respectively (Table 2). Eight lichen species were documented from all seven vegetation types: *Lecidella stigmatea*, *Melanelia elegantula*, *Physcia*

caesia, *Physcia dubia*, *Rhizoplaca chrysoleuca*, *Rhizoplaca melanophthalma*, *Xanthoparmelia mexicana* and *Xanthoria elegans*, all of which have a wide distribution in the Rocky Mountains and West Temperate forests (Brodo et al. 2001).

Rock substrates were present in all 22 sites and had the highest number of inhabitation, with 97 species occurring on rock (Table 2, Figure 3). The most common species found on rock were the crustose species *Aspicilia cinerea*, *Candelariella aurella*, *Lecanora garovaglii*, *Lecidella stigmataea*, *Lobothallia alphoplaca*, and the foliose species *Physcia caesia*, *Rhizoplaca chrysoleuca*, *Rhizoplaca melanophthalma*, *Xanthoparmelia mexicana* and *Xanthoria elegans*. Wood/bark substrates were present in many of the sites and had the second highest distribution of lichens inhabiting them, with 69 species found on wood/bark. The most common species found on wood/bark were *Hypogymnia physodes*, *Letharia vulpina*, *Melanelia elegantula*, *M. subolivacea* and *Physcia adscendens*. On soil, the most common species were *Peltigera rufescens*, *Psora tuckermanii* and *Xanthoparmelia wyomingica*, all of which have broad distributions in the region (Brodo et al. 2001). *Cladonia* species, especially *Cladonia fimbriata*, were abundant on moist decaying wood, soil, moss, and litter.

The greatest diversity of lichens, 88 species, was found in the mountain mahogany grasslands vegetation, with the following 13 species found only in that vegetation type: *Acarospora heppii*, *Anisomeridium carinthiacum*, *Aspicilia desertorum* group, *Candelariella lutella*, *Lecanora cadubriae*, *L. willeyi*, *Lecidea plana*, *Megaspora verrucosa*, *Phaeophyscia hirsuta*, *Placynthiella uliginosa*, *Protoparmelia badia* and *Pyrrhospora elabens* (Tables 2 and 3). The diverse substrates in this vegetation type

include mountain mahogany, limber pine, juniper, big sagebrush (*Artemisia tridentata*), rock, moss and exposed soil, which could account for this large diversity of lichens.

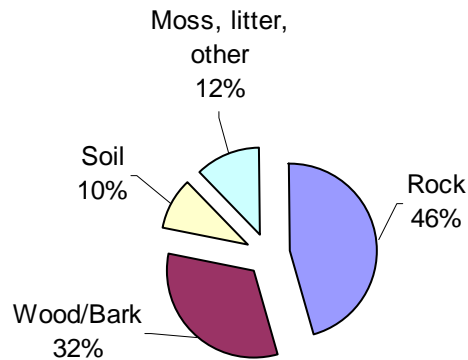


Figure 3. Distribution of lichen species by substrate

Eighty-seven species were found in moist Douglas fir forest, 12 of which were exclusive to this vegetation type: *Arthonia lapidicola*, *Bryoria fuscescens*, *Dermatocarpon reticulatum*, *Evernia prunastri*, *Hypocenomyce scalaris*, *Letharia columbiana*, *Nodobryoria abbreviata*, *Parmelia saxatilis*, *Parmeliopsis ambigua*, *Petigera neckeri*, *Rhizocarpon geographicum* and *Rhizoplaca subdiscrepens* (Tables 2 and 3). Because of the similar moisture content and conifer wood substrate, many of these species are characteristic of the Pacific Northwest and northern boreal forests (Brodo et al. 2001, McCune and Geiser 1997).

Sixty-six species were in the dry grasslands, 11 of which were exclusive to this vegetation type: *Caloplaca epithallina*, *Caloplaca holocarpa* group, *Catapyrenium* cf.

globosum, *Leanora hagenii*, *Lecidea auriculata*, *Psora cerebriformis*, *P. decipiens*, *P. icterica*, *Sarcogyne regularis*, *Staurothele areolata* and *Staurothele fissa*. The three *Psora* species are characteristic of arid conditions, while the other seven were on exposed rock (Table 2).

Table 3. Numbers of lichen species in Lewis and Clark Caverns State Park according to vegetation type. # of sites = number of sites in each vegetation type. # of species = number of species found in each vegetation type. % of total = % of total number of species (164) found in each vegetation type. # sp. only in veg. = number of species found only in one type of vegetation. % sp. only in veg. = % of total number of species (164) found only in one type of vegetation.

	Exposed Rock	Dry grass.	Mt. mahog.	Doug. fir grass.	Willow grass.	Decid. cotton.	Moist Doug. fir
# of sites	3	4	3	3	1	3	5
# of species	70	66	88	69	20	53	87
% of total	43	40	54	42	12	32	53
# sp. only in veg.	9	11	13	7	1	1	12
% sp. only in veg.	5.5	6.7	7.9	4.3	0.6	0.6	7.3

Deciduous cottonwood communities contained 53 lichen species with one exclusive species, *Physconia enteroxantha*.

Douglas fir grasslands contained 69 species with seven exclusive species: *Bryoria fremontii*, *Buellia punctata*, *Caloplaca jungermanniae*, *Cladonia cariosa*, *Diplotomma alboatrum*, *Rimularia insularis* and *Umbilicaria krascheninnikovii*.

Exposed rock sites contained 70 species with nine species only found there: *Buellia* cf. *elegans*, *Caloplaca decipiens*, *Collema fuscovirens*, *Lecidoma demissum*,

Phaeophyscia constipata, *Physciella chloantha*, *Polysporina urceolata*, *Thyrea confusa* and *Verrucaria inficiens*.

The willow grassland had the least diversity, with 20 species total, and one exclusive species, *Flavopunctelia soledica*. This single site had the majority of lichens occurring on rock scree, while the only other substrates available were willow shrubs and a dead cottonwood tree that had abundant *Physcia adscendens* and *Xanthoria fulva*. One tiny tuft of *Usnea hirta* was found. In addition to the fact that there was only one site for collection for willow grassland, the intermittent flooding of the site could be a source of such low diversity.

Four documented lichens in the park were unexpected based on past knowledge of their geographic distribution. *Evernia prunastri*, which is most common in the west Cascade Mountains and Bitterroot Range (McCune and Goward 1995), was present in one moist Douglas fir forest site in the park. The high moisture content of the site, with the close proximity to the Continental Divide, apparently provided adequate conditions for its presence. *Parmelia hygrophila*, typical of the Pacific Northwest, was present in seven moist sites which were in Douglas fir grassland, deciduous cottonwood and moist Douglas fir forest vegetation types. The foliose lichen *Thyrea confusa* was reported for the first time in Montana. It was present in an exposed rock site, similar to the dry exposed substrates of the Plains where it is more commonly found in the central states (Brodo et al. 2001; McCune and Goward 1995). *Punctelia subrudecta* is most common on the coasts, but was present in the mountain mahogany grasslands and the deciduous cottonwood communities (Brodo et al. 2001).

Several lichens were found on atypical substrates within the park. Lichens that usually occupy only rock substrates, but were found on old dry wood include: *Aspicilia cinerea*, *Lecanora garovaglii*, *Melanelia tominii*, *Rhizocarpon disporum*, *Rhizoplaca chrysoleuca* and *Rhizoplaca melanophthalma*. Their substitution of wood for rock is most likely due to the slow decomposition rates in several of the dry exposed sites, making the wood a stable surface like rock. Dead sagebrush was a common substrate for these lichens. Two lichens were found on noncalcareous rock that are usually found only on calcareous substrates: *Dermatocarpon reticulatum* and *Endocarpon pusillum* (Brodo et al. 2001).

Analysis of Distributions in Lewis and Clark Caverns State Park

Jaccard's Index of similarity (IS_J) illustrates the similarities of lichens among the seven vegetation types (Table 3). The highest similarity between vegetation types was nearly equal between two groupings: deciduous cottonwood and Douglas fir grassland sharing 39 species (Appendix A) and 47% IS_J , and Douglas fir grassland and moist Douglas fir forest sharing 49 species (Appendix A) and 46% IS_J (Table 4). The similarity of lichen compositions between the deciduous cottonwood and Douglas fir grassland can be attributed to the open grassland characteristic of each which favors crustose species on dry rock. Nineteen of the 39 common species were on rock, with both vegetation types having sites with either calcareous or noncalcareous rock substrates. Both vegetation types have bark and wood in addition to rock substrates and have moist, shaded soils below their canopies.

Table 4. Jaccard's Index of Similarity coefficients showing the similarity of lichen species between all seven vegetation types. The number before the colon represents the number of species in common and the percentage following the colon is Jaccard's Index of Similarity.

Type of Vegetation	Dry grass.	Mt. mahog.	Doug. fir grass.	Willow grass.	Decid. Cotton.	Moist Doug. fir
Exposed rock	36: 36%	44: 39%	33: 31%	11: 14%	28: 29%	34: 28%
Dry grassland		41: 36%	34: 34%	13: 18%	30: 34%	35: 30%
Mt. mahogany grass.			44: 39%	15: 16%	40: 40%	51: 41%
Douglas fir grassland				14: 19%	39: 47%	49: 46%
Willow grassland					15: 26%	14: 15%
Deciduous cottonwood						43: 44%
Moist Douglas fir forest						

The Douglas fir grasslands and moist Douglas fir had high similarity due to similar habitats provided by the common Douglas fir tree. Some lichens are particular about the substrate they inhabit, even to the point of choosing one bark type over another due to differing chemistry, texture and water holding capacities (Brodo 1973). Twenty of the 49 species in common were found on bark or wood. Douglas fir trees keep their lower branches and therefore create a broad base of shaded cover, and provide similar light exposure on the soil and rocks, and similar moisture at the bases of the trees and on the soil. Eighteen of the common species were found on rock substrates and 11 were found on moist soils and mosses.

The moist Douglas fir forests and deciduous cottonwood vegetations held the third rank in similarity (44% IS_J), with 22 of the 43 species in common occurring on rock. Both vegetation types have predominantly noncalcareous rock substrates, bark and wood substrates as well as shading.

Four vegetation types had nearly equal similarity indices (IS_J) with mountain mahogany grassland: Exposed rocky with 44 species in common (39% IS_J); Douglas fir forest grassland with 44 species in common (39% IS_J); deciduous cottonwood with 40 species in common (40% IS_J); and moist Douglas fir forest with 51 species in common (41% IS_J). As mentioned previously, mountain mahogany grasslands had the largest number of species, which was explained by the diverse array of substrates. This also accounts for the high overlap of lichen species with other vegetation types.

Exposed rock and the dry grassland had 36% lichen similarity (IS_J) and 36 species in common. These sites had high solar exposures and shared the same soil and rock substrates.

The grasslands all had relatively high similarities: dry grasslands and mountain mahogany grasslands 36% IS_J; dry grasslands and Douglas fir grassland 34% IS_J; dry grassland and Douglas fir grasslands 34% IS_J. The grasslands all offer rock substrates and exposed soil.

The willow grassland has the least number of species in common due to the fact that there was only one site of collection, therefore limiting the total number of species present.

Comparison of Lewis and Clark Caverns State Park with other studies in Montana and Wyoming

The lichen composition of Lewis and Clark CSP was compared with seven other pristine areas in Montana and Wyoming; Yellowstone National Park (Eversman et al. 2002), Glacier National Park (DeBolt and McCune 1993), Anaconda-Pintler Wilderness (Schubloom 1995), Elkhorn Mountains (Schubloom 1995), Gates of the Mountains

Wilderness (Schubloom 1995) and Grand Teton National Park (Eversman 1998). Jaccard's similarity coefficients suggest that the lichen flora of Lewis and Clark CSP is most similar to that of Grand Teton National Park, with 102 species in common and 36% IS_j (Figures 4 and 5). Forty-four per cent of the common species were foliose, 38% crustose, seven per cent fruticose, five per cent squamulose with all five of the present *Cladonia* species shared. Both parks have continental climate influences and have calcareous and noncalcareous rock substrates, and have shared plant communities that include moist Douglas fir forests, grasslands and sagebrush scrublands (Eversman 1998). However Grand Teton National Park is much larger in size and has a much larger elevation range, from 2030 m to 4150 m, creating sub-alpine and alpine habitats and forest types not present in Lewis and Clark CSP, allowing for greater lichen diversity (221 species).

Yellowstone National Park shared the highest number of species with Lewis and Clark CSP, 123 species, and ranked second in similarity (31% IS_j). Forty-four percent of the common species were foliose, 39% were crustose, five per cent were fruticose, eight per cent were squamulose with all five *Cladonias* shared. Yellowstone National Park, with 359 lichen species, covers a much larger area and elevation range, 2,100 to 3,210 m, than Lewis and Clark CSP and has forest types not present in Lewis and Clark CSP, allowing for a more diverse lichen flora (Despain 1990). Subalpine fir (*Abies lasiocarpa* (Hook.)), lodgepole pine (*Pinus contorta* Dougl.), Engelman spruce (*Picea engelmannii* Parry) and whitebark pine (*Pinus albicaulis* Engelm.) are some dominant tree species of Yellowstone National Park that are not present in Lewis and Clark CSP.

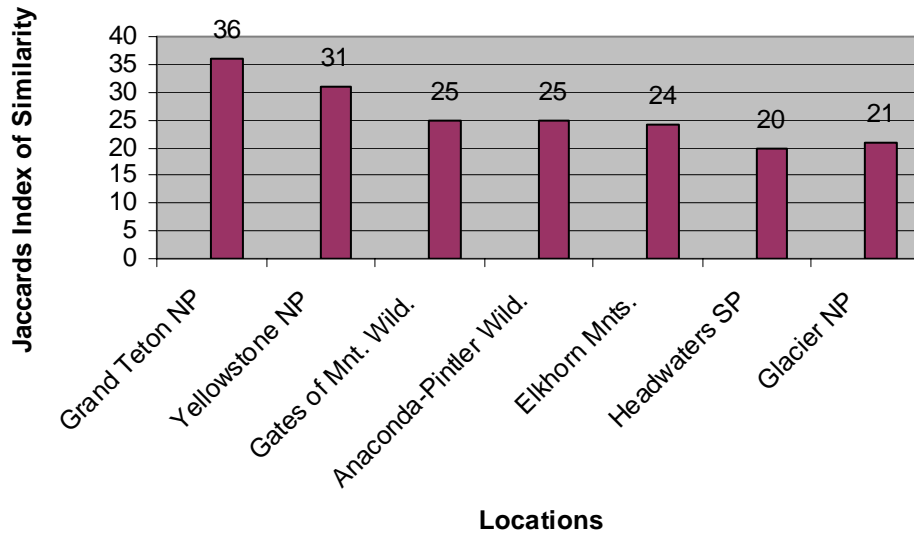


Figure 4. Jaccard's Index of Similarity between Lewis and Clark Caverns State Park and seven other pristine habitats in Montana and Wyoming.

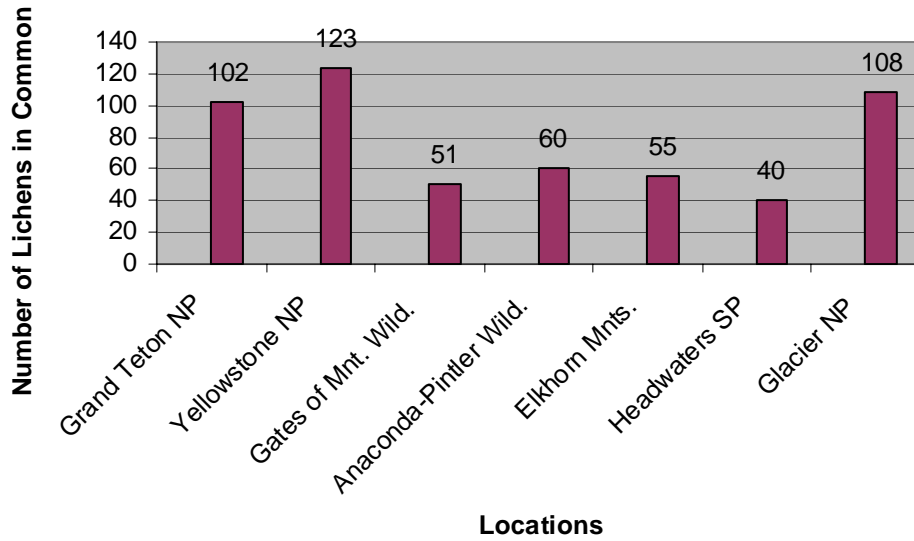


Figure 5. Numbers of lichens in common between Lewis and Clark Caverns State Park and seven other pristine habitats in Montana and Wyoming.

Gates of the Mountains Wilderness and Anaconda-Pintler Wilderness had the third highest similarity in lichen compositions (25% IS_j), and Elkhorn Mountains falling shortly behind with 24% IS_j . Both Lewis and Clark CSP and Gates of the Mountains Wilderness are located in the Madison limestone formation, have similar annual precipitation (25.9 cm in Gates of the Mountains Wilderness), similar elevation ranges (1140m to 2100 m in Gates of the Mountains Wilderness) and have Douglas fir as a dominant tree species. Forty-three per cent of the species in common were foliose, 35% crustose, 16% fruticose, 12% squamulose and four out of the five *Cladonia* species were shared as well. The Anaconda-Pintler Wilderness and Elkhorn Mountains have higher elevation ranges than Lewis and Clark CSP that result in more precipitation and more diverse vegetation types. The higher elevations of these two sites support whitebark pine (*Pinus albicaulis* Engelm.), *Picea* species and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). The Anaconda-Pintler Wilderness had 26 foliose, 25 crustose, five fruticose and four *Cladonia* species in common with Lewis and Clark CSP. The Elkhorn Mountains had 27 foliose and 18 crustose, six fruticose and four *Cladonia* species in common with Lewis and Clark CSP.

Glacier National Park had the second highest number of species in common with Lewis and Clark CSP (108 species), but the second lowest similarity coefficient (21%). With Glacier National Park straddling the Continental Divide, it has two very different climate types as mentioned previously, with the moist western side of the Continental Divide having more lichens than the dryer east side. The lichen diversity is also increased by its large elevation gradient, ranging from 970 to 3,190 m. Even though

there were a high number of similar species between the parks, the large diversity present in Glacier National Park (425 species) offsets the similarity coefficient. Glacier National Park had fifty-two foliose, 39 crustose, seven squamulose, five fruticose and all five *Cladonia* species were in common with Lewis and Clark CSP.

Headwaters State Park is only about four km² in size, consists of limestone rock formations and soils, and lacks much diversity in vegetation, which consists primarily of willow and cottonwood along the river, and is dry grassland on Fort Rock. With 78 lichen species identified in Headwaters State Park, over half (51%) were common with Lewis and Clark Caverns State Park; twenty-one of them being foliose, 15 crustose, three squamulose and one *Cladonia* species.

Conclusion

A total of 164 lichen species reported from Lewis and Clark Caverns State Park represents comparable diversity to other pristine locations in Montana and Wyoming. Along with this high diversity of lichens, it can be assumed that the air quality and substrate quality (vegetation and rock) are not disturbed in the park. The functional role of lichens in the park as pioneering organisms and food/shelter materials for animals and insects should be noted. Their progress in developing more soil substrates richer in nutrients is an important factor in the succession of the community (Hale 1983; Brodo et al. 2001), as well as in the production of suitable forage and housing for animal life (Longton 1992; Brodo et al. 2001). Hence the preservation of lichens within the park and elsewhere is important in maintaining the health and diversity of our ecosystems.

A complete lichen floristic record has now been established for Lewis and Clark Caverns State Park. This record can further be used as a reference for future studies at Lewis and Clark CSP and other areas for comparison. In addition, the inclusion of another species into the Montana state list of lichens is of interest for tracing either its appearance or disappearance from the state.

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APPENDICES

APPENDIX A

Common Lichen Species among Vegetation Types

Appendix A. Species in common between vegetation types within Lewis and Clark
Caverns State Park.

Exposed rock and dry Grassland

Acarospora strigata
Aspicilia caesiocinerea
A. calcarea group
A. cinerea
A. contorta
A. desertorum group
Caloplaca fraudans
C. saxicola
Candelariella athallina
C. rosulans
C. terrigena
Collema crispum
C. tenax
Dermatocarpon miniatum
Dimelaena oreina
Fulgensia desertorum
Lecanora argopholis
L. garovaglii
L. muralis
Lecidea tessellata
Lecidella patavina
L. stigmatea
Lobothallia alphoplaca
Melanelia elegantula
M. tominii
Phaeophyscia orbicularis
Physcia caesia
P. dubia
Placidium squamulosum
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Rinodina bischoffii
Toninia sedifolia
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans

Exposed rock and mountain mahogany

Acarospora strigata

A. veronensis
Aspicilia calcarea group
A. cinerea
A. contorta
Caloplaca fraudans
C. saxicola
Candelariella dispersa
C. rosulans
C. terrigena
C. xanthostigma
Collema crispum
Dimelaena oreina
Lecanora argopholis
L. garovaglii
L. muralis
Lecidea tessellata
Lecidella carpathica
L. euphorea
L. patavina
L. stigmathea
Letharia vulpina
Lobothallia alphoplaca
Melanelia elegantula
M. infumata
M. subolivacea
M. tominii
Physcia biziana
P. caesia
P. dimidiata
P. dubia
Physconia isidiigera
Pleopsidium chlorophanum
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Sporastatia testudinea
Toninia sedifolia
Umbilicaria hyperborea
U. phaea
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans
X. polycarpa

Exposed Rock and Douglas fir grassland

Acarospora strigata
Aspicilia caesiocinerea
A. calcarea group
A. cinerea
A. contorta
Caloplaca fraudans
Candelariella athallina
C. rosulans
Dimelaena oreina
Lecanora argopholis
L. garovaglii
L. hagenii
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Lobothallia alphoplaca
Melanelia disjuncta
M. elegantula
M. subolivacea
Parmelia sulcata
Physcia caesia
P. dimidiata
P. dubia
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
U. virginis
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans
X. polycarpa
X. sorediata

Exposed rock and willow grassland

Lecanora muralis
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
Phaeophyscia sciastra
Physcia caesia
P. dubia
Rhizoplaca chrysoleuca

R. melanophthalma
Xanthoparmelia mexicana
Xanthoria elegans

Exposed rock and deciduous cottonwood

Acarospora veronensis
Aspicilia caesiocinerea
A. cinerea
A. contorta
Caloplaca fraudans
C. saxicola
Candelariella rosulans
Dimelaena oreina
Lecanora argopholis
L. garovaglii
L. muralis
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Lobothallia alphoplaca
Melanelia elegantula
M. subolivacea
M. tominii
Parmelia sulcata
Physcia caesia
P. dimidiata
P. dubia
Physconia isidiigera
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans

Exposed rock and moist Douglas fir forest

Acarospora glaucocarpa
Aspicilia caesiocinerea
A. cinerea
Caloplaca fraudans
Candelariella rosulans
Dimelaena oreina
Diplotomma alboatrum
Lecanora dispersa

L. garovaglii
L. muralis
Lecidea tessellata
Lecidella euphorea
L. stigmatea
Letharia vulpina
Melanelia disjuncta
M. elegantula
M. infumata
M. subolivacea
M. tominii
Parmelia sulcata
Physcia caesia
P. dimidiata
P. dubia
Physconia isidiigera
Pleopsidium chlorophanum
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
U. phaea
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans

Dry grassland and mountain mahogany grassland

Acarospora strigata
Aspicilia calcarea group
A. cinerea
A. contorta
Caloplaca citrina
C. fraudans
C. saxicola
Candelariella aurella
C. rosulans
C. terrigena
Collema crispum
Dimelaena oreina
Diploschistes muscorum
Lecanora argopholis
L. crenulata
L. garovaglii
L. marginata

L. muralis
Lecidea tessellata
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
M. tominii
Peltigera rufescens
Physcia adscendens
P. caesia
P. dubia
Physconia muscigena
Psora tuckermanii
Rhizocarpon disporum
Rhizoplaca chrysoleuca
R. melanophthalma
Staurothele drumondii
Toninia sedifolia
Umbilicaria torrefacta
Xanthoparmelia mexicana
X. plittii
X. wyomingica
Xanthoria elegans
X. fulva

Dry grassland and Douglas fir grassland

Acarospora strigata
Aspicilia caesiocinerea
A. calcarea group
A. cinerea
A. contorta
Caloplaca fraudans
Candelariella athallina
C. aurella
C. rosulans
Cladonia chlorophaea
C. pyxidata
Dimelaena oreina
Lecanora argopholis
L. garovaglii
L. hagenii
Lecidea tessellata
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula

Ochrolechia upsaliensis
Peltigera rufescens
Physcia adscendens
P. caesia
P. dubia
Physconia muscigena
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria torrefacta
Xanthoparmelia mexicana
X. plittii
X. wyomingica
Xanthoria elegans
X. fulva

Dry grassland and willow grassland

Candelariella aurella
Lecanora muralis
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
Physcia adscendens
P. caesia
P. dubia
Rhizoplaca chrysoleuca
R. melanophthalma
Xanthoparmelia mexicana
Xanthoria elegans
X. fulva

Dry grassland and deciduous cottonwood

Aspicilia caesiocinerea
A. cinerea
A. contorta
Caloplaca fraudans
C. saxicola
Candelariella aurella
C. rosulans
Cladonia chlorophae
Dimelaena oreina
Diploschistes muscorum
Lecanora argopholis
L. garovaglii

L. muralis
Lecidea tessellata
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
M. tominii
Physcia adscendens
P. caesia
P. dubia
Rhizocarpon disporum
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria torrefacta
Xanthoparmelia mexicana
X. plittii
Xanthoria elegans
X. fulva

Dry grassland and moist Douglas fir forest

Aspicilia caesiocinerea
A. cinerea
Caloplaca fraudans
Candelariella aurella
C. rosulans
Cladonia chlorophaea
Dimelaena oreina
Diploschistes muscorum
D. scruposus
Lecanora garovaglii
L. muralis
L. rupicola
Lecidea tessellata
Lecidella stigmatea
Melanelia elegantula
M. tominii
Ochrolechia upsaliensis
Peltigera rufescens
Physcia adscendens
P. caesia
P. dubia
Physconia muscigena
Psora tuckermanii
Rhizocarpon disporum
Rhizoplaca chrysoleuca

R. melanophthalma
Staurothele drumondii
Umbilicaria torrefacta
Verrucaria nigrescens
Xanthoparmelia mexicana
X. plittii
X. wyomingica
Xanthoria elegans
X. fulva

Mountain mahogany grassland and Douglas fir grassland

Acarospora strigata
Aspicilia calcarea group
A. cinerea
A. contorta
Caloplaca fraudans
Candelariella aurella
C. rosulans
C. vitellina
Cladonia fimbriata
C. pocillum
Dimelaena oreina
Hypogymnia austerodes
H. imshaugii
H. physodes
Lecanora argopholis
L. cenisia
L. garovaglii
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Lobothallia alphoplaca
Melanelia elegantula
M. exasperatula
M. subolivacea
Peltigera rufescens
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. stellaris
Physconia muscigena
Psora tuckermanii
Rhizoplaca chrysoleuca

R. melanophthalma
Umbilicaria hyperborea
U. torrefacta
Usnea substerilis
Xanthoparmelia mexicana
X. plittii
X. subdecepiens
X. wyomingica
Xanthoria elegans
X. fulva
X. polycarpa

Mountain mahogany grassland and willow grassland

Candelariella aurella
Lecanora muralis
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
Physcia adscendens
P. caesia
P. dubia
Rhizoplaca chrysoleuca
R. melanophthalma
Xanthoparmelia mexicana
X. subdecepiens
Xanthoria elegans
X. fallax
X. fulva

Mountain mahogany grassland and deciduous cottonwood

Acarospora veronensis
Aspicilia cinerea
A. contorta
Caloplaca fraudans
C. saxicola
Candelariella aurella
C. rosulans
Cladonia fimbriata
C. pocillum
Dimelaena oreina
Diploschistes muscorum
Hypogymnia physodes
Lecanora argopholis
L. garovaglii

L. muralis
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Lobothallia alphoplaca
Melanelia elegantula
M. subolivacea
M. tominii
Peltigera ponojensis
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. stellaris
Physconia isidiigera
Punctelia subrudecta
Rhizocarpon disporum
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
U. torrefacta
Usnea substerilis
Xanthoparmelia mexicana
X. plittii
X. subdecepiens
Xanthoria elegans
X. fulva

Mountain mahogany and moist Douglas fir forest

Aspicilia cinerea
Caloplaca fraudans
Candelariella aurella
C. rosulans
C. vitellina
Cladonia fimbriata
C. pocillum
Cyphelium pinicola
Dimelaena oreina
Diploschistes muscorum
Hypogymnia austerodes
H. imshaugii
H. physodes
Lecanora garovaglii
L. muralis

L. saligna
Lecidea tessellata
Lecidella euphorea
L. stigmatea
Letharia vulpina
Melanelia elegantula
M. exasperatula
M. infumata
M. subaurifera
M. subolivacea
M. tominii
Peltigera ponojensis
P. rufescens
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. stellaris
Physconia isidiigera
P. muscigena
Pleopsidium chlorophanum
Psora tuckermanii
Rhizocarpon disporum
Rhizoplaca chrysoleuca
R. melanophthalma
Staurothele drumondii
Trapeliopsis flexuosa
Umbilicaria hyperborea
U. phaea
U. torrefacta
Usnea substerilis
Xanthoparmelia mexicana
X. plittii
X. wyomingica
Xanthoria elegans
X. fulva

Douglas fir grassland and willow grassland

Candelariella aurella
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
Physcia adscendens
P. caesia

P. dubia
Rhizoplaca chrysoleuca
R. melanophthalma
Usnea lapponica
Xanthoparmelia mexicana
X. subdecepiens
Xanthoria elegans
X. fulva

Douglas fir grassland and deciduous cottonwood

Aspicilia caesiocinerea
A. cinerea
A. contorta
Caloplaca arenaria
C. fraudans
Candelariella aurella
C. rosulans
Cladonia chlorophaea
C. fimbriata
C. pocillum
C. pyxidata
Dimelaena oreina
Hypogymnia physodes
Lecanora argopholis
L. garovaglii
Lecidea tessellata
Lecidella stigmathea
Letharia vulpina
Lobothallia alphoplaca
Melanelia elegantula
M. subolivacea
Parmelia hygrophila
P. sulcata
Peltigera didactyla
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. stellaris
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
U. torrefacta
Usnea substerilis

Xanthoparmelia coloradoensis
X. mexicana
X. plittii
X. subdecepiens
Xanthoria elegans
X. fulva

Douglas fir grassland and moist Douglas fir forest

Aspicilia caesiocinerea
A. cinerea
Caloplaca fraudans
Candelariella aurella
C. rosulans
C. vitellina
Cladonia chlorophaea
C. fimbriata
C. pocillum
C. pyxidata
Dimelaena oreina
Hypogymnia austerodes
H. imshaugii
H. physodes
H. tubulosa
Lecanora garovaglii
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Melanelia disjuncta
M. elegantula
M. exasperatula
M. subolivacea
Ochrolechia upsaliensis
Parmelia hygrophila
P. sulcata
Peltigera canina
P. didactyla
P. polydactyla
P. rufescens
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. stellaris
Physconia muscigena

Platismatia glauca
Psora tuckermanii
Rhizoplaca chrysoleuca
R. melanophthalma
Tuckermannopsis chlorophylla
Umbilicaria hyperborea
U. torrefacta
Usnea substerilis
Xanthoparmelia mexicana
X. plittii
X. wyomingica
Xanthoria elegans
X. fulva

Willow grassland and deciduous cottonwood

Candelaria concolor
Candelariella aurella
Lecanora muralis
Lecidella stigmatea
Lobothallia alphoplaca
Melanelia elegantula
Physcia adscendens
P. caesia
P. dubia
Rhizoplaca chrysoleuca
R. melanophthalma
Usnea hirta
Xanthoparmelia mexicana
X. subdecepiens
Xanthoria elegans
X. fulva

Willow grasslands and moist Douglas fir forest

Candelariella aurella
Lecanora muralis
Lecidella stigmatea
Melanelia elegantula
Phaeophyscia sciastra
Physcia adscendens
P. caesia
P. dubia
Rhizoplaca chrysoleuca
R. melanophthalma
Usnea hirta

Xanthoparmelia mexicana
Xanthoria elegans
X. fulva

Deciduous cottonwood and moist Douglas fir forest

Aspicilia caesiocinerea
A. cinerea
Caloplaca fraudans
Candelariella aurella
C. rosulans
Cladonia chlorophaea
C. fimbriata
C. pocillum
C. pyxidata
Dimelaena oreina
Diploschistes muscorum
Hypogymnia physodes
Lecanora garovaglii
L. muralis
Lecidea tessellata
Lecidella stigmatea
Letharia vulpina
Melanelia elegantula
M. subolivacea
M. tominii
Parmelia hygrophila
P. sulcata
Peltigera didactyla
P. ponojensis
Physcia adscendens
P. caesia
P. dimidiata
P. dubia
P. phaea
P. stellaris
Rhizocarpon disporum
Rhizoplaca chrysoleuca
R. melanophthalma
Umbilicaria hyperborea
U. torrefacta
Usnea hirta
U. substerilis
Xanthoparmelia mexicana
X. plittii

Xanthoria elegans

X. fulva

APPENDIX B

List of Lichen Species in Lewis and Clark Caverns State Park Including Author Citations

Appendix B. A list of lichens from Lewis and Clark Caverns State Park, including their author citations.

Acarospora glaucocarpa (Ach.) Korber
Acarospora heppii (Nageli ex Hepp) Nageli ex Korber
Acarospora strigata (Nyl.) Jatta
Acarospora veronensis A. Massal.
Anisomeridium carinthiacum (Steiner) R. C. Harris
Arthonia lapidicola (Taylor) Branth & Rostrup
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arnold
Aspicilia calcarea group (L.) Mudd
Aspicilia cinerea (L.) Korber
Aspicilia contorta (Hoffm.) Kremp
Aspicilia desertorum group (Kremp.)
Bryoria fremontii (Tuck.) Brodo & D. Hawksw
Bryoria fuscenscens (Gyel.) Brodo and Hawksw.
cf. Buellia elegans Poelt (Weber 1990)
Buellia punctata (Hoffm.) Massal.
Caloplaca arenaria (Pers.) Mull. Arg.
Caloplaca citrina (Hoffm.) Th. Fr.
Caloplaca decipiens (Arnold) Blomb. & Forss.
Caloplaca epithallina Lynge
Caloplaca jungermanniae (Vahl) Th. Fr.
Caloplaca fraudans (Th. Fr.) H. Olivier
Caloplaca holocarpa group (Hoffm. ex Ach.) M. Wade
Caloplaca saxicola (Hoffm.) Nordin
Candelaria concolor (Dickson) Stein
Candelariella athallina (Wedd.) Du Rietz
Candelariella aurella (Hoffm.) Zahlbr.
Candelariella dispersa (Rasanen) Hakul.
Candelariella lutella (Vainio) Rasanen
Candelariella rosulans (Mull. Arg.) Zahlbr.
Candelariella terrigena Rasanen
Candelariella vitellina (Hoffm.) Zahlbr.
Candelariella xanthostigma (Ach.) Lettau
Catapyrenium cf. globosum J. W. Thomson
Cladonia cariosa (Ach.) Sprengel
Cladonia chlorophaea (Florke ex Sommerf.) Sprengel
Cladonia fimbriata (L.) Fr.
Cladonia pocillum (Ach.) Grognot
Cladonia pyxidata (L.) Hoffm.
Collema crispum (Hudson) F. H. Wigg
Collema fuscovirens (With.) J. R. Laundon
Collema tenax (Sw.) Ach.
Cyphelium pinicola Tibell
Dermatocarpon miniatum (L.) W. Mann
Dermatocarpon reticulatum H. Magn.
Dimelaena oreina (Ach.) Norman

Diploschistes muscorum (Scop.) R. Sant.
Diploschistes scruposus (Schreber) Norman
Diplotomma alboatrum (Hoffm.) Fotow
Endorcarpon pusillum (Hedwig)
Evernia prunastri (L.) Ach.
Flavopunctelia soledica (Nyl.) Hale
Fulgensia desertorum (Tomin) Poelt
Hypocenomyce scalaris (Ach.) M. Choisy
Hypogymnia austerodes (Nyl.) Rasanen
Hypogymnia imshaugii Krog
Hypogymnia physodes (L.) Nyl.
Hypogymnia tubulosa (Schaerer) Hav.
Lecanora albellula Nyl. (Printzn 2001)
Lecanora argopholis (Ach.) Ach.
Lecanora cadubriae (A. Massal.) Hedl.
Lecanora cenisia Ach.
Lecanora crenulata Hook.
Lecanora dispersa (Pers.) Sommerf.
Lecanora garovaglii (Korber) Zahlbr.
Lecanora hagenii (Ach.) Ach.
Lecanora marginata (Schaerer) Hertel & Rambold
Lecanora muralis (Schreber) Rabenh.
Lecanora rupicola (L.) Zahlbr.
Lecanora saligna (Schrader) Zahlbr.
Lecanora willeyi Tuck.
Lecidea auriculata Th. Fr.
Lecidea plana (J. Lahm) Nyl.
Lecidea tessellata (Anzi) Arnold
Lecidella carpathica Korber
Lecidella euphorea (Florke) Hertel
Lecidella patavina (A. Massal.) Knoph & Leuckert
Lecidella stigmatea (Ach.) Hertel & Leuckert
Lecidoma demissum (Rutstr.)
Letharia columbiana (Nutt.) J. W. Thomson
Letharia vulpina (L.) Hue
Lobothallia alphoplaca (Wahlenb.) Hafellner
Megaspora verrucosa (Ach.) Hafellner & V. Wirth
Melanelia disjuncta (Erichsen) Essl.
Melanelia elegantula (Zahlbr.) Essl.
Melanelia exasperatula (De Not.) Essl.
Melanelia infumata (Nyl.) Essl.
Melanelia subaurifera (Nyl.) Essl.
Melanelia subolivacea (Nyl.) Essl.
Melanelia tominii (Oksner) Essl.
Nodobryoria abbreviata (Mull. Arg) Common & Brodo
Ochrolechia upsaliensis (L.) A. Massal.
Parmelia hygrophila Goward & Ahti
Parmelia saxatilis (L.) Ach.

Parmelia sulcata Taylor
Parmeliopsis ambigua (Wulfen) Nyl.
Peltigera canina (L.) Willd.
Peltigera didactyla (With.) J.R. Laundon
Peltigera neckeri Hepp ex Mull. Arg.
Peltigera ponojensis Gyelnik
Peltigera polydactyla (Necker) Hoffm.
Peltigera rufescens (Weiss.) Humb.
Phaeophyscia constipata (Norrlin & Nyl.) Moberg
Phaeophyscia hirsuta (Mereschk.)
Phaeophyscia orbicularis (Necker) Moberg
Phaeophyscia sciastra (Ach.) Moberg
Physcia adscendens (Fr.) H. Olivier
Physcia biziana (A. Massal.) Zahlbr.
Physcia caesia (Hoffm.) Furnr.
Physcia dimidiata (Arnold) Nyl.
Physcia dubia (Hoffm.) Lettau
Physcia phaea (Tuck.) J.W. Thomson
Physcia stellaris (L.) Nyl.
Physciella chloantha (Ach.) Essl.
Physconia enteroxantha (Nyl.) Poelt
Physconia isidiigera (Zahlbr.) Essl.
Physconia muscigena (Ach.) Poelt
Placidium squamulosum (Ach.) Breuss
Placynthiella uliginosa (Schrader) Coppins & P. James
Platismatia glauca (L.) Culb. & C. Culb.
Pleopodium chlorophanum (Wahlenb.) Zopf
Polysporina urceolata (Anzi) Brodo
Protoparmelia badia (Hoffm.)
Psora cerebriformis W. A. Weber
Psora decipiens (Hedwig) Hoffm.
Psora icterica (Mont.) Mull. Arg.
Psora tuckermanii R. Anderson ex Timdal
Punctelia subrudecta (Nyl.) Krog
Pyrrhospora elabens (Fr.) Hafellner
Rhizocarpon disporum (Nageli ex Hepp) Mull. Arg.
Rhizocarpon geographicum (L.) DC.
Rhizoplaca chrysoleuca (Sm.) Zopf
Rhizoplaca melanophthalma (DC.) Leuckert & Poelt
Rhizoplaca subdiscrepans (Nyl.) R. Sant.
Rimularia insularis (Nyl.) Rambold & Hertel
Rinodina bischoffii (Hepp) A. Massal.
Sarcogyne regularis Korber
Sporastatia testudinea (Ach.) A. Massal.
Staurothele areolata (Ach.) Lettau
Staurothele drumondii (Tuck.) Tuck.
Staurothele fissa (Taylor) Zwackh
Thyrea confusa Henssen (Henssen & Jorgensen)

1990)

Toninia sedifolia (Scop.) Timdal
Trapeliopsis flexuosa (Fr.) Coppins & P. James
Tuckermannopsis chlorophylla (Willd.) Hale
Umbilicaria hyperborea (Ach.) Hoffm.
Umbilicaria krascheninnikovia (Savicz) Zahlbr.
Umbilicaria phaea Tuck.
Umbilicaria torrefacta (Lightf.) Schrader
Umbilicaria virginis Schaerer
Usnea hirta (L.) F. H. Wigg.
Usnea lapponica Vainio
Usnea substerilis Mot.
Verrucaria inficiens Breuss
Verrucaria nigrscens Pers.
Xanthoparmelia coloradoensis (Gyelnik) Hale
Xanthoparmelia mexicana (Gyelnik) Hale
Xanthoparmelia plittii (Gyelnik) Hale
Xanthoparmelia subdecepiens (Vainio) Hale
Xanthoparmelia wyomingica (Gyelnik) Hale
Xanthoria candelaria (L.) Th. Fr.
Xanthoria elegans (Link) Th. Fr.
Xanthoria fallax (Hepp) Arnold
Xanthoria fulva (Hoffm.) Poelt & Petutschnig
Xanthoria polycarpa (Hoffm.) Rieber
Xanthoria sorediata (Vainio) Poelt

APPENDIX C
Vegetation Photographs

Appendix C. Photographs of the seven vegetation types within Lewis and Clark Caverns State Park.

Dry Exposed Rock



Limestone



Belt Arkose (La Hood Conglomerate)

Dry Grassland



Mountain Mahogany Grassland



Douglas fir Grassland



Willow Grassland



Deciduous Cottonwood



Moist Douglas fir Forest

