LICHENS OF THE YELLOWSTONE ECOSYSTEM

Prepared for the

EAST SIDE PROJECT

COLUMBIA RIVER BASIN ECOSYSTEM
MANAGEMENT PLAN

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INTRODUCTION

The location focus of this report is the southwest portion of Yellowstone National Park, headwaters of the Snake River, a tributary of the Columbia River. Besides Yellowstone Park, Grand Teton National Park is included in this drainage; no systematic lichen collection for that park is known and assumptions of species expected are made on the basis of collections in Yellowstone Park and southwestern Montana.

Reference is frequently made to the "Yellowstone Ecosystem", also sometimes called the "Greater Yellowstone Ecosystem". This is a large area that, in locally understood terms, includes Yellowstone National Park and the Yellowstone Plateau, Grand Teton National Park, the Beartooth Plateau region, seven mountain ranges (Gallatin, Madison, Centennial, Grand Tetons, Gros Ventre, Absaroka, and Beartooth) and their valleys, and the Red Rock Wildlife Refuge. It includes six national forests: Gallatin, Beaverhead, Targhee, Bridger-Teton, Shoshone, and Custer, administered by the United States Forest Service; the Red Rocks Wildlife Refuge administered by the U.S. Fish and Wildlife Service; several thousand acres administered by the Bureau of Land Management; public land under the domain of the states of Montana, Wyoming and Idaho; and private lands.

The most distinguishing characteristics of the Greater Yellowstone Ecosystem are the lack of native ponderosa pine (*Pinus* ponderosa) except in the northeasternmost portion near Red Lodge, Montana; the dominance of lodgepole pine (*Pinus* contorta) as both a successional and climax species; and the range of the grizzly bear (*Ursus* horribilis). About 80% of the forested regions of Yellowstone Park (disregarding fires) is lodgepole pine, and a similar percentage is true for Grand Teton National Park. The dominance of lodgepole pine is thought to be due to rhyolite soils (Yellowstone) (Despain, 1990) and fire history (both parks). Lodgepole pine is abundant throughout the mountain ranges adjacent to the parks also.

In elevational gradients, the forests, other than lodgepole pine, are limber pine (*Pinus* flexilis) usually with Rocky Mountain juniper (Juniperus scopulorum), Douglas fir (Pseudotsuga menziesii), spruce/subalpine fir (mostly *Picea engelmannii/Abies* lasiocarpa), and whitebark pine (*Pinus* albicaulis) near timberline. Accessible alpine areas are best developed above timberline on the Beartooth Plateau, east of Yellowstone Park; a few peaks (e.g., Mount Washburn, Electric Peak) in Yellowstone Park; and a few isolated peaks in adjacent mountain ranges.

The climate is dry continental, with relatively few sites of moist spruce/subalpine fir forest that are generally above 7000 feet (2121 m); spruce stands occur along streams to lower elevations, closer to 1818 m.

Major collections on which this report is based have been from Yellowstone National Park, the Beartooth Plateau, and the Gallatin and Absaroka mountain ranges that include parts of the Shoshone National Forest in Wyoming and the Custer and Gallatin forests in Montana. The latitudes range from about 44° to 46" N and longitudes from 109° 15' to 111"; elevations range from about 1818 to 3400 m. Supporting observations come from the Anaconda-Pintler Wilderness Area and adjacent forest in the Beaverhead, Deerlodge, and Bitterroot National Forests (St. Clair and Newberry, 1993), and the Bridger, Gallatin, Beartooth, and Absaroka mountains, Gallatin National Forest (Eversman, unpublished records). Collections made by a graduate student for a M.S. thesis in the Anaconda-Pintler Wilderness Area and Elkhorn Mountains (Deerlodge National Forest) were also consulted (Schubloom, unpublished data).

Voucher specimens for all species collected by Eversman and Schubloom are in the Montana State University Herbarium (MONT).

TABLE 1. LIST OF LICHEN SPECIES FOR EAST SIDE PROJECT, COLUMBIA RIVER BASIN ECOSYSTEM MANAGEMENT PLAN, EXPECTED FOR SNAKE RIVER DRAINAGE IN THE YELLOWSTONE ECOSYSTEM. SPECIES ARE LISTED ALPHABETICALLY, WITH THEIR RELATIVE ABUNDANCE GIVEN AS C+ (COMMON AND ABUNDANT IN ITS HABITAT), C (COMMON, SOMETIMES ABUNDANT), **C-** (LESS COMMON AND ABUNDANT, BUT NOT RARE), AND **R** (RARE). SPECIES GROUPS INDICATES THEIR HABITAT AND GROWTH FORM, AND SPECIES FUNCTION IN THE ECOSYSTEM IS GIVEN WHERE KNOWN.

SPECIES	Comm on Rare	Species Group	Ecosystem Function	Indicator Values
Acarospora chlorophana	c-	Rock crust	Rock weathering	Old growth
Acarospora fuscata	c	Rock crust	Rock weathering	Old growth
Acarospora schleicheri	c-	Soil crust	Soil stabilization	
Acarospora smaragdula	c-	Rock crust	Rock weathering	
Alectoria imshaugii	r	Epiphyte fruticose	Forage	Old growth
Alectoria sarmentosa ssp. sarmentosa	r	Epiphyte fruticose	Forage	Old growth
Arthonia glebosa	r	Soil crust	Soil stabilization	Old growth
Aspicilia caesiocinerea	c+	Rock crust	Rock weathering Lowers albedo	
Aspicilia calcarea	c-	Rock crust	Rock weathering	
Aspicilia candida	r	Rock crust	Rock weathering	
Aspicilia cinerea	c	Rock crust	Rock weathering	
Aspiciia supertegens	c-	Rock crust	Rock weathering	
Baeomyces rufus	r	Forest soil	Colonizer	Disturbed sites
Bellemerea alpina	c	Rock crust	Rock weathering	
Bellemerea **cinereorufescens**	c-	Rock crust	Rock **weathering**	

Biatora vernalis	c-	Moss, bark		
Brodoa oroarctica	c-	Alpine rock macrolichen	Rock weathering	Alpine
Bryonora castanea	r	Alpine soil	Soil stabilization	Alpine
Bryoria abbreviata	c-	Fruticose epiphyte		Old growth
Bryoria capillaris	c-	Fruticose epiphyte	Forage	Old growth
Bryoria fremontii	c+	Fruticose epiphyte	Forage	Old growth
Bryoria fuscescens	c+	Fruticose epiphyte	Forage	Old growth
Bryoria lanestris	c+	Fruticose epiphyte	Forage	Old growth
Buellia elegans	c-	Steppe soil	Soil stabilization	
Buellia erubescens	c	Tree crust		Old growth
Buellia papillata	c	Alpine, steppe detritus	Binds, stabilizes	Old growth
Buellia punctata	c-	Tree crust		
Caloplaca cerina	c-	Tree crust		
Caloplaca cladodes	r	Rock crust	Rock weathering	
Caloplaca epithallina	c+	Lichens on rock crust		
Caloplaca saxicola	c-	Rock crust	Rock weathering	
Caloplaca stillicidiorum	c-	Detritus, moss	Binds, stabilizes	
Caloplaca tiroliensis	c	Detritus, moss	Binds, stabilizes	High elevation
Candelaria concolor	c-	Tree crust		
Candelariella aurella	c+	Rock crust	Rock weathering	
Candelariella terrigena	c-	Soil crust	Stabilizes	
Candelariella vitellina	c	Rock crust	Rock weathering	

Catapyrenium cinereum	c-	Soil	Soil stabilization	Alpine
Catapyrenium lachneum	c	Soil	Stabilization	
Cetraria ericetorum	c	Alpine soil	Forage?	High elevation
Cetraria islandica	c	Alpine soil	Forage?	High elevation
Cetraria nivalis	c	Alpine soil	Forage?	Alpine
Chrysothrix chlorina	c-	Rock crust	Rock weathering	Sheltered
Cladina mitis	r	Soil fruticose	Forage?	Thermal basins YNP
Cladonia bacillaris	c-	Rotting logs, tree bases		Old growth
Cladonia cariosa	c	Forest soil	Pioneer, stabilizer	
Cladonia carneola	c-	Rotting logs		Old growth
Cladonia cenotea	c	Rotting logs		Old growth
Cladonia cervicornis subsp. verticillata	c	Soil, humus		Old growth
Cladonia chlorophaea	c+	Soil	Stabilizes	
Cladonia coccifera	c-	Soil, humus		Old growth
Cladonia coniocraea	c	Rotting logs		Old growth
Cladonia cornuta	c-	Forest soil		
Cladonia deformis	c-	Rotting logs		Old growth
Cladonia ecmocyna	c	Forest soils	Stabilizes	Old growth
Cladonia fimbriata	c+	Rotting logs		
Cladonia gracilis	c	Forest soils		Old growth
Cladonia mateocyatha	c-	Forest soils		
Cladonia multiformis	c	Forest soils		Old growth

Cladonia ochrochlora	c	Forest soils		
Cladonia pleurota	c-	Forest soils		Old growth
Cladonia pocillum	c-	Alpine soils	Pioneer, stabilizes	Alpine
Cladonia pyxidata	c+	Soil	Pioneer, stabilizes	
Cladonia sulphurina	c	Rotting logs		Old growth
Coelocaulon aculeatum	c-	Grassland soil		Alpine
Coelocaulon muricatum	c	Grassland soil	Stabilizes	Alpine
Collema coccophorum	c-	Soil	N-fixation	
Collema tenax	c	Soil	N-fixation	
Collema undulatum var. granulosum	c-	Mossy rock	N-fixation	
Cyphelium notarisii	c	Old wood		
Cyphelium tigillare	c	Old wood		
Dactylina madreporiformis	c	Alpine soil	Stabilizes	Alpine
Dactylina ramulosa	r	Alpine soil		
Dermatocarpon intestiniforme	c-	Rock macrolichen		Moist rock
Dermatocarpon miniatum	c	Rock macrolichen	Habitat	
Dermatocarpon moulinsii	c	Rock macrolichen		
Dermatocarpon reticulatum	c	Rock macrolichen		
Dermatocarpon rivulorum	r	Rock macrolichen		Wet rock
Dermatocarpon vagans	r	Vagrant soil		Alpine
Dimelaena oreina	c	Rock crust	Rock weathering	
Diploschistes muscorum	c	Soil, moss	Stabilizes	
Diploschistes scruposus	c-	Rock crust		

Diplotomma penichrum	r	Tree crust		Moist
Endocarpon pulvinatum	r	Rock crust		
Ephebe solida	r	Mossy rock	N-fixation	Moist
Evernia divaricata - alp var	c-	Gravelly soil	Stabilization	Alpine
Fulgensia bracteata	c	Grassland soil	Stabilization	Calcareous
Fulgensia fulgens	c	Grassland soil	Stabilization	Calcareous
Hypocenomyce scalaris	c	Burned wood		

Species	Common/ Rare	Species Group	Ecosystem Function	Indicator Value
Hypogymnia austerodes	c+	Conifer branches, foliose	Invertebrate habitat	Old growth
Hypogymnia enteromorpha	r	Conifer branches, foliose	Invertebrate habitat	Old growth
Hypogymnia imshaugii	c+	Conifer foliose		Old growth
Hypogymnia metaphysodes	r	Conifer branches, foliose	Invertebrate habitat	Old growth
Hypogymnia physodes	c+	Conifer branches, foliose	Nutrient cycling	Old growth
Hypogymnia tubulosa	c-	Conifer branches, foliose	Invertebrate habitat	Old growth
Icmadophila ericetorum	r	Shady moss, humus		Old growth
Imshaugia aleurites	c-	Conifers, foliose		Old growth
Lecanora argopholis	c-	Rock crust	Rock weathering	
Lecanora beringii	c	Detritus	Binding soil, detritus	Alpine meadow
Lecanora cenisia	c-	Rock crust	Rock weathering	
Lecanora crenulata	c-	Rock crust	Rock weathering	
Lecanora epibryon	c-	Moss, detritus	Binding soil, detritus	Alpine meadow
Lecanora garovaglii	c-	Rock crust	Rock weathering	
Lecanora hageni	c	Tree crust		
Lecanora muralis	c+	Rock crust	Rock weathering	
Lecanora novomexicana	c+	Rock crust	Rock weathering	
Lecanora piniperda	c	Tree crust		
Lecanora polytropa	c+	Rock crust	Rock weathering	
Lecanora pulicaris	c	Tree crust		

Lecanora rupicola	c	Rock crust	Rock weathering	
Lecanora thomsonii	c-	Rock crust	Rock weathering	
Lecidea atrobrunnea	c+	Rock crust	Rock weathering	Lowers albedo
Lecidea auriculata	c	Rock crust	Rock weathering	
Lecidea berengeriana	c	Moss, humus		Old growth
Lecidea elabens	c	Tree crust		Old growth
Lecidea marginata	c-	Rock crust	Rock weathering	
Lecidea plana	c	Rock crust	Rock weathering	
Lecidea tessellata	c	Rock crust	Rock weathering	
Lecidella euphorea	c	Rotting wood		Old growth
Lecidella stigmatea	c	Rock crust	Rock weathering	
Lecidoma demissum	r	Moss, soil crust	Soil stabilizing	
Lepraria neglecta	c-	Soil crust	Pioneer	Alpine
Leprocaulon subalbicans	c-	Soil crust	Pioneer	Alpine
Leproloma angardianum	c	Moss, soil crust	Pioneer	Alpine
Leptogium californicum	r	Moss on rock	N-fixer	
Leptogium gelatinosum	r	Moss on rock	N-fixer	Moist
Leptogium saturninum	c-	Moss on rock	N-fixer	Old growth
Letharia columbiana	c+	Conifer, fruticose	Forage	
Letharia vulpina	c+	Conifer, fruticose	Forage	
Massalongia carnosa	c	Rock, mossy	N-fixer	
Megaspora verrucosa	c	Detritus on soil	Binds soil, detritus	Alpine
Melanelia albertana	r	Moss on rock		
Melanelia elegantula	c-	Tree foliose	Invertebrate habitat	
Melanelia exasoeratula	c	Tree foliose	Invertebrate habitat	

Melanelia granulosa	c	Rock macrolichen	Invertebrate habitat	
Melanelia infumata	c	Rock macrolichen	Invertebrate habitat	
Melanelia sorediata	c	Rock macrolichen	Invertebrate habitat	
Melanelia stygia	c	Rock macrolichen		
Melanelia subelegantula	c	Tree foliose	Invertebrate habitat	
Melanelia subolivacea	c	Tree foliose	Invertebrate habitat	
Melanelia substygia	c	Rock macrolichen	Invertebrate habitat	
Micarea assimilata	r	Moss, soil crust	Binds soil, detritus	
Neofuscelia loxodes	c-	Rock macrolichen		
Nephroma parile	c	Moss, moss on rock	N-fixer	Moist
Ochrolechia androgyna	r	Tree crust		
Ochrolechia upsaliensis	c	Detritus,soi l	Binds soil, detritus	
Pannaria conoplea	r	Soil, moss crust		
Pannaria leucophaea	r	Moss on soil		Old growth
Pannaria pezizoides	c	Mossy soil crust	N-fixer	
Pannaria praetermissa	c-	Mossy soil crust	N-fixer	Old growth
Parmelia saxatilis	c	Rock macrolichen	Invertebrate habitat	
Parmelia sulcata	c+	Tree foliose	Invertebrate habitat	
Parmeliella cyanolepra	c-	Moss crust	N-fixer	Old growth
Parmeliopsis ambigua	c+	Tree foliose		
Parmeliopsis hyperopta	c+	Tree foliose		
Peltigera aphthosa	c+	Soil foliose	N-fixer	
Peltigera canina	c+	Soil foliose	N-fixer	
Peltigera collina	c	Soil foliose	N-fixer	

Peltigera horizontalis	c-	Mossy rock	N-fixer	
Peltigera kristinsonii	c	Soil, moss	N-fixer	
Peltigera malacea	c-	Soil, moss	N-fixer	
Peltigera rufescens	c+	Soil, moss	N-fixer, pioneer	
Peltigera venosa	c	Soil, moss	N-fixer	
Phaeophyscia constipata	c-	Rock macrolichen		
Phaeophyscia endococcinea	c-	Rock macrolichen		
Phaeophyscia orbicularis	c-	Rock macrolichen		
Phaeophyscia rubropulchra	r	Rock macrolichen		
Phaeophyscia sciastra	c-	Mossy rock macrolichen		Old growth
Phaeorrhiza nimbosa	c	Detritus, moss	Binds soil, detritus	Alpine
Physcia adscendens	c	Tree foliose	Invertebrate habitat	Excess N
Physcia aipolia	c	Tree foliose	Invertebrate habitat	
Physcia biziana	r	Rock macrolichen		
Physcia caesia	c	Rock macrolichen	Pioneer	
Physcia dubia	r	Rock macrolichen		
Physcia phaea	c	Rock macrolichen		
Physcia stellaris	c	Tree foliose		Deciduous
Physconia detersa	c-	Rock, tree foliose		
Physconia enteroxantha	c-	Moss on rock		Old growth
Physconia grisea	c-	Mossy rock		Old growth
Physconia muscigena	c+	Soil, moss	Binds soil	
Physconia perisidiosa	r	Moss on rock		
Placopsis gelida	r	Rock crust	N-fixer	
Placynthiella uliginosa	c-	Old logs		Old growth

Placynthium nigrum	c-	Rock crust		
Platismatia glauca	c	Conifer foliose	Invertebrate habitat	
Polychidium muscicola	r	Moss		Old growth
Porpidia macrocarpa	c-	Rock crust	Rock weathering	
Protoparmelia badia	c	Rock crust	Rock weathering	
Pseudephebe minuscula	r	Rock macrolichen		Alpine
Pseudephebe pubescens	c+	Rock macrolichen		Lowers albedo
Psora decipiens	c-	Soil crust	Soil stabilization	
Psora globifera	c	Soil, rock crevices		
Psora himalayana	c-	Soil	Soil stabilization	
Psora nipponica	c	Soil, rock crevices		
Psora rubiformis	c-	Soil	Soil stabilization	
Psora tuckermanii	c-	Soil	Soil stabilization	
Psoroma hypnorum	c	Mossy soil	Soil stabilization	
Rhizocarpon disporum	c-	Rock crust	Rock weathering	Lowers albedo
Rhizocarpon geminatum	c	Rock crust	Rock weathering	Lowers albedo
Rhizocarpon geographicurn	c+	Rock crust	Rock weathering	
Rhizocarpon grande	c	Rock crust	Rock weathering	
Rhizocarpon riparium	c	Rock crust	Rock weathering	
Rhizoplaca chrysoleuca	c	Rock macrolichen	Forage?	
Rhizoplaca haydenii	r	Soil vagrant		Alpine
Rhizoplaca melanophthalma	c+	Rock macrolichen	Forage	
Rimularia insularis	c-	On rock crusts		

Rinodina olivaceobrunnea	c	Soil, detritus	Soil stabilization	Alpine
Rinodina turfacea	r	Soil, detritus	Soil stabilization	Alpine
Solorina bispora	r	Soil	Soil stabilization	Alpine
Solorina crocea	c-	Soil	N- fixer	
Solorina spongiosa	r	Wet moss		Moist
Sporastatia polyspora	r	Rock crust		
Sporastatia testudinea	c	Rock crust	Rock weathering	Lowers albedo
Squamarina lentigera	c	Soil crust	Soil stabilization	Calcareous
Staurothele drummondii	r	Rock crust	Rock weathering	
Staurothele fissa	r	Rock crust	Rock weathering	
Staurothele fuscocuprea	c-	Rock crust	Rock weathering	
Stereocaulon alpinum	c	Soil fruticose	N-fixing	
Stereocaulon glareosum	c-	Soil fruticose	N-fixing	
Stereocaulon paschale	c-	Soil fruticose	N-fixing	
Stereocaulon tomentosum	c	Soil fruticose	N-fixing	
Tephromela armeniaca	c	Rock crust	Rock weathering	
Thamnolia subuliformis	r	Soil	Soil stabilization	Alpine
Thamnolia vermicularis	c	Soil	Soil stabilization	Alpine
Thelomma ocellatum	r	Wood	Wood decay	
Toninia caeruleonigricans	c-	Soil	Soil stabilization	
Toninia candida	c-	Moss on rock		Calcareous
Toninia squalida	c-	Moss on rock		
Trapeliopsis flexuosa	c-	Rotting logs, wood	Wood decay	Old growth
Trapeliopsis granulosa	c	Moss, detritus	Binds moss, detritus	Old growth
Tremolechia atrata	r	Rock crust		

Tuckermannopsis chlorophylla	c	Conifer foliose		
Tuckermannopsis merrillii	r	Conifer foliose		
Tuckermannopsis platyphylla	r	Conifer foliose		
Umbilicaria americana	c	Rock macrolichen		Moist shade
Umbilicaria decussata	r	Rock macrolichen		
Umbilicaria deusta	r	Rock macrolichen		Moist, old growth
Umbilicaria hirsuta	r	Rock macrolichen		
Umbilicaria hyperborea	c	Rock macrolichen		Lowers albedo
Umbilicaria kraschenínnikovii	c+	Rock macrolichen	Forage	Lowers albedo
Umbilicaria phaea	c-	Rock macrolichen		
Umbilicaria torrefacta	c	Rock macrolichen		
Umbilicaria vellea	c-	Rock macrolichen		Moist shade
Umbilicaria virginis	c+	Rock macrolichen	Forage	Lowers albedo
Usnea alpina	r	Conifer fruticose		
Usnea hirta	c-	Conifer fruticose	Forage	Air quality
Usnea lapponica	c+	Conifer fruticose	Forage	Air quality
Verrucaria glaucovirens	c-	Rock crust	Rock weathering	
Verrucaria nigrescentoidea	c-	Rock crust	Rock weathering	
Vulpicida pinastri	c	Tree foliose		
Vulpicida tilesii	c-	Alpine soil	Soil stabilization	Alpine
Xanthoparmelia chlorochroa	c-	Soil vagrant	Soil stabilization	Steppe
Xanthoparmelia coloradoensis	c	Rock macrolichen	Forage?	Alpine
Xanthoparmelia cumberlandia	c	Rock macrolichen		

Xanthoparmelia lineola	c	Rock macrolichen		
Xanthoparmelia mexicana	c	Rock macrolichen		
Xanthoparmelia novomexicana	c-	Rock macrolichen		
Xanthoparmelia plittii	c	Rock macrolichen		
Xanthoparmelia subdecipiens	c	Rock macrolichen		
Xanthoparmelia wyomingica	c	Soil vagrant	Soil stabilization	Alpine
Xanthoria candelaria	c-	Rock crust		Shady moist
Xanthoria elegans	c+	Rock crust	Rock weathering	Excess N
Xanthoria fallax	c+	Tree foliose		Excess N
Xanthoria polycarpa	c-	Tree foliose		
Xanthoria sorediata	c	Rock crust	Rock weathering	
Xylographa abietina	r	Tree crust		Old growth

TABLE 2. LIST OF LICHEN SPECIES IN THE YELLOWSTONE ECOSYSTEM BY SPECIES GROUPS: THE LICHEN SPECIES GROUPS ARE DESCRIBED IN MORE DETAIL IN THE TEXT. FOR EACH TYPE, THE MOST COMMON AND ABUNDANT SPECIES ARE LISTED IN FIRST GROUP **A** AND THE LESS COMMON SPECIES ARE IN A SECOND GROUP **B**. SPECIES OF SPECIAL INTEREST ARE NOTED SEPARATELY.

Species Characteristic of Conifer Forests -- Tree Substrates

Arboreal Fruticose Species

A. Bryoria fremontii (Tuck.) Brodo & D. Hawksw.
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.
Bryoria lanestris (Ach.) Brodo & D. Hawksw.
Letharia columbiana (Nutt.) Thomson
Letharia vulpina (L.) Hue
Usnea hirta (L.) Weber ex Wigg
Usnea lapponica Uainio

Bryoria abbreviata (Muell. Arg.) Brodo & D. Hawskw.
North America endemic, species of special interest

B. Alectoria imshaugii Brodo & D. Hawksw.
Alectoria sarmentosa (Ach.) Ach. subsp. sarmentosa
Bryoria *capillaris* (Ach.) Brodo & D. Hawksw.
Usnea alpina Mot.

Bryoria pseudofuscescens has been collected north of the Yellowstone Ecosystem; it may be present.

Foliose Lichens on Tree Branches

A. Hypogymnia austerodes (Nyl.) Rasanen
Hypogymnia imshaugii Krog
Hypogymnia physodes (L.) Nyl.
Melanelia elegantula (Zahlbr.) Essl.
Melanelia exasperatula (Nyl.) Essl.
Melanelia subelegantula (Essl.) Essl.
Melanelia subolivacea (Nyl. in Hasse) Essl.
Parmelia sulcata Tayl.

B. Hypogymnia enteromorpha Ach.) Nyl.
Hypogymnia metaphysodes (Asah.) Rass.
Hypogymnia tubulosa (Schaerer) Havaas
Platismatia glauca (L.) Culb. & C. Culb.
Tuckermannopsis chlorophylla (Willd. in Humb.) Hale
Tuckermannopsis merrillii (DuRietz) Hale
Tuckermannopsis platyphylla Tuck. Hale

Foliose Lichens on Tree Trunks

A. Also on tree branches
Hypogymnia austerodes
Hyppogymnia imshaugii
Hypogymnia physodes
Melanelia elegantula
Melanelia exasperatula
Melanelia subelegantula
Melanelia subolivacea
Parmelia sulcata

Tree bases

Parmeliopsis ambigua (Wulfen in Jacq.) Nyl.
Parmeliopsis hyperopta (Ach.) Arnold
Vulpicida pinastri (Scop.) J.-E. Mattson & Lai

Mostly on deciduous trees

Physcia adscendens (Fr.) H. Olivier
Physcia aipolia (Ehrh. ex Humb.) Furnr.
Physcia stellaris (L.) Nyl.
Xanthoria *fallax* (Hepp in Arn.) Arn.
Xanthoria polycarpa (Hoffm.) Rieber
Also includes species of Melanelia
Physcia species tend to grow with Xanthoria species

B. Imshaugia aleurites has been collected north of the Yellowstone Ecosystem; it may also be present in the Yellowstone Ecosystem

Tree Crusts

A. Buellia erubescens Arn.
Buellia punctata (Hoffm.) Mass.
Lecanora *hagenii* (Ach.) Ach.
Lecanora piniperda Koerber
Lecanora pulicaris (Pers.) Ach.

B. Caloplaca cerina (Ehrh. ex Hedwig) Th.Fr.
Candelaria *concolor* Dickson) B. Stein
Diplotomma penichrum (Tuck.) Szat.
Lecidea elabens Fr.
Ochrolechia *androgyna* (Hoffm.) Arnold
Xylographa abietina (Pers.) Zahlbr.

Rock Substrates

Macrolichens on Alpine Rock

A. Brodoa oroarctica (Krog) Goward
Pseudephebe *pubescens* (L.) M. Choisy
Rhizoplaca chrysoleuca (Sm.) Ach.
Rhizoplaca melanophthalma (DC in Lam. & DC.) Leuck. & Poelt
Umbilicaria *hyperborea* (Ach.) Hoffm.
Umbilicaria kraschenneninikovii (Savicz) Zahlbr.
Umbilicaria *virginis* Schaerer
Xanthoparmelia coloradoensis (Gyelnik) Hale

All are locally abundant so no secondary group is designated.

Macrolichens on Rock in Montane and Subalpine Zones

A. *Caloplaca* saxicola (Hoffm.) Nordin
Dermatocarpon miniatum (L.) Mann
Melanelia granulosa (Lynge) Essl.
Melanelia infumata (Nyl.) Essl.
Melanelia sorediata (Ach.) Goward & Ahti
Melanelia stygia (L.) Essl.
Melanelia substygia (Rasanen) Essl.
Parmelia saxatilis (L.) Ach.
Phaeophyscia endococcina (Koerber) Moberg
Phaeophyscia sciastra (Ach.) Moberg
Physcia caesia (Hoffm.) Furnr.
Umbilicaria torrefacta (Lightf.) Schrader

Xanthoparmelia cumberlandia (Gyelnik) Hale
Xanthoparmelia lineola (Berry) Hale
Xanthoparmelia *mexicana* (Gyelnik) Hale
Xanthoparmelia plittii (Gyelnik) Hale
Xanthoparmelia *subdecipiens* Vainio) Hale

Placopsis *gelida* (L.) Lindsay: a species of special interest because of rare occurrence

B. Dermatocarpon *intestiniforme* (Koerber) Hasse
Dermatocarpon moulinsii (Mont.) Zahlbr.
Dermatocarpon reticulatum Magnusson
Dermatocarpon rivulorum (Arnold) Dalla Torre & Sarnth.
Neofuscelia *loxodes* (Nyl.) Essl.
Phaeophyscia *constipata* (Norrlin & Nyl.) Moberg
Phaeophyscia orbicularis (Neck.) Moberg
Phaeophyscia rubropulchra (Degel.) Moberg
Physcia biziana (Mass.) Zahlbr.
Physcia callosa Nyl.
Physcia dubia (Hoffm.) Lettau
Physcia phaea (Tuck.) Thomson
Pseudephebe *minuscula* (Nyl. ex Arnold) Brodo & D. Hawsksw.
Umbilicaria americana sp.nov.
Umbilicaria decussata (Vill.) Zahlbr.
Umbilicaria deusta (L.) Baumg.
Umbilicaria hirsuta (Sw. ex Westr.) Ach.
Umbilicaria phaea Tuck.
Umbilicaria torrefacta (Lightf.) Schrad.
Umbilicaria *vellea* (L.) Ach.

Lichen Crusts on Rock

A. Acarospora chlorophana (Wahlenb. ex Ach.) Massal.
Acarospora fuscata (Nyl.) Arnold
Aspicilia caesiocinerea (Nyl. ex Malb.) Arnold
Candelariella aurella (Hoffm.) Zahlbr.
Candelariella vitellina (Hoffm.) Muell. Arg.
Dimelaena oreina (Ach.) Norman
Lecanora *muralis* (Schreber) Rabenh.
Lecanora novomexicana (B. de Lesd.) Zahlbr.
Lecanora polytropa (Hoffm.) Rabenh.
Lecidea atrobrunnea (Ramond in Lam. & DC.) Schaerer
Lecidella stigmatea (Ach.) Hertel & Leuck.
Porpidia macrocarpa (DC. in Lam. & DC.) Hertel & Schwab
Rhizocarpon disporum (Naeg. ex Hepp) Muell & Arg.
Rhizocarpon geminatum Koerb.
Rhizocarpon geographicum (L.) DC.
Sporastatia testudinea (Ach.) Massal.
Xanthoria elegans (Link) Th.Fr.
Xanthoria sorediata (Vainio) Poelt

B. Acarospora smaragdula (Wahlenb. in Ach.) Massal.
Aspicilia *candida* (Anzi) Hue
Aspicilea cinerea (L.) Koerber
Aspicilia supertegens Arn.
Bellemerea alpina (Sommerf.) Clauz & Roux
Bellemerea cinereorufescens (Ac;h.) Clauz. & Roux
Caloplaca *cladodes* (Tuck.) Zahlbr.
Caloplaca saxicola (Hoffm.) Nordin

Diploschistes scruposus (Schreber) Norman
Endocarpon pulvinatum Th.Fr.
Lecanora argopholis (Ach.) Ach.
Lecanora cenisia (Ach.)
Lecanora crenulata Hook.
Lecanora dispersa (Pers.) Sommerf.
Lecanora garovaglii (Koerber) Zahlbr.
Lecanora rupicola (L.) Zahlbr.
Lecanora thomsonii Magnusson (= Lecanora novomexicana?)
Lecidea auriculata Th.Fr.
Lecidea marginata Schaerer
Lecidea *plana* (Lahm in Koerber) Nyl.
Lecidea tessellata Floerke
Massalongia carnosa (Dickson) Koerber
Placynthium nigrum (Huds.) Gray
Protoparmelia badia (Hoffm.) Hafellner
Rhizocarpon grande (Floerke ex Flotow) Arnold
Rhizocarpon riparium Rasanen
Sporastatia polyspora Nyl.) Grumm.
Staurothele drummondii (Tuck.) Tuck.
Staurothele fissa (Tayl.) Zwackh.
Staurothele fuscocuprea (Nyl.) Zach.
Tephromela armeniaca (DC.) Hertel & Rambold
Tremolecia atrata (Ach.) Hertel
Verrucaria glaucovirens Grumm.
Verrucaria nigrescentoidea Fink
Xanthoria candelaria (L.) Th.Fr.

Lichens Growing on Lichens on Rock

Caloplaca epithallina Lynge
Rimularia insularis (Nyl.) Rambold & Hertel

Nitrogen-Fixing Species

A. Collema *tenax* (Swartz) Ach.
Nephroma *parile* (Ach.) Ach.
Pannaria praetermissa Nyl. in Chyd. & Furuhi.
Peltigera aphthosa (L.) Willd.
Peltigera *canina* (L.) Willd.
Peltigera *collina* (Ach.) Schrader
Peltigera malacea (Ach.) Funck
Peltigera rufescens (Weis) Humb.
Peltigera venosa (L.) Hoffm.

B. Collema coccophorum Tuck.
Collema flaccidum (Ach.) Ach.
Collema undulatum var. granulosum Laurer ex Flotow
Ephebe *solida* Bornet
Leptogium californicum Tuck.
Leptogium gelatinosum (With.) Laundon
Massalongia carnosa (Dickson) Koerber
Pannaria conoplea
Pannaria leucophaea (Uahl) P. Joerg.
Pannaria pezizoides (Weber) Trevisan
Parmeliella cyanolepra (Tuck.) Herre
Peltigera kristinssonii Vitik.
Polychidium muscicola (Swartz) Gray
Solorina crocea (L.) Ach.
Stereocaulon alpinum Laurer ex Funck
Stereocaulon *paschale* (L.) Hoffm.
Stereocaulon tomentosum Fr.

Lichens on Wood and Burned Wood

Cyphelium notarisii (Tul.) Blomb. & Forss.
Cyphelium tigillare (Ach.) Ach.
Thelomma ocellatum (Koerber) Tibell

Lichens on Rotting Logs and Tree Bases

A. Cladonia carneola (Fr.) Fr.
Cladonia cenotea (Ach.) Schaerer
Cladonia coniocraea auct. fide Ahti
Cladonia *deformis* (L.) Hoffm.
Cladonia fimbriata (L.) Fr.
Cladonia sulphurina (Michaux) Fr.
Lecidella euphorea (Floerke) Hertel
Trapeliopsis granulosa (Hoffm.) Lumbsch.

B. Cladonia bacillaris Nyl.
Cladonia ochrochlora Floerke
Placynthiella uliginosa (Schrader) Coppins & P. James
Trapeliopsis flexuosa (Fr.) Coppins & P. James

Lichens on Moss on Soil, Rock and Tree Bases

A. Lecidea berengeriana (Massal.) Nyl.
Physconia *detersa* (Nyl.) Poelt
Physconia enteroxantha (Nyl.) Poelt
Physconia grisea **(Lam.) Poelt**
Trapeliopsis granulosa (Hoffm.) Lumbsch.

B. Biatora *vernalis* (L.) Fr.
Icmadophila ericetorum (L.) Zahlbr.
Physconia perisidiosa (Erichs.) Moberg
Toninia *candida* (Weber) Th.Fr.
Toninia *squalida* (Schleicher x Ach.) Massal.

Macrolichens on Soil and Humus-Rich Soil

A. Cladonia cariosa (Ach.) Sprengel
Cladonia cervicornis (Ach.) subsp. verticillata (Hoffm.) Ahti
Cladonia chlorophaea (Floerke ex Sommerf.) Sprengel
Cladonia coccifera (L.) Willd.
Cladonia ecmocyna Leighton
Cladonia gracilis (L.) Willd.
Cladonia mateocyatha Robb.
Cladonia multiformis G.K. Merr.
Cladonia pyxidata (L.) Hoffm.

B. Cladina mitis (Wallr.) Hale & Culb.
Cladonia cornuta L.) Hoffm.
Cladonia multiformis G.K. Merr.
Cladonia pleurota (Floerke) Schaerer
Psoroma hypnorum (Vahl) Gray

Lichen Crusts on Detritus on Soil

A. Buellia papillata (Sommerf.) Tuck.
Caloplaca tiroliensis Zahlbr.
Diploschistes muscorum (Scop.) R. Sant.
Lecanora epibryon **(Ach.)** Ach.

Ochrolechia upsaliensis (L.) Massal.
Pachyospora (Megaspora) verrucosa (Ach.) Mass.
Phaeorrhiza nimbosa (Fr.) Mayrh. & Poelt
Physconia muscigena (Ach.) Nyl.
Rinodina olivaceobrunnea Dodge & Baker
Trapeliopsis granulosa (Hoffm.) Lumbsch.

B. Caloplaca stillicidiorum (Vahl) Lynge
Lecanora beringii Nyl.
Lecidoma demissum (Rutstr.) G. Schneider & Hertel
Micarea assimilata (Nyl.) Coppins
Rinodina turfacea (Wahlenb.) Koerber

Crusts on Soil

A. Acarospora schleicheri (Ach.) Massal.
Buellia elegans Poelt
Catapyrenium lachneum (Ach.) R. Sant.
Fulgensia bracteata (Hoffm.) Rasanen
Fulgensia fulgens (Swartz) Elenkin
Psora decipiens (Hedwig) Hoffm.
Psora globifera (Ach.) Mass.
Psora himalayana (Church. Bab. Timdal
Psora nipponica (Zahlbr.) G. Schneider
Psora rubiformis (Ach.) Hook.
Psora tuckermanii Anders. ex Timdal
Squamarina lentigera (Weber) Poelt
Toninia caeruleonigricans (Lightf.) Th.Fr.

B. Arthonia glebosa Tuck.
Candelariella terrigena Rasanen
Catapyrenium cinereum (Pers.) Koerber
Lepraria *neglecta* (Nyl.) Lettau
Leprocaulon subalbicans (Lamb) Lamb & Ward
Leproloma angardianum (Ovestedal) Laund.
Solorina bispora Nyl.

Macrolichens on Alpine Soil

A. Cetraria ericetorum Opiz.
Cetraria islandica (L.) Ach.
Cetraria nivalis (L.) Ach.
Cladonia pocillum (Ach.) 0. Rich.
Cladonia pyxidata (L.) Hoffm.
Coelocaulon muricatum (Ach.) Laundon
Dactylina madreporiformis (Ach.) Tucker
Peltigera rufescens (Weis.) Humb.
Thamnolia vermicularis (Swartz) Ach. ex Schaerer
Xanthoparmelia wyomingica (Gyelnik) Hale

Vagrant species: species of special interest

Aspicilia sp.
Dermatocarpon vagans Imsh.
Rhizoplaca haydenii (Tuck.) W. Weber

B. Coelocaulon aculeatum (Schreber) Link
Dactylina ramulosa (Hook.) Tuck.
Evernia divaricata (L.) Ach. - alpine variant
Stereocaulon alpinum Laurer ex Funck.
Stereocaulon tomentosum Fr.
Vulpicida tilesii Ach.) J.-E. Mattson & Lai

TABLE 3. ECOSYSTEM FUNCTIONS OF FUNCTIONAL GROUPS OF LICHEN SPECIES FOR AREA OF SOUTHWEST YELLOWSTONE NATIONAL PARK AND ADJACENT MONTANA AND WYOMING.

A "+" in a column indicates that one or more members of the functional group perform the indicated ecosystem function.

# - number of species in the functional group included in summaries
N = Nitrogen fixation
F = Forage for ungulates
SS = Soil stabilization, watershed control
W = Rock or wood weathering
LA = Lowers albedo
H = Invertebrate habitat
BN = Bird nests

SPECIES GROUP	#	N	F	SS	W	LA	H	BN
ORGANIC SUBSTRATES								
Charred wood	1							
Wood, fenceposts	3				+			
Rotting logs	11			+	+		+	
Detritus	15			+	+		+	
Moss on soil, rock	21	+		+			+	
On other lichens	2						+	
EPIPHYTES								
Foliose	21		?				+	+ +
Fruticose	12		+				+	+ +
Crusts	13						+	+
ROCK LICHENS								
Macrolichens	46		+			+	+ +	
Crusts	55				+ +	+	+	
SOIL LICHENS								
Nitrogen fixers	26	+	+	+			+	
Forest soil	14			+			+	
Fruticose alpine	16	+	+	+			+	
Vagrant	6		?	+			+ +	
Crusts	20	+		+			+	

TABLE 4. INDICATOR FUNCTIONS FOR SPECIES GROUPS IN THE YELLOWSTONE ECOSYSTEM

Air Qual = Air quality = indicator of high air quality
High N = indicator of excess nitrogen in system
$CaCO_3$ = indicator of calcareous rock or soil substrate
Old Growth = indicates long period of time without disturbance; applied to forest, steppe, and alpine ecosystems
Moist = wet seeps or moist creek and waterfall areas

SPECIES GROUP	# spp	Air Qual	High N	$CaCO_3$	Old Growth	Moist
ORGANIC SUBSTRATES						
Charred wood	1	+				
Wood fenceposts, stumps	3	+				
Rotting logs	11	+			+	
Detritus	15	+			+	
Moss on soil, rock	21	+			+	+
On other lichens	2	+				+
EPIPHYTES						
Foliose	23	+	+		+	
Fruticose	12	+			+	
Crustose	11	+	+		+	
ROCK LICHENS						
Macro	46	+	+		+	+
Crusts	55	+	+	+	+	
SOIL LICHENS						
Nitrogen-fixers	26	+			+	
Forest soil	14	+			+	
Fruticose	16	+			+	
Vagrant	6	+			+	
Crusts	20	+		+	+	

[FRUTCONI.ESP]

CONIFER FORESTS: ARBOREAL FRUTICOSE SPECIES (FORAGE)

1. Biogeography of taxonomic group

The species of this group are fruticose lichens on branches and trunks of conifer trees, characteristic of boreal conifer forests in the northern Rocky Mountains. The biogeography of most of them is either circumpolar or disjunct western North America - northern Europe (Brodo & Hawksworth, 1977; Poelt, unpublished keys). Since the greatest amount of forested land in the Rocky Mountains is national forest or national park, the federal lands are essential in their distribution. Yellowstone, Grand Teton, and Glacier national parks are heavily forested and also have fruticose arboreal lichen species.

2. a. List of major species

Bryoria fremontii (Tuck.) Brodo & D. Hawksw. - Disjunct W. North America- N. Europe, boreal
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.- Circumpolar boreal
Bryoria lanestris (Ach.) Brodo & D. Hawksw. - Circumpolar boreal
Letharia columbiana (Nutt.) Thomson - NW N. America-N Europe, boreal
Letharia vulpina (L.) Hue - NW N. America-N Europe, boreal
Usnea hirta (L.) Weber ex Wigg - Circumpolar boreal
Usnea lapponica Uainio (group) - Circumpolar boreal

Associated species:

Bryoria abbreviata (Muell. Arg.) Brodo & D. Hawksw. North America endemic; apparently widespread but not common or abundant.

b. Habitat associations, processes and requirements

The species are components of forests of *Pinus* contorta, Pseudotsuga menziesii, Abies lasiocarpa, *Picea* engelmannii, and *Pinus* albicaulis near the Continental Divide in southwestern Montana and Yellowstone National Park. *Pinus* ponderosa is not native in the Greater Yellowstone Ecosystem.

They require air of high quality, since tested species tend to be sensitive or moderately sensitive to air pollutants (Eversman, 1978; St. Clair & Newberry, 1993). The species are characteristic of relatively dry to moist forests, becoming larger in size, more robust, and in denser populations where more moisture is available, generally at the higher elevations. The lichen species and communities are most robust in older, mature forests of lodgepole pine, Douglas fir, and spruce/subalpine fir (old growth).

c. Distributions

Bryoria fuscescens, B. lanestris, Usnea hirta, and U. lapponica are circumboreal in conifer forests; Letharia vulpina, L. columbiana and Bryoria fremontii appear to be disjunct in conifer forests in western North 'America and northern Europe. Bryoria abbreviata is a North American endemic with a west coast affinity; it is apparently at the eastern edge of its range near Yellowstone Park and occurs only occasionally.

All of the species range from low elevations on lodgepole pine or Douglas fir to timberline on whitebark pine, generally in partial shade with some direct or indirect sunlight; Bryoria abbreviata is the species most likely to be found in the deepest shade.

d. Function in the ecosystem

In this region, anecdotes of elk, mule deer, and whitetail deer feeding on these arboreal lichens are common, but no quantified data are available.

The lichens photosynthesize, so they **are** primary producers. Since they are potentially metabolically active during warmer periods during the winter, their relative contribution to ecosystem primary production may be higher than their biomass may indicate.

Communities of fruticose lichens on branches intercept minerals as they wash through canopies; minerals are released when lichens fall as forest-floor litter. Some fruticose lichens are involved in mineral cycling of N, P, K, Ca, and Mg in Oregon forests (Pike, 1978). More recently, in California, N, Ca, Mg, Na, and Cl were enhanced in soils under oak by fruticose lichen litter (Knops, Nash & Schlesinger, Abstract, Fifth International Mycological Congress, Vancouver, August, 1994). The same kind of contribution is assumed to occur here, but no quantitative data are available.

Biomass, photosynthetic capabilities at low temperatures, and contributions to litter have not been measured; none of them fix nitrogen. Occasionally, invertebrates are found in collected specimens, so they may be habitat for some species. Birds use lichens as a casual or intentional part of their nests.

e. Sensitivity to disturbance

A primary disturbance is fire, usually wildfire; in eastern Montana, small tufts of Usnea hirta were found on shaded trunks of mature *Pinus* pondsrosa 19 years after the trunks had been charred by fire. Since no recolonization on charred tree trunks has been observed in Yellowstone Park, burned in 1988, recolonization time on living charred trees in this area is estimated at between six and 20 years. Bryoria lanestris and Letharia *vulpina* colonize tops of subalpine fir in mature lodgepole pine/subalpine fir/whitebark pine stands in an estimated eight to ten years (Eversman, et al., 1987).

Logging on public and private land, and clearing land for rural homes on private land decrease numbers of trees, impacting available substrate for arboreal lichens.

f. Trends in populations

The general trend of populations of arboreal lichens is probably downward, as forest stands are logged and cleared for country homes in the mountain residential and recreational areas.

Decreasing air quality in some locales may contribute to decreasing lichen populations, but the air quality in forested land in this region is good, except for intense smelting and refining areas near East Helena, so no decrease in lichens due to local point-source air pollution is expected in the Yellowstone Ecosystem.

3. **Less common arboreal fruticose lichens**

Alectoria imshaugii Brodo & D. Hawksworth. - Northwest North America
Alectoria sarmentosa subsp. sarmentosa - Northwest North America
Bryoria *capillaris* (Ach.) Brodo & D. Hawksw.- Circumpolar boreal moist
Usnea alpina Mot. - North American boreal (rare)

These four species have been reported from the Anaconda-Pintler Wilderness Area and vicinity in southwest Montana so are listed as possible species to be found farther south in the Snake River drainage (southwest Yellowstone National Park, Grand Teton National Park, Targhee National Forest).

4. **Preferred range of successional stages**

In Yellowstone Park, *Pinus contorta* is both a successional and a climax species on the rhyolite soils (DeSpain, 1983). Fruticose lichen species tend to be on the upper part of the trunk and higher branches (Eversman, et al., 1987) rather than on the lower part of tree trunks in pine forests.

Lichen growth increases in mature Douglas fir and spruce/subalpine fir stands, probably because of greater available moisture at higher elevations. Subalpine fir trunks are a substrate preferred over pines and spruce (Eversman, et al., 1987); subalpine fir bark is smoother and does not flake off as readily as the bark of pine and spruce.

Lesica, et al. (1990) found Bryoria species more abundant in second-growth forests (mean tree age 73 years) than in old growth (mean tree age 324 years). In my observations in the colder, drier Yellowstone region, the most copious Bryoria growth is in the oldest unburned forests, spruce/subalpine fir forests near Yellowstone Lake and the northeast part of Yellowstone Park which has not burned for at least 200 years.

5. **Habitat**

The above species are found in all the following vegetation cover classes: SAF206 (Englemann spruce-subalpine fir), SAF208 (whitebark pine), SAF210 (interior Douglas fir), and SAF218 (lodgepole pine) [Attachment 1].

Fruticose lichen species may colonize a forest stand during Structural Stage 2 (stem exclusion: open canopy) and become more common and abundant as stages age and provide more'substrate and generally moister, less windy conditions (Structural Stages 3-7). [Attachment 2].

Best fruticose lichen growth is in forests where fires are least often -- Fire Group Ten (LVI, 151-300), with less growth in moist lower subalpine communities (Fire Group Nine, LI, 76-150).

Small tufts of the fruticose species are in lodgepole pine (3 - PICO) stands. In some locations of infrequent fire where lodgepole pine or whitebark pine (PIAL, but no larch in the Yellowstone ecosystem) is old and large, Letharia *vulpina* and L. columbiana cover entire old, mostly sunny trees. Letharia species are the fruticose arboreal lichens most likely to be in the krummholz stands of Englemann spruce/subalpine fir (7 - ABLA/PIEN, plus PIAL) at timberline. All species of the arboreal group are best developed in the subalpine fir/Engelmann spruce continuous forest, with less robust communities in Douglas fir (4 - PSME). Farther west and north of the Yellowstone Ecosystem (Elkhorn and Big Belt Mountains), the same arboreal species are found in the ponderosa pine/Douglas fir type (17 - PIPO/PSME), with the less robust communities as in Douglas fir. Tufts of the arboreal species are occasionally found on Artemisia tridentata in Rocky Mountain juniper zones (13 - JUSC, 28 grass/forb).

6. **Environmental factors determining occurrence of arboreal fruticose lichens**

My best-guess estimate of the relative contribution of each of the following environmental factors is about .333 for each factor.

a. Old conifer species: lodgepole pine, Douglas fir, spruce, subalpine fir, whitebark pine. The lichens are generally not present in clearcuts, recently burned areas, valleys and riparian areas.

b. High air quality: many arboreal fruticose species, especially the genus Usnea, are sensitive to sulfur dioxide and ozone. Letharia species are considered relatively pollution-tolerant.

c. Adequate atmospheric moisture: best communities are developed at montane and subalpine elevations with lower temperatures and higher relative humidity and precipitation than in valleys. At timberline, desiccating winds decrease lichen growth.

7. Key ecological functions for the functional group: arboreal fruticose lichens

a. Forage for browsing animals (elk, deer, moose?), particularly in fall and winter.

a. Primary production: photosynthesis potential throughout the year with available moisture (melting snow), temperature near freezing, not just in summer.

c. Intercept minerals in throughfalls in canopies, concentrate them, and contribute to mineral (N, Ca, Mg, Na, Cl) enhancement in forest soils as litter

Decreasing abundance of the functional group decreases primary productivity and winter survival forage for browsing animals; in drier forests, more lichen growth is relatively higher in the canopy and is more inaccessible for forage. Decreasing arboreal fruticose species may change forest nutrient cycling influenced by lichen interception of minerals.

8. Special habitats

Oldest forests in the most moist habitats (e.g., Douglas fir in cold-air drainages, old spruce-fir in the higher subalpine) in the Yellowstone Ecosystem have the greatest amount of stable substrate for fruticose lichens, including branches and trunks. Protecting them from development seems critical for maintaining biodiversity.

9. **Issues** for **analysis**

Evidence is mounting that lichens, particularly fruticose species when abundant and robust, play an important role in nutrient cycling in a forest ecosystem. Data available from East Side Project forests, mainly in the forests more influenced by Pacific air flows, would be important in establishing contributions of lichens in forest ecosystems to nutrient availability and cycling.

10. **Unknown Information**

The biomass of lichens in most inland forests in climate regimes close to the Continental Divide has not been estimated; therefore, the relative contribution of lichens to litter mass, atmospheric nutrient interception, and nutrient cycling in these cold, dry forest systems is not known.

The value of fruticose arboreal species to the large ungulates of this area has not been quantified; observations of large mammals ingesting these lichens is anecdotal and their importance to diet is estimated only.

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[CONFOLIO.ESP]

CONIFER FORESTS: FOLIOSE LICHENS ON TREE BRANCHES

1. **Biogeography of taxonomic** group

The major group of species is in the Parmeliaceae, with species that are typical of northern Rocky Mountain coniferous forests. Their optimum survival is dependent on maintenance of mature conifer forests, most of which are in federal land -- national forest or national park. Distribution of species follows Goward, et al, (1994); Poelt, unpublished keys, and Wetmore (1967).

2. List of major foliose species on conifer branches

Hypogymnia austerodes (Nyl.) Rasanen - Circumpolar boreal
Hypogymnia imshaugii Krog - Western North America
Hypogymnia physodes (L.) Nyl. - Circumpolar
Melanelia elegantula (Zahlbr.) Essl. - Western North America
Melanelia exasperatula (Nyl.) Essl. - Circumpolar
Melanelia subelegantula (Essl.) Essl. - Western North America
Melanelia subolivacea (Nyl. in Hasse) Essl. - Western North America, Eastern North America, Western Europe
Parmelia sulcata Tayl. - Circumpolar boreal

3. Habitat associations, processes and requirements

The species in this list are most abundant on tree branches in mature conifer forests from low lodgepole pine to subalpine whitebark pine, spruce, and subalpine fir. Melanelia species are likely to also be collected from aspen, cottonwood, and hawthorne bark than the other genera. Foliose species often are intermixed with the fruticose arboreal lichen species on branches and on some trunks.

Hypogymnia species and Parmelia sulcata are more abundant on middle aged and older branches, but Melanelia species are frequently on relatively young branches and tips of trees as well as on older branches.

Most foliose lichens are moderately sensitive to air pollution; one of their growth requirements is unpolluted air. Both fruticose and foliose species have a role in nutrient and mineral cycling in forests (Pike, 1978).

C. **Distributions**

The foliose species listed above are widespread innorthwestern North America in conifer forests. Hypogymnia austerodes, H. physodes, and Melanelia exasperatula are circumpolar in boreal forests; Hypogymnia imshaugii, Melanelia elegantula, and M. subelegantula are more restricted to western North America (Esslinger, 1975). Melanelia subolivacea extends from western North America through eastern North America and western Europe. The species are found in southwestern Montana and northwestern Wyoming mostly on conifer branches, some young conifer trunks, and aspen in stands of lodgepole pine, Douglas fir, subalpine fir, and Engelmann spruce. The foliose species are less abundant on whitebark pine branches at and near timberline. Their elevational range is from high valleys (1818 m) to nearly alpine (2727 m).

Species of Hypogymnia which are very common and abundant in Douglas fir, Engelmann spruce, and subalpine fir forests, are very sparse in central parts of Yellowstone Park dominated by lodgepole pine, although robust Hypogymnia species are in other lodgepole pine stands on the periphery of and mountains surrounding Yellowstone Park. Hypogymnia, Melanelia, and Parmelia species in this group are generally montane more than high subalpine or timberline species. They appear to be somewhat more shade-tolerant than fruticose arboreal species, ‘although the two types frequently grow together.

d. Function in the ecosystem

They photosynthesize, so contribute to primary production of the ecosystem. They are part of forest floor litter and contribute to the nutrition system of the forest.

Invertebrates such as ticks and mites hide behind and under them. Photographs of bird nests frequently show foliose lichen species such as Parmelia sulcata as part of the nest-buiding materials. They do not seem to be a consistent part of the diet of large mammals as fruticose. species are; however, no stomach content analysis or direct observations have been recorded.

e. Sensitivity to disturbance

Fires burn them and their substrate, and, except for Melanelia spec-ies, they seem to recolonize more slowly than fruticose species; no foliose species were observed on charred ponderosa pine trunks after 19 years in eastern Montana and none have been observed recolonizing burned tree trunks in Yellowstone Park since the fires in 1988. However, small Melanelia thalli are observed on branches less than 10 years old on locally harvested Douglas fir used for Christmas trees, so Melanelia seems to colonize branches within 10 years. I estimate from observations on lichens toward the top of subalpine fir in a 150-year old forest of lodgepole pine with small numbers of subalpine fir and whitebark pine, at about 2121 m in Yellowstone Park, that it takes about 10-15 years to become established on bark (Eversman, et al., 1987), but many more years to form large thalli.

Tree cutting for timber and clearing space for homes and recreational facilities in montane areas remove substrate and change light regimes; this might favor Melanelia, but not Hypogymnia species.

f. Trends in gogulatipns

The general trend of populations of arboreal foliose lichens is probably downward, as forest stands are logged for timber and cleared for development in mountain residential and recreational areas. Trees (substrates) disappear and clearing changes light and wind conditions for lichens, probably adversely; in an already relatively dry continental climate, increasing light and decreasing relative humidity stress shade-tolerant species. However, as noted above, Melanelia colonizes young Douglas fir and subalpine fir branches and bole tips and this genus may be increasing.

Air quality in this region is generally good, so no downward trends due to air pollution have been noted.

3. Less common (conspicuous) arboreal lichens

Hypogymnia enteromorpha (Ach.) Nyl. - Western North America
Hypogymnia metaphysodes (Asah.) Rass. - Western N.A.-E. Eurasia
Hypogymnia tubulosa (Schaerer) Havaas - Circumpolar boreal
Platismatia glauca (L.) Culb. & C. Culb. - Circumpolar ± boreal
Tuckermannopsis chlorophylla (Willd. in Humb.) Hale
Circumpolar ± boreal
Tuckermannopsis merrillii (DuRietz) Hale - Western North America
Tuckermannopsis *platyphylla* Tuck. Hale - Western North America

These species are more common in more moist forests of northwestern North America than they are in drier inland forests near the Continental Divide in the Yellowstone Ecosystem. Since they have been reported from southwestern Montana, they are listed as possible species present in the Snake River drainage.

Platismatia *glauca* and *Lobaria* pulmonaria (the latter is not in the Yellowstone Ecosystem) are part of the epiphytic lichen mass that increases cycling of some minerals (N, P, K, Ca, Mg) in Oregon forests (Pike, 1978). In forests where large Hypogymnia thalli grow on and fall off branches of conifers, they may be significant instruments in nutrient cycling

4. Preferred range of successional stages

The major foliose species listed above are on twigs and branches of lodgepole pine, which is sometimes successional and sometimes climax in Yellowstone Park; the same species are also on Douglas fir, Engelmann spruce, subalpine fir, and to a lesser extent on whitebark pine near timberline. There is more lichen growth on branches than on trunks of conifers in the Yellowstone Ecosystem. They are in all successional stages of forests, but best developed on subalpine fir in lower subalpine communities. The same suite of lichen species can also be found in ponderosa pine/Douglas fir forest types north and west of the Yellowstone Ecosystem, but is not as robust as in moister Douglas fir, Engelmann spruce, and subalpine fir stands. As a stand ages, the growth of all the species becomes more robust; nearly 100% of conifer branches can be covered with *Hypogymnia* imshaugii.

5. Habitat conditions

The foliose arboreal species grow in the Yellowstone Ecosystem, decreasingly from most robust to least robust, in the following SAF Western Forest Cover Types: SAF206 (Engelmann spruce/subalpine fir); SAF210 (interior Douglas fir); SAF209 (whitebark pine); SAF208 (lodgepole pine) [Attachment 1].

Melanelia species seem to be pioneers, colonizing young conifers and can be part of Structural Stage 1 (Stand Initiation) through the oldest stages. [Attachment 2]. Robustness of the other genera/and species is best in older' structural stages when trees are older and larger -- stages 4 (Understory Reinitiation) through 7 (Old Forest Single Stratum).

The foliose lichen groups grow best in montane zones where fires are least frequent, Fire Groups Ten (cold upper subalpine, LVI, 151-300) and Nine (moist lower subalpine, LI, 76-150). They occur in lower numbers and robustness in timberline stands (LEI, 300+), presumably because of harsh weather conditions, and where fires are more frequent, (e.g., Fire Group Five, dry Douglas fir, NLF, 26-75).

This group of lichen species occurs in the following Overstory-Understory groups [Attachment 41: lodgepole pine (3, PICO; 28 grass/forb understory); Douglas fir (4, PSME; 28, grass/forb understory); subalpine fir/Engelmann spruce (7, ABLA/PIEN); lodgepole pine (3 with 25, ABLA/PIEN understory). Near-timberline whitebark pine (PIAL) also occasionally has these species but subalpine larch is not native in the Yellowstone Ecosystem. Best growth is in the subalpine fir/Engelmann spruce zone (7).

6. **Key Environmental Factors**

Environmental factors contributing to the best growth of foliose lichens on trees are below. Relative contribution of each factor is estimated at about .40 for the first two factors, and .20 for the third.

a. Stable substrate of adequate age: long periods of no logging, fires or clearing for development

b. Adequate moisture: higher subalpine/elevations have more robust communities than lower, drier forest stands. The continental climate of the Yellowstone Ecosystem is less conducive to foliose lichen growth than the milder, moister conditions of the Pacific Northwest.

c. High air quality: absence of air pollutants, particularly sulfur dioxide and ozone

7. Key functions of arboreal foliose lichen species

a. Mineral and element cycling
b. Animal forage?
c. Invertebrate habitat

In areas where the *Hypogymnia* and Melanelia species are robust, they seem to form a conspicuous part of the litter on the ground. If they were not present, mineral cycling in the forest system would probably be decreased.

8. Special habitats

Undisturbed, old forest stands in subalpine fir/Englemann spruce zones, with some canopy openings, not deep shade, are sites where the best foliose lichen communities develop.

9. Specific issues for analysis

Contributions of foliose (and fruticose) arboreal species to nutrient cycling in the cold dry forests in the Yellowstone Ecosystem are not known; studies comparable to those of Pike (1978) and Knops, et al. in California (see below) would be appropriate.

10. Unknown information

No data have been collected for the inland forests near the Continental Divide in southwestern Montana and western Wyoming on contributions that lichens make to nutrient cycling in the forests, their importance to litter, or mineral interception from throughfall. While biomass of lichens in these relatively dry forests is low, the entire forest systems are less productive than coastal forests and those under more Pacific influence farther west of the Yellowstone Ecosystem; relative contribution of lichens in some areas might be considerable. None of them are nitrogen-fixers, as many foliose arboreal species farther northwest are.

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[TRUNKSCN.ESP]

FOLIOSE LICHENS ON TREE TRUNKS

Some of the same foliose species characteristic of conifer tree branches are also common on tree trunks (boles). Other species are characteristic of conifer tree bases, and yet others are more common on deciduous trees, mostly aspens and cottonwoods. The functional group "Foliose Lichens on Tree Trunks" will be divided into three groups: 1) Common foliose species also on branches; 2) Species mostly on bases of conifer trunks (boles); 3) Species more common on deciduous trees (aspen, cottonwood) than on conifers.

1. Biogeography of taxonomic group

The species in the lists below are common and abundant components of coniferous forests in the Yellowstone Ecosystem. Their distributions are generally broad, circumpolar boreal and/or temperate, with the species occurring in most forests.

2. a. List of major species

1) **Foliose species on tree boles,** also abundant on conifer branches. In the Yellowstone Ecosystem, the species are generally fairly high on the trunk, not at the base.

Hypogymnia austerodes (Nyl.) Rasanen - Circumpolar boreal.
Hypogymnia imshaugii Krog – Western North America
Hypogymnia physodes (L.) Nyl. - Circumpolar boreal
Melanelia elegantula (Zahlbr.) Essl. – Western North America
Melanelia exasperatula (Nyl.) Essl. - Circumpolar
Melanelia subelegantula (Essl.) Essl. – Western North America
Melanelia subolivacea (Nyl. in Hasse) Essl. - Western N. America
Parmelia sulcata Tayl. – Circumpolar boreal

2) **Species on bases of conifers.** In some cases, the species are also found higher on the trunk, especially on subalpine fir, but on most lodgepole pines and Douglas fir they are generally at the base.

Parmeliopsis ambigua (Wulfen in Jacq.) Nyl. - Circumpolar
Parmeliopsis hyperopta (Ach.) Arnold – Circumpolar
Vulpicida pinastri (Scop.) J.-E. Mattsson & Lai Circumpolar

3) **Species mostly on aspen or cottonwood bark (deciduous trees)**

Physcia adscendens (Fr.) H. Olivier – Circumpolar boreal temp
Physcia aipolia (Ehrh. ex Humb.) Furnr. - Circumpolar boreal temperate
Physcia stellaris (L.) Nyl. – Circumpolar

Melanelia species are also frequent on bark of deciduous trees. Physcia species tend to be associated with Xanthoria *fallax*. Xanthoria *fallax* and X. polycarpa are usually considered minutely foliose and may be included in this section; they are also considered crusts on trees in another section.

b. Habitat associations, processes and requirements

The first two groups of species are characteristic of epiphytic foliose species on conifers near the Continental Divide in southwestern Montana and northwestern Wyoming. They are on all species of conifers -- lodgepole pine, Douglas fir, Englemann spruce, subalpine fir, and whitebark pine. Their abundance on tree trunks depends on age and texture of the bark; very scaly bark of lodgepole pine, whitebark pine, and Englemann spruce is somewhat less hospitable to foliose lichen growth than the smoother subalpine fir and grooved Douglas fir.

The best development of the foliose communities on tree trunks is probably above one's head among the branches, with the exceptions of Parmeliopsis ambigua and Vulpicida pinastri, which rarely grow above the base of the tree. Physcia species and Xanthoria *fallax* prefer bark of aspen, cottonwood, hawthorne and other deciduous trees, but also grow on subalpine fir.

All the species require stable substrate, adequate moisture, and unpolluted air. Presence of Xanthoria and Physcia species indicates an excess of available nitrogen.

c. Distributions

Distributions in the Yellowstone Ecosystem are wide, in all types of forests; they are least well developed in dry lodgepole pine stands and best developed, most robust in higher, moister subalpine fir/Engelmann spruce stands. Cottonwoods along larger streams and mature aspen groves are habitats for most of the corticolous Physcia species and Xanthoria *fallax*.

d. Function in the ecosystem

Ticks and mites live under foiiose species on bark of trees. Their use as food is not known; slugs and snails that feed on lichens in other parts of the country are not in the Yellowstone Ecosystem and large mammals have not been documented feeding on tree foliose species as they have on fruticose. Lichens are primary producers, so contribute photosynthate to the ecosystem, and may have a role in mineral and nutrient cycling in forests as litter.

e. Sensitivity **to disturbance**

The greatest disturbance is disappearance of conifer substrate because of logging for timber and clearing for recreational and residential development. Recolonization time on appropriate substrates is not known, but is probably at least 20 years, except for species of Melanelia which may colonize smooth bark surfaces within 10 years. Many species are at least moderately sensitive to air pollutants, particularly sulfur dioxide and ozone.

f. Trends in populations

The basic trend of species on conifers is probably downward as forests and tree stands disappear for timber and recreational and residential development. However, as more deciduous species are planted in landscaping, species of Physcia and Xanthoria *fallax* may increase. There is no evidence that decreasing air quality has affected lichens in the Yellowstone Ecosystem.

3. **Species not included in #2**

Imshaugia aleurites (Ach.) S. F. Meyer has been collected north of the Yellowstone Ecosystem, and may be present in the Snake River drainage; it has a circumpolar distribution but is not common in Montana.

4. **Successional stages**

The species of all three functional groups **are** more abundant and robust in mature conifer stands than in young; the species on conifers are more robust in Douglas fir and spruce/subalpine fir stands than in successional or climax lodgepole pine or in timberline whitebark pine stands. Mature cottonwoods and aspens are more likely than young saplings to have lichen species on them.

5. **Habitat**

The species on conifers are in the following **Vegetation** Cover **Classes:** SAF206 (Engelmann spruce/subalpine fir); SAF208 (whitebark pine); SAF210 (interior Douglas fir); and SAF218 (lodgepole pine), with Melanelia and Physcia (with Xanthoria *fallax*) in SAF217 (aspen) and SAF235 (cottonwood - willow). [Attachment 11.

With the apparent exception of Melanelia species which can colonize young smooth bark in about 10 years, colonization of lichens on their tree substrates generally takes at least 20-30 **years**, so the Structural Stages [Attachment 21 where lichens form visible thalli is Structural Stage 3 (Stem Exclusion: Closed Canopy) on medium-sized trees. As the Structural Stages proceed, lichen growth tends to increase in robustness and density, especially in Douglas fir and Engelmann spruce/subalpine fir forests.

The best, most robust communities of foliose lichens on conifer tree boles are in Engelmann spruce/subalpine fir forests, Fire Groups Nine (Lethal, infrequent, LI, 76-150) and Ten (Lethal, very infrequent, LVI, 151-300). Foliose lichen communities are also in Douglas fir habitat types, Fire Group Five (nonlethal, frequent, NLF, 26-75), and even less well-developed in Fire Group Seven (lodgepole pine; mixed, frequent, MF 26-50). Timberline ribbon forests and islands of mostly whitebark pine are in Fire Group Zero, rarely burns. [Attachment 31.

Physcia *adscendens*, P. aipolia, P. stellaris, and Xanthoria *fallax,* with Melanelia elegantula and M. subolivacea are most abundant on cottonwoods in riparian areas that **seem** to fit Fire Regime Class Zero (rarely burns) best, or in aspen groves that are in Fire Groups Nine, Seven, and Five. [Attachment 31. This group is **most** abundant in the Overstory Type 12 (Hardwood - *Acer,* Populus) with Understory Types 28 (grass/forb) or 29 (shrub). [Attachment 4].

Overstory types that have the first two groups of foliose lichens are lodgepole pine (3, PICO), Douglas fir (4, PSME), subalpine fir, Engelmann spruce (7, ABLA/PIEN), and farther north and west of the Yellowstone Ecosystem, ponderosa pine, Douglas fir (17, PIPO/PSME). Understory species are either grass/forb (28) or shrub (29).

6. **Environmental factors which determine occurrence**

The first two environmental factors are rated .40 'apiece, with the third factor contributing .20. In the second group, each factor is about .50.

For the two first groups -- [*Hypogymnia,* Melanelia, Parmelia] and [Parmeliopsis, Vulpicida pinastril-- environmental factors are:

a. Presence of conifer stands at least 30-50 years old; the older the stand, the more robust the lichen communities. Douglas fir and subalpine fir/spruce have better-developed lichen communities than lodgepole pine or whitebark pine.

b. Montane climate: more moisture than valleys, less harsh than alpine

c. High air quality.

The group with Physcia species and Xanthoria *fallax* favors:

a. Bark of deciduous trees (Populus tremuloides, P. angustifolia) at least **20-30** years old

b. Lack of browsing on bark by large mammals (elk), a common occurrence on aspen.

c. High air quality

7. Key functions of lichen species on tree trunks

a. Nutrient cycling (litter)
b. Invertebrate habitat
c. Forage?

Removing foliose lichens from tree trunks would probably have the largest effect on forest element cycling; however, foliose lichens on tree trunks are not **as** abundant in the cold, dry Yellowstone forests as they are in more moist, warmer conifer forests in areas of Pacific influence.

8. Special habitats

In the Yellowstone Ecosystem, foliose species are most abundant on trunks of subalpine fir and deciduous species, aspen, cottonwood, and hawthorne. Spruce and Douglas fir also have thalli of the foliose species. Habitats with deciduous trees and subalpine fir, therefore, are the most advantageous for foliose species on tree trunks.

9. **Specific issues for analysis**

These groups are less conspicuous in the Yellowstone Ecosystem than in moister forests to the northwest; they do not seem to be especially problematic.

10. Unknown information

Contributions of these species to animal forage, nutrient cycling in forests, and primary productivity are not known.

[TREECRST.ESP]

CRUSTOSE SPECIES ON TREES: TREE CRUSTS

With the exceptions of minutely foliose orange Xanthoria *fallax* and X. polycarpa, these are rather inconspicuous residents of tree branches and trunks. Most of the species reported in this section have been collected from conifers, but some also occur on deciduous trees.

1. Biogeography of functional group

The distribution of most species is widespread in North American and European boreal forests, on both conifers and deciduous trees. Their distribution is not as dependent on federal lands, national forests and parks, as fruticose and foliose arboreal species. They often grow at lower elevations which are more frequently private land holdings. Tree crust lichen species are generally more tolerant of air pollution than fruticose and foliose species.

Federal lands contribute to the distribution of the species, especially those on conifers; deciduous trees with lichens on them are frequently at lower elevations on public and private lands.

2. a. List of major species

Buellia erubescens Arn. – Western North America-Europe
Buellia punctata (Hoffm.) Mass. – Cosmopolitan
Lecanora *hagenii* (Ach.) Ach. – Boreal
Lecanora piniperda Koerber – Boreal
Lecanora pulicaris (Pers.) Ach. – Boreal
Xanthoria *fallax* (Hepp in Arn.) Arn. – Cosmopolitan

b. Habitat associations, processes and requirements

The tree crust species are characteristic of conifer branches and bark on the upper part of the trunks more than at tree bases. Their functions in ecosystems are not clear; they probably offer some habitat and food to small invertebrates. The most conspicuous member of this group is Xanthoria *fallax* which is most common on deciduous trees, including aspens, cottonwoods, and horticultural shrubs and green ash in towns; it is usually associated with Physcia adscendens and P. aipolia and indicates an excess of nitrogen. The crusts grow under and among the fruticose and foliose species on the branches. Crustose species on forest trees can be used as indicators of age and continuity of tree stands (Tibell, 1992).

c. Distributions

The species are generally widely spread throughout the Rocky Mountains, including the Yellowstone Ecosystem. They are in all forest types -- lodgepole pine, Douglas fir, spruce/subalpine fir and, to a lesser extent, whitebark pine -- on bark of conifers and deciduous trees.

d. Function in the Ecosystem

They probably function as food and microhabitat for small invertebrates, and help in decomposition and cycling of minerals in old dead outer bark on **branches and trees and dead wood.**

e. Sensitivity to disturbance

As a general rule, crustose species are less sensitive to air pollution than are fruticose and foliose species. In a lodgepole pine stand more than 150 years old, Lecanora piniperda recolonized the top of subalpine fir at about the same time *Hypogymnia* austerodes did, in 15-20 years. The crusts tend to be more abundant in middle-aged and old branches than in young ones.

f. Trends in populations

Species on shaded mature conifers are probably decreasing as forest stands are cut for timber and development. However, they also grow on deciduous trees, which increase with conifer clearing and development, so their populations as a whole would seem to be increasing slightly.

3. **Species not included in Group 2**

Caloplaca cerina (Ehrh. *ex* Hedwig) Th.Fr. - Circumpolar boreal temp.
Candelaria concol or (Dickson) B. Stein - Circumpolar temperate
Diplotomma penichrum (Tuck.) Szat. - Circumpolar boreal
Lecidea elabens Fr. - Boreal
Ochrolechia androgyna (Hoffm.) Arnold -Circumpolar arctic temperate
Xanthoria polycarpa (Hoffm.) Rieber - Circumpolar
Xylographa abietina (Pers.) Zahlbr. - Pan-boreal

Species of this group have been rarely collected in the Yellowstone Ecosystem and southwestern Montana; they appear to be more characteristic of moister conifer forests and deciduous trees than of high, dry continental forests.

4. **Preferred range of successional stages**

The species prefer late successional stages to earlier ones. The best-developed crusts on conifers are on older mature Douglas fir, lodgepole pine, Engelmann spruce, and subalpine fir, with some also on subalpine whitebark pine. Likewise, older but not necessarily oldest aspens and cottonwoods have crusts on their bark.

5. **Habitats**

Xanthoria *fallax* grows on big sagebrush, Artemisia tridentata, so it can be found in CRB002 (mixed grass-agriculture-shrubland) and SRM402 (mountain big sagebrush). All the crust species are found in SAF206 (Engelmann spruce/subalpine fir), SAF208 (whitebark pine), SAF210 (interior Douglas fir), SAF217, aspen), SAF218 (lodgepole pine), and to a lesser extent in SAF235 (cottonwood-willow).

The species communities are best developed in later structural stages where trees are mature, Structural Stages 4-7. (Attachment 21.

The species are presumably rather slow growing, so they are most common and abundant in forests where fires are infrequent -- Fire Groups Nine (moist lower subalpine, LI, 76-150) and Ten (cold upper subalpine, LVI, 151-300). Colonization occurs when trees are younger, but substrates and lichens disappear in fires. [Attachment 3]

The overstory species in the Yellowstone Ecosystem are lodgepole pine (3, PICO), Douglas fir (4, PSME), subalpine fir/Engelmann spruce (7, ABLA/PIEN), hardwood (12, Populus, *Acer*), and, when on sagebrush, Rocky Mountain juniper

(13, JUSC). Understory species are 25 (ABLA/PIEN) under old lodgepole Pine, 28 (grass/forb), 29 (shrub), or 30 (bare ground).

6. Environmental factors that determine occurrence

The first two environmental factors are estimated to each contribute about .40 to realized fitness of the species, with the other two factors each contributing about .10.

a. Mature conifer or hardwood trees

b. Adequate moisture

c. Lack of browsing by large ungulates on tree branches

d. High air quality (some species)

7. Functions in the ecosystem

a. Xanthoria species, along with associated Physcia species, indicate excess nitrogen where they occur.

b. Invertebrate habitat

c. Weathering and decomposition of dead bark and wood

The species are relatively inconspicuous on trees, and their loss from a system would not immediately be noticed. However, they probably play a role in weathering and eventual recycling of outer dead bark of the trees. Invertebrate populations may be adversely affected by decreasing populations of these species.

8. Special habitats

Most species in this group are like other forest lichens -- they grow best where forests have been undisturbed for hundreds of years. Old forests that are protected from timbering and development have the best lichen growth. However, in areas of heavy air pollution, tree crusts are frequently the only type of epiphytic lichen; some species can be indicators of poor air quality.

9. Specific issues for analysis

Where forests are protected for growth of the more conspicuous fruticose and foliose lichens, the crusts will also be most abundant.

10. Areas of unknown information

Their contribution to bark mineral cycling and forest nutrient cycling as a whole is unknown.

Tibell, L. 1992. Crustose lichens as indicators of forest continuity in boreal coniferous forests. Nordic Journal of Botany 12: 427-450.

[ROCKALP.ESP]

MACROLICHENS ON ALPINE ROCK

1. Biogeography of taxonomic group

This group of species includes macrolichens that grow on rock in alpine meadows (fellfields and Geum turf), boulder fields, rock of patterned ground, bedrock and outcrops. They. along with several crustose species, are the only alpine rock species. Most saxicolous species are circumpolar at high latitudes, extending southward at high elevations above 5000-7000 feet (1910-2320 m). The distribution of most of these rock macrolichens tends to be less specific to arctic-alpine locations than arctic-alpine soil lichens but some of the macrolichens in this section are most characteristic of rock above timberline (more than 2828 m in elevation). Distributions noted in this report follow those of Egan (1971), Hale (1990), and Thomson (1979). Alpine is defined as high elevations at and above krummholz timberline; subalpine extends slightly below timberline from island and krummholz stands to the continuous forest.

The lands at the highest elevations in western Montana and Wyoming that contain this set of lichens tend to be federal lands -- national forests (Flathead, Deerlodge, Beaverhead, Lewis and Clark, Helena, Gallatin, Custer, Shoshone, Bridger-Teton, Targhee) and national parks (Glacier, Yellowstone, and Grand Teton). However, state and private lands at lower elevations in Montana and Wyoming also have many of the same saxicolous species. The most extensive study of alpine lichens in this region has been on the Beartooth Plateau including Custer and Showhone National Forests (Eversman, ms in preparation), adjacent to Yellowstone National Park. Since many of the same species occur in alpine, subalpine, and montane regions in Glacier and Yellowstone National Parks (DeBolt & McCune, 1993; Eversman, 1990), it is assumed that these species are a major component of rock lichen communities in high mountains of western Montana and Wyoming.

2. **a. List** of **Major Species: Alpine and Subalpine Rock Macrolichens**

Brodoa oroarctica (Krog) Goward - Circumpolar arctic alpine
Pseudephebe *pubescens* (L.) M. Choisy - Circumpolar alpine-subalpine
Rhizoplaca chrysoleuca (Sm.) Ach. - Circ. arctic-boreal-temperate
Rhizoplaca melanophthalma (DC in Lam. & DC.) Leuck. & Poelt
Circumpolar arctic-boreal-alpine
Umbilicaria hyperborea (Ach.) Hoffm. - Circumpolar arctic boreal
Umbilicaria kraschenninikovii (Savicz) Zahlbr. - Circ., NW N America
Umbilicaria *virginis* Schaerer - Circumpolar arctic alpine
Xanthoparmelia coloradoensis (Gyelnik) Hale Western North America

Xanthoparmelia coloradoensis is restricted in range to the western United States, Mexico, and Hawaii (Hale, 1990); the other species are circumpolar arctic-alpine.

b. Habitat associations, processes and requirements

All the rock substrates considered in this report are granitic and basaltic, none are calcareous. Macrolichens that extend downward through montane and valley elevations are considered in the separate section "Macrolichens on Rock in Montane and Subalpine Zones".

The lichen species require undisturbed, sunny exposed rock that is stable, not being moved by glaciers, frost heaving, rock slides, rock glaciers, mining, or road-building. Rock must also be free from trampling by feet or vehicles, and not shaded by taller vascular plants.

Rock macrolichens apparently thrive best under low snow conditions, O-25 cm of snow per year, in sites where they can be free of snow more than 150-200 days per year (Walker, et al., 1993). These sites tend to be tops of slight ridges where winds are nearly unremitting. Benedict (1990a) documented disappearance of transplanted Umbilicaria *virginis* within three years when covered by snow 282-299 days per year.

Since they are metabolically adapted to cold temperatures and can photosynthesize during relatively warm periods in winter months (Longton, 1988), it is possible that their contribution to primary production of an alpine system is relatively large.

c. **Distributions**

The species in this group have wide distributions -- most are cirumpolar arctic-alpine-boreal and are common on rock in valleys as well as mountains. Umbilicaria hyperborea tends to be more abundant at lower elevations than U. virginis; both grow with U. kraschenninikovii. Xanthoparmelia coloradoensis is primarily alpine and subalpine, and Brodoa oroarctica is exclusively alpine.

Saxicolous macrolichens thrive best where rocks are snow-free more than 150-200 days per year, which explains their presence in windy, rockier sites rather than depressions with more snow depth. Lichen communities observed on the Beartooth Plateau verify trends also observed by Flock (1979) and Willard (1979) in Colorado.

d. Function **in ecosystem**

The rock species listed above are about 6.0% of the total vegetation cover in dry, windy rocky fellfields; they are 2.0% of the total vegetation cover in less windy, less rocky alpine turfs (Eversman, ms. in prep). They photosynthesize, so they are primary producers. Their contribution to alpine primary productivity may be more important than their cover percentage indicates, since they are adapted to cold harsh conditions and can remain metabolically active year-round (Kappen, 1993; Longton, 1988).

A primary role is in rock weathering, the first step in soil formation. Although frost action is important in alpine and subalpine locations, the combined physical and chemical actions of lichens increases weathering rate (Adamo, et al., 1993; Ascaso, et al., 1990; Lawrey, 1984).

Rhizoplaca chrysoleuca, Umbilicaria kraschenninikovii, and U. *virginis* are forage species, identified from the rumens of mountain goats killed by hunters in the Beartooth Mountains in 1993 (Varley and Eversman, ms. in prep.); in one goat, the percentage of lichen was 2.5% of the total rumen food content. They lick lichen off rock, apparently especially from vertical cliffs and wind-swept rock when snow is deep. Recent video footage shows the golden-mantled ground squirrel (Spermophilus lateralis) licking and chewing lichen from rock in a high pass in Glacier National Park (Donnell White, unpublished); the lichen species are not obvious but look in the video like yellow-green and gray foliose species (Xanthoparmelia coloradoensis? Physcia?)

Small invertebrates are sometimes found under larger thalli, but less under saxicolous species than terricolous and muscicolous species.

The macrolichens with dark pigments -- Pseudephebe *pubescens* and some thalli of Umbilicaria, along with dark crustose species -- may decrease albedo of alpine areas with light-colored granitic rock and high snow cover.

e. **Sensitivity to disturbance**

Foot traffic along trails and at visitor centers removes lichen growth. Recolonization on rock in mine spoils on the Beartooth Plateau by small thalli of *Umbilicaria* sp. is occurring 50 years after the mine closed (Eversman, ms. in prep.).

Sensitivity to air pollutants is not known; in cases of acid precipitation flushes or ozone, some species may be impacted but sensitivity of most alpine species to pollution is not clear. Sigal in Lawrey (1984) reported concentric rings of necrotic tissue in Umbilicaria *mammulata* in Tennessee, perhaps due to acid deposition.

Manipulation of snow deposition or a climate change toward colder, wetter weather that build more snow depth would cause death of saxicolous lichens, particularly faster-growing species in the genus Umbilicaria (Benedict 1990a). Global change toward warmer climates would spread vascular vegetation farther upward in elevation; increases in vascular vegetation would shade and outcompete present alpine lichen communities, decreasing soil and rock alpine lichen communities:

f. **Trends in populations of rock macrolichens**

The trend of rock lichens in areas of road construction and proposed mining activities (e.g., the Beartooth Plateau) is or will be downward; disturbance and inversion of rock surfaces destroys lichen growth on them. On the other hand, where activities stop, colonization apparently occurs within 50 years and population trends are upward. The current geologic stability of many alpine meadows indicates that populations of rock macrolichens are generally stable.

3. **Secondary macrolichens on rock in alpine habitats**

Brodoa oroarctica, Rhizoplaca chrysoleuca, Umbilicaria hyperborea, and Xanthoparmelia coloradoensis are less common and abundant than the other four macrolichens designated alpine macrolichens, but they are locally abundant so no secondary group is designated.

4. **Successional stages for alpine macrolichens**

Lichens are principal organisms in primary succession on bare rock surface; since moss cover on rock is almost nonexistent in alpine communities of this area, lichens are almost the only organisms in primary succession.

'The rock surfaces with lichens are in mature undisturbed, stable communities -- boulder fields, outcrops, rock in inactive patterned ground, fellfield -- not currently subject to movement from frost heaving, rock slides, glacial activity, etc.

5. **Habitats**

Attachment #1 lists Alpine Tundra as CRB005, the CRB Specific Cover Type. Alpine meadows are in Fire 'Group Ten, with lethal, very infrequent fires (LVI, 151-300).

When available rock substrates extend downward in elevation, they cross Fire Group Zero (canyons, ribbon forests; rarely burns) and Fire Group Nine (lower subalpine; lethal, infrequent; LI, 76-150).

6. **Environmental factors for each functional group**

The key environmental factors are alpine, with harsh winds, intense solar radiation, and temperature extremes; but perhaps these have the secondary effect of reducing competition. My estimate of direct environmental factors are about .5 for each of these factors:

a. Stable rock substrate: not disturbed by construction, rock slides, frost heaving, foot traffic

b. Snow: snow depth of O-50 cm per year, that can blow off or melt to provide a minimum of 150-200 snow-free days per year. At least four snow-free weeks per summer.

7. Key ecological functions for alpine macrolichens

a. Primary succession on rock surfaces

b. Rock weathering

c. Animal forage

d. Invertebrate habitat

e. Lower albedo in areas of light bedrock

f. Esthetics: adding color to monochromatic rock landscapes

Decreasing macrolichens on rock would have the greatest influence on rock weathering rates, although in high elevations, freeze-thaw cycles are also important in rock weathering. Since there are few mosses that colonize alpine rock sites in this region, primary succession would also slow down. Food for some mammals (mountain goats) would decrease, as would invertebrate habitat. To this observer, lack of the colorful lichen growth would make for a more bland, uninteresting landscape in high elevations.

8. Special habitats

Most of the pristine alpine habitat required for well-developed rock communities occurs on federal land, particularly in the National Forests and National Parks. Wilderness areas where no mining or road-building can occur are probably especially important. Well-developed communities of saxicolous lichens occur where there are few disturbances -- stability of the rock surfaces, little trampling, sunny exposed sites, and (probably) pollution-free air.

9. Issues for analysis

Subalpine and alpine areas close to roads may serve as sources of rock with lichens for home construction, where colorful rocks are popular for walls and fireplaces. This may be detrimental to some areas considered valuable for their scenic attractions. Supplies of such construction rock from National Forest land should be monitored. It takes 50 years to begin to recolonize rock surfaces at about 3000 m, and many more years to obtain mature thalli and communities.

10. Unknown information

The sensitivity of most saxicolous species to air pollution is not known. Large areas of Montana and Wyoming mountains are granitic and volcanic, with no buffering calcareous minerals, and are considered to be susceptible to sulfur and nitrogen oxides in precipitation, particularly snow melt flushes in the spring.

Relative contributions of lichens to primary productivity of alpine systems is unknown; they can be metabolically active and photosynthesize during parts of the year when vascular plants are not.

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[ROCKBOR.ESP]

MACROLICHENS ON ROCK IN MONTANE AND SUBALPINE ZONES

Some rock macrolichens -- Pseudephebe *pubescens,* Rhizoplaca chrysoleuca, R. malanophthalma, Umbilicaria kraschenninikovii -- range from valley elevations to alpine, their primary requirement apparently being unshaded, exposed substrate. Other saxicolous species are not in alpine regions. This section addresses foliose and umbilicate lichens on rock that have not been collected in the high alpine regions in Yellowstone Park or on the Beartooth Plateau. Their distribution in the Yellowstone Ecosystem tends to be montane and subalpine, below timberlines.

Xanthoria elegans, a minutely foliose species, is considered under the section dealing with rock crusts.

1. **Biogeography of saxicolous foliose and umbilicate lichens**

In general, these lichens have not been found on high alpine rock above timberline (>2800 m). Their distribution is either circumpolar boreal or more limited to parts of North America. In some cases they are listed as being only on calcareous rock, but no collections in this report were made from calcareous rock so they can also live on granitic, rhyolitic and other kinds of volcanic rock. Distributions are based on Esslinger (1975), Goward, et al. (1994) , Thomson (1979, 1984), and Wetmore (1967). Nomenclature follows Egan (1987).

Federal lands, national parks and national forests, are essential in their distribution and since rock substrates also extend downward in elevation into state and private lands, those holdings are also important. Rock containing these lichens can be commercially important for construction of businesses and residences; they are collected and transplanted, leading to visually denuded landscapes.

2. a. List of macrolichens (foliose, umbilicate) on sunny exposed rock below timberline

Caloplaca saxicola (Hoffm.) Nordin - Western North America
Dermatocarpon miniatum (L.) Mann - Circumpolar boreal
Melanelia granulosa (Lynge) Essl. - North America-W. Eurasia
Melanelia infumata (Nyl.) Essl. - North America-W. Eurasia
Melanelia sorediata (Ach.) Goward & Ahti - Circumpolar boreal
Melanelia stygia (L.) Essl. - Circumpolar boreal
Melanelia substygia (Rasanen) Essl. - Circumpolar boreal
Parmelia saxatilis (L.) Ach. - Circumpolar boreal
Phaeophyscia endococcina (Koerber) Moberg - Circumpolar
Phaeophyscia sciastra (Ach.) Moberg - Circumpolar
Physcia caesia (Hoffm.) Furnr. - Circumpolar
Umbilicaria torrefacta (Lightf.) Schrader Circumpolar
Xanthoparmelia cumberlandia (Gyelnik) Hale North-South America
Xanthoparmelia lineola (Berry) Hale - Western U.S. - Southern Hemisphere
Xanthoparmelia *mexicana* (Gyelnik) Hale Cosmopolitan
Xanthoparmelia plittii (Gyelnik) Hale North-South America
Xanthoparmelia subdecipiens (Vainio) Hale North-South America

Species of **special concern:** Placopsis *gelida* (L.) Lindsay

This species has been collected only once in this region, from a partly sunny basaltic cliff face in the Gallatin Range north of Yellowstone Park. Its distribution is listed as circumpolar arctic-temperate, with oceanic influence (Thomson, 1979); If it is in the eastern part of the region considered in the East Side Project, it should be other places also.

b. Habitat associations, processes and requirements

Rock substrates include boulders, rock and outcrops in fields, subalpine meadows, and in limber, lodgepole, and whitebark pine forests. They are also in sunny openings in Douglas fir and spruce/subalpine fir forests. In general, the species grow together in various configurations, but Physcia species tend to be in somewhat more protected habitats associated with mosses.

They are on rock with or without associated crustose species; they sometimes grow over slower-growing crustose thalli. Lichens on rock are primary producers, and primary succession organisms, contributing to weathering and soil formation.

c. Distributions

On a broad scale, the species are distributed either in a circumpolar North America – northern European axis or in a north-south axis in North and South America (with some interesting distributions in the southern hemisphere, also).

They are reported from the arctic (Thomson, 1979) but are not alpine in the Yellowstone Ecosystem. They are most abundant in high mountain valleys (more than 1515 meters) through montane to subalpine (less than 2870 m). Benedict (1990b) demonstrated cold temperature injury to Xanthoparmelia lineola, X. plittii, and X. subdecipiens, and to a lesser extent Melanelia substygia, Physcia caesia, Umbilicaria vellea, Rhizoplaca chrysoleuca, R. melanophthalma, and Umbilicaria hyperborea in Colorado, which indicates that some macrolichens cannot tolerate the extreme cold and harshness of alpine environments.

d. Function in the ecosystem

They are organisms of primary succession on bare rock surface; their rhizine growth, expansion and contraction with wetting and drying, chemical weathering due to lichen acids, and trapping of blowing soil particles all contribute to eventual weathering of rock surface to soil (Adamo, et al., 1993; Lawrey, 1984). It is possible that in cold climates with freeze-thaw cycles lichens are less important than in warm climates without such cycles, but rock under lichen pads is usually softer and more crumbly than bare rock.

They provide habitat for small invertebrates, and since they photosynthesize, they are primary producers. Lichens with dark brown and black pigments growing on light-colored rock substrates can lower the total albedo of the ecosystem.

If esthetics are important in perception of ecosystems, lichens on rock are the subject of more photographs than bare rock (except by geologists, perhaps). They are becoming economically important as more lichen-covered rock are being used in landscaping and walls and fireplaces in home and business construction.

e. Sensitivity to disturbance

Stable rock surfaces are necessary for lichen colonization; mining, construction, glacial and other geologic activity turn over lichen-covered surfaces and at the same time expose new surfaces for colonization. Based on a rock wall at about 1818 m in a valley mouth with cold-air drainage, a mature lichen community with many species and relatively little rock surface (mostly basaltic) has formed in about 60 years. In an observed alpine regions, colonization of a rock surface takes more than 50 years. Recovery from disturbance depends on the location.

A long-lasting increase in snow cover that buries rock surfaces for more than 150-200 days per year causes death and disappearance of rock lichens (Benedict, 1990; Walker, et al, 1993). Weather modification programs or changing precipitation and wind patterns that build snow deposition would cause death of rock macrolichens that are under snow most of the year.

f. Trends in populations

Populations of the groups are probably stable since they are not adversely affected by removal of forest shade by logging or development. However, population trends in areas where rock is being taken for landscaping are probably downward. Most lichens do not transplant particularly well and grow slowly.

3. Other species

Dermatocarpon intestiniforme (Koerber) Hasse - Circumpolar
Dermatocarpon moulinsii (Mont.) Zahlbr. - Circumpolar ±
Dermtocarpon reticulatum Magnusson – Western North America
Dermatocarpon rivulorum (Arnold) Dalla Torre & Sarnth. - Circumpolar
Neofuscelia *loxodes* (Nyl.) Essl. - Western N. America-W. Eurasia
Phaeophyscia *constipata* (Norrlin & Nyl.) Moberg - North America-Western Eurasia
Phaeophyscia orbicularis (Neck.) Moberg - Circumpolar ±
Phaeophyscia rubropulchra (Degel.) Moberg - Circumpolar boreal temperate
Physcia biziana (Mass.) Zahlbr. - Western North America
Physcia callosa Nyl. - Western North America
Physcia dubia (Hoffm.) Lettau – Circumpolar arctic boreal
Physcia phaea (Tuck.) Thomson.- N. America – Western Eurasia
Pseudephebe *minuscula* (Nyl. ex Arnold) Brodo & D. Hawksw. - Circumpolar arctic-alpine (rare)
Umbilicaria americana sp. nov. – North America boreal
Umbilicaria decussata (Vill.) Zahlbr. – Circumpolar
Umbilicaria deusta (L.) Baumg. – Circumpolar
Umbilicaria hirsuta (Sw. ex Westr.) Ach.
Umbilicaria phaea Tuck. – Western North America
Umbilicaria torrefacta (Lightf.) Schrad – Circumpolar
Umbilicaria vellea (L.) Ach. - Circumpolar

Umbilicaria americana and U. vellea are characteristic of very moist rock along streams. Species of Physcia and Phaeophyscia are usually on mostly shaded rock with mosses. The other species are occasional on mostly exposed rock at elevations below alpine. Most of them have a wide geographical distribution, circumpolar in boreal areas, but some are more restricted to North America.

4. Preferred range of successional stages

The lichens themselves are on bare rock surface, so they are primary succession organisms. However, rock surfaces covered with macrolichens are part of a mature, undisturbed ecosystem in late successional stages.

5. Habitat

Substrates for the rock lichens can be in many of the Vegetation Cover Classes: CRB001 (agricultural land use); CRB002 (mixed grass-agriculture - shrubland); CRB003 (seral shrubland-regeneration); CRB004 (subalpine herbaceous); CRB006 (barren); SAF206 (Engelmann spruce/subalpine fir); SAF208 (whitebark pine); SAF210 (interior Douglas fir); SAF218 (lodgepole pine); SRM101 (bluebunch wheatgrass); SRM104 (antelope bitterbrush-bluebunch wheatgrass); SRM304 (Idaho fescue - bluebunch wheatgrass); SRM421 (chokecherry-serviceberry-rose); SRM607 (wheatgrass-needlegrass). [Attachment 11.

Lichens growing on sunny, exposed rock can be part of a mature grassland or an opening in a mature forest. On the assumption that a disturbance to forest will disturb associated rock communities, mature rock 'communities will be associated with older forest structural stages, 4-7.

Lichens on rocks are subject to fire effects similar to the vascular plants around them, so the least disturbed rock communities will be where fire occurs least often: Fire Group Nine (subalpine, LI, 76-150); Fire Group Ten (LVI, 151-300); and Fire Group Zero (rocky, rarely burns) [Attachment 3].

Dominant overstory species in the Yellowstone Ecosystem include lodgepole pine (3, PICO); Douglas fir (4, PSME); Engelmann spruce/subalpine fir (7, ABLA/PIEN), and 13 (Rocky Mountain Juniper). Understory species are generally grass/forb (28). shrub (29), or bare ground (30). [Attachment 4].

6. Environmental factors determining occurrence of the saxicolous species

The factors listed contribute to the occurrence of the species; I estimate about .50 for stable rock, substrate, and .25 for each of the other factors:

a. Stable rock substrate

b. Adequate moisture

c. Snow-free more than 150-200 days per year

7. Key functions for subalpine and boreal saxicolous macrolichens

a. Rock weathering

b. Invertebrate habitat

c. Animal forage

d. Lower albedo (dark species on light rock)

These species are important elements of ecosystems in rock weathering and invertebrate habitat, and perhaps in animal forage. Esthetically, their disappearance from a landscape would be highly conspicuous to the trained eye and subtle and probably undefined to a more casual observer.

8. Special habitats

Rock undisturbed by trampling, fires, rock and earth movement, and changes in snow deposition patterns are needed by most macrolichens.

9. Specific issues for analysis

Collection of rocks that have these lichens growing on them may be an issue in some easily accessible roadside locations that also have scenic value.

10. Unknown information

Sensitivity to air pollutants for most of these species is unknown, as is their contribution to forage for large ungulates that abound in the Yellowstone Ecosystem.

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[ROCKCRST.ESP]

LICHEN CRUSTS ON ROCK

1. Biogeography of group

The large group of lichens forming crusts on rock has a wide geographical distribution, generally circumpolar arctic alpine, with distributions that extend south from the arctic to alpine and subalpine rocks in the Rocky Mountains. Distributions are from Egan (1971), Poelt (unpublished keys in English), Thomson (1979), and Wetmore (1967).

2.a. List of species

Acarospora chlorophana (Wahlenb. ex Ach.) Massal. Circumpolar arctic alpine
Acarospora fuscata (Nyl.) Arnold - North temperate-polar
Aspicilia caesiocinerea (Nyl. ex Malb.) Arnold - Circumpolar arctic alpine
Candelariella aurella (Hoffm.) Zahlbr. - Circumpolar arctic alpine
Candelariella vitellina (Hoffm.) Muell. Arg. - Circumpolar
Dimelaena oreina (Ach.) Norman - Circumpolar arctic alpine temperate
Lecanora *muralis* (Schreber) Rabenh. - Circumpolar boreal temperate
Lecanora novomexicana (B. de Lesd.) Zahlbr. - Western United States
Lecanora polytropa (Hoffm.) Rabenh. - Circumpolar alpine arctic boreal
Lecidea atrobrunnea (Ramond in Lam. & DC.) Schaerer - Circumpolar arctic alpine

Lecidella stigmatea (Ach.) Hertel & Leuck. - Circumpolar arctic alpine
Porpidia macrocarpa (DC. in Lam. & DC.) Hertel & Schwab - Circumpolar arctic alpine temperate
Rhizocarpon disporum (Naeg. ex Hepp) Muell & Arg. - Circumpolar arctic alpine
Rhizocarpon geminatum Koerb. - Circumpolar arctic alpine
Rhizocarpon geographicum (L.) DC. - Circumpolar arctic alpine
Sporastatia testudinea (Ach.) Massal. - Circumpolar arctic alpine
Xanthoria elegans (Link) Th.Fr. - Cosmopolitan
Xanthoria sorediata (Vainio) Poelt - Circumpolar arctic alpine

b. Habitat associations, processes and requirements

The species inhabit generally sunny exposed rock in elevations from valleys to alpine, 3400 m. Most rock in the Yellowstone Ecosystem is not calcareous; bedrock and boulders are granitic or derived from volcanic flows, andesite or basaltic, and all these species are found on the non-calcareous rock. Xanthoria elegans and X. sorediata are indicators of nitrogen deposits by animals and birds. Rhizocarpon geographicum grows at the mouths of fumaroles in thermal areas in Yellowstone Park.

c. Distributions

Rock substrates are generally in open fields and meadows at all elevations, and in clearings in all forest types. The lichen species seem to be likewise distributed in all vegetation types, wherever appropriate rock substrate is located.

d. Function in the ecosystem

The rock crusts are active in rock weathering (Adamo, 1993; Lawrey, 1984), although their importance' is debated. The soft, usually crumbly rock under lichen crusts seems to indicate they are important, even in this area of constant freeze-thaw cycles.

Where dark-pigmented species (Aspicilia caesiocinerea, Lecidea atrobrunnea) are abundant on light-colored rock in high-snow areas, they probably decrease albedo of the ecosystem.

Mountain goats, golden-mantled ground squirrels, and other mammals have been observed feeding on macrolichens; they probably coincidentally ingest rock crusts also. Crusts may be habitats for small invertebrates.

Color on rock is esthetically pleasing in landscapes, and such rock attracts the attention of visitors, photographers, architects, and designers (see below).

e. Sensitivity to disturbance

Their sensitivity to air pollutants is not generally known. When rock is disturbed during construction, mining or geologic activity, it takes more than 50 years for rock to be recolonized in alpine areas. Trampling along trails disturbs lichen crusts on rock. The trend of using lichen-covered rock in construction of homes and businesses is not particularly beneficial to lichens (see below).

f. Trends in population

In areas of geologic activity, mining, and construction, the populations are decreasing. Where such activity stops, populations slowly recover. Moving lichen-covered rock to homes and businesses in environments where they are not native, and where they may be exposed to more air pollution, promotes a definite downward trend in rock crust lichens.

3. Secondary species

Acarospora smaragdula (Wahlenb. in Ach.) Massal.
Circumpolar arctic alpine
Aspicilia *candida* (Anzi) Hue - Circumpolar arctic
Aspicilia cinerea (L.) Koerber - Circumpolar arctic alpine
Aspicilia supertegens Arn. - Circumpolar arctic alpine
Bellemerea *alpina* (Sommerf.) Clauz & Roux - Arctic-boreal
Bellemerea cinereorufescens - Circumpolar arctic alpine
Caloplaca *cladodes* (Tuck.) Zahlbr. - Circumpolar arctic alpine
Caloplaca saxicola (Hoffm.) Nordin - North America
Diploschistes scruposus - Schreber) Norman - Circumpolar
Endocarpon pulvinatum - Circumpolar ±, wet rock
Lecanora argopholis (Ach.) Ach. - Arctic-boreal
Lecanora cenisia (Ach. - Panboreal
Lecanora crenulata Hook. - Circumpolar arctic alpine
Lecanora dispersa (Pers.) Sonunerf. - Arctic boreal
Lecanora garovaglii (Koerber) Zahlbr. - Circumpolar arctic alpine
Lecanora rupicola (L.) Zahlbr. - Circumpolar boreal alpine
Lecanora *thomsonii* Magnusson - Arctic alpine (= Lecanora novomexicana?)
Lecidea auriculata Th.Fr. - Circumpolar arctic alpine
Lecidea marginata Schaerer - Circumpolar arctic alpine
Lecidea *plana* (Lahm in Koerber) Nyl. - Arctic alpine
Lecidea tessellata Floerke - Circumpolar temperate
Massalongia carnosa (Dickson) Koerber - Circumpolar arctic alpine
Placynthium nigrum (Huds.) Gray - North temperate - Boreal
Protoparmelia badia (Hoffm.) Hafellner - Circumpolar arctic alpine
Rhizocarpon grande (Floerke ex Flotow) Arnold - Circumpolar
arctic boreal temperate
Rhizocarpon riparium Rasanen - Circumpolar arctic alpine

Sporastatia polyspora (Nyhl.) Grumm. - Arctic alpine
Staurothele drummondii (Tuck.) Tuck. - Arctic alpine
Staurothele fissa (Tayl.) Zwackh. - Europe-North America arctic
Staurothele fuscocuprea (Nyl.) Zsch. - Circumpolar arctic alpine
Tephromela armeniaca (DC.) Hertel & Rambold - Circumpolar arctic alpine
Tremolecia atrata (Ach.) Hertel - Arctic alpine
Verrucaria glaucovirens Grunun. - Boreal - temperate
Verrucaria nigrescentoidea Fink - Temperate
Xanthoria candelaria (L.) Th.Fr. - Cosmopolitan (also on bark)

The extensive list of secondary species is generally circumpolar arctic-alpine and boreal in distribution, but less abundant, especially the species of Staurothele and Verrucaria, at the highest elevations than the first group. Massalongia carnosa and Placynthium nigrum have cyanobacteria and are nitrogen-fixers, usually on calcareous rock. Endocarpon pulvinatum and Staurothele fissa indicate wet rock.

Population trends are similar to those of the species in the major list -- where they grow on rock in undisturbed areas, their populations are probably stable or increasing. However, they decrease in numbers where rock is disturbed by geologic forces, construction, mining, and collection for landscaping and home decor.

4. **Preferred range of successional stages**

The lichens themselves are pioneers, primary successors on rock substrates, and the crusts are frequently overgrown by faster-growing macrolichens. Rock substrates are in stabilizing conditions or, for maximum lichen crust development, in mature undisturbed habitats.

5. Habitats

Rocks with lichen crusts are in a variety of vegetation types [Attachment 11: CRB005, alpine tundra (mostly members of the first group); CRB006 (barren, although with lichen growth I don't consider it barren); SAF206 (Engelmann spruce/subalpine fir); SAF208 (whitebark pine); SAF210 (interior Douglas fir); SAF218, (lodgepole pine); SRM101 (bluebunch wheatgrass) ; SRM104 (antelope bitterbrush-bluebunch wheatgrass); SRM107 (juniper-big sagebrush-bluebunch wheatgrass); SRM304 (Idaho fescue-bluebunch wheatgrass); SRM402 (mountain ? big sagebrush); SF34607 (wheatgrass-needlegrass).

The rocks with lichen crusts can be in open sites in any of the Structural Stages, l-7 [Attachment 2].

Lichens on rock are susceptible to fire damage and crusts are best developed in areas with the least fire frequency [Attachment 3]: Fire Group Zero, Rarely Burns; LEI, 300+; Fire Group Ten, upper subalpine and timberline (LVI, 151-300); and Fire Group Nine, moist lower subalpine (LI, 76-150).

6. **Key environmental factors determining occurrence**

The first two factors are estimated to each contribute about .45 to relative fitness, with the third factor about .10:

a. Stable rock substrates

b. Lack of shading by overstory

c. High air quality

7. **Functions in ecosystem**

a. Primary succession, rock weathering

b. Lower albedo

c. Invertebrate habitat

d. Esthetics

Decreasing populations of rock crusts would decrease rates of primary succession and rock weathering, and in some ecosystems where dark lichens cover light-colored rock, albedo would be reduced. Scenic value would be reduced in areas where scenic value is considered a resource.

8. **Special habitats**

Undisturbed rock cliffs, outcrops, and boulders are necessary for rock crusts. Some species are usually on calcareous substrates (*Aspicilia candida,* Verrucaria glaucovirens), and Staurothele fissa usually is on rock that is frequently wet.

9. **Specific issues for analysis**

Preserving rock with crusts in highly visible areas from collection for landscaping and decor might be an issue in areas high in scenic value.

10. **Unknown information**

Quantitative data are not available for effects on albedo, and there is disagreement about the extent to which lichens contribute to rock weathering.

LICHENS GROWING ON OTHER LICHENS

1. **Biogeography of group**

The two species are circumpolar arctic-alpine, wherever rock crusts grow. Federal lands with rock outcrops and boulders with mature lichen crusts contribute significantly to the distribution of the two species.

2.a. Species

Caloplaca epithallina Lynge - Circumpolar arctic alpine
Rimularia insularis (Nyl.) Rambold & Hertel - Arctic alpine

b. Associations, processes and requirements

The two lichens are on crusts of Aspicilia, Lecanora, Lecidea, Rhizocarpon and other lichen species on rock.

c. **Distributions**

Caloplaca epithallina is widespread in boreal, subalpine, and alpine areas where crusts of host genera cover rock. Rimularia insularis has a preference for Lecanora rupicola, and is never very abundant.

d. Function in the ecosystem

They are epiphytic on other lichens.

e. **Sensitivity to disturbance**

They are subject to the same kinds of disturbance their host species are -- construction, mining, geologic movement, long-lying snow cover -- and take longer to recover from disturbance since they grow on crusts which themselves take much more than 50 years to develop.

f. **Trends in populations**

Their populations are down in areas of disturbance of rock, but stable and increasing where rock and lichen substrates are undisturbed.

3. No secondary species are known.

4. **Preferred range of successional stages**

Lichen crusts are primary succession organisms on rock surfaces; the epiphytes on them are late-succession species. Rocks that have well-developed crusts with epiphytes are in old stable ecosystems.

5. Habitats

Rock crusts are generally on boulders and outcrops that are stable, in subalpine and alpine areas, CRB004 (subalpine herbaceous) and CRB005 (alpine tundra). They are also in clearings in high elevation forest types, SAF206 (Engelmann spruce/subalpine fir), SAF208 (whitebark pine), and in the Yellowstone Ecosystem, the ubiquitous lodgepole pine (SAF218).

6. Environmental factors determining occurrence

Stable rock substrate with mature lichen crusts on them are the primary environmental factor determining their occurrence.

7. Functions in the ecosystem

They are apparently not parasitic, but epiphytic on other lichens; however, they shade and may inhibit some of the physiological processes on the portions of lichens on which they are growing.

8. Special habitats

The species growing on other lichen species are characteristic of old stable rock communities that indicate areas of little or no disturbance in high elevation habitats.

9. Issues for analysis

Activities that disrupt lichen crusts on rock, including mining, construction, development and collection for landscaping, will contribute to decline of these species.

10. Areas of unknown information

Degree to which they disrupt physiological activity of the species on which they grow is not clear.

[NFIXSOIL.ESP]

NITROGEN FIXING LICHENS

1. Biogeography of group

The nitrogen fixing lichen species in the Greater Yellowstone Ecosystem are on soil and moss on the forest floor, soil or rock. The cyanobacterium in most of them is Nostoc, which contains the enzyme complex nitrogenase that fixes atmospheric nitrogen. Fixed nitrogen becomes available to the ecosystem with leaching and when the thalli die and decompose.

The major species in this group are in the Peltigeraceae, genera Peltigera and Nephroma. and Collemataceae, genera Collema and Leptogium. A secondary group of species is in the genera Ephebe, Massalongia, Pannaria, Parmeliella, Placynthium, Polychidium, Solorina, and *Stereocaulon.*

The geographical distribution of the species is mostly circumpolar boreal, sometimes arctic and alpine, and temperate. They are generally best developed in the spruce/subalpine fir forests in mostly shady habitats, but some species are also in Douglas fir and older lodgepole and whitebark pine stands, and in alpine and subalpine grassland.

Since most forested land is federal -- national parks and national forests -- public lands are critical in maintaining healthy communities. The Bureau of Land Management manages some areas that could be habitat for these species. Land trades between the Forest Service and private companies occur, changing management of areas and habitat.

Distributions of species are based on Bird (unpublished keys from Alberta), Egan (1971), Goffinet and Howard (1994), Goward, et al. (1994), Poelt (unpublished keys in English), and Wetmore (1967).

2. **a. List of major species: nitrogen-fixing species on forest floors (soil, moss, mossy rock)**

Collema tenax (Swartz) Ach. - Circumpolar
Nephroma *parile* (Ach.) Ach. - Circumpolar arctic-temperate
Pannaria praetermissa Nyl. in Chyd. & Furuhi. - Circumpolar arctic boreal
Peltigera aphthosa (L.) Willd. - Circumpolar
Peltigera canina (L.) Willd. - Circumpolar boreal temperate
Peltigera collina (Ach.) Schrader - Circumpolar W N America-Europe
Peltigera malacea (Ach.) Funck - Circumpolar boreal
Peltigera rufescens (Weis) Humb. - Circumpolar boreal
Peltigera venosa (L.) Hoffm. - Circumpolar

b. Habitat associations, processes, and requirements

The species listed above are frequently part of the flora on moist, shaded soil and moss on forest floors, from relatively dry alpine meadow and lodgepole pine stands (particularly Collema *tenax* and Peltigera rufescens) to moist subalpine fir/spruce stands. They all characteristically grow on or with moss on soil, on soil and moss on rock, but not usually right on' rock.

The major process they have in common, besides photosynthesis, is nitrogen fixation.

c. **Distributions**

Distributions in the Yellowstone Ecosystem are wide, in all types of forests; however, they are least well developed in dry lodgepole pine stands and best developed, most robust in higher moister subalpine fir/Engelmann spruce stands and **along** streams in cold-air drainage valleys.

Most of the species are characteristic of circumpolar boreal forests and subalpine forests and are generally widespread in the Rocky Mountains.

d. Function in the ecosystem

Their most important function is supplying fixed nitrogen to soil systems when leaching occurs and when they die and decompose (Greenfield, 1992); Gunther (1989) estimated a contribution of 0.04-0.21 k N ha^{-1} yr^{-1} in a subarctic Alaska watershed. Species with antibiotic or medicinal properties (Peltigera canina, P. *polydactyla*) may also have allelopathic characteristics that influence moss and seedling communities near them (Estrella, et al., 1992). Soil crusts that have nitrogen-fixing species in them can be a primary source of nitrogen in arid soils (Evans and Ehleringer, 1993). In some bare areas as along trails, Peltigera species are important ground cover, stabilizing soil and preventing erosion, although they disappear with trampling.

e. Sensitivity to disturbance

Peltigera rufescens and P. canina can be pioneer species on disturbed sites; in alpine areas it takes nearly 50 years for P. rufescens to form small thalli; the colonization time is probably less in conifer forests. All the species appear to be better developed in mature forests, which gives an estimated time of at least 100 years for establishment of-healthy growth. They are sensitive to trampling by two- and four-legged animals along trails and in grazing areas.

f. Trends in populations

With the exceptions of Peltigera rufescens, P. canina,, and Collema *tenax*, which have a rather wide range of habitats and can be in sites more open than mature forest, I would estimate that the general trend in populations is down as more old forest disappears with logging and development.

3. List of minor species of nitrogen-fixing lichens on forest floors (soil, soil in rock crevices, moss, mossy rock) and meadows

Collema coccophorum Tuck.	Circumpolar
Collema flaccidum (Ach.) Ach.	Circumpolar boreal
Collema undulatum var. granulosum Laurer ex Flotow	
Ephebe *solida* Bornet	Boreal moist
Leptogium californicum Tuck. --	Western temperate (rare)
Leptogium gelatinosum (With.) Laundon -	Circumpolar (rare)
Leptogium saturninum (Dickson) Nyl.	Circ. boreal-arctic-temperate
Massalongia carnosa (Dickson) Koerber	Circumpolar boreal arctic
Pannaria conoplea	
Pannaria leucophaea (Vahl) P. Joerg.	Circumpolar boreal
Pannaria *pezizoides* (Weber) Trevisan	Circumpolar arctic boreal
Parmeliella cyanolepra (Tuck.) Herre	Western temperate boreal
Peltigera kristinssonii Vitik.	Montane, subalpine, alpine
Polychidium muscicola (Swartz) Gray	Circumpolar boreal
Solorina crocea (L.) Ach.	Circumpolar arctic alpine
Stereocaulon alpinum Laurer ex Funck	Circumpolar arctic montane
Stereocaulon tomentosum Fr.	Circumpolar boreal montane

Stereocaulon species and Solorina crocea are more abundant in alpine and high subalpine sites. Other species are generally small foliose species that contain cyanobacteria (Nostoc or Stigonema) and are more limited to undisturbed shady spots than most of the first group of species (#2). They are probably even more sensitive to disturbance such as logging that removes canopy cover than the species listed in #2. The most rare species is Ephebe *solida,* found only once near a waterfall in a mature lodgepole pine stand. Most collections of Peltigera polydactyla and similar species need reexamination in light of the recent publication by Goffinet and Hastings (1994). Solorina crocea is not very common in Yellowstone Ecosystem forests.

4. Preferred range of successional stages

Peltigera rufescens is a pioneer on disturbed sites, and is also found in openings in mature forests. Collema *tenax* and Peltigera canina also have wide ranges of habitats, from alpine meadow to young forest to mature forests, although not in deep shade. The other species in both lists 2 and 3 are characteristic of undisturbed shady sites best developed in mature forests, particularly subalpine fir/spruce **and** Douglas fir. In mature lodgepole pine and whitebark pine forests, they are present, but mostly in protected moist areas near streams and waterfalls.

5. **Habitat conditions**

The species are in the following Vegetation Cover Classes [Attachment 1]: SAF206 (Engelmann spruce/subalpine fir); SAF208, whitebark pine; SAF210 (interior Douglas.fir); SAF218 (lodgepole pine). If there is not too much tall grass and shrub undergrowth, they can also be in SAF217 (aspen). Solorina and Stereocaulon species are also in alpine areas (CRB005.

Colonization time of lichens varies. The pioneer species (Peltigera rufescens, P. canina) can grow in rather open conditions, so they are probably present in Structural Stages 1 and 2. However, most of the species grow best in Structural Stages 3-7, where moist shady conditions are present. The second group of species is most likely to be found near streams and waterfalls in the oldest Structural Stages, 5-7.

The best, most robust communities of the nitrogen-fixing lichens on soil and moss are in Engelmann spruce/subalpine fir forests, Fire Groups Nine (Lethal, infrequent, LI, 76-150) and Ten (Lethal, very infrequent; LVI, 151-300. The nitrogen fixing species are also in Douglas fir habitat types, Fire Group Five (nonlethal, frequent; NLF, 26-75). In Fire Group Seven (lodgepole pine; mixed, frequent, MF 26-50) and Fire Group Zero (ribbon and timberline stands of whitebark pine, rarely burns), only some of the faster-growing Peltigera species are consistently present. [Attachment 3].

Overstory types [Attachment 4] that have the nitrogen-fixing species are listed in decreasing order of robustness of the species: Engelmann spruce/subalpine fir (7, ABLA/PIEN) and Douglas fir (4, PSME), with lodgepole pine (3, PICO) a distant third except for moist sites near streams and waterfalls. Understory species are sparse grass/forb (28) or relatively bare ground (30).

6. **Environmental factors which determine occurrence**

Collema *tenax,* Peltigera rufescens, and P. canina are exceptions to the generalizations about favorable environmental factors for the list of soil and moss-dwelling nitrogen-fixing species. As mentioned above, they can be in dry, open sites in meadows and grasslands as well as in openings in mature **forests.**

The following environmental factors are interconnected, so each of them is about .25 of total fitness.

a. Presence of moist conifer stands **at least 100** years old -- spruce/subalpine fir and mature Douglas fir are better sites than lodgepole pine or whitebark pine.

b. Montane conditions: relatively high precipitation and relative humidity

c. Shady rocks, rock crevices, mossy soil

d. Banks of streams and waterfalls

7. Key functions

a. Nitrogen fixation

b. Soil stabilization, especially Peltigera species

d. Invertebrate habitat

e. Allelopathic effects

In arid soils, Collema species and other nitrogen-fixing lichens are part of crusts that contribute a relatively substantial amount of fixed nitrogen to the soils; lack of the nitrogen because of removal of crusts may decrease soil nitrogen.

8. Special habitats

Again with the exceptions named above, the species need stable, moist shaded, untrampled sites, with available rock and relatively bare soil not covered with vascular plants. Rocky ledges and outcrops in small canyons and along streams are important to the small rarer group.

9. **Specific issues for analysis**

Protection of mountain stream banks and small canyons is essential for most of these species.

10. **Unknown information**

Contributions of the nitrogen-fixing lichen species to fixed nitrogen in most forest ecosystems is unknown.

Allelopathic effects of lichens on nearby germinating seedlings, other lichens, and other organisms are possible because of antibiotic effects of compounds in thalli.

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[OTHERSPP.ESP]

LICHENS ON WOOD AND BURNED WOOD

1. Biogeography of group

Some lichen species are on wooden fenceposts and decorticated trees, or usually just on burned wood. Their distribution is wide in North America and Europe, and is probably circumpolar.

Their distributions include federal lands but do not depend on federal lands since many fenceposts and charred trees are on private land **as** well as public land.

2.a. List of species

On wood:

Cyphelium notarisii (Tul.) Blomb. & Forss. - Circumpolar temperate
Cyphelium tigillare (Ach.) Ach. – Circumpolar temperate
Thelomma ocellatum (Koerber) Tibell - Circumpolar temperate montane

On burned wood:

Hypocenomyce *scalaris* (Ach. ex Liljeblad) M. Choisy – Circumpolar temperate montane

b. Habitat associations, processes and requirements

The species on wood can be from low valley to subalpine elevations, but they are most abundant in valley and montane environments. They colonize old trees when the bark falls off and wooden fenceposts, rarely are they on bark. Perhaps they require the permanent nature of wood rather than the rough, temporary substrate of bark. Hypocenomyce *scalaris* is almost exclusively on lodgepole pine charred by forest fires: perhaps it needs some of the carbon released by the fire.

c. Distributions

Geographically the species are widespread in conifer and temperate forests, valleys, and grasslands (fenceposts) in the Rocky Mountains. They can be locally abundant where the proper substrates occur, but their distribution is spotty.

d. Function in the ecosystem

Their rhizines and lichen acids are probably weathering the wood, helping to recycle elements tied up in the wood; most recycling occurs when the lichens fall to the ground as litter. They, like most lichens, are microhabitats for invertebrates.

e. Sensitivity to disturbance

No Hypocenomyce *scalaris* has yet been observed on the trees burned in Yellowstone Park in 1988, so colonization after a fire appears to take longer than seven years. New young fenceposts and decorticated trees require many years to acquire a crust of Cyphelium or Thelomma. Their resistance to air pollution is greater than foliose or fruticose species, and they can live along highways so they do not seem to be particularly sensitive to human activities.

f. Trends in populations

The populations of Hypocenomyce *scalaris* may cycle up and down with forest fire cycles, disappearing with fire and reappearing between fires on charred trees. Cyphelium and Thelomma species are probably decreasing where metal fenceposts are replacing old wooden posts, and stable or increasing where trees are diseased or aging and losing their bark.

3. Less common species on wood

Three species listed as common on trees are often frequently on old fenceposts and decorticated trees: Letharia vulpina and L. columbiana cover dead decorticated trees near timberline and Xylographa abietina may also be on wood, not on bark. Letharia is functioning the same on old wood as it does on branches and trunks of living trees, as forage and contributing to nutrient flow in forests.

4. Preferred range of successional stages

Hypocenomyce *scalaris* is a pioneer on snags in burned forests. The other species-are pioneer crusts on wood; the wood substrates are in mature grasslands and forests that have not burned for many years.

5. Habitats

Cyphelium and Thelomma are on fenceposts and wood in many vegetation cover classes [Attachment 11: CRB002 (mixed grass-agriculture-shrubland), CRB003 (seral shrubland-regeneration), CRB004 (subalpine herbaceous); SAF206 (spruce/subalpine fir), SAF208 (whitebark pine), SAF210 (Douglas fir), SAF218 (lodgepole pine), and SAF217 (aspen); and in rangeland cover types SRM101 (bluebunch wheatgrass), SRM104 (antelope bitterbrush/bluebunch wheatgrass), SRM107 (juniper/big sagebrush/bluebunch wheatgrass), SRM304 (Idaho fescue/bluebunch wheatgrass), SRM402 (sagebrush), and SRM421 (chokecherry-serviceberry-rose). Hypocenomyce *scalaris* is usually in forest types SAF206 (spruce/subalpine fir), SAF208 (whitebark pine), SAF210 (Douglas fir), and SAF218 (lodgepole pine).

The species can be in any structural stage, on snags remaining after fires and on decorticated trees and stumps [Attachment 2].

Cyphelium species are best developed where 'fire is least frequent, but that is partly a function of where they are -- near agricultural land where fires are not allowed to burn. Naturally, they are in Fire Groups Nine (LI, 76-150) and Ten (LVI, 151-300), and colonizing in areas where fires are more frequent (e.g.., Seven - MF, 26-50 or Five - NLF, 26-75). In the Yellowstone Ecosystem, Hypocenomyce *scalaris* is usually in old lodgepole pine forests in which some trees did not burn and some did, Groups Nine (LI, 76-150) and Ten (LVI, 151-300). [Attachment 31.

Overstory species are lodgepole pine (3, PICO), Douglas fir (4, PSME), subalpine fir/Engelmann spruce (ABLA/PIEN), Rocky Mountain juniper (13, juniper) and, to a much lesser extent, whitebark pine (PIAL). Understory species are usually grass/forb (28) or shrub (29).

6. Environmental factors determining occurrence

Cyphelium notarisii, C. tigillare, and Thelomma ocellatum can live on wood and fenceposts near urban areas and highways, so they are probably not particularly sensitive to air pollutants. Their major requirement is wood substrate that is relatively old.

Hypocenomyce *scalaris* needs fires that leave charred snags.

7. Key functions in the ecosystem

a. Wood decomposition

b. Invertebrate habitat

Wood decomposition in relatively dry climates is very slow; lichen growth speeds up the process.

8. Special habitats: wood and decorticated trees are in many habitats.

9. **Specific issues for analysis:** none

10. Areas of unknown information: their effects on wood decomposiiton rates are not known.

[ROTTLOGS.ESP]

LICHENS ON ROTTING LOGS AND TREE BASES

1. **Biogeography of group**

Most of this group is composed of Cladonia species that are circumpolar, widespread in boreal and some temperate forests in North America and Eurasia.

2.a. List of species

Cladonia carneola (Fr.) Fr. - Circumpolar arctic alpine
Cladonia cenotea (Ach.) Schaerer - Circumpolar arctic alpine
Cladonia coniocraea auct. fide Ahti - Circumpolar
Cladonia *deformis* (L.) Hoffm. - Circumpolar arctic boreal
Cladonia *fimbriata* (L.) Fr. - Circumpolar arctic temperate
Cladonia sulphurina - (Michaux) Fr. - Circumpolar northern
Lecidella euphorea (Floerke) Hertel - Circumpolar boreal temperate

b. Habitat associations, processes and requirements

The species are found on downed logs, usually with mosses, and on very moist horizontal old tree roots in old forests of lodgepole pine, Douglas fir, and spruce/subalpine fir. They occur also in subalpine whitebark pine stands where snow accumulation does not linger too long into the summer. The downed logs may or may not still have their bark. The lichens presumably contribute to physical and some chemical decomposition of the bark or wood.

The species require old forest with adequate shade and moisture, and downed trees.

c. **Distributions**

The species are widely distributed in western Montana and the northern Rocky Mountains in old lodgepole pine, Douglas fir, spruce/subalpine fir, and whitebark pine forests from lower montane to subalpine elevations.

d. Function in the ecosystem

The lichens on old logs, along with the mosses, are contributing to weathering and release of minerals tied up in the wood and bark. Lichens and mosses form mats that absorb water as snow melts, contributing to soil stabilization and keeping decaying logs wet enough for faster decomposition in the cold, dry forests of this region. They are habitat for many invertebrates.

e. Sensitivity to disturbance

The lichens indicate a relatively long period of stability after fire or logging; these species have not yet appeared on burned downed logs after the Yellowstone fires and are not expected to for many years. They are characteristic of old undisturbed forests with adequate shade and moisture.

f. Trends in populations

Since the species are so widespread, the populations overall are probably stable. In areas being cut for timber or cleared for development, their populations trends are downward; in aging forests, their populations are probably trending upward.

3. Secondary species

Cladonia bacillaris Nyl. - Circumpolar
Cladonia ochrochlora Floerke - Circumpolar temperate
Placynthiella uliginosa (Schrader) Coppins & P. James - Northern boreal
Trapeliopsis flexuosa (Fr.) Coppins & P. James

These are occasional species in the Yellowstone Ecosystem and parts of western Montana; they have the same general ecological requirements as the list of major species, but are rare. Their rarity makes them more sensitive to disturbances such as fires, logging, and development. Their substrates are decaying wood in soil and moist horizontal tree bases, characteristic of old forests.

4. Preferred range of successional stages

The group of wood-decaying species is mostly in old forests, with adequate shade and conditions moister than younger, more open forests.

5. Habitats

The species are in these SAF Western Forest Cover Types [Attachment 1]: SAF206 (Engelmann spruce/subalpine fir); SAF208 (whitebark pine); SAF210 (interior Douglas fir); and SAF218 (lodgepole pine). They are more common in the spruce/fir and Douglas fir types than the lodgepole or whitebark pine.

They are more typical of older Structural Stages 5-7 [Attachment 2]; since they colonize fallen trees and need shade and adequate moisture, they are less common in Structural Stages l-4.

They are most abundant in forests with infrequent fires: Fire Groups Nine (moist lower subalpine, LI, 76-150) and Ten (cold, upper subalpine, LVI, 151-300). The species are not very abundant in the high subalpine forests; that may not be a result of infrequent fires, but of deep snow that melts late, making a very short growing season. [Attachment 3].

The overstory species [Attachment 4] are: lodgepole pine (3, PICO); Douglas fir (4, PSME); subalpine fir/Engelmann spruce (7, ABLA/PIEN); and occasionally whitebark pine (PIAL). Dominant understory species are generally grass/forb (28) or short shrub (29) such as Vaccinium scoparium.

6. Environmental factors that determine occurrence

The first two factors each probably contribute about .45 to realized fitness, and the third about .10:

a. Undisturbed old forest

b. Adequate moisture (but not too much snow)

c. High air quality

7. Functions in the ecosystem

a. Wood decay, mineral cycling

b. Invertebrate habitat

c. Watershed properties, soil stabilization

Lichen growth on old logs increases decay and recycling of minerals tied up in the wood and bark; this may be important in the cold, dry forests of the Yellowstone Ecosystem where decomposition is very slow. Without the saturation properties of mats of lichens and mats, snow runoff would probably be faster and less controlled, leading to more soil instability.

8. Special habitats

Old forests with downed logs and large horizontal roots are the most hospitable habitats for these lichen species.

9. Specific issues for analysis

Except for the rare species in the Yellowstone Ecosystem, the species as a group have a wide distribution and need no more attention than any other group.

10. Unknown information

Contributions of lichen growth on decaying wood to the speed of the decay and return of recyclable minerals to forest systems are not known. Influence of lichen mats on watershed properties has not been quantified.

[MOSSBASE.ESP]

LICHENS ON MOSS ON SOIL AND ROCK, AND TREE BASES

1. Biogeography of group

Most of the species are circumpolar, or nearly so, in arctic-boreal vegetation types. The group includes crusts or small foliose species, and are characteristic of mature conifer forests. They have a wide distribution in the northern and central Rocky Mountains and in the Pacific Northwest.

Federal lands in national forests and parks are important in maintaining old forests, the major habitats for this group.

2a. List of major species

Lecidea berengeriana (Massal.) Nyl. - Circumpolar arctic-alpine
Physconia *detersa* (Nyl. Poelt - Circumpolar
Physconia enteroxantha (Nyl.) Poelt - Circumpolar ±
Physconia grisea (Lam.) Poelt - Circumpolar boreal temperate
Trapeliopsis granulosa (Hoffm.) Lumbsch. - Circumpolar

b. Habitat associations, processes and requirements

This group of lichen species inhabits mossy soil, moss-covered rock, moss on soil and rock, and litter and tree bases that may be mossy. They are generally species of forests, not usually grasslands (steppes) or alpine areas, and require relatively undisturbed, moist partly shady habitat.

c. **Distributions**

The species have been recorded from most conifer forests in this area -- mature lodgepole pine, Douglas fir, and Engelmann spruce/subalpine fir. They are less common in subalpine whitebark pine, perhaps because of longer-lying snow cover.

d. Function in the ecosystem

Many small invertebrates inhabit the moss-lichen community on rocks and soil. Lichen growth directly on old bark helps break down and recycle minerals of the bark. The combination mats of moss and lichen form a spongy layer that helps in watershed properties, stabilizing soil.

e. Sensitivity to disturbance

They are characteristic of older undisturbed, mostly shady sites under trees more than 100 years old. They are susceptible to trampling, clearing of overstory trees, and fire. Such communities were burned in the 1988 Yellowstone fires, and have not yet started to recover.

f. Trends in populations

As overstory trees are cleared for timber and development, increased exposure and dryness have an adverse impact on such communities. I suspect the population trend is downward in such areas. As burned and logged areas recover, these lichens will recover. The overall population trend is probably slightly downward.

3. **Secondary species**

Biatora *vernalis* (L.) Fr. - Circumpolar arctic alpine boreal
Icmadophila ericetorum (L>) Zahlbr. - Circumpolar boreal
Physconia perisidiosa (Erichs.) Moberg - Circumpolar ±
Solorina spongiosa (Ach.) Anzi - Northern North America-Europe
Toninia *candida* (Weber) Th.Fr. - Arctic-boreal
Toninia *squalida* (Schleicher ex Ach.) Massal. - Circumpolar arctic alpine

These species have been collected only occasionally from the Yellowstone area and southwestern Montana; they are found in the same habitats and substrates as the above-listed species but are much less common. They are susceptible to the same kinds of disturbances as the major species, and their population trends are probably the same -- stable to upward in aging forests and downward in logged and developed areas. Solorina spongiosa indicates persistently wet moss.

4. **Preferred range of successional stages**

Collections of the species has been primarily from mature Douglas fir and spruce/subalpine fir forests, in undisturbed, mostly shady sites. The species are generally less common in lodgepole and whitebark pine stands, except in moist areas along small mountain streams.

5. **Habitats**

They are in the following SAF Western Forest Cover Types [Attachment 1]: SAF206 (Engelmann spruce/subalpine fir); SAF208 (whitebark pine), SAF210 (interior Douglas fir); and SAF218 (lodgepole pine). If there is not too much understory, they may be found in mature aspen (SAF217), but rarely.

The species are characteristic of older Structural Stages [Attachment 2]: Stages 4-7, where trees are large and shade is considerable.

The moss-lichen communities are best developed where fires are least frequent: Fire Group Nine, moist lower subalpine (LI, 76-150) and Fire Group Ten, cold, upper subalpine, but not at timberline (:VO. 151-300). Some species may occur in protected sites in Fire Group Fiver, cool, dry Douglas fir (NLF, 26-75).

6. **Key environmental factors determining occurrence**

The first two factors are estimated to each contribute about .45 of the realized fitness, and the third factor about .10:

a. Old stable substrates

b. Adequate moisture (but not too much persistent snow cover)

c. High air quality

7. **Key functions in the ecosystem**

a. Soil stabilization; as part of the spongy layer that controls water flow with snow melt, they help stabilize soil.

b. Invertebrate habitat

c. Some dead outer bark decay and mineral cycling

8. Special habitats

Old mature forests are necessary for best development of these moss-lichen communities.

9. Specific issues for analysis

Preserving mature and old-growth forests particularly in Douglas fir and spruce/alpine zones for other species, such as those in the nitrogen-fixing group will also help protect this group. The moss cover in the cold dry Rocky Mountain forests is not as substantial as in Pacific-influenced forests, and lichen growth may play a larger role in watershed properties and mineral cycling.

10. Areas of unknown information

Very little is really known about these species in terms of effects on watershed, and their interactions with associated mosses and invertebrates.

[SOILFOR.ESP]

MACROLICHENS ON SOIL AND HUMUS-RICH SOIL

This is a category of lichens that prefer soil substrate over any other substrate, but the species may also grow on mossy soil and moist tree bases. It does not include nitrogen-fixing species that are also on soil and mossy or humus-rich soil.

1. Biogeography of the group

Most of the species are in the genus Cladonia with a circumpolar boreal, distribution characteristic of montane conifer forests, and with representatives that cross to the alpine-arctic and to the temperate. The lichens tend to be on soil but are also on rotting wood on soil (Cladonia cenotea, C. deformis, C. chlorophaea).

National forests and parks provide the most critical habitats, because the moist shaded sites are generally in mature forests. Private lands with mature forests are also good habitat.

2a. List of major lichens in this group

Cladonia cariosa (Ach.) Sprengel - Circumpolar arctic temperate
Cladonia cervicornis (Ach.) subsp. verticillata (Hoffm.) Ahti Cosmopolitan
Cladonia chlorophaea (Florke ex Sommerf.) Sprengel Cosmopolitan
Cladonia coccifera (L.) Willd. - Circumpolar arctic boreal
Cladonia ecmocyna Leighton - Circumpolar
Cladonia gracilis (L.) Willd. - Cosmopolitan
Cladonia mateocyatha Robb. - Western North America
Cladonia multiformis G.K. Merr. - Circumpolar
Cladonia pyxidata (L.) Hoffm. - Cosmopolitan

b. Habitat associations, processes and requirements

This group of lichens occurs mostly on forest floors, on mineral soil or soil with moderate amounts of litter or moss; they are not generally exclusively on tree roots or rotting wood but can also grow on those substrates. They prefer partly open canopies, not deep shade, and are in all forest types from low-elevation dry lodgepole pine to moist spruce/subalpine fir to subalpine forests in the whitebark pine zone. These species are more likely to be found in mature lodgepole pine forests than many other groups.

c. Distributions

The species most restricted in distribution is Cladonia mateocyatha, which is very robust in older lodgepole pine communities in the Yellowstone Ecosystem and pine communities farther north. The other species are circumpolar boreal or cosmopolitan in distribution. This group is among the least specific in their environmental requirements, growing at various elevations and in a variety of forest types (see below).

d. Function in the ecosystem

The spongy layer of lichens and associated mosses forms a layer important in water regulation in forest soils; melting snow and rain water soak in more gradually, preventing rapid leaching and runoff and contributing to soil stability. Leachates from thalli and minerals from dead and decomposing lichens add to soil nutrient content, including fixed carbon.

They provide habitat for invertebrates, but not known as forage for vertebrates.

e. Sensitivity to disturbance

The mats of Cladonia are largest in middle-elevation older lodgepole pine and relatively open Douglas fir and spruce-subalpine fir zones, but are also in fairly disturbed sites such as along forest trails (Cladonia cariosa, C. pyxidata) . They are sensitive to fire and have disappeared from many burned sites in the Yellowstone Ecosystem. Cladonia mateocyatha, C. chlorophaea, and C. pyxidata growing in unburned sites adjacent to burned sites show no signs yet of recolonizing the burned sites seven years after the fires.

f. Trends in populations

The populations are probably staying decreasing in burned, logged and developed areas, but returning to and increasing in aging lodgepole pine stands. Development for winter sports will probably not be a problem; development for summer recreation sites will probably decrease their populations.

3. Minor species

Cladina mitis (Wallr.) Hale & Culb. - Circumpolar
Cladonia cornuta (L.) Hoffm. - Circumpolar
Cladonia multiformis G. K. Merr - North America
Cladonia pleurota (Floerke) Schaerer Circumpolar
Psoroma hypnorum (Vahl) Gray Circumpolar arctic boreal

Cladina mitis has been found in the Yellowstone Ecosystem only in thermal areas, on bare open soil not directly affected by hot springs or geysers. The other species are occasional in most of the forest types. Their development is more robust in Douglas fir forests, subalpine spruce/subalpine fir and whitebark pine zones than in drier lodgepole pine forests.

4. **Preferred range of successional stages**

The group of major lichens, more than most other groups, is an important part of the lichen flora of successional or climax'stands of lodgepole pine. The species are also in openings and partial shade of mature Douglas fir, spruce/subalpine fir, and whitebark pine stands. The second group of species is better developed in mature forests other than lodgepole pine.

5. Habitat conditions

The species are in the following Vegetation Cover Classes (Attachment 1): SAF206 (Engelmann spruce/subalpine fir); SAF208, whitebark pine; SAF210 (interior Douglas fir); SAF218 (lodgepole pine). A relatively sparse undergrowth favors development of these lichen species.

Cladonia cariosa and C. pyxidata may be part of Structural Stages 1-2, forming ground mats as the canopy develops; the other species prefer older Structural Stages, 3-8. The lichen mats in general are not in deep shade [Attachment 2].

The species are probably not present in Fire Groups Two or Three where fires burn frequently (NLVF, O-25) through soil litter. They can occur in small patches in Fire Groups Five (cool, dry Douglas fir; NLF, 26-75) and Seven (lodgepole pine; MF, 26-50). The Cladonia mats are best represented **in** the forests with longest intervals between fires -- Fire Groups Nine (subalpine; LI, 76-150), Ten (cold upper subalpine, LVI, 151-300), and the Lethal, extremely infrequent, 300+. [Attachment 3].

Overstory types with forest soil lichens are Engelmann spruce/subalpine fir (7, ABLA/PIEN) and Douglas fir (4, PSME), lodgepole pine (3, PICO), and, out of the Yellowstone Ecosystem ponderosa pine/Douglas fir (17, PIPO/PSME). Understory species are sparse grass/forb (28) or relatively bare ground (30).

6. Environmental factors which determine occurrence

The first two factors are probably about .45 each, with the third factor about .10.

a. Old forest (stability of habitat)

b. Relatively sparse vascular plant undergrowth

c. Partial shade

7. Key functions

a. Watershed properties, soil stability

b. Habitat for invertebrates

c. Contribute carbon to forest soil

Lichen mats are more abundant than moss in many areas of the cold, dry Yellowstone Ecosystem forests; the lichens are probably important in regulating water flow from snow melt in many places. Without lichen cover, the soil would have fewer recycled nutrients; the lichens grow where vascular plants do not flourish and are a major undergrowth in some localized spots.

8. Special habitats

Moderately old forests,. probably more than 100-150 years of age, provide the best habitat, but most species are generalists with wide distribution ranges.

9. Specific issues for **analysis:** none for this group

10. Unknown information

While these species are very widespread, their contributions to element cycling, soil watershed properties, and animal nutrition are not known.

[DETRITUS.ESP]

LICHEN CRUSTS ON DETRITUS ON SOIL

1. **Biogeography of the group**

The group of major species is widespread, circumpolar arctic-alpine and temperate. Many species range throughout the Rocky Mountains, from Alaska (Thomson, 1979) to New Mexico (Egan, 1971).

Federal lands are important in their distribution because most of the high elevation sites are in national parks and national forests; lower elevation sites can be in private holdings that are probably in a zone destined for timber harvest.

2a. List of major species

Buellia papillata (Sommerf.) Tuck. - Circumpolar arctic boreal
Caloplaca tiroliensis (Zahlbr.) - Circumpolar arctic alpine
Diploschistes muscorum (Scop.) R. Sant. - Circumpolar arctic alpine
Lecanora epibryon (Ach.) Ach. - Circumpolar arctic alpine
Ochrolechia upsaliensis (L.) Massal. - Circumpolar arctic alpine
Pachyospora (Megaspora) verrucosa (Ach.) Mass. - Circumpolar arctic alpine
Phaeorrhiza nimbosa (Fr.) Mayrh. & Poelt -Circumpolar arctic alpine'
Physconia muscigena (Ach.) Nyl. - Circumpolar arctic alpine
Rinodina olivaceobrunnea Dodge & Baker - Western North America-Europe
Trapeliopsis granulosa (Hoffm.) Lumbsch. - Circumpolar boreal-temperate

b. Habitat associations, processes and requirements

They are frequently reported as growing on mosses, but in the Yellowstone Ecosystem most of these species are more common on detritus, particularly Selaginella *densa* at alpine elevations. They grow over and bind the detritus and adjacent soil, forming a crust that contributes to soil stabilization in windy alpine areas. They grow where vascular plants are sparse or low in stature and'the lichens are not shaded.

c. **Distributions**

The species in the above list are generally not in dense forests; they tend to be in high elevation meadows near and above timberline, with major exceptions of Physconia muscigena and Trapeliopsis granulosa which are in relatively shaded sites on moss in forest stands as well as exposed alpine meadows.

d. **Function in ecosystem**

In addition to binding detritus and adjacent soil in an erosion-resistant crust, the action of the rhizines and lichen acids may be helping in decomposition of the woody remains of Selaginella and other plant detritus on the soil. The crust provides habitat for small invertebrates.

e. **Sensitivity to disturbance**

The crusts are best developed in stable meadow (or forest) sites free from grazing, mining, development, trampling and other kinds of disturbance. None of these species are present on mine spoil mounds at 3000 m that are about 51 years old; some semi-woody plant litter has collected on the mounds, but none of the detritus-binding lichens are yet present. In lower, less harsh environments, colonization by detritus-dwellers may be faster.

f. **Trends in populations**

In areas of disturbance from mining, construction, and certain kinds of development, lichen populations are decreasing. In old meadows and forest edges with accumulating detritus, the lichen populations are stable or increasing.

3. **List of secondary species**

Caloplaca stillicidiorum (Vahl) Lynge - Circumpolar arctic alpine
Lecanora beringii Nyl. - Arctic
Lecidoma demissum (Rutstr.) G. Schneider & Hertel - Circumoolar arctic alpine
Micarea assimilata (Nyl.) Coppins - Circumpolar arctic alpine
Rinodina turfacea (Wahlenb.) Koerber - Circumpolar arctic alpine

These are generally high-elevation species, growing on detritus of Selaginella and other plants in meadows with very sparse, short vascular plants. They bind soil and detritus, decreasing erosion especially in windy areas.

4. **Preferred range of successional stages**

They develop best on detritus and soil (and moss) that occur in mature undisturbed meadows (late successional).

5. **Habitats**

Lichen crusts on detritus are best developed in alpine tundra (CRB005) and subalpine herbaceous (CRB004). They are also in more open sites in forest types: whitebark pine (SAF208) and lodgepole pine (SAF218), and Douglas fir (SAF210) and spruce/subalpine fir (SAF206). [Attachment 1].

Lichens growing on detritus are part of a mature meadow or grassland or an opening in a mature forest. On the assumption that disturbance to a grassland or forest will disturb associated soil/detritus communities, and that a soil detritus lichen community takes time to recover, older forest structural stages 4-7 will support the best detritus-dwelling lichens. [Attachment 2].

The best-developed detritus lichen communities will occur where fire disturbance is least frequent [Attachment 3]: Fire Group 0 (Rarely Burns) in alpine and upper timberline and Fire Group Ten (LVI, 151-300) in upper subalpine and timberline habitat types.

Detritus crusts are in clearings and at the edges of subalpine fir/Engelmann spruce (7, ABLA/PIEN) and whitebark pine (ABLA). [Attachment 41.

6. *Key* **environmental factors determining occurrence**

Each of these factors is approximately equal in determining realized fitness:

a. Undisturbed openings, meadows

b. Accumulated litter (detritus)

c. Sparse, low-stature vascular vegetation

7. *Key* **functions in the ecosystem**

a. Binding soil and detritus for soil stability

b. Decomposition of organic litter

c. Contribution of carbon to soil system

d. Invertebrate habitat

These crusts cover loose soil and detritus and contribute to soil stability in areas that frequently have high winds; soil erosion may increase without these lichens. In helping decompose semi-woody tissues of Selaginella, grasses, and other vascular plants, lichens growing on plant detritus help break down dead plant material for cycling nutrients. Photosynthates contribute carbon to the soil. Without these processes, mineral recycling in ecosystems slow to change might be even slower. The crusts are habitat for some invertebrates.

8. **Special habitats**

Old stable meadows, forest edges, and forest clearings are important for these lichens; excess grazing should be prohibited in such habitats.

9. **Specific issues for analysis.** None for this group

10. **Areas of unknown information**

Decomposition rates of organic detritus with no lichens cover and decomposition rates of detritus with lichens cover is not known; real contribution of lichens to nutrient-poor high elevation systems is unknown.

[SOILCRST.ESP]

CRUSTS ON SOIL

The species are predominantly on soil in shrublands and grasslands (steppe), unforested mountain slopes, and alpine meadows. Most of the areas included have soils derived from granitic or volcanic bedrock; species from calcareous substrates are marked. In some cases, species are on soil in rock crevices or near rock outcrops.

1. **Biogeography of lichen crusts on soil**

These species have generally a broad geographical range, circumpolar or in both western North America and Eastern Europe. Distributions are based on Laundon (1989, 1992), Poelt (unpublished keys), Thomson (1979), Timdal (1986), and Wetmore (1967).

Federal lands in forests and parks are important in providing relatively undisturbed higher elevation meadows for best development of soil crusts. Since crusts develop at valley and montane elevations also, state and private lands also provide habitats for soil crusts.

2.a. List of species

Acarospora schleicheri (Ach.) Massal. - Circumpolar
Buellia elegans Poelt - Arctic Europe-North America
Catapyrenium lachneum (Ach.) R. Sant. - Circumpolar
Fulgensia bracteata (Hoffm.) Rasanen - Arctic boreal - calcareous
Fulgensia fulgens (Swartz) - Western North America - calcareous
Psora decipiens (Hedwig) Hoffm. - Circumpolar
Psora globifera (Ach.) Mass. - Circumpolar ± arctic alpine
Psora himalayana (Church. Bab.) Timdal - N. America - Asia arctic alpine boreal
Psora nipponica (Zahlbr.) G. Schneider - Circumpolar ±
Psora rubiformis (Ach.) Hook. - W. North America - W. Europe arctic alpine
Psora tuckermanii Anders. ex Timdal - W. North America
Squamarina lentigera (Weber) Poelt - Arctic-Western Plains
Toninia caeruleonigricans (Lightf.) Th.Fr. - calcareous

b. Habitat associations, processes and requirements

The species listed are generally in shrublands and grasslands (steppes) at low or valley and higher montane elevations, on soil between grasses, forbs, and shrubs; on soil between rocks, and in rock crevices. Collema *tenax*, a nitrogen-fixing species, and free-living cyanobacteria and algae are also frequently associated with these species. They form crusts that are important in soil stabilization, contribute nitrogen and carbon to the soil and are easily damaged by trampling by people and animals.

c. **Distributions**

Fulgensia bracteata, F. fulgens, Squamarina lentigera, and Toninia caeruleonigricans are typical of grasslands in the eastern part of Yellowstone Park and adjacent valleys; their distribution in the Snake River drainage is not known. Psora species are frequently on soil in and near rock ledges and outcrops. Acarospora schleicheri ranges from valleys to alpine meadows.

d. Function in the ecosystem

Soil crusts are important in binding soil and preventing soil erosion in areas of high wind, rain-drop splashing, and fast water runoff (Eldridge & Greene, 1994; St. Clair, et al, 1993). In addition to fixed nitrogen, carbon is added to the soil (Beyer & Klopatek, 1991; Lange, et al., 1994). Lichens serve as microhabitat for small invertebrates (Byazrov and Melekhina, 1992). Their use as food is unknown.

e. Sensitivity to disturbance

Soil crusts are delicate and disappear rapidly with trampling and grazing by domestic animals, and by dense concentrations of grazing animals such as bison and elk. The tiny hummocky appearance of a soil with soil crust lichens indicates that the grassland has not been recently disturbed. Time of full recovery after grazing and trampling is 20-30 years (Anderson, et al, 1982).

f. Trends in populations

In areas of trampling by humans and grazing by wild and domestic animals, population trends are down. In undisturbed grasslands, populations are stable.

3. Secondary species

Arthonia glebosa Tuck.
Candelariella terrigena Rasanen - American arctic alpine
Catapyrenium cinereum (Pers.) Koerber - Circumpolar arctic alpine boreal
Lepraria *neglecta* (Nyl.) Lettau - Arctic-alpine Europe-North America
Leprocaulon subalbicans (Lamb) Lamb & Ward - Arctic alpine
Leproloma angardianum (Ovstedal) Laund. - Arctic alpine bipolar
Solorina bispora (Nyl. - Circumpolar

The species in the "secondary list" are more characteristic of subalpine and alpine meadows with relatively sparse and short vascular vegetation. Species of Lepraria, Leprocaulon, and Leproloma are pioneer species in alpine areas with late-lying snow that causes very short summer growing seasons. They have circumpolar arctic-alpine or world-wide distributions.

4. Preferred range of successional stages

Soil crust species are indicative of generally stable, undisturbed shrubland and grassland that has not been subjected to grazing and trampling pressures. Some species are early successional in subalpine and alpine habitats that are often covered with snow late into the summer and are colonizers of mostly bare'soil (Acarospora schleicheri, Lepraria neglecta, Leproloma angardianum) .

5. Habitats

Soil crust species in the first group can be in several Vegetation Cover Classes [Attachment 1]: CRB002 (mixed grass-agriculture-shrubland); CRB004 (subalpine herbaceous); SRM104 (antelope bitterbrush-bluebunch wheatgrass); SRM402 ? (mountain big sagebrush); SRM607 (wheatgrass-needlegrass). The species of the second group are more characteristic of CRB004 (subalpine herbaceous) and CRB005 (alpine tundra).

Since the species are characteristic of grasslands, Structural Stages

[Attachment 2] are not applicable.

Lichen crusts are best developed where fires are least frequent [Attachment 3]: Fire Group 0 (Rarely Burns) in areas of upper timberline; Fire Group Ten, (LVI, 151-300) in upper subalpine and timberline habitat types; and less expected lichen growth in Fire Group Lethal, frequent (LF, 26-75) in juniper and sagebrush communities.

Lichen crusts may be at the edges of subalpine fir/Engelmann spruce (7, ABLA/PIEN) and whitebark pine (ABLA), and Part of juniper stands (13, JUSC).

6. Key environmental factors determining occurrence

Three environmental factors contribute to development of soil crusts with an estimated contribution of about .40 each for the first and .10 for the second:

a. Available substrate with short or sparse vascular vegetation

b. Undisturbed by fires, grazing or trampling

c. High air quality

7. Key functions in the ecosystem

a. Soil stabilization: prevention of wind erosion, water runoff

b. Colonization by some species (Leproloma, Lepraria)

c. Invertebrate habitat

d. Contribute carbon and nitrogen to soils under crusts

Loss of these species leads to increased erosion of soils that are frequently in windy sites. Less carbon and nitrogen would be contributed to soil without lichen crusts.

8. Special habitats

Shrublands, grasslands and meadows at all elevations with sparse vascular cover will develop soil crusts if they are not disturbed by grazing and trampling. Delicate alpine systems might be especially sensitive to grazing pressures since their growing season is short and recovery periods are long.

9. Specific issues for analysis

Grazing permits may allow a number of animals on land that trample and destroy soil crusts, increasing erosion, decrease carbon flow to soils, and, when nitrogen fixing organisms are part of the crust, decrease nitrogen-fixation.

10. Areas of unknown information

No quantification of contributions of carbon and nitrogen by soil crusts in a cold forest/meadow system has been made.

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[SOILALP.ESP]

MACROLICHENS ON ALPINE SOIL

Included in this group are the primary and secondary fruticose species (genera Cetraria, Cladonia, Coelocaulon, Dactylina, Thamnolia and others); two nitrogen-fixers (genus Stereocaulon); and vagrant forms (Aspicilia, Dermatocarpon, Rhizoplaca) that are characteristic of alpine meadows on the Beartooth Plateau and parts of Yellowstone Park. The term tundra may be used for alpine meadows, but I have preferred to reserve tundra as a term for arctic systems.

1. **Biogeography of group**

This group of species includes macrolichens that grow on soil, generally among vascular plants, in alpine meadows with coarse gravelly soils at and above timberline. Most species are circumpolar at high latitudes, extending southward through elevations above about 7000 feet (2121 m) in the Rocky Mountains from Alaska and Canada through Montana and Wyoming., Some of them extend as far south as Colorado and Arizona alpine regions (Egan, 1971). Distributions of species follow Egan (1971), Imshaug, 1957), Karnefelt (1979) and Thomson (1967, 1979, 1984).

The highest elevations in western Montana and Wyoming that contain this set of lichens are federal lands -- national forests (Flathead, Deerlodge, Beaverhead, Lewis and Clark, Helena, Gallatin, Custer, Shoshone, Bridger-Teton, Targhee) and national parks (Glacier, Yellowstone, and Grand Teton). Lichen flora has been described for Yellowstone (Eversman, 1990) and Glacier (Debolt and McCune 1992) National Parks, but the lichen flora of Grand Teton National Park, in the Snake River drainage, that contains alpine flora has not been investigated. The most extensive study of alpine lichens has occurred on the Beartooth Plateau, Custer and Shoshone National Forests (Eversman, ms in preparation), adjacent to Yellowstone National Parks where two alpine areas were extensively collected. Since many of the same species occur in alpine areas in Glacier National Park, it is assumed that these species are a major component of alpine meadows in the Rocky Mountains of western Montana and Wyoming.

2.a. List of major soil macrolichens in alpine meadows*

Cetraria ericetorum Opiz. Circumpolar arctic-alpine
Cetraria islandica (L.) Ach. Circumpolar arctic-alpine
Cetraria nivalis (L.) Ach. Circumpolar arctic-alpine
Cladonia pocillum (Ach.) 0. Rich. Cosmopolitan
Cladonia pyxidata (L.) Hoffm. Cosmopolitan
Coelocaulon muricatum (Ach.) Laundon Circumpolar arctic-boreal
Dactylina madreporiformis (Ach.) Tucker Circumpolar arctic-alpine
Peltigera rufescens (Weis.) Humb. Circumpolar arctic-alpine, boreal
Thamnolia vermicularis (Swartz) Ach. ex Schaerer
Xanthoparmelia wyomingica (Gyelnik) Hale Western North America

Species of special concern: vagrant forms of lichens that ordinarily grow in a crustose form attached to rock. Transitional morphs between crustose adnate on rock and free-growing on soil occur; they are increasingly "knobby" in appearance as they are less attached to the rock (Rosentreter 1993; Rosentreter & McCune, 1992; Weber, 1977). I am not sure I have seen a true Aspicilia fruticulosa.

Aspicilia sp. Variable forms run a transition between knobby attached

Aspicilia still attached to rock to true vagrant fruticose forms on the soil. Forms have been collected on Mt. Washburn, Yellowstone National Park, on the Beartooth Plateau, and in lower grassland sites.

Dermatocarpon vagans Insh. This is considered to be the vagrant form of D. reticulatum (Rosentreter & McCune, 1992). It has been collected only on Mt. Washburn where bedrock and outcrops are granitic and basaltic.

Rhizoplaca haydenii (Tuck.) W.Weber Rhizoplaca melanophthalma is very abundant on rock in alpine meadows on the Beartooth Plateau east of Yellowstone Park. In two separate meadows, transitional forms from umbilicate saxicolous to vagrant terricolous occur. Bedrock and rock outcrops are granitic.

Another vagrant species, Xanthoparmelia chlorochroa (Tuck.) Hale, is locally abundant at lower elevations in sagebrush-grassland.

b. Habitat associations, processes and requirements

Alpine meadows on the Beartooth Plateau can be separated into three distinct, although intergrading, vegetation types -- a) fellfield, gravel and rock, dominated by cushion plants such as Silene acaulis, Eritrichum nanum and Phlox multiflora; on most snow-free, windy ridges. b) Geum rossii turf with some graminoids and many forbs, with some rock and bare ground available for lichen substrate; more protected from the wind, and with fewer snow-free days than fellfields; and c) a dense turf dominated by Deschampsia cespitosa and Carex elynoides or C. scopulorum, with very little soil and rock substrate, relatively well-developed soils, and more than 150-200 snow-free days (Johnson and Billings, 1972; Walker, et al., 1993). The terricolous macrolichens grow mainly in the *Geum* turf, and to a slightly lesser extent (based on cover) in the fellfields.

Habitat requirements include:

1) Available substrate -- rock and soil not covered by vascular plants.

2) Associated vascular plants of low stature to prevent shading.

3) Apparently an annual snow-free period of more than 150 days (Willard, 1979; Walker, et al, 1993)

4) Some protection from wind, since they are not most abundant in the windiest fellfield.

5) Minimum disturbance from pocket gophers (*Thomomys* colpoides) that leave eskers and mounds of soil, unstable soil, and result in wind, scarps.

c. Distributions

Most of the soil macrolichens listed above are components of a circumpolar arctic-alpine lichen flora, with the exception of Xanthoparmelia wyomingica, which has a western North America distribution (Hale, 1990). The vagrant lichens have limited local distributions (Rosentreter, 1993 ; Rosentreter and McCune, 1992); in the Yellowstone region, they are on alpine and subalpine grassland, in areas of high, but not the highest, winds.

In the alpine areas included in this report, Mt. Washburn and Electric Peak in Yellowstone National Park and accessible meadows adjacent to Highway 212 on the Beartooth Plateau, the distributions are not uniform. For example, Cetraria ericetorum, C. islandica, and C. nivalis are common on the Beartooth Plateau, but were not collected in Yellowstone Park; they have been reported from the Anaconda-Pintlar Wilderness Area in Montana (St. Clair, 1993) and from Glacier National Park (Debolt and McCune 1992). Dactylina madreporiformis is in Yellowstone Park, Beartooth Plateau, and Anaconda-Pintler Wilderness area, but not in Glacier Park. Vagrant forms of Aspicilia, Rhizoplaca, and Dermatocarpon have been observed only in one or two sites each in Yellowstone Park or on the Beartooth Plateau.

d. Role or Function in the ecosystem

The total percent cover for this group of species in fellfields is about 4.2%. and in the Geum turf about 6.7% total vegetation cover (Eversman, ms in preparation). Lichens are photosynthetic so are primary producers; their adapations to cold climates indicate that they can remain physiologically active throughout the year when conditions allow, not just during the 12-week spring and summer. Soil crusts with lichens have been shown to add carbon to soil (Beymer & Klopatek, 1991); mats of macrolichens may be assumed to likewise add carbon to alpine soil.

There is only anecdotal evidence that the resident large mammals -- bighorn sheep, mountain goats, elk, and mule deer -- feed on this set of lichens. Native invertebrates, small insects and arachnids, take cover under these lichens, mosses, and the accompanying vascular vegetation.

Cladonia pocillum and C. pyxidata are important colonizer species, with species of Leproloma, on disturbed soil from late snow melt (snow beds) and mining.

e. Sensitivity to disturbance

Alpine meadows are very sensitive to trampling disturbance by two- and four-legged mammals and vehicles. Fortunately, visitor pressure at a primary visitor center, West Summit Outlook at Beartooth Pass, is less than in more hospitable climate settings, but close to the parking lot, trampling has destroyed vascular and non-vascular vegetation. Grazing by domestic sheep in Wyoming has continuing effects. Mine spoils near chromite mine in Montana, inactive since 1943, are now showing signs of revegetation by mostly native vascular plants, mosses and lichens. Roads closed for many years are still evident as scars across meadows, as at the chromite mine.

The alpine environment is sensitive to climate changes. Warmer temperatures and longer growing seasons allow trees and other plants to grow higher on the slopes. changing timberline elevations and decreasing alpine meadow space. More snow, in a wetter, colder climate regime, would have a major impact because slow snow melt means shorter summers with a correspondingly shorter growing season. More competition from vascular plants and soil and rock buried by snow more of the year would contribute to loss of lichen vegetation (Benedict, 1990).

Anthropogenic air pollution, with more loading of sulfur and nitrogen compounds into delicate alpine meadow ecosystems, could again change competetive balances, perhaps favoring vascular plants, decreasing lichen abundance. Conversely, more nitrogen may decrease winter hardening of vascular plants, contributing to mortality. Experimental evidence is lacking concerning these speculations.

f. Trends in populations of alpine soil macrolichens

In undisturbed alpine meadows, no trend in populations is evident; lichens are slow-growing and it is assumed that the populations examined in Yellowstone and on the Beartooth Plateau are stable. Since growth rates of most alpine plants are slow, recovery from disturbances such as mining or trampling is slow, taking well over 50 years (Eversman, ms in preparation).

Cladonia pocillum or *C. pyxidata* squamules and tiny thalli of Peltigera rufescens are the first lichens colonizing mine spoils.

3. Secondary macrolichens in alpine meadows

Coelocaulon aculeatum (Schreber) Link	Circumpolar arctic boreal
Dactylina ramulosa (Hook.) Tuck.	Circumpolar arctic alpine
Evernia divaricata (L.) Ach.	Alpine variant. Only in fellfields, attached to large pieces of gravel.
Stereocaulon alpinum Laurer ex Funck.	Circumpolar arctic montane
Stereocaulon tomentosum Fr.	Circumpolar boreal montane
Vulpicida tilesii (Ach.) J.-E. Mattson & Lai	Circumpolar alpine subalpine

Coelocaulon aculeatum is much less common than C. muricatum; Dactylina ramulosa is rare. Evernia divaricata is the arctic-alpine form of the species that normally grows on conifers; it has been collected on the Beartooth Plateau only from three rocky fellfield sites, from two sites in Glacier National Park, and not at all in Yellowstone Park. Stereocaulon alpinum is more widespread than S. tomentosum in alpine meadows; S. tomentosum is in slightly more protected sites closer to timberline. Stereocaulon species have cephalodia on the thallus that contain cyanobacteria species that fix nitrogen; fixed nitrogen is released into the system when the thalli are leached or die.

No grazing on these species by large mammals has been observed, even though they are in mountain goat habitat, and they have thalli large enough to be apparent to the animals.

4. Preferred successional stages of groups 2 and 3.

The soil macrolichens of group 2 are in well-developed stable, climax alpine meadow communities where no apparent disturbances from trampling, grazing, mining, or pocket gophers occur. Increased lichen cover is correlated with less vascular plant cover, so the greatest lichen populations are developed in rocky, gravelly fellfields and the somewhat more dense *Geum* turf above timberline.

The terricolous and muscicolous lichens of group 3 are likewise in well-developed stable, climax alpine meadow communities with no obvious disturbances.

The pioneer species on soil appear to be Cladonia pyxidata and C. pocillum squamules, with no podetia forming until a sizable patch occurs; Leproloma membranaceum and Lepraria *neglecta* grow on soil and Polytrichum piliferum mats in areas recovering from mining disturbance and where snowbeds cover the soil into late summer. Peltigera rufescens can also be a pioneer species, as on recovering mine mounds more than 50 years old.

5. Province data and habitats

Attachment #1 lists Alpine Tundra as CRB005, the CRB Specific Cover Type. Since the area analyzed here is above timberline, Attachment #2, Appendix A on Structural Stage, is not applicable.

The Fire Regime Class, Attachment #3, is apparently Fire Group Ten (LVI, 151-300, lethal, very infrequent fires). No evidence of fire has been observed on the Beartooth Plateau; the fires of 1988 in Yellowstone National Park burned whitebark pine stands on Mt. Washburn, but did not burn through the alpine meadows examined previously on Mt. Washburn or on Electric Peak.

Attachment #4, Overstory and Understory Species, is not applicable.

The Beartooth Plateau is an extensive area of well-developed alpine meadows above timberline; the meadows described are relatively flat, but with enough relief to segregate into well-defined communities -- fellfield, Geum turf, and a grass-sedge turf. The species lists in the previous sections are from representative meadows on the Beartooth, and two sizeable meadows at and above timberline in Yellowstone Park. Smaller alpine areas exist in other Montana and Wyoming mountain ranges, but sharper peaks in other areas offer less opportunity for the meadow development as examined on the Beartooth Plateau. Lichen species listed here should be present in other alpine areas in western Montana and Wyoming. Because of a more oceanic, less continental climate in Glacier National Park, I would expect more species there.

6. Environmental factors for each functional group

The factors are arranged in order of assumed importance, with the first three factors each contributing about .30 to relative fitness, and the last factor about .10. Quantitative measurements are available only for snow-free days, based on Colorado data.

a. Short cold growing season for vascular plants that reduces competition and shading that inhibit lichen growth

b. Available stable substrate: bare coarse soil not covered or shaded by vascular plants.

c. Critical number of snow-free days: more than 150-200 snow-free days per year, with O-50 cm of snow.

d. Lack of trampling and grazing by people and domestic animals

7. **Key ecological functions for alpine soil macrolichens**

a. Soil colonization and stabilization

b. Addition of carbon to soil

c. Nitrogen fixation (Stereocaulon)

d. Forage for mammals?

d. Invertebrate habitat

Decreasing the populations of soil macrolichens in alpine meadows would decrease soil colonization and stabilization in areas of high winds, decrease carbon and nitrogen in alpine soils, and provide less habitat and forage for animals.

8. Special habitats

By definition, alpine meadows are those at and above timberline, usually a krummholz type with tree islands above solid forest line. Alpine meadows are disjunct in terms of occurring only at the highest elevations in the mountain ranges of the Rocky Mountains. Below timberlines, variable in elevation, the growing season allows growth of wood and taller vascular vegetation that outcompetes and shadows most lichen growth. Trampling and compacting by feet, horses, and vehicles during recreational use quickly destroy a community not adapted to these stresses; therefore, protection against overuse of the alpine environment is necessary to maintain the lichen communities, as well as most of the associated vascular plants.

Although little data are available for alpine systems, grazing by domestic sheep, and associated trampling by horse and sheep hooves and wagons, disrupts non-vascular soil crusts and vascular plants. Grazing by mountain goats occurs in some meadows observed; the grazing itself seems to have little effect, but goat "wallows", where the goats roll apparently to coat themselves with dust, are evident on a small scale. These, along with pocket gopher activity, destablize some meadow communities.

On a global scale, climatic warming affects timberlines and upward invasion of lower-elevation vascular plants; conversely, climatic cooling, with more moisture, would have an opposite effect, extending alpine meadows downward in elevation. However, most alpine soil and rock lichens disappear with fewer than 150-200 snow-free days per year (Walker, et al., 1993).

It is not clear what effects air pollution have on alpine systems. Cetraria cucullata, closely related to C. nivalis found in alpine meadows, and two species of Cladina not found in alpine meadows exhibit decreased photosynthetic rates and chlorophyll contents when exposed to gaseous sulfur dioxide fumigation in the field (Moser, et al., 1980). It is expected that sulfur or nitrogen increases from air pollution would have a fertilizer effect and change competitive balances and presumably combinations of species in thee communities. The soils in a granitic area such as the Beartooth Plateau have a relatively low pH, about 5.5 (Nimlos & McConnell, 1965), so are less buffered against acid precipitation than more calcareous regions.

9. Specific issues for analysis

Using lichen species distributions can give insight on snow cover and growing season lengths in areas where measurements of snow depth and length of cover are difficult to obtain.

10. Unknown information

Effects of anthropogenic air pollution on alpine meadows are relatively unknown. Many arboreal lichens are known to be sensitive to air pollution, particularly sulfur gases and ozone, but sensitivity of alpine species is untested. Change of soil chemistry due to air pollutants is likewise untested; as stated above, it may be that adding sulfur or nitrogen to alpine meadows will have a fertilizer effect that differentially affects species, and will change the present nature of communities, vascular and nonvascular. Increasing vascular plant cover and its stature would tend to favor vascular plants at the expense of soil lichens. This is an effect that is not allowed in Class I Wilderness Areas.

Nutrient cycling in alpine systems is slow because of the low temperatures and heavy snow cover in many places throughout an alpine system. Some lichens fix nitrogen, but the actual contribution to the system is unknown. The possible addition of carbon from photosynthesis may also be important.

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Discussion of an alpine system would not be complete without mentioning four species of vascular plants that are characteristic of fellfields and dry rocky sites with little snow because they are so important in colonizing and stabilizing sites that are also critical to some alpine lichens.

1. Biogeography of group

Four vascular plant species are important in arctic and alpine locations; they are limited to such sites. Federal lands in alpine areas are essential for their distribution and protection.

2a. List of species

Dryas octopetala var. hookeriana (Juz.) Breit. (mountain dryad)
Eritrichium nanum (Ville.) Schrad (alpine forget-me-not)
Silene acaulis L. (moss campion)
Phlox pulvinata Wherry Cronq. (cushion phlox)

b. Habitat associations, processes and requirements

Dryas octopetala is a species of very limited distribution on the Beartooth Plateau, in Yellowstone and Grand Teton national parks, and other alpine areas of the Yellowstone Ecosystem (Despain, 1975). It is a pioneer that colonizes windy, gravelly soil and forms stabilizing mats.

The other three species are characteristic of fellfields, windy rocky and gravelly ridges that are parts of meadows. They are "cushion plants," with a rounded shape that is efficient at deflecting wind. Where alpine meadow turf vegetation is more dense, in areas of less wind and more snow accumulation, cushion plants cannot compete and thus disappear.

c. **Distributions**

These plants are circumpolar arctic alpine (Hitchcock and Cronquist, 1973), and occur in the Rocky Mountains only at the highest elevations **above** timberline and in windy, dry rocky sites in meadows, usually at the top of small ridges. The three cushion plants occur together on the Beartooth Plateau, but their distribution is scattered in other alpine areas. Silene acaulis and Phlox pulvinata are reported from Yellowstone National Park (Despain, 1975); S. acaulis and possibly Eritrichium nanum are in Glacier National Park (Lesica, 1985), but Phlox pulvinata is not. *Dryas* octopetala is on the Beartooth Plateau, and in Yellowstone and Glacier national parks.

d. Function in the ecosystem

They are important colonizers of bare rocky soil and stabilize soil in windy sites. *Dryas* octopetala has nitrogen-fixing nodules on its roots (Zwinger and Willard, 1972), contributing to fixed nitrogen in the soil. They are habitat for small invertebrates, but do not seem to be grazed by mountain goats.

e. **Sensitivity to disturbance**

Grazing and trampling are harmful to these plants, although grazing pressure is slight because they are in habitats not very inviting to the grazing animals, except perhaps domestic sheep. The growth rate of moss campion has been estimated at about 0.45 cm diameter growth per year in Colorado (Benedict, 1989); a few very small cushions of moss campion are beginning to colonize mine spoils 50 years old (Eversman, ms. in prep.).

f. Trends in populations

Populations in the undisturbed alpine meadows on the Beartooth Plateau are stable or increasing. Trampling near a visitor stop on Beartooth Pass has caused deterioration of cushion plant species.

3. **No other species group considered here.**

4. Preferred **successional stage**

Mountain dryad is an important colonizer of windy, gravelly sites. The cushion plants are colonizers in dry rocky fellfields; they disintegrate in the center as they age, and grasses and other flowering plants start to grow in the dead part.

5. **Habitat**

They are characteristic of alpine tundra (CRB005).

Since they grow above timberline, Attachments 2, Structural Stages, and 4, Overstory, are not applicable.

They grow in Fire Group Zero, where fires are rare, or in Fire Group Ten (alpine meadows, LVI, 151-300). (Attachment 31.

6. **Environmental factors determining their occurrence**

The following characteristics of harsh windy alpine environments contribute somewhat equally to their occurrence:

a. O-25 cm snow accumulation per year (Walker, et *al., 1993)*

b. Not covered with snow during any of the growing season; they are not in snowbeds.

c. Dry, gravelly soils

7. *Key* **ecological** functions

a. Colonizing and stabilizing soil

b. Invertebrate habitat

c. Forage?

These vascular plants are slow-growing, but important plants in that they *grow* where few other vascular plants can. Without them, wind erosion of soil would increase. Lichens grow on bare soil between the cushions and few other vascular plants that are in the cushion plant communities.

8. **Special habitats**

Windy, dry, rocky slopes and ridges in high alpine meadows are the special habitats for these plants.

9. **Specific issues for analysis**

Protecting the high alpine from trampling pressure and development is important for these species.

10. Unknown information

Contributions of fixed nitrogen by mountain dryad have not been studied for most alpine regions.

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