



Cladonia fimbriata, a very common species growing on old moist logs, and one of the major species recolonizing forest sites after the 1988 fires.

Lichens in Yellowstone National Park

Sharon Eversman

THE BRIGHT SPLASHES of yellow-green or orange color on rocks are due to the presence of lichens; the gray-green and black “beards” hanging from spruce branches are likewise lichens. Lichens are partnerships of algae and fungi, unique because when the two components are together, the resulting form is different from the algae and fungi separately. The algae, usually green, contribute carbon compounds (sugars) to the fungus. The fungus provides a framework, good at absorbing water from the atmosphere, in which the algae can live.

Lichens have different growth forms. The bushy or fruticose form (e.g., *Letharia*, *Usnea*, *Bryoria*), most common on conifer trees, is about 7% of the total number of species identified in Yellowstone National Park (YNP). Foliose, flat leafy forms (e.g., *Parmelia*, *Xanthoria*, *Xanthoparmelia*, *Umbilicaria*) grow on all substrates, and are 34% of the species. Crustose species (e.g., *Lecanora*, *Lecidea*, *Rhizocarpon*) form crusts tightly attached to substrates and are 44% of the total. The genus *Cladonia* has squamules with little fruiting bodies that look like trumpets or oboes pointing upward; *Cladonia* and another squamulose species (*Psora*) are 6% of the total. A rare form is called a “pin” lichen—it has a crustose part with a little

fruiting body protruding up like a dressmaker’s pin; they (2% of the species) are found on moist Douglas-fir bark and shady rock cliffs. “Reindeer lichen,” species of *Cladonia*, are rare in the Yellowstone region, but stunted forms of *Cladonia mitis* (gray-white, abundantly branched) can be seen in three thermal basins—Biscuit Basin, Norris Geyser Basin, and Phantom Fumarole on the Pitchstone Plateau. Reindeer lichens are more common in moister areas north of YNP, so we assumed that there was adequate moisture in these basins for their growth.

The ecological roles of lichens vary with their substrate and growth form (Brodo et al., 2001). Lichens on rocks help break down the rock, a first step in soil formation. On soil, crusts that contain lichens help stabilize soil against erosion. Elk and deer have been observed eating the fruticose forms, especially *Bryoria*, on trees, and mountain goats eat foliose lichens (*Rhizoplaca*, *Umbilicaria*) on rocks. Birds and flying squirrels sometimes use lichens as a construction material for their nests. Reindeer lichen is a major survival food for caribou and reindeer in far northern countries. Some native peoples have used lichens as medicines and food, and in many places, lichens are boiled to make dyes. In all cases, since lichens have relatively slow growth rates compared to plants, their presence

indicates stable, undisturbed conditions.

We have identified about 367 species of lichens in the park, collected from 87 sites in six different vegetation communities since 1977 (Aho, unpublished data; Eversman et al. 1987, 2002; Eversman and Horton 2004). Lichens are most abundant and diverse in the moister Douglas-fir and Engelmann spruce/subalpine fir forests, with 206 and 256 species found there, respectively (Eversman et al. 2002). That compares to 152 species in lodgepole pine forests and 133 in lodgepole/whitebark pine stands. We collected 97 species in alpine regions and 146 in the grasslands, which included aspen stands and big sagebrush. Although scientific names are used more often than common names in literature and among lichenologists, Table 1 gives common names of the genera mentioned in this paper and their growth form (Brodo et al. 2001).

Moisture and available substrate contribute to lichen diversity. For example, 425 lichen species were reported from Glacier National Park (Debolt and McCune 1993), which is smaller than YNP but more diverse in forest type because it lies mostly west of the Continental Divide and generally lower in elevation. In comparing distribution of 305 lichen species east and west of the divide in Montana, Eversman (2004) reported that 32.3% of the species have been found only west of the divide, especially in forests influenced by Pacific air masses; 55.7% were on both sides of the divide, and just 12% were only east of the divide. Most of the sites from which lichens have been collected in YNP have been east of the divide, probably contributing to the lower count of species than in Glacier National Park. In extensive surveys in YNP through 1998 (Eversman et al. 1987, 2002), we found that about 41% of the lichen species grow on rock, 25% are on bark and wood, 18% live on soil, and 16% are on other lichens and mosses.

In considering forest sites in Yellowstone, pines grow in drier, more exposed sites than other conifer species and tend to self-prune their lower branches. Douglas-fir, Engelmann spruce,

and subalpine fir are more likely to keep their lower branches, providing more substrate for epiphytic species (non-parasitic organisms that grow upon or attached to a living plant). We took advantage of a 1984 windstorm that blew down thousands of trees, mostly lodgepole pine, between Norris Geyser Basin and Canyon Village, to identify lichens that grew on tree trunks all the way to the top, out of view from normal eye level when the trees are standing (Eversman et al. 1987). Twelve species were identified on a total of 15 trees; all 12 species were on subalpine fir, nine were on whitebark pine, and four were on lodgepole pine. While subalpine fir supported lichen growth from ground level to tree top, lodgepole pine supported one species at ground level (*Parmeliopsis ambigua*, a common yellow-green foliose lichen) and the other three species (*Bryoria* sp., *Lecanora piniperda*, *Letharia vulpina*) at more than six meters above ground level where branches were present. Those lichens were close to the axils of branches and where

Genera	Common name
<i>Acarospora</i>	Cobblestone, cracked lichens (crustose on rock)
<i>Aspicilia</i>	Sunken disk lichens (crustose on rock)
<i>Bryoria</i>	Horsehair, tree-hair lichens, bear hair (fruticose on bark)
<i>Candelariella</i>	Goldspeck, yolk lichens (crustose on rock, wood)
<i>Cetraria</i>	Iceland, Icelandmoss, heath lichens (foliose on bark, alpine soil)
<i>Cladonia</i>	Reindeer lichens, pixie cup, trumpet lichen (squamulose on soil, decaying logs, moss)
<i>Collema</i>	Jelly lichen, tarpaper lichens (foliose on rock, soil)
<i>Evernia</i>	Oakmoss lichen (fruticose on alpine gravelly soil)
<i>Flavocetraria</i>	Snow lichen (foliose on alpine soil)
<i>Hypogymnia</i>	Tube lichens (foliose on bark)
<i>Lecanora</i>	Rim lichens (crustose on rock, bark)
<i>Lecidea</i>	Disk, tile lichens (crustose on rock, bark, wood)
<i>Lepraria</i>	Dust lichens (crustose on rock, moss, soil, wood)
<i>Leptogium</i>	Jellyskin, vinyl lichens (foliose on rock, bark)
<i>Letharia</i>	Wolf lichen (fruticose on wood, bark)
<i>Melanelia</i>	Camouflage, brown lichens (foliose on rock, bark)
<i>Parmelia</i>	Shield lichens (foliose on bark, rock)
<i>Parmeliopsis</i>	Starburst lichens (foliose on bark, wood)
<i>Peltigera</i>	Pelt lichens, dog-lichens (foliose on soil, moss)
<i>Physcia</i>	Rosette lichens (foliose on bark, rock)
<i>Psora</i>	Scale lichens (squamulose on soil, rock)
<i>Rhizocarpon</i>	Map lichen (crustose on rock)
<i>Rhizoplaca</i>	Rock-posy lichens, rockbright (foliose on rock)
<i>Umbilicaria</i>	Rock tripe (foliose on rock)
<i>Usnea</i>	Beard lichen, old man's beard (fruticose on bark, wood)
<i>Vulpicida</i>	Sunshine lichens, yellow ruffle lichens (foliose on bark, alpine soil)
<i>Xanthoparmelia</i>	Rock shield, tumbleweed shield (foliose on soil, rock, bark)
<i>Xanthoria</i>	Sunburst, orange lichens (foliose on bark, rock)

Table 1. Common names of genera mentioned in this paper (Brodo, et al. 2001) with growth form and most common substrates.



Typical lichen communities on conifer branches. On the upper branch (left to right) are the chartreuse *Letharia vulpina* (wolf lichen); black stringy *Bryoria fuscescens*; and gray-green *Usnea substerilis*. In addition to tufts of *Usnea* on the lower branch is the gray foliose *Hypogymnia imshaugii*.

the bark was still relatively young and smooth, not as scaly as older bark. We determined the pH of distilled water solutions in which one-gram samples of outer bark were soaked in 30 ml for one hour. The pH of the solutions in which subalpine fir had been soaked averaged 4.94, significantly higher than those of lodgepole pine (pH 3.78) and whitebark pine (pH 4.03). Absorption of water by dry bark, and drying times of saturated pieces of bark after one and four hours, were not significantly different among the species, indicating that probably the pH and texture of the bark are more important in allowing colonization and retention of lichens on these three conifer species. Subalpine fir bark is smoother, less scaly than that of lodgepole or whitebark pine.



Foliose *Xanthoparmelia chlorochroa* among rocks on soil near Gardiner. This is a species characteristic of grasslands, and usually associated with the presence of pronghorns.



Yellow-green foliose *Xanthoparmelia plittii* on rock. Growth of the thallus occurs on the margins, and the older inner part dies leaving substrate for other lichens to grow. The grayish grainy appearance is due to many isidia, little packages of alga and fungus for asexual dispersal.

In alpine areas, the 97 identified lichen species were primarily on rock and soil, as would be expected. The species on rock are frequent at nearly all elevations in this region. Five common species on soil in alpine meadows on the Beartooth Plateau (Eversman 1995)—*Cetraria ericetorum*, *C. islandica*, *Flavocetraria nivalis*, *Evernia divaricata* and *Vulpicida tilesii*—were not found at any alpine sites in YNP. No obvious explanation is apparent.

In grasslands, the species that grow on soil are generally inconspicuous. The lichens are part of soil crusts, or microbiotic crusts, that also include mosses, algae, diatoms, and cyanobacteria. One common black crust species, *Collema tenax*, has cyanobacteria that fix nitrogen and contribute to the nitrogen content of the soil. A yellow-green foliose species, *Xanthoparmelia chlorochroa*, can be common in sagebrush-grasslands, but becomes very rare where there is significant trampling or grazing by ungulates. Two exclosures near Gardiner, Montana, illustrate the difference between areas where animals are excluded and where grazing animals are present; the exclosures have carpets of the lichen. According to *Lichen Use By Wildlife in North America* by Stephen Sharnoff and Roger Rosentreter (Bureau of Land Management, Idaho) at the website www.lichen.com, pronghorn in some areas are known to eat *X. chlorochroa*.

Aspen and cottonwood bark support similar lichen growth patterns—generally the foliose species of the genera *Melanelia* (brown), *Xanthoria* (orange), and *Physcia* (gray-white). Evidently, there is enough nitrogen present in the runoff through leaves down the bark to support the nitrophilic *Xanthoria* species.



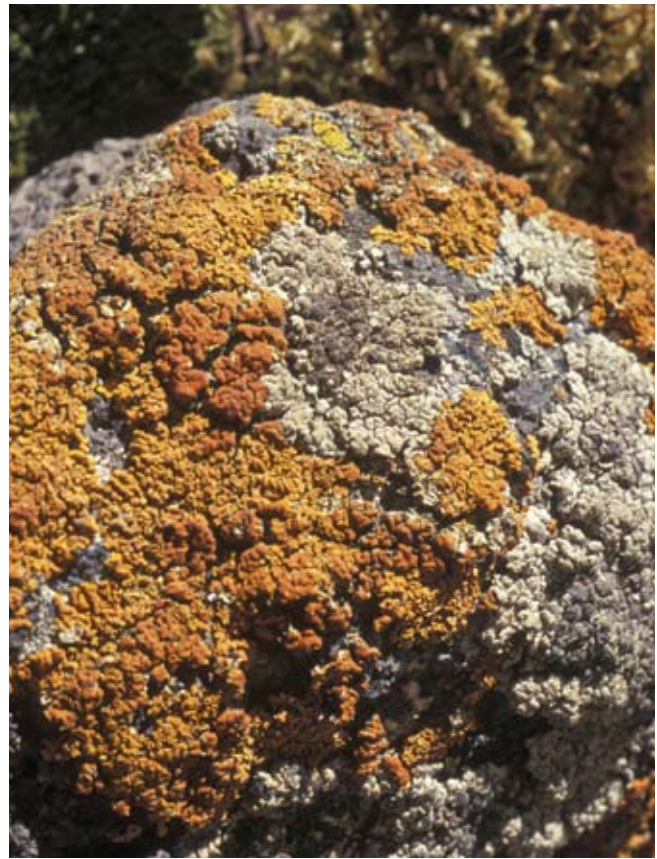
A species of crustose *Porpidia* growing on rock near Bechler Falls.

On rock, the bright orange genus *Xanthoria* (sens. lat.) indicates the presence of birds and other animals—their urine or droppings leave high concentrations of soluble nitrogen, which supports the growth of *Xanthoria*. At Sheepstealer Cliffs, the white uric acid crystals from yellow-bellied marmots are at the top of rock columns, and the orange *Xanthoria* grows lower on the columns; they are indicators of the marmots' presence. In high elevation sites, pika caves can be located in talus slopes by observing the orange color. On boulders in the Lamar Valley, the orange *Xanthoria* advertises the presence of perching birds.

About 80% of all lichens are a symbiotic partnership between a unicellular green alga and a fungus; the alga is 5–10% of the lichen, and the fungus 90–95%. The remaining species have cyanobacteria as the only photosynthesizing partner or as a second photosynthetic partner; cyanobacteria fix nitrogen. Lichens with cyanobacteria tend to be gray or black in color and live in relatively moist habitats, especially on soil with moss or where rock is close to seeps. The most common nitrogen-fixing genera are *Peltigera* on soil (15 species in Yellowstone), *Collema* on soil or rock (5 species) and *Leptogium*, mostly on rock (6 species).

Since most lichen species grow very slowly, 1–2 mm in diameter per year in the case of many crustose species on rock, they are good indicators of stable environmental conditions. The black and yellow-green growth of lichens (*Lecanora*, *Lecidea*, *Rhizocarpon*, *Xanthoparmelia*, *Candelariella*) on the granite boulders in the Lamar Valley and talus slopes elsewhere, for example, indicate that the rock has not moved for hundreds, if not thousands of years. The presence of many species in old Douglas-fir and Engelmann spruce/subalpine fir forests indicates that fire has not burned there for at least 300 years. Many studies have shown that the number of lichen species increases with time after fire.

In 2001, we undertook a study to identify the lichen species that had recolonized burned substrates after the 1988 fires (Eversman and Horton 2004). Our hypothesis was that drier lodgepole pine sites would have fewer recolonizing lichen



Orange foliose *Xanthoria elegans* and crustose *Lecanora argopholis* on rock. The presence of *Xanthoria* indicates that this rock is a favorite perch of birds or small mammals.

species than the more moist Douglas-fir and Engelmann spruce. We soon realized that we were seeing more moss growth than lichen growth; the ubiquitous moss species were *Bryum caespitium* and *Ceratodon purpureus*, and there was significantly more moss growth in the Engelmann spruce sites than in the other forest sites (Douglas-fir, lodgepole pine, whitebark pine). The original hypothesis was partially supported—burned Douglas-fir sites had a total of 15 recolonizing lichen species (in the genera *Bryoria*, *Candelariella*, *Cladonia*, *Lepraria*, *Letharia*, *Melanelia*, *Parmelia*, *Parmeliopsis*, *Physcia*, *Usnea*, *Xanthoparmelia* and *Xanthoria*), lodgepole pine and Engelmann spruce sites each had 11 lichen species, and whitebark pine sites had 5 species (genera *Cladonia*, *Lepraria*, *Melanelia*, *Parmeliopsis*, and *Xanthoria*). *Peltigera rufescens* and *P. didactyla* were on burned soil. These recolonizing lichen species are among the most common species in the park according to our previous collections, and nearly all of them have asexual reproductive structures called soredia—powdery or granular “starter packages” of both the alga and fungus that are efficiently dispersed by wind. When soredia land in a suitable habitat, they can immediately start growing. Lichens without soredia must recolonize after the appropriate algae and fungi find each other and form their symbiosis.

The lichen thalli seen in 2001, 13 years after the fires, were generally small. The longest tuft of the fruticose *Bryoria fuscescens* was 32 mm in an Engelmann spruce site, followed by *Letharia vulpina* in a lodgepole pine site, and 16 mm for *Usnea substerilis* in a Douglas-fir site. The little foliose thalli of *Melanelia exasperatula*, *Parmelia sulcata*, *Parmeliopsis ambigua*, *Physcia* spp., *Xanthoparmelia* sp., and *Xanthoria fulva* were rarely more than 1–2 cm in diameter on logs or snags. The genus *Cladonia*, however, grows relatively fast on shaded horizontal logs, especially close to the ground; *Cladonia squamules* and associated moss species (*Bryum caespitium*, *Ceratodon purpureus*) accounted for most of the recolonization on logs and bases of snags. It was not always possible to tell if rocks with lichen growth had been burned and recolonized, or if capricious fires left unburned rocks or parts of rocks. On rocks that had obviously been burned, granitic boulders between Mammoth Hot Springs and Tower Junction had nine lichen species and burned rhyolite near Madison Junction had six species. Again, the recolonizing lichens (*Candelariella aurella*, *Lecanora novomexicana*, *Lecanora polytrapa*, *Lecidea atrobrunnea*, *Aspicilia* spp., *Rhizocarpon geographicum*, *Physcia dubia*, *Umbilicaria hyperborea* and *Xanthoria elegans*) are among the most common species in the park. A widely available book, *Lichens of North America*, (Brodo et al. 2001), has excellent illustrations of and information about these species, as does the website www.lichen.com. Another website, <http://www.ies.wisc.edu/nplichen>, lists all lichens from all the national parks, as well as reference papers and element analysis results.

Lichens, especially fruticose species with their large surface area, are sensitive to certain gaseous air pollutants and particulate matter. In cities, lichens disappear due to the presence of sulfur dioxide and ozone. The lodgepole pines that surround thermal areas have little to no lichen growth on their trunks and branches, probably because of particulate

Element	YNP ¹ (n=18)	GTNP ² (n=6)	Anaconda–Pintler ³ (n=3)	Gates of the Mountains ³
Potassium	3,183	3,400	4,860	5,697
Phosphorus	1,390	900	2,341	1,989
Calcium	1,188	1,188	1,603	1,228
Sulfur	1,004	1,100	810	1,220
Magnesium	441	574	251	209
Iron	168	358	449	482
Aluminum	144	405	259	253
Manganese	52	76	359	46
Sodium	36	104	55	16
Zinc	24	25	25	25
Boron	21	17	21	13
Titanium	12	15	11	14
Lead	3	1	5	5
Copper	2	2	6	6
Nickel	1	0	2	1
Arsenic	1	na	0.1	0.1
Chromium	0.6	0.6	1.03	0.9
Vanadium	0.3	1	0.2	0
Cadmium	0.2	0.2	8	0
Cobalt	0.1	0	0.5	0.2
Mercury	0.1	na	na	na
Molybdenum	0.1	0	0.1	0.03

¹ Bennett and Wetmore 1999

² Schanz 1996. Unpublished data, Montana State University

³ Schubloom 1995

Table 2. Comparative tissue analysis for *Bryoria fremontii* from Yellowstone National Park (YNP) and Grand Teton National Park (GTNP). The Anaconda–Pintler and Gates of the Mountains Wilderness Areas in Montana are included for comparison, although the number of samples is very small. Values are means in parts per million (ppm), in descending order based on values from Yellowstone National Park, and na = not available.

matter deposited by the geothermal activity. It is curious that a bright yellow-green species, probably *Rhizocarpon geographicum*, grows at the mouth of many fumaroles; it is evidently not sensitive to the hydrogen sulfide and other gases emanating from the fumarole.

Lichens can accumulate heavy metals and other elements from the atmosphere without apparent detrimental effects, so their tissues can be analyzed to indicate atmospheric chemistry. Three separate studies in the Yellowstone region have compared *Letharia vulpina* and *Bryoria fremontii* with collections from other locations in Montana and Grand Teton National Park (Tables 2, 3). The YNP

collection sites, chosen to avoid proximity to geothermal areas, were at Divide Lake, the Pebble Creek trail, Dunraven Picnic Area, Lake Butte, Snake River by the South Entrance, and the west side of Yellowstone Lake.

We expected higher levels of sulfur in YNP compared to the Montana and Grand Teton National Park locations because of geothermal activity. The sulfur contents in the lichens from YNP were more similar to those from the Gates of the Mountains Wilderness area, downwind of a former lead smelting operation near Helena. (Tables 2 and 3). The sulfur content in *Bryoria* from Grand Teton National Park was

Element	YNP ¹ (n=15)	Anaconda– Pintler ² (n=18)	Gates of the Mountains ² (n=9)
Calcium	3727	1707	3729
Potassium	2861	3994	4288
Sulfur	862	610	830
Phosphorus	756	2154	1954
Magnesium	693	284	192
Aluminum	267	325	349
Iron	232	538	390
Manganese	93	132	83
Sodium	31	66	73
Zinc	27	22	24
Titanium	17	55	51
Boron	5	6	6
Lead	3	6	7
Copper	2	3	4
Nickel	1	3	2
Arsenic	0.7	0.2	0.13
Chromium	0.6	1.3	1.3
Vanadium	0.4	0.3	0.04
Cadmium	0.4	2.2	0
Copper	0.2	0.5	0.6
Mercury	0.1	na	na
Molybdenum	0.1	0.1	0.1

¹ Bennett and Wetmore 1999

² Schubloom 1995

Table 3. Tissue analysis for *Letharia vulpina* collected from Yellowstone National Park (YNP) and two wilderness areas in Montana. Values are means in parts per million.

slightly higher than in YNP, and is perhaps related to drift from YNP. The sulfur content of the lichens in the Anaconda-Pintler Wilderness sites, upwind of mining and smelting activities in the Butte-Anaconda area, was lower than any other locations (Tables 2 and 3). Bennett and Wetmore (1999) correlated the sulfur level with that of mercury, rarely measured in other studies. Based on their other studies, they concluded that the levels of mercury and sulfur were elevated throughout YNP, probably related to the geothermal activity. The level of arsenic, although low, is also higher in YNP than that found in other studies.

Lichens are interesting in themselves because of their various colors and shapes, and their symbiotic system, but their presence advertises the

environmental conditions in which they live. Where they are abundant, they indicate appropriate habitat, clean air, and stable environmental conditions. Where they are absent, one looks for signs of disturbance or pollution.

YS

Acknowledgments

I am grateful for assistance with collections and identifications through the years from I. M. Brodo, Don Despain, Kathryn Glew, Dan Gustafson, Carol Johnson, Dan Macrae, Thomas H. Nash, III, William A. Weber and Cliff Wetmore. John Varley, Hank Harlow, and Jim Bennett have helped secure funding. Funding for projects has come from Yellowstone National Park (CX-1200-2-B040, PX No. 1570-3-2107), the University of Wyoming/National Park Service, USGS (R-9801448), and Montana State University.



COURTESY OF AUTHOR

Sharon Eversman is Associate Professor of Biology in the Ecology Department at Montana State University, Bozeman, where she teaches general biology, botany, and ecology. Her BA is from the University of Iowa—Iowa City, MS from Montana State University, and PhD from Arizona State University—Tempe. Her early work with lichens documented the effects of air pollutants on lichens, and more recently she has been characterizing the lichen communities in Yellowstone and Grand Teton national parks, and Montana.

References

- Bennett, J. P., and C. M. Wetmore. 1999. Geothermal elements in lichens of Yellowstone National Park, USA. *Environmental and Experimental Botany* 2:191–200.
- Brodo, I. M., S. D. Sharnoff, and S. Sharnoff. 2001. *Lichens of North America*. Yale University Press, New Haven. 795 pp.
- Debolt, A., and B. McCune. 1993. Lichens of Glacier National Park. *The Bryologist* 96: 192–204.
- Eversman, S., C. Johnson, and D. Gustafson. 1987. Vertical distribution of epiphytic lichens on three tree species in Yellowstone National Park. *The Bryologist* 90: 212–216.
- Eversman, S. 1995. Lichens of alpine meadows on the Beartooth Plateau, Montana and Wyoming, U.S.A. *Arctic and Alpine Research* 27:400–406.
- Eversman, S., C. M. Wetmore, K. Glew, and J. P. Bennett. 2002. Patterns of lichen diversity in Yellowstone National Park. *The Bryologist* 105:27–42.
- Eversman, S. 2004. Macrolichens of the forests of Montana and Yellowstone and Glacier Ecosystems. pp. 213–223 in *Fungi in Forest Ecosystems: Systematics, Diversity and Ecology*. Edited by C. Cripps. The New York Botanical Garden, New York.
- Eversman, S., and D. Horton. 2004. Recolonization of burned substrates by lichens and mosses in Yellowstone National Park. *Northwest Science* 78:85–92.
- Schubloom, L.A. 1995. Lichens as air quality indicators in three areas of southwestern Montana: lichen floristics and elemental analysis. M.S. Thesis, Montana State University, Bozeman. 129 pp.