Lichens of Yellowstone National Park Phase II

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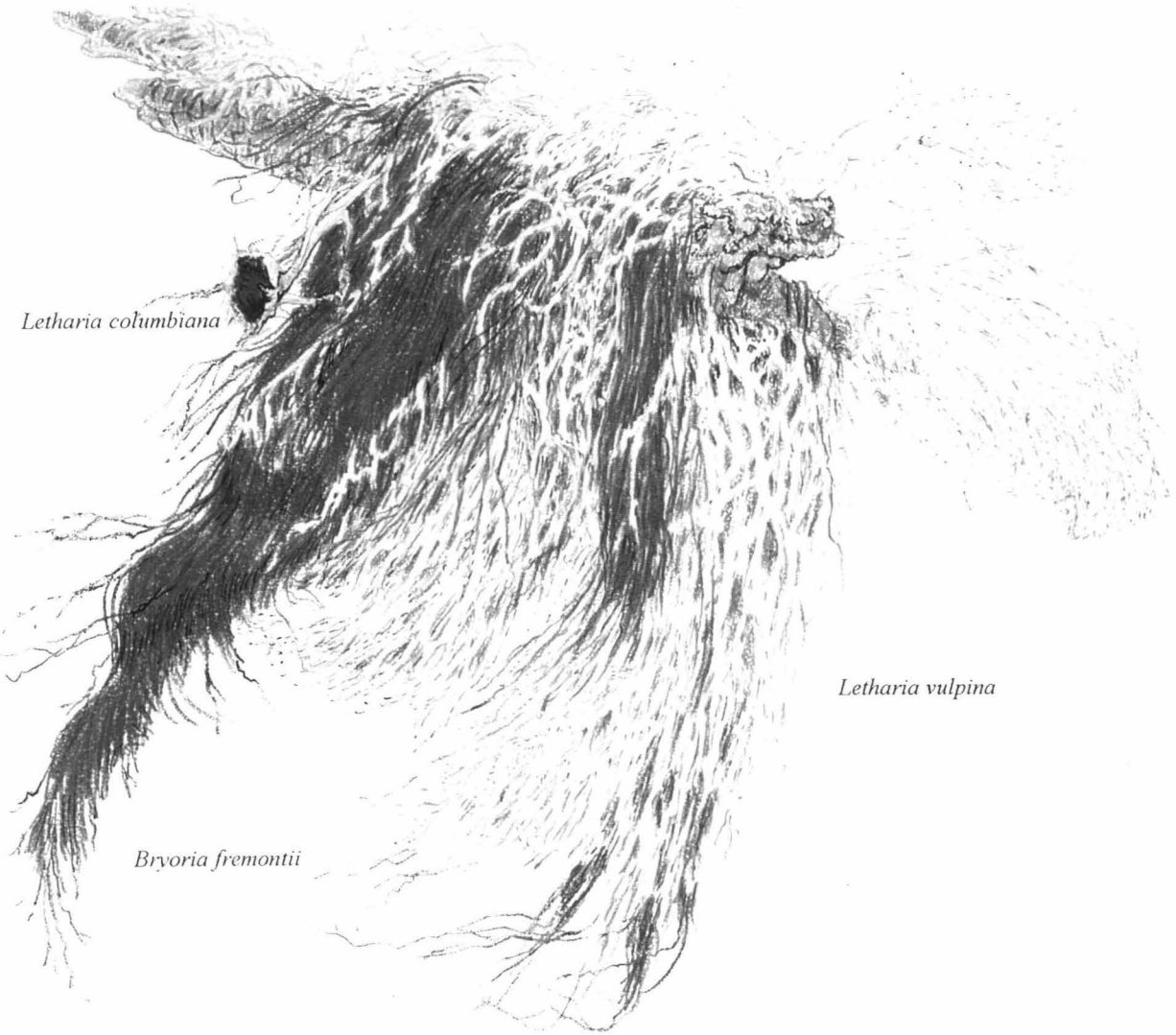

Lichens of Yellowstone

National Park

Phase II

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LICHENS OF YELLOWSTONE NATIONAL PARK. PHASE II

Abstract. Three hundred sixty-four lichen species in 105 genera have been identified from 84 sites in Yellowstone National Park; 190 species are reported from the park for the first time. About 41% of the species were saxicolous, 25% were corticolous or lignicolous, 18% were terricolous, and 16% were on rotting wood, mosses, litter or other lichens. About 44% of the species were crustose, 34% were foliose, 7% were fruticose; the remaining, including *Cladonia*, were squamulose or "pin" lichens. Twenty-nine species were collected from 20 or more sites (common), and 174 species were identified from three or fewer sites (rare). Douglas fir burned in 1988 is being recolonized by eight species, and burned soil in a Douglas fir forest zone is being recolonized by *Peltigera didactyla* and *P. rufescens.* Forty-three species have been reported as being sensitive or intermediately sensitive to air pollutants. *Bryoria fremontii* and *Letharia vulpina* tissues were analyzed for elemental content; except for mercury, the levels of most elements were similar to those recorded in other parts of the region.

Introduction

Lichens are valuable indicators of environmental conditions. Because they grow slowly, their presence is an indication of ecological stability and integrity (Hale, 1983; Ladyman & Muldavin, 1996; Wetmore & Bennett, 1996). An inventory of species present in an area is considered mandatory for establishing baseline information for monitoring of atmospheric and terrestrial quality (Nash, *et al.*, 1993). The presence of species sensitive to air pollutants indicates high air quality because photosynthesis, respiration, nitrogen fixation, growth and reproduction are decreased by air pollutants such as sulfur dioxide, ozone, PAN, and heavy metals (Gries, 1996). Since many species, especially fruticose epiphytes, obtain most of their nutrients from the atmosphere (Nash, 1996), their tissues can be analyzed for elements as an indication of atmospheric chemistry and nutrient cycling (Nieboer, *et al.*, 1978; Wetmore, 1995).

The National Park Service maintains an updated list of lichen flora in national parks as a baseline inventory of species present (Wetmore & Bennett, 1996). In the northern Rocky Mountains, the national parks and other areas of national interest that have been surveyed include Glacier National Park, Montana (DeBolt & McCune, 1993); Anaconda-Pintler Wilderness Area (St. Clair & Newberry, 1993a; Schubloom, unpublished thesis); the Cabinet Mountains of northwest Montana (St. Clair & Newberry, 1993b); the alpine meadows of the Beartooth Plateau (Eversman, 1995); and Grand Teton National Park (Eversman, 1998). The first survey of Yellowstone National Park (Eversman, 1990) reported only 186 species, and was considered to have reported less than half the species probably present in the park (Wetmore & Bennett, 1996).

With the support of the United States Geological Survey, the second study of Yellowstone National Park was undertaken in 1998 to more completely catalog the lichen flora. The objectives of the study were to: 1) expand the collections in order to more fully document the lichen flora of the park; 2) chemically analyze the tissues of appropriate lichen species as an indication of air quality; and 3) document return of lichens to locations burned in 1988.

Description of Yellowstone National Park

The park covers 8950 km^2, between latitudes $44^0$08' and $45^0$07'N and longitudes $109^0$50' and $111^0$10'W, in northwest Wyoming and parts of adjacent Montana and Idaho. It is a large volcanic plateau ranging from about 1660 to 3335 m, with most of the elevations between 2120 and 2425 m. About 20% of the area is sagebrush-grassland (*Artemisia tridentata, A. cana; Festuca idahoensis, Agropyron spicatum,* others), particularly in the northern part of the park. Of the 80% of the park that is forested, about 80% is lodgepole pine (*Pinus contorta*) abundant throughout the park and considered both successional and climax on rhyolitic soils (DeSpain, 1990). The soils derived from rhyolite, a light-colored volcanic rock, are porous and infertile. The maintenance of lodgepole pine dominance is considered to be related also to the fire history of the park (DeSpain, 1990). The other major tree species, in moister locations and where soils are generally more fertile, are Douglas fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Whitebark pine (*Pinus albicaulis*) grows at upper timberline. Alpine meadows generally are above about 2800 m in elevation. Nearly all of the rock substrates are non-calcareous volcanics, rhyolite, granite, andesite, and basalt; however, calcareous outcrops are in the Mammoth Hot Spring area (travertine) and occasional limestone canyons (Pebble Creek). Average precipitation ranges from 25-30 cm at Mammoth Hot Springs and 56 cm at West Yellowstone to over 250 cm in the highest mountain peaks in the southwest and southeast parts of the park. Most of the precipitation falls at snow, and much of the area is snow-covered from November through June.

Methods and Sites

Between 15 July and 15 August 1998, Sharon Eversman, Clifford Wetmore and Katherine Glew collected over 3000 specimens of lichens from 54 sites (Figure 1). Sites 1-54 were the collection sites of 1998; sites 55-84 were sites reported by Eversman (1990), and renumbered for non-duplication of site numbers (Table 1). For elemental analysis, samples of *Bryoria fremontii* were collected from six sites: 1, Divide Lake; 22, Dunraven Picnic Area; 30, along Pebble Creek; 36, picnic area on the northwest shore of Yellowstone Lake; 37, Lake Butte; and 45, ridge near the south Entrance (Figure 2). *Letharia vulpina* was collected from five sites: 1, 22, 30, 36, 37 (Figure 3).

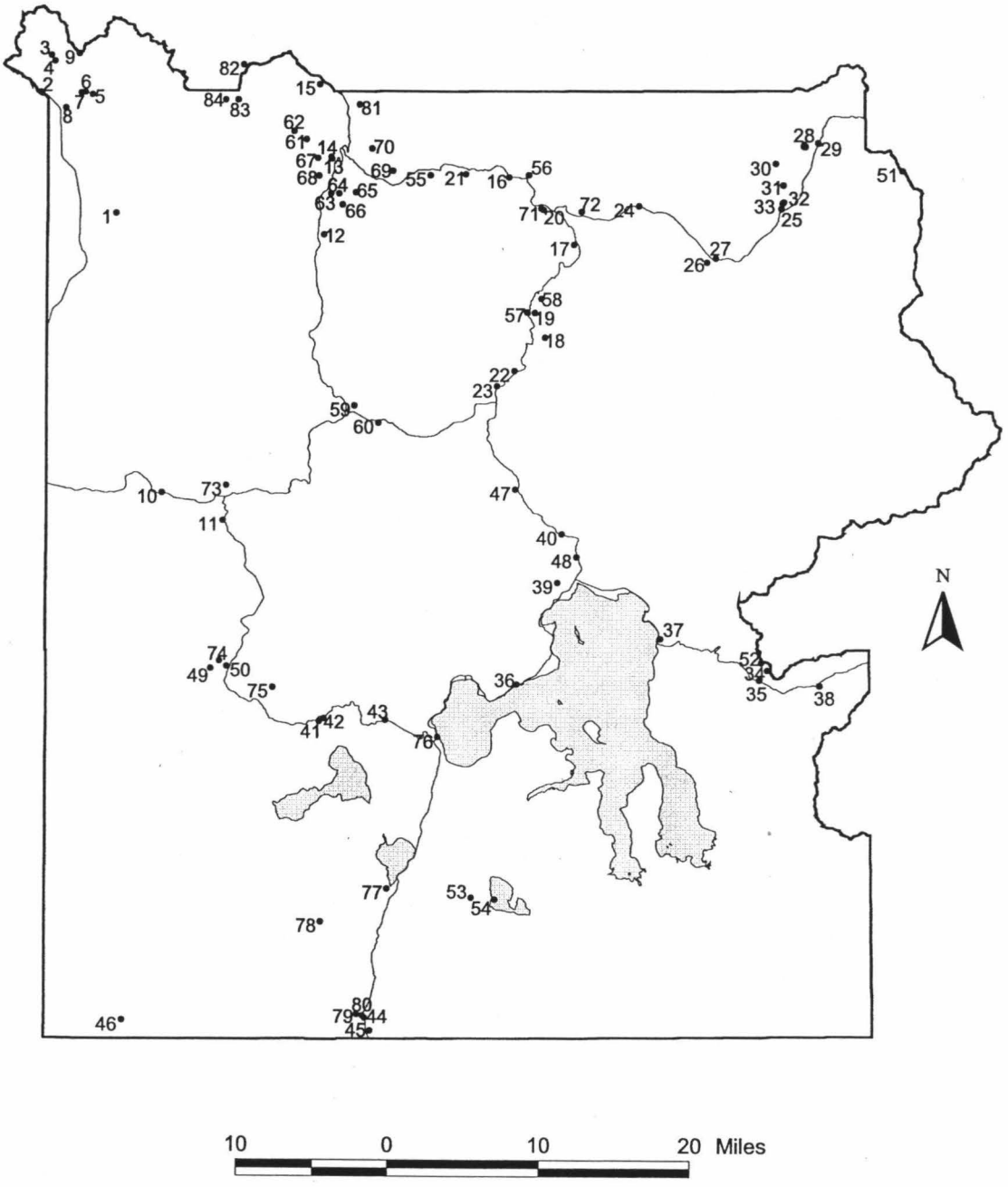

Figure 1. Lichen collection sites in Yellowstone National Park. Site descriptions are in Table 1. Sites numbered 1-54 were collection sites in 1998; sites 55-84 were reported in Eversman (1990).

Table 1: LICHEN COLLECTION SITES, 1998 and those reported in Eversman, 1990, Yellowstone National Park, Wyoming (Park and Teton counties) and Montana (Park and Gallatin counties). Sites 1-54 were sites collected in 1998; sites 55-84 were reported in Eversman, 1990. Sites 13, 14, 19, 35, 41, 46, and 49 were collected both prior to and during 1998; prior site numbers are designated. Collectors at each site are named.

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1. Divide Lake adjacent U.S. Highway 191, northwest corner of the park. 49 km N of West Yellowstone, MT. Lodgepole pine, spruce, subalpine fir around ephemeral lake. 2182m. 44^{0}54'49"N, 111^{0}03'04"W. 15 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore. **Elemental Analysis Collections (*Bryoria fremontii, Letharia vulpina*).**

2. Talus slope and adjacent grassland on west side of Black Butte along U.S. Highway 191, northwest corner of park. 45 km N of West Yellowstone, MT. 2030 m. 45^{0}01'40"N, 111^{0}06'26"W. 15 July 1998. Gallatin Co., Montana. Eversman, Glew, Wetmore.

3. Trail to Big Horn Peak along Black Butte Trail; 0.8 km beyond trail junction. Along stream with lodgepole pine, some subalpine fir and whitebark pine. 5 km E of Hwy 191. 48 km N of West Yellowstone. 2300 m. 45^{0}03'46"N, 111^{0}04'.95'W 15 July 1998. Gallatin Co, Montana. Eversman, Wetmore.

4. Black Butte Trail to Big Horn Peak, near trail junction, 4 km from trail head, 4 km E of Hwy. 191. 45 km N of West Yellowstone.. South-facing hillside with large old Douglas fir, lodgepole pine, quaking aspen. 2300 m. 45^{0}03'26"N, 111^{0}05'19"W. 16 July 1998. Gallatin Co., Montana. Eversman, Wetmore.

5. Steep north-facing slope, 3 km up Specimen Creek above East Fork. Northwest corner of park. 10 km E of Hwy. 191. Engelmann spruce, lodgepole pine, subalpine fir, *Vaccinium scoparium, Ptilium.* 2212 m. 45^{0}01'32"N, 111^{0}02'15"W. 17 July 1998. Park Co., Montana. Eversman, Glew, Wetmore.

6. Along Specimen Creek at East Fork crossing. On stump by stream. 42 km N of West Yellowstone, 6 km E of Hwy. 191 2176 m. 45^{0}01'39"N, 111^{0}02'48"W. 17 July 1998. Gallatin Co., Montana. Eversman, Glew, Wetmore.

7. East-facing volcanic flow and rock outcrops near trail along Specimen Creek. 42 km N of West Yellowstone, 5 km E of Hwy. 191. 2167 m. 45^{0}01'37"N, 110^{0}03'09"W. 17 July 1998. Gallatin Co., Montana. Eversman, Glew, Wetmore.

8. Talus slope near trailhead, Specimen Creek, 42 km N of West Yellowstone, 0.5 km from Hwy. 191. 2182 m. 45^{0}00'46"N, 111^{0}04'25"W. 18 July 1998. Gallatin Co., Montana. Eversman, Glew, Wetmore.

9. Big Horn Peak. 90 km N of West Yellowstone. Trail and trees along trail; alpine meadow and rock outcrops. 10 km E of Hwy. 191. 3009 m. 45^{0}03'51"N, 111^{0}03'19"W. 16 July 1998. Gallatin Co., Montana. Glew.

10. Base of Mt. Jackson, Madison River Canyon, 15 km E of West Yellowstone. Adjacent West Entrance Road. Douglas fir, rhyolitic rock. 2060 m. 44^{0}38'58"N, 110^{0}56'36"W. 19 July 1998. Teton Co., Wyoming. Eversman, Glew, Wetmore.

11. Firehole Canyon above falls, 1.6 km from junction with main road between Madison Junction and Old Faithful. Rock cliffs along stream, Engelmann spruce, lodgepole pine. Adjacent loop road. 2152 m. 44^{0}37'24"N, 110^{0}51'43"W. 19 July 1998. Teton Co., Wyoming. Eversman, Glew, Wetmore.

12. Sheepeater Cliffs, 9 km S of Mammoth Hot Springs. South facing basaltic cliffs and talus above Gardner River. 0.5 km E of North Loop Road. 2182 m. 44^{0}53'38"N, 110^{0}43'35"W. 20 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

13. Along trail to Sepulcher Mountain, Upper Terrace Loop, 1.6 km S of Mammoth. Travertine outcrops and Douglas fir. 0.5 km from north Loop Road. 2121 m. 44^{0}57'54"N, 110^{0}42'58"W. 20 July 1998. Park Co., Wyoming. (Site 1,1990). Eversman, Glew, Wetmore.

14. Douglas fir with Rocky Mountain juniper and snowberry, on ridge above trail to Sepulcher Mountain, Upper Terrace Loop, 1.7 km S of Mammoth. 2182 m. 44^{0}58'00"N, 110^{0}43'00" W. 20 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

15. Grazing exclosure 1.6 km W of Gardiner, northern edge of park. Sagebrush-grassland, exposed rock. Adjacent gravel road. 1606 m. 45^{0}02'09"N, 110^{0}43'54"W. 21 July 1998. Park Co., Montana. Eversman, Glew, Wetmore.

16. Douglas fir/Engelmann spruce forest with andesitic talus slope, north-facing slope. 6.4 km W of Tower Junction. Adjacent north Loop Road. 2060 m. 44^{0}56'52"N, 110^{0}28'34"W. 22 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

17. Bowl above Tower Falls Campground, NE-facing hillside with old Douglas fir, lodgepole pine. Previously burned site. Adjacent north Loop Road. 2130 m. 44^{0}53'03"N, 110^{0}23'22"W. 22 July 1998 Park Co., Wyoming. Eversman, Glew, Wetmore.

18. Mt. Washburn, east flank near top above Mt. Washburn trail, east of observation tower. 0.4 km E of north Loop Road. Alpine meadow, rock outcrops. 2788 m. 44^{0}47'48"N, 110^{0}25'44"W. 23 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

19. Mt. Washburn, basaltic outcrops south of parking lot for Chittenden Trail to top. Subalpine meadow, west exposure. 0.5 km E of north Loop Road. 2667 m. 44^{0}49'13"N, 110^{0}26'32"W. 23 July 1998. Park Co., Wyoming. (Site 4c, 1990). Eversman, Glew, Wetmore.

20. Burned Douglas fir stand along north Loop Road, 2 km W of tower Junction. Regenerating Douglas fir and lodgepole pine. Adjacent north Loop Road. 2060 m. 44^{0}55'30" N, 110^{0}26'00"W. 24 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

21. Burned and unburned basalt outcrops at Blacktail Plateau Drive exit. Douglas fir regenerating. Adjacent north Loop Road, 14 km E of Mammoth Hot Springs. 2121 m. 44^{0}57'20"N, 110^{0}32'36'W. 29 May 1996 (unburned). Eversman. 24 July 1998 (burned). Park Co., Wyoming. Eversman, Glew, Wetmore.

22. Dunraven Picnic area, 3 km N of Canyon Village. Along small stream with Engelmann spruce, lodgepole pine, subalpine fir. NE-facing slope. Adjacent north Loop Road. 2576 m. 44^{0}45'55"N, 110^{0}28'10"W. 24 July 1998. Park Co, Wyoming. Eversman, Glew, Wetmore. ***Elemental Analysis***

***Collections* (*Bryoria fremonii, Letharia vulpina*).**

23. Cascade Trail Picnic Ground, 1.6 km NE of Canyon Village. Gentle S-facing slope, lodgepole pine. Adjacent north Loop Road. 2455 m. 44°45'03"N, 110°29'33"W. 24 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

24. Granite glacial erratic boulders in sagebrush/Idaho fescue and scattered Douglas fir. West end of Lamar Valley, 10 km E of Tower Junction. Adjacent to road (north side); south exposure. 1970 m. 44°55'13"N, 110°18'07"W. 25 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

25. Shaded limestone canyon adjacent Pebble Creek at Pebble Creek Campground. Spruce, Douglas fir, subalpine fir. 1.5 km N of Northeast Entrance Road. 2151 m. 44°55'02"N, 110°06'45"W. 25 July 1998. Park Co, Wyoming. Eversman, Glew, Wetmore.

26. Old *Populus angustifolia* along Lamar River, Lamar Valley Picnic Area. 17 km E Tower Junction. Adjacent Northeast Entrance Road. 1985 m. 44°53'25"N, 110°12'42"W. 26 July 1998. Park Co., Wyoming. Eversman, Wetmore.

27. Grazing exclosure around middle-aged aspen, N side of road, 17 km E of Tower Junction. Dense understory: Rocky Mountain juniper, sagebrush, *Potentilla fruticosa.* Adjacent Northeast Entrance Road. 2091 m. 44°52'15"N, 110°11'58"W. 26 July 1998. Park Co, Wyoming. Eversman, Wetmore.

28. East base of Barronette Peak along Soda Butte Creek. Steep N-facing hillside with spruce, subalpine fir, lodgepole pine. 0.5 km N of Northeast Entrance Road. 2182 m. 44°58'44"N, 110°03'47"W. 26 July 1998. Park Co., Wyoming. Eversman, Wetmore.

29. Grazed Idaho fescue meadow along road (benchmark). East base of Barronette Peak, adjacent Northeast Entrance Road. 2212 m. 44°58'47"N, 110°08'50"W. 26 July 1998. Park Co., Wyoming. Eversman, Wetmore.

30. Along Pebble Creek, above backcountry camp 6.5 km from Pebble Creek Campground. Englemann spruce, lodgepole pine, some Douglas fir. 7 km N of Northeast Entrance Road. 2288 m. 44 57'35"N, 110 07'10"W. 27 July 1998. Park Co., Wyoming. Elemental analysis collections. ***Elemental analysis collection (Bryoria fremontii, Letharia vulpina).*** Eversman, Glew, Wetmore.

31. Pebble Creek Trail at first stream, on W-facing slope with big old Engelmann spruce, a few Douglas fir and subalpine fir. 5 km N of Northeast Entrance Road. 2303 m. 44°56'22"N, 110°06'36"W. 27 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

32. Pebble Creek Trail above switchback. Large old Douglas fir above meadow, W-facing slope. 4.5 km N of Northeast Entrance Road. 2288 m. 44°05'53"N, 110°06'34"W. 27 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

33. Rocks above cliffs below switchback, 0.5 km above Pebble Creek Campground on Pebble Creek Trail. 1 km N of Northeast Entrance Road. Douglas fir. 2090 m. 44°55'19"N, 110°06'38"W. 27 July 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

34. Avalanche Peak Trail, at first stream crossing. 11 km E of Yellowstone Lake on East Entrance Road, 1

km N of road. SE-facing hillside in deep snow area with Engelmann spruce, subalpine fir, whitebark pine, lodgepole pine. 2848 m. 44°28'51"N, 110°08'05"W. 5 August 1998. Park Co., Wyoming. Eversman, Wetmore.

35. Across road from Avalanche Peak Trailhead, adjacent East Entrance Road. 11 km E of Yellowstone Lake near Eleanor and Sylvan lakes. N-facing slope along little stream. Engelmann spruce, subalpine fir, whitebark pine, lodgepole pine. 2590 m. 44°28'16"N, 110°08'40"W. 5 August 1998. Park Co., Wyoming. (Site 26, 1990). Eversman, Wetmore.

36. Picnic area along NW shore of Yellowstone Lake, 11 km W of Bridge Bay Campground. Engelmann spruce, lodgepole pine, subalpine fir. Adjacent South Loop Road. 2352 m. 44°28'05"N, 110°28'02"W. 6 August 1998. Teton Co., Wyoming. ***Elemental analysis collections (Bryoria fremontii, Letharia vulpina)***. Eversman, Glew, Wetmore.

37. Lake Butte, N side of Yellowstone Lake, East Entrance Road. Old Douglas fir, north side of butte, 1.5 km N East Entrance Road. 2545 m. 44°30'40"N, 110°16'29"W. 6 August 1998. Teton Co., Wyoming. ***Elemental analysis collections (Bryoria fremontii, Letharia vulpina).*** Eversman, Glew, Wetmore.

38. Steep cliff and gully adjacent East Entrance Road, 4 km W of East Entrance. Douglas fir, Engelmann spruce, lodgepole pine. 2300 m. 44°27'56"N, 110°03'57"W. 6 August 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

39. Top of loop trail on Elephant Back Ridge, 2.4 km W of Fishing Bridge. Ridge with lodgepole pine, whitebark pine. 2 km NW of South Loop Road. 2606 m. 44°34'17"N, 110°24'47"W. 7 August 1998. Teton Co., Wyoming. Eversman, Glew, Wetmore.

40. Shaded slope at LeHardy's Rapids Picnic Area, 9 km N of Fishing Bridge along Yellowstone River. 0.5 km S of South Loop Road. Engelmann spruce, lodgepole pine, subalpine fir, whitebark pine, moss. 2400 m. 44°36'38"N, 110°24'27"W. 7 August 1998. Park Co., Wyoming. Eversman, Glew, Wetmore.

41. Along Spring Creek, Divide Lookout Trailhead, 0.5 km S of South Loop Road, just W of Craig Pass. Along stream and on N-facing slope with Engelmann spruce, subalpine fir, lodgepole pine. 2438 m. 44°25'59"N, 110°43'56"W. 9 August 1998. Teton Co., Wyoming. (Site 19, 1990). Eversman, Glew, Wetmore.

42. North-facing rhyolitic rock cliffs with lodgepole pine, subalpine fir, Engelmann spruce. Adjacent to and S of South Loop road near Craig Pass. 2500 m. 44°26'09"N, 110°43'33"W. 10 August 1998. Teton Co., Wyoming. Eversman, Wetmore.

43. Ridge north of and adjacent to South Loop Road, Craig Pass between Old Faithful and West Thumb. Lodgepole pine, whitebark pine. 2545 m. 44°26'05"N, 110°38'35"W. 10 August 1998. Teton Co. Wyoming. Eversman, Wetmore.

44. Moose Falls on Crawfish Creek, 2 km N of South Entrance. Cliffs on south side of creek below falls, adjacent South Entrance Road. Engelmann spruce, lodgepole pine. 2121 m. 44°09'07"N, 110°40'19"W. 11 August 1998. Teton Co., Wyoming. Across creek from site 24 (Eversman, 1990). Eversman, Wetmore.

45. Ridge above junction of Lewis and Snake rivers, 0.5 km N of South Entrance. 0.5 km E of South Entrance Road. Lodgepole pine with some subalpine fir, whitebark pine. 2090 m. 44°08'24"N, 110°39'55"W. 12 August 1998. Teton Co., Wyoming. ***Elemental analysis collections (Bryoria fremontii).*** Eversman, Wetmore.

46. Trail between Bechler Falls and Cave Falls, Bechler and Cave rivers. Lodgepole pine, Engelmann spruce, subalpine fir, whitebark pine. Dense undergrowth: pine grass, snowberry, serviceberry. 1 km from campground road. 1915 m. 44°08.977'N, 110°59.707'W. 14 August 1998. Teton Co., Wyoming (Site 25, 1990). Eversman, Glew.

47. Sulphur Mountain, 11 km NW of Fishing Bridge. Sagebrush-grassland hill, rocks. Adjacent to and west of South Loop Road. 2403 m. 44°39'10"N, 110°28'09"W. 8 August 1998. Park Co., Wyoming. Glew, Wetmore.

48. NW slope above a small valley, 3.2 km N of Fishing Bridge along Yellowstone River. Engelmann spruce, subalpine fir, lodgepole pine. Adjacent to, W of South Loop Road. 2424 m. 44°35'19"N, 110°23'14"W. 8 August 1998. Park Co., Wyoming. Glew, Wetmore.

49. Below Mystic Falls near Biscuit Basin. N-facing slope above stream. Lightly burned area with Engelmann spruce, subalpine fir, young lodgepole pine. 0.5 km from North Loop Road. 2394 m. 44°28'59"N, 110°52'40"W. 9 August 1998. Teton Co., Wyoming. Glew, Wetmore.

50. Biscuit Basin, 3.2 km NW of Old Faithful. On soil near thermal pools and geysers. Engelmann spruce, lodgepole pine. 0.5 km W of South Loop Road. 2212 m. 44°29'07"N, 110°51'22"W. 4 August 1998. Teton Co., Wyoming. (Site 17a, 1990). Eversman, Glew, Wetmore.

51. Republic Pass, 6 km S of Cooke City, Montana. High alpine ridge, meadows. 12 km W of Northeast Entrance Road. 3164 m. 44°57'09"N, 109°57'13"W. 26 July 1998. Park Co., Wyoming. Glew.

52. Avalanche Peak, East Entrance Road, 18 km W of East Entrance. Alpine ridge. 3.5 km N of E. Entrance Road. 3202 m. 44°29'16"N, 110°08'31"W. 5 August 1998. Park Co., Wyoming. Glew.

53. Mt. Sheridan, west side of Heart Lake, 11 km E of South Entrance Road. Trees and meadow below timberline on ESE side; alpine meadow and rocks on west side. 3124 m. 44°15'57"N, 110°31'45"W. 10 August 1998. Teton Co., Wyoming. Glew.

54. Heart Lake, west side at base of Mt. Sheridan. 13 km E of South Entrance Road. Engelmann spruce, subalpine fir, lodgepole pine. 2325 m. 44°15'50"N, 110°29'51"W. 10 August 1998. Teton Co., Wyoming. Glew.

55. Blacktail Deer Plateau, 14 km E Mammoth Hot Springs. *Artemisia tridentata Festuca idahoensis* grassland; granite erratics. 2060 m. 44°56'59"N, 110 °4'56"W. 25 May 1977. Park Co., Wyoming. (Site 2, 1990). Eversman.

56. Trailhead to Yellowstone River, north of Loop Road. 2km W. Tower Junction, 6 km W Tower Falls. Douglas fir, andesitic talus, N-facing slope. 1939 m. 19 October 1977. 44°56'59"N, 110°26'58"W. Park Co., Wyoming. (Site 3, 1990). Eversman.

57. Northwest slope of Mt. Washburn. Whitebark pine on west side of North Loop Road and Chittenden Road. 2558 m. 44°49'15"N, 110°27'10"W. 19 October 1977. Park Co., Wyoming. (Site 4a, 1990). Eversman.

58. Northeast slope of Mt. Washburn. Sagebrush-grassland, east of North Loop Road. 2497 m. 44°50'01"N, 110°26'02"W. 19 October 1977. Park Do., Wyoming. (Site 4b, 1990). Eversman.

59. Campground at Norris Junction near Gibbon River. Young lodgepole pine near dormant thermal area. 0.5 km N of Norris-Canyon Road. 2285 m. 44°43'57"N, 110°41'05". 15 June 1978. Park Co., Wyoming. (Site 5, 1990). Eversman.

60. Virginia Cascades Road, 4.5 km E of Norris Junction, Norris-Canyon Road. Windfall area of 1984. Lodgepole pine, few whitebark pine and subalpine fir. 2303 m. 44°42'58"N, 110°39'10"W. 15 June 1978. Park Co., Wyoming. (Site 6, 1990). Eversman.

61. Exposed ridge on loop trail to Sepulcher mountain; exposed rock in meadow. 4 km NW Mammoth Hot Springs (burned in 1988). 2515 m. 44°59'00"N, 110°45'01"W. 31 August 1982. Park Co., Wyoming. (Site 8a, 1990). Eversman.

62. Summit of Sepulcher Mountain. 5.5 km NW Mammoth Hot Springs. Exposed rock , whitebark pine (burned in 1988). 2925 m. 44°59'30"N, 110°45'59"W. Park Co., Wyoming. 31 August 1982. (Site 8b, 1990). Eversman.

63. Bunsen Peak, 5 km S of Mammoth Hot Springs, trail on south and west sides. Adjacent North Loop Road. Lodgepole pine, whitebark pine (burned in 1988). 2394 m. 44°55'57"N, 110°43'W. 9 September 1982. Park Co., Wyoming. (Site 9a, 1990). Eversman.

64. Bunsen Peak summit, 5 km S of Mammoth Hot Springs. Whitebark pine. 2595 m. 44°55'58"N, 110°42'20"W. 9 September 1982, 28 July 1983. Park Co., Wyoming. (Site 9b, 1990). Eversman.

65. Bunsen Peak, north and east sides along service road. Old Douglas fir. 2121 m. 44°56'01"N, 110°40'59"W. 28 July 1983. Park Co., Wyoming. (Site 9c, 1990). Eversman.

66. Bunsen Peak, base on south along service road. Old lodgepole pine. 2194 m. 44°55'20"N, 110°42'05"W. 28 July 1983. Park Co., Wyoming. (Site 9d, 1990). Eversman.

67. Clagett Butte, 3 km WSW Mammoth Hot Springs. Lodgepole pine. 2426 m. 44°57'58"N, 110°44'00"W. 2 September 1983. Park Co., Wyoming. (Site 10, 1990). Eversman.

68. Terrace Mountain, 4.5 km SW Mammoth Hot Springs. Lodgepole pine, calcareous rock. 2388 m. 44°56'58"N, 110°43'59"W. 3 September 1983. Park Co., Wyoming. (Site 11, 1990). Eversman.

69. Mount Everts, southeast slopes, 6 km SE Mammoth Hot Springs, Sagebrush grassland, basaltic outcrops. 2185 m. 44°57'15"N, 110°N37'59"W. 1 September 1982. Park Co., Wyoming. (Site 12a, 1990). Eversman.

70. Mount Everts, summit. 4 km E Mammoth Hot Springs. Meadow, whitebark pine. 2376 m. 44°58'30"N, 110°39'39"W. 1 September 1982. Park Co., Wyoming. (Site 12b, 1990). Eversman.

71. Tower Ranger Station at Tower Junction. Douglas fir; shaded and exposed granitic rock on E-facing slope. 2061 m. 44°55'02'N, 110°25'50"W. 8 August 1984. Park Co., Wyoming. (Site 13, 1990). Eversman.

72. Lamar River Valley, 4 km E Tower Junction, near Trumpeter Lakes. Sagebrush grassland, Douglas fir, granite glacial erratics. 1848 m. 44°54'55"N, 110°22'45"W. 8 August 1984. Park Co., Wyoming. (Site 14, 1990). Eversman.

73. Purple Mountain, 2 km N Madison Junction. Lodgepole pine, whitebark pine at top; rhyolite. 2555 m. 44°39'25"N, 110°51'25"W. 1 August 1984. Teton Co., Wyoming. (Site 16, 1990). Eversman.

74. Mystic Falls Scenic Overlook above Biscuit Basin, 4 km NW of Old Faithful. Lodgepole pine, rock outcrops (burned in 1988). 2388 m. 44°29'25"N, 110°51'59"W. 2 August 1984. Teton Co., Wyoming. (Site 17b, 1990). Eversman.

75. Mallard Lake Trail, SW of Mallard Lake, 4 km E of Old Faithful. Spruce along river, lodgepole pine; rhyolite outcrops. 2400 m. 44°27'55"N, 110°47'40"W. 31 July 1984. Teton Co., Wyoming. (Site 18, 1990). Eversman.

76. Trail near Duck Lake, west of road. West Thumb, Yellowstone Lake. Engelmann spruce, subalpine fir. 2351 m. 44°25'05"N, 110°34'25"W. 7 August 1984. Teton Co., Wyoming. (Site 20, 1990). Eversman.

77. Lewis Falls, Lewis River, flowering south from Lewis Lake. 15 km N of South Entrance. Lodgepole pine, rhyolitic outcrops. 2346 m. 44°16'28'N, 110°38'30"W. 14 August 1984. Teton Co., Wyoming. (Site 21, 1990). Eversman.

78. Pitchstone Plateau trail, 6 km from trail head near Phantom Fumarole. Trailhead 12 km N of South Entrance. Engelmann spruce, subalpine fir. 2590 m. 44°09'19"N, 110°40'59"W. 15 August 1984. Teton Co., Wyoming. (Site 23, 1990). Eversman.

79. Crawfish Creek above Moose Falls, west side of South Entrance Road, 2 km N of South Entrance. Lodgepole pine along stream. 2125 m. 44°09'19"N, 110°40'59"W. 15 August 1984. Teton Co., Wyoming. (Site 23, 1990). Eversman.

80. Crawfish Creek across from Moose Falls, east of South Entrance Road, 2 km N of South Entrance. Moist shady area N side of stream. 2100 m. 44°09'15"N, 110°40'30"W. 15 August 1984. Teton Co., Wyoming. (Site 24, 1990). Eversman.

81. Mount Everts, northwest slopes 1 km E of trailhead on Gardiner River, 3 km SE of Gardiner, MT. 1818 m. 45°01'00"N, 110°40'41"W. 1 September 1982. Park Co., Montana. (Site 27, 1990). Eversman.

82. Electric Peak, trailhead near patrol cabin, border of Gallatin National Forest and Yellowstone National Park. 5 km S of Corwin Springs, Montana. Douglas fir, lodgepole pine, Engelmann spruce. 2424 m. 45°03'15"N, 110°50'04"W. 8 September 1982. Park Co., Montana. (Site 28a, 1990). Eversman.

83. Electric Peak, alpine meadow, north side at upper timberline. Whitebark pine islands, granitic outcrops. 3030 m. 45°01'15"N, 110°50'30"W. 8 September 1982. Park Co., Montana. (Site 28b, 1990). Eversman.

84. Electric Peak summit. Alpine meadow, granitic outcrops. 3316 m. 45°01'15"N, 110°51'30"W. 8 September 1982. Park Co., Montana. (Site 28c, 1990). Eversman.

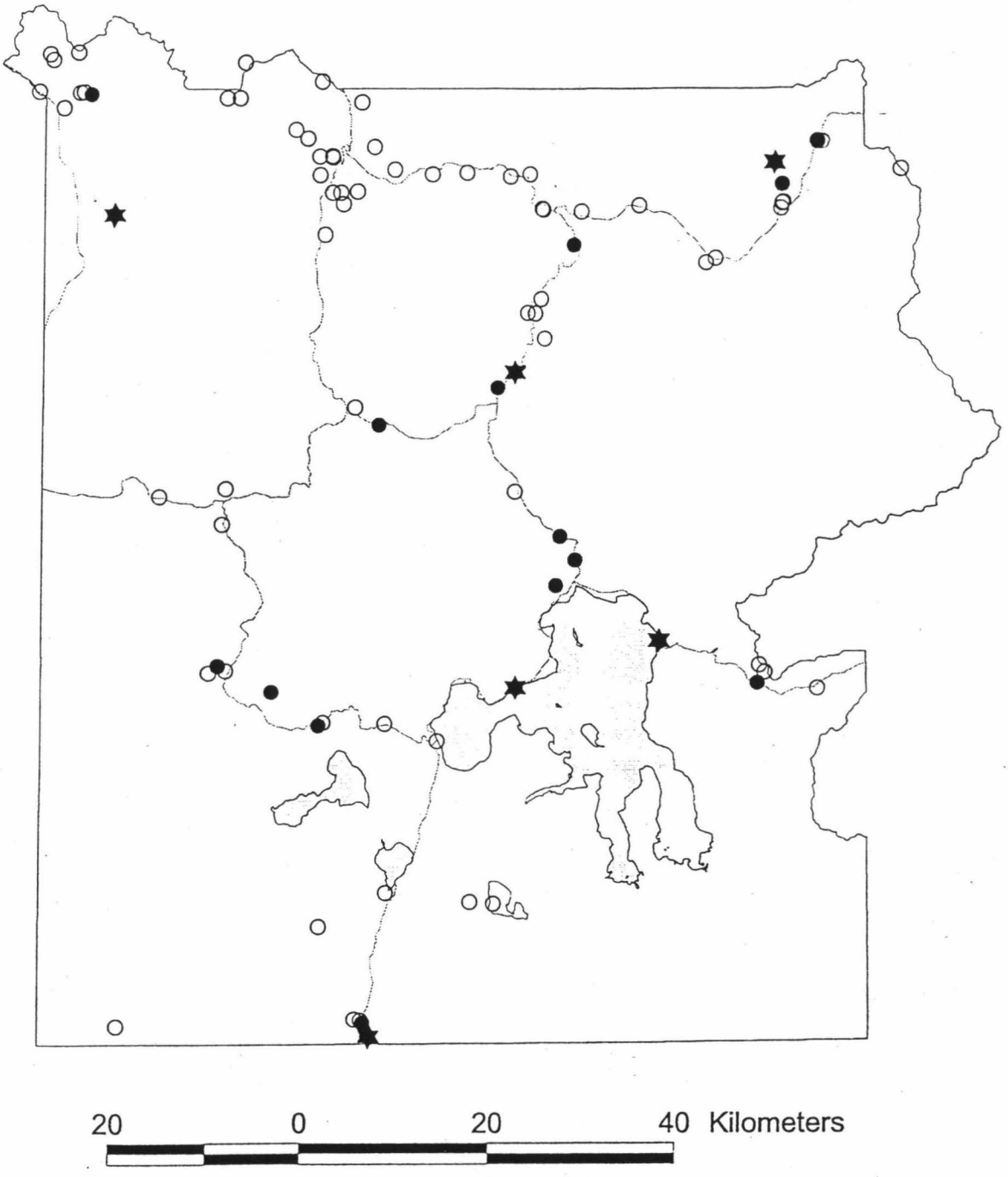

Figure 2. Distribution of *Bryoria fremontii* collected in Yellowstone National Park (black circles). Open circles represent all collection sites. Stars represent sites from which samples were collected for elemental analysis (sites 1, 22, 30, 36, 37, 45).

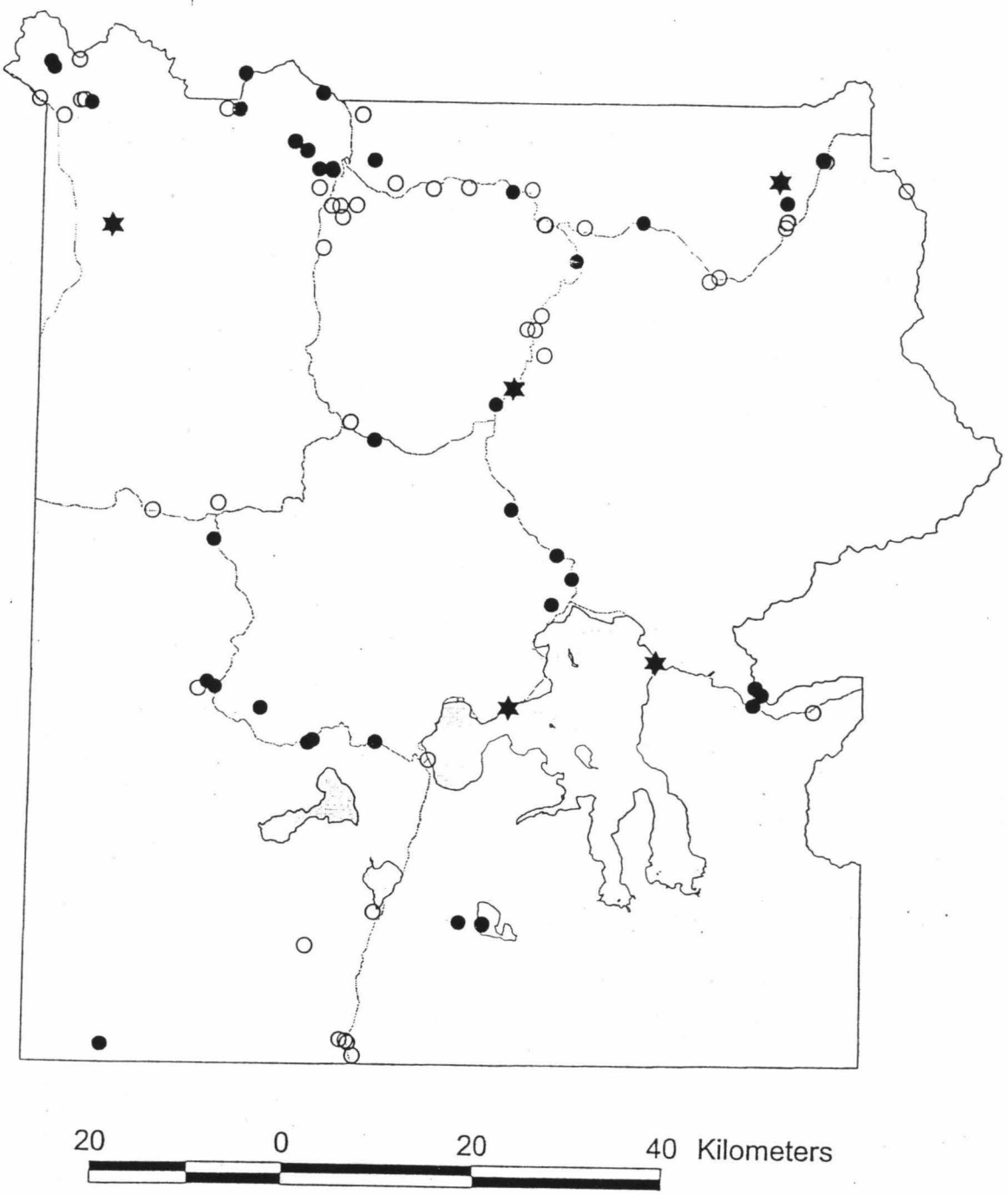

Figure 3. Distribution of *Letharia vulpina* collected in Yellowstone National Park (black circles). Open circles represent all collection sites. Stars represent sites from which samples were collected for elemental analysis (sites 1, 22, 30, 36, 37).

Latitude and longitude of each site were recorded on the hand-held GPS of each collector; however, for the report, Wetmore's readings were used and checked against topographic maps (National Geographic, Trails Illustrated topographic maps for each quarter of the park). The latitude and longitude given by the GPS were generally accurate according to the maps. Glew recorded her alpine sites with a GPS, and Eversman used topographic maps for sites 55-84.

Selection of sites was made by consulting the maps for elevation, slope and aspect in order to concentrate on Douglas fir, spruce and subalpine fir stands, and alpine sites. It was also decided to collect from sites that were reasonably accessible, so that time was spent collecting not hiking, although Glew had agreed to concentrate on the alpine sites that involved long strenuous hikes (Table 1: sites 9, 51, 52, 53, 54). In most cases non-duplication of previously-collected sites was wanted; however, some duplications occurred in interesting sites or inadvertently.

At each site, the collectors spent at least one hour, or, in many cases, half a day or more, examining every substrate present for lichen collection. Since part of an inventory of species is to determine habitat, distribution and abundance of a species, each species encountered at each site was usually collected by each collector unless we were confident another person had it. If any species are under-represented, they are probably the most common and abundant ones. Wetmore seemed to concentrate more on tree substrates and Eversman concentrated more on rock substrates, but we all tried to examine every substrate. We worked independently and spread out over a site. When only one collection of a specimen occurred at a site, it was rare at that site, and many species were rare in the park. When all three of us had a specimen from a location, it was either special (*e.g., Caloplaca cladodes,* site 33) or common and abundant. We left each site only when we were convinced we had found every species present. Each person's collection was well over 1000 specimens.

Identification of specimens occurred at Montana State University, the University of Minnesota, the University of Washington and the Field Museum of Natural History by each collector, and a composite list of species was made (Table 2). The list of species includes specimens from the total of 84 collection sites from 1977 through 1998. Appendices 1, 2, and 3 list the lichens collected and identified by Eversman, Glew and Wetmore, respectively. Identification included standard morphological, chemical and chromatographic techniques (Bird, unpublished keys; Brodo, 1991; Culberson, 1972; Esslinger, 1975; Goffinet & Hastings, 1994; Imshaug, 1951; Laundon, 1989, 1992; Lindblom, 1997; McCune & Goward, 1995; Ryan, unpublished keys; Ryan & Nash, 1991, 1993; Thomson, 1967, 1979, 1984, 1997; Timdal, 1986; Wetmore & Karnefelt, 1998). Nomenclature is according to Esslinger (1998).

Voucher specimens are presently in the herbaria of Montana State University and the University of Minnesota and in the personal collection of Katherine Glew. When all identifications are complete, a set of voucher specimens will be deposited in the herbarium of Yellowstone National Park.

TABLE 2: LICHENS COLLECTED AND IDENTIFIED FROM YELLOWSTONE NATIONAL PARK.

Three hundred sixty-four species in 105 genera reported from Yellowstone National Park are listed and their collection sites (Table 1) are given. Nomenclature is according to Esslinger (1998). Sites numbered 1-54 are from 1998; sites numbered 55-84 are sites from which collections were reported in Eversman, 1990. Species reported for the first time from Yellowstone National Park are marked with an asterisk (*).

Acarospora fuscata (Schrader) Arnold: 1, 2, 40, 46, 47

**Acarospora glaucocarpa* (Ach.) Koerber: 8, 13, 14, 15, 25

Acarospora schleicheri (Ach.) A. Massal.: 19, 61, 62

**Acarospora stapfiana* (Muell.Arg.) Hue: 15

**Acarospora strigata* (Nyl.) Jatta: 8

**Acarospora veronensis* A. Massal.: 2, 8, 9, 15, 45, 51, 81

Agrestia hispida (Mereschk.) Hale & Culb.): 15, 55

**Amandinea (Buellia) punctata* (Hoffm.) Coppins & Scheid.: 3, 11, 15, 24, 26, 28, 35

* *Arthonia mediella* Nyl.: 4

Aspicilia caesiocinerea (Nyl. *ex* Mahlbr.) Arnold: 2, 8, 9, 10, 12, 15, 18, 19, 22, 24, 40, 44, 45, 46, 47, 49 53, 55, 61, 62, 64, 66, 69, 70, 74, 76, 77, 78, 79, 84

Aspicilia candida (Anzi) Hue: 25, 84

Aspicilia cinerea (L.) Koerber: 2, 8, 10, 11, 16, 21, 24, 33, 40, 42, 44, 45, 49, 50, 61, 71, 72, 74, 76, 79

**Aspicilia contorta* (Hoffm.) Kremp.: 2, 15, 24, 29, 33, 42, 44, 46, 47

**Aspicilia filiformis* Rosentreter: 43

**Aspicilia laevata* (Ach.) Arnold: 5, 7, 20, 21, 42, 45, 46, 49

**Baeomyces rufus* (Hudson) Rebent.: 40

Bellemerea alpina (Sommerf.) Clauzade & Roux: 8, 22, 34, 35, 42, 49, 52, 57, 64, 67, 74, 75

**Bellemerea cinereorufescens* (Ach.) Clauzade & Roux: 2, 9, 22, 35, 40, 42, 45, 49

**Biatora albohyalina* (Nyl.) Bagl. & Carestia: 48

**Biatora turgidula* (Fr.) Nyl.: 11, 28

**Biatoropsis usnearum* Rasanen: 28

Bryoria fremontii (Tuck.) Brodo & D. Hawksw.: 1, 5, 17, 22, 23, 28, 30, 31, 35, 36, 37, 39, 40, 41, 44, 45, 48, 60, 74, 75

Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.: 1, 3, 5, 10, 14, 16, 17, 21, 22, 24, 28, 30, 31, 33, 36, 37, 39, 41, 44, 45, 48, 49, 62, 63, 66, 67, 68, 69, 70

Bryoria lanestris (Ach.) Brodo & D. Hawskw.: 20, 23, 24, 33, 37, 39, 40, 46, 49, 54, 56, 57, 58, 59, 60, 61, 62, 64, 65, 69, 72, 73, 75, 76, 78, 82

Buellia erubescens Arnold: 3, 5, 10, 11, 17, 22, 31, 35, 36, 42, 43, 49, 67, 68

**Buellia griseovirens* (Turner & Borrer *ex* Sm.) Almb.: 17

**Buellia leptocline* (Flotow) A. Massal.: 30

Buellia papillata (Sommerf.) Tuck.: 11, 18, 19, 21, 24, 40, 49, 67, 69

**Buellia triphragmioides* Anzi: 27

**Lecanora meridionalis* H. Magn.: 49

Lecanora muralis (Schreber) Rabenh.: 1, 4, 7, 9, 10, 11, 14, 15, 16, 18, 19, 21, 29, 33, 36, 37, 46, 51, 53, 61, 62, 63, 68, 70, 76, 83

Lecanora nigromarginata H. Magn.: 15, 62, 66

Lecanora novomexicana H. Magn.: 8, 9, 18, 24, 45, 50, 58, 63, 71, 73, 74, 79, 81, 83

**Lecanora phaedrophthalma* Poelt: 2, 12, 15, 16, 21, 24, 33

Lecanora piniperda Koerber: 4, 14, 23, 26, 31, 34, 35, 43, 46, 56, 60, 61, 62, 63, 66, 67, 69, 70, 72, 73, 81

Lecanora polytropa (Hoffm.) Rabenh.: 2, 6, 8, 10, 21, 22, 30, 35, 36, 39, 40, 42, 43, 44, 45, 47, 51, 52, 53, 57, 67, 73, 77

**Lecanora pulicaris* (Pers.) Ach.: 45

Lecanora rupicola (L.) Zahlbr.: 2, 3, 8, 11, 12, 16, 21, 24, 33, 47, 52, 58, 63, 64, 69, 73, 74, 84

Lecanora saligna (Schrader) Zahlbr.: 24, 36, 43, 45, 65

**Lecanora varia* (Hoffm.) Ach.: 1, 3, 4, 5, 14, 16, 17, 22, 28, 30, 32, 34, 37, 39, 40, 41, 45, 47, 48, 49

Lecidea atrobrunnea (Ramond *ex* Lam. & DC.) Schaerer: 1, 2, 3, 5, 7, 8, 9, 10, 12, 16, 18, 21, 24, 30, 33, 34, 36, 37, 38, 39, 42, 44, 45, 46, 47, 49, 51, 52, 53, 58, 61, 62, 64, 66, 69, 70, 73, 75, 76, 77, 81

**Lecidea auriculata* Th. Fr.: 8, 39

**Lecidea confluens* (Weber) Ach.: 49

**Lecidea lapicida* (Ach.) Ach.: 2, 16, 24, 37, 42

**Lecidea syncarpa* Zahlbr.: 10

Lecidea tessellata Floerke: 1, 8, 11, 12, 15, 16, 24, 30, 42, 45, 46, 47, 53, 55, 58, 62, 69, 81

**Lecidella carpathica* Koerber: 7, 8, 12, 22, 37, 42, 45

**Lecidella elaeochroma* (Ach.) Hazsl.: 14, 28, 31

Lecidella euphorea (Floerke) Hertel: 4, 5, 14, 22, 26, 27, 28, 30, 37, 40, 44, 61

**Lecidella patavina* (A. Massal.) Knoph & Leuckert: 16, 18, 25, 44, 47

Lecidella stigmatea (Ach.) Hertel & Leuckert: 1, 9, 10, 15, 16, 18, 30, 33, 36, 37, 39, 44, 46, 62, 66

**Lecidoma demissum* (Rustr.) Gotth. Schneider & Hertel: 9, 35, 39, 43

**Lepraria cacuminum* (A. Massal.) Lohtander: 7, 8, 24, 39, 42, 43, 46, 52, 53

**Lepraria caesioalba* (deLesd.) J. R. Laundon: 12, 24, 39, 43

**Lepraria lobificans* Nyl.: 8, 25

Lepraria incana (L.) Ach.: 7, 16, 63, 73, 79

Lepraria neglecta (Nyl.) Erichsen: 8, 11, 12, 21, 24, 40, 67

Leprocaulon albicans (Th.Fr.) Nyl. *ex* Hue: 11, 42, 67

**Leprocaulon gracilescens* (Nyl.) Lamb. & Ward: 11

**Leproloma diffusum* J. R. Laundon: 44

Leproloma membranaceaum (Dickson) Vainio: 71, 75, 80

**Leptochidium albociliatum* (Desmaz) M. Choisy: 21

**Leptogium burnetiae* C. W. Dodge: 11

**Leptogium gelatinosum* (With.) J. R. Laundon: 44

**Leptogium hirsutum* Sierk: 11

**Leptogium lichenoides* (L.) Zahlbr.: 25

Leptogium saturninum (Dickson) Nyl.: 21, 25, 71

Leptogium tenuissimum (Dickson) Koerber: 13

Letharia columbiana (Nutt.) J. W. Thomson: 6, 9, 16, 17, 18, 22, 23, 30, 34, 35, 36, 39, 41, 52, 53, 57, 60, 61, 62, 67, 69, 73, 75, 76, 78, 82

Letharia vulpina (L.) Hue: 1, 3, 4, 5, 11, 13, 14, 15, 16, 17, 22, 23, 24, 28, 30, 31, 34, 35, 36, 37, 39, 40, 41, 42, 43, 46, 47, 48, 50, 52, 53, 54, 60, 61, 62, 67, 70, 74, 75, 82, 83

Lobothallia alphoplaca (Wahlenb.) Hafellner: 7, 8, 15, 16, 19, 33, 38, 61, 62, 69

Megaspora verrucosa (Ach.) Hafellner & V.Wirth: 14, 18, 19, 44, 47, 83

Melanelia disjuncta (Erichsen) Essl.: 2, 10, 11, 12, 16, 21, 24, 42, 71, 75, 77

Melanelia elegantula: (Zahlbr.) Essl.: 3, 4, 5, 11, 14, 15, 18, 19, 20, 22, 24, 26, 27, 32, 36, 37, 62, 67, 69, 70, 73, 82

**Melanelia exasperata* (DeNot.) Essl.: 24

Melanelia exasperatula (Nyl.) Essl.: 1, 3, 11, 13, 17, 20, 22, 26, 27, 28, 30, 31, 35, 36, 37, 40, 45, 46, 47, 48, 49, 54, 60, 61, 62, 63, 65, 66, 70, 73, 75, 79, 82

Melanelia infumata (Nyl.) Essl.: 9, 18, 21, 24, 69, 70, 71, 79

Melanelia sorediata (Ach.) Goward & Ahti: 2, 16, 42, 79

Melanelia stygia (L.) Essl.: 61, 69, 75

Melanelia subelegantula (Essl.) Essl.: 1, 9, 22, 36, 37, 41, 46, 50, 57, 60, 63, 67, 69, 70, 71, 74

Melanelia subolivacea (Nyl.) Essl.: 10, 14, 16, 17, 29, 46, 61, 62, 67, 69, 70, 79, 80

Melanelia tominii (Oksner) Essl.: 2, 8, 11, 12, 16, 21, 24, 55, 71, 75

**Micarea denigrata* (Fr.) Hedl.: 28

**Micarea melaena* (Nyl.) Hedl.: 4

**Micarea misella* (Nyl.) Hedl.: 43

Mycobilimbia berengeriana (A. Massal.) Hafellner & V. Wirth: 16, 28, 31, 35, 37, 38, 41, 42, 44, 48, 61, 63

**Mycobilimbia epixanthoides* (Nyl.) Lettau: 35, 37

**Mycobilimbia hypnorum* (Lib.) Kalb & Hafellner: 5, 40

Mycobilimbia (Toninia) lobulata (Sommerf.) Hafellner: 81

**Mycobilimbia sabuletorum* (Schreber) Hafellner: 7

**Mycobilimbia tetramera* (DeNot.) W. Brunnbauer: 7, 30

**Mycocalicium subtile* Szat.: 43

Neofuscelia loxodes (Nyl.) Essl.: 67, 69

**Neofuscelia verruculifera* (Nyl.) Essl.: 2, 12, 24

Nephroma parile (Ach.) Ach.: 5, 16, 38, 49, 75, 80

Nodobryoria (Bryoria) abbreviata (Muell. Arg.) Common & Brodo: 82

**Ochrolechia androgyna* (Hoffm.) Arnold: 3, 5, 16, 17, 38, 40, 42, 46

Ochrolechia upsaliensis (L.) A. Massal.: 2, 18, 19, 51, 61, 62, 63, 65, 69

**Ophioparma lapponica* (Rasanen) Hafellner & R. W. Rogers: 11

**Pannaria pezizoides* (Weber) Trevisan: 22, 35, 38, 49

**Parmelia fraudans* (Nyl.) Nyl.: 11, 17

**Parmelia hygrophila* Goward & Ahti: 46

Rhizoplaca melanophthalma (DC.) Leuckert & Poelt: 2, 8, 9, 10, 11, 12, 15, 16, 18, 19, 21, 24, 30, 33, 46, 47, 51, 52, 53, 62, 66, 67, 68, 69, 70, 75, 81

Rhizoplaca peltata (Ramond) Leuckert & Poelt: 15

Rimularia insularis (Nyl.) Rambold & Hertel: 2, 65

Rinodina archaea (Ach.) Arnold: 10, 18, 22, 38, 42, 43, 44, 49, 60

Rinodina confragosa (Ach.) Koerber: 69

Rinodina gennarii Bagl.: 69

**Rinodina mniaraea* (Ach.) Koerber: 35, 43

**Rinodina turfacea* (Wahlenb.) Koerber: 18, 19, 21, 77, 80

**Sarcogyne regularis* Koerber: 14, 25

**Sclerophora peronella* (Ach.) Tibell: 48

Solorina crocea (L.) Ach.: 35, 39, 40, 42, 43, 75

Sporastatia testudinea (Ach.) A. Massal.: 2, 9, 18, 19, 42, 47, 51, 52, 53, 64, 69, 70, 83, 84

Squamarina lentigera (Weber) Poelt: 14

**Staurothele areolata* (Ach.) Lettau: 12, 15, 33, 46

**Staurothele clopimoides* (Arnold) J. Stein: 38

Staurothele drummondii (Tuck.) Tuck.: 25, 46, 68, 70, 81, 83

**Staurothele fissa* (Taylor) Zwackh.: 25

**Stereocaulon glareosum* (Savicz) H. Magn.: 39, 43

**Stereocaulon paschale* (L. Hoffm.: 5, 10, 35, 39, 40, 48

Stereocaulon tomentosum Fr.: 5, 10, 23, 35, 39, 40, 43, 48, 78

**Tephromela aglaea* (Sommerf.) Hertel & Rambold: 16

Tephromela armeniaca (DC.) Hertel & Rambold: 18, 22, 64

Thamnolia subuliformis (Ehrh.) Culb.: 18, 19

Thamnolia vermicularis (Sw.) Ach. *ex* Schaerer: 19

**Thelocarpon epibolum* Nyl.: 5, 40

**Thelomma ocellatum* (Koerber) Tibell: 17

**Thrombium epigaeum* (Pers.) Wallr.: 39, 43

Toninia candida Weber: Th. Fr.: 13, 25

**Toninia ruginosa* (Tuck.) Herre: 10

Toninia sedifolia (Scop.) Timdal: 2, 8, 27

Toninia squalida (Ach.) A. Massal. 79

Trapeliopsis flexuosa (Fr.) Coppins & R. James: 14, 16, 17, 23, 35, 37, 39, 40, 41, 42, 43, 44, 45, 47, 78

**Trapeliopsis granulosa* (Hoffm.) Lumbsch: 25, 38, 39, 40, 41

**Tuckermannopsis chlorophylla* (Willd.) Hale: 10, 14, 17, 28, 37

**Umbilicaria americana* Poelt & T. Nash: 11, 12, 42, 46

**Umbilicaria angulata* Tuck.: 11

Umbilicaria deusta (L.) Baumb.: 42, 77

Umbilicaria hirsuta (Sw. *ex* Westr.) Hoffm.: 71

Species Categorized by Abundance

Lichens were collected from 84 sites in Yellowstone Park. In the following lists, species are considered **common** if they were reported from 20 or more sites, or more than 23.5% of the sites; **intermediately common** if they were collected from four to 19 sites (between 5 and 23% of the sites); and **rare** if they were collected from one to three sites (less than 5% of the sites).

Common (≥20 sites)

The most common species on tree branches and trunks, in descending order, and the percentage of sites from which they were collected, were: *Letharia vulpina* (48.8%), *Parmeliopsis ambigua* (40.5%), *Melanelia exasperatula* (39.3%), *Bryoria fuscescens* (34.5%), *Letharia columbiana* (30.9%), *Bryoria lanestris* (30.9%), *Melanelia elegantula* (26.2%), *Lecanora piniperda* (25.0%), *Usnea substerilis* (25.0%), *Bryoria fremontii* (23.8%), *Lecanora varia* (23.8%), and *Lecanora circumborealis* (23.8%), The most common species on rock were *Lecidea atrobrunnea* (48.8%), *Rhizocarpon geographicum* (41.7%), *Aspicilia caesiocinerea* (35.7%), *Rhizoplaca melanophthalma* (32.1%), *Xanthoria elegans* (30.9%), *Lecanora muralis* (30.9%), *Umbilicaria hyperborea* (29.8%), *Candelariella vitellina* (27.4%), *Lecanora polytropa* (27.4%), *Aspicilia cinerea* (23.8%), and *Umbilicaria kraschenninikovii* (23.8%). The most common species on soil and litter, all in forest vegetation types, were *Peltigera rufescens* (51.2%), *Cladonia fimbriata* (38.1%), *Peltigera canina* (32.1%) *Psoroma hypnorum* (30.9%), *Peltigera aphthosa* (25.0%) and *P. venosa* (23.8%).

Intermediate (4-19 sites)

Species collected from ten to 19 sites (12 to 23% of the sites) were: *Bellemerea alpina, Buellia erubescens, Caloplaca epithallina, C. holocarpa, C. tiroliensis, C. xanthostigma, Candelariella aurella, Cladonia cariosa, C. cenotea, C. cervicornis, C. chlorophaea, C. coniocraea, C. deformis, C. ecmocyna, C. macrophyllodes, C. pyxidata, C. sulphurina, Cyphelium pinicola, Dermatocarpon miniatum, Diploschistes scruposus, Hypogymnia*

austerodes, Lecanora argopholis L. bicincta, L. cadubriae, L. cenisia, L. garovaglii, L. novomexicana, L. rupicola, Lecidea tessellata, Lecidella euphorea, L. stigmatea, Lobothallia alphoplaca, Melanelia disjuncta, M. subelegantula, M. subolivacea, M. tominii, Mycobilimbia berengeriana, Parmelia sulcata, Parmeliopsis hyperopta, Peltigera leucophlebia, P. malacea, Phaeophyscia decolor, P. sciastra, Physcia caesia, P. dubia, P. phaea, Physconia muscigena, Pleopsidium flavum, Porpidia crustulata, Protoparmelia badia, Pseudephebe pubescens, Psora nipponica, Rhizocarpon disporum, Rhizoplaca chrysoleuca, Sporastatia testudinea, Trapeliopsis flexuosa, Umbilicaria virginis, Usnea lapponica, Vulpicida pinastri, Xanthoparmelia cumberlandia, Xanthoria fulva, X. sorediata and *Xylographa vitiligo.*

Species that were collected from four to nine sites (4.8% to 10.7% of the sites) were *Acarospora fuscata, A. glaucocarpa, A. veronensis, Amandinea punctata, Aspicilia contorta, A. laevata, Bellemerea cinereorufescens, Buellia papillata, Calicium viride, Caloplaca adnexa, C. arenaria, C. chrysodeta, C. citrina, C. furfuracea, C. saxicola, C. sinapisperma, C. trachyphylla, Candelaria concolor, C. rosulans, Cetraria aculeata, C. muricata, Cladina mitis, Cladonia carneola, C. cornuta, C. pocillum, Cyphelium inquinans, Dermatocarpon reticulatum, Dimelaena oreina, Diploschistes muscorum, Endocarpon pulvinatum, Fuscopannaria ahlneri, F. praetermissa, Hypocenomyce scalaris, H. xanthococca, Hypogymnia imshaugii, H. physodes, Lecanora chlorotera, L. crenulata, L. fuscescens, L. hagenii, L. impudens, L. intricata, L. phaedrophthalma, L. saligna, Lecidea lapicida, Lecidella carpathica, L. patavina, Lecidoma demissum, Lepraria cacuminum, L. caesioalba, L. incana, L. neglecta, Megaspora verrucosa, Melanelia infumata, M. sorediata, Nephroma parile, Ochrolechia androgyna, O. upsaliensis, Pannaria pezizoides, Parmelia saxatilis, Parmeliella cyanolepra, Peltigera collina, P. didactyla, Phaeorrhiza nimbosa, Physcia adscendens, P. aipolia, P. stellaris, Physconia detersa, Placynthiella oligotropha, P. uliginosa, Platismatia glauca, Polychidium muscicola, Pseudephebe minuscula, Psora decipiens, P. globifera, P. himalayana, P. tuckermanii, Rhizocarpon geminatum, R. grande, Rinodina archaea, R. turfacea, Solorina crocea, Staurothele areolata, Staurothele drummondii, Stereocaulon paschale, S. tomentosum, Trapeliopsis granulosa, Tuckermannopsis chlorophylla, Umbilicaria americana, U. torrefacta, U. vellea, Xanthoparmelia chlorochroa, X. coloradoensis, X. lineola, X. mexicana, X. plittii, X. wyomingica, Xanthoria candelaria, X. fallax, X. oregana,* and *X. polycarpa.*

Rare Species (≤3 sites)

One hundred seventy-four species were collected from three or fewer sites (less than 3.5% of the sites): *Acarospora schleicheri, A. stapfiana, A. strigata, Agrestia hispida, Arthonia mediella, Aspicilia candida, A. filiformis, Baeomyces rufus, Biatora albohylina, B. turgidula, Biatorposis usnearum, Buellia griseovirens, B. leptocline, B. triphragmioides, B. turgescens, Calicium glaucellum, Caloplaca cerina, C. chrysodeta, C. chrysophthalma, C. cladodes, C. decipiens, C. ferruginea, C. grimmiae, C. jungermanniae, C. lactea, C. modesta, Candelariella dispersa, C. terrigena, Catapyrenium cinereum, C. psoromoides, Chaenotheca furfuracea, C. hispidula, C. stemonea, C. trichialis, Chaenothecopsis debilis, Chrysothrix chlorina, Cladonia bacilliformis, C. borealis, C decorticata, C. multiformis, C. norvegica., C. ochrochlora, C. pleurota, C. polycarpoides, C. squamosa, C. subulata, C. symphycarpa, C. verruculosa, Collema coccophorum, C. fuscovirens, C. polycarpon, C. subflaccidum, C. undulatum, Cystocoleus ebeneus, Dactylina madreporiformis, Dermatocarpon leptophyllodes, Endocarpon pusillum, Evernia mesomorpha, Flavopunctelia soredica, Fulgensia bracteata, F. fulgens, Fuscopannaria leucophaea, F. mediterranea,, Hypogymnia tubulosa, Icmadophila ericetorum, Lecania erysibe, Lecanora argentea, L. dispersa, L. hagenii, L. hypoptoides, L. intricata, L. meridionalis, L. nigromarginata, L. pulicaris, Lecidea auriculata, L. confluens, L. syncarpa, Lecidella elaeochroma, Lepraria lobificans, Leprocaulon albicans, L. gracilescens, Leproloma diffusum, L. membranaceum, Leptochidium albociliatum, Leptogium burnetiae, L. gelatinosum, L. hirsutum, L. lichenoides, L. saturninum, L. tenuissimum, Melanelia exasperata, M. stygia, Micarea denigrata, M. melaena, M. misella, Mycobilimbia epixanthoides, M. hypnorum, L. lobulata, M. sabuletorum, M. tetramera, Mycocalicium subtile, Neofuscelia loxodes, N. verruculifera, Nodobryoria abbreviata, Ophioparma lapponica, Parmelia fraudans, P. hygrophila, Peltigera elizabethae, P. kristinssonii, P. membranacea, P. polydactylon, P. ponojensis, P. praetextata, P. retifoveata, Phaeophyscia endococcina, P. hispidula, P. nigricans, P. orbicularis, Phaeorrhiza sareptana, Physcia biziana, P. dimidiata, P. wainioi, P. enteroxantha, P. isidiigera, P. leucoleiptes, P. perisidiosa, Placynthiella dasaea, P. icmalea, Placynthium nigrum, Porpidia macrocarpa, Protoblastenia rupestris, Psora cerebriformis,, P. icterica, P. montana, P. russellii, Rhizocarpon hochstetteri, R. macrosporum, R. riparium,*

Rhizoplaca peltata, Rimularia insularis, Rinodina confragosa, R. gennarii, R. mniaraea, Sarcogyne regularis, Sclerophora peronella, Squamarina lentigera, Staurothele clopimoides, S. fissa, Stereocaulon glareosum, Tephromela aglaea, T. armeniaca, Thamnolia subuliformis, T. vermicularis, Thelocarpon epibolum, Thelomma ocellatum, Thrombium epigaeum,, Toninia candida, T. ruginosa, T. sedifolia, T. squalida, Umbilicaria angulata, U. deusta, U. hirsuta, U. proboscidea, Usnea hirta, Verrucaria acrotella, V. fuscella, V. muralis, V. nigrescentoidea, Vulpicida canadensis, Xanthoparmelia lavicola, X. subdecipiens, Xanthoria mendozae, X. montana, and *X. ulophyllodes.*

Discussion of Lichen Flora

A total of 364 species in 105 genera is now reported from Yellowstone National Park, nearly twice the number listed in1990. Some names have changed because of new genus monographs, *e.g., Xanthoria* (Lindblom, 1997). As might be expected, most of the additions to the original list are crustose species in the genera *Acarospora, Aspicilia, Buellia, Caloplaca, Lecanora, Lecidea, Lecidella* and *Rhizocarpon* (Table 2). However, several additions to macrolichen genera *Cladonia, Dermatocarpon, Leptogium, Peltigera, Phaeophyscia, Platismatia, Psora, Umbilicaria* and *Xanthoria* were also made. About 44% of the total number of species were crustose with species of *Aspicilia, Caloplaca, Lecanora, Lecidea,* and *Rhizocarpon* the most abundant. Foliose and umbilicate species, primarily *Melanelia, Peltigera, Umbilicaria* and *Xanthoria*, comprised about 34% of the total number. Fruticose species (*Bryoria, Letharia, Pseudephebe, Stereocaulon, Usnea)* were about 7% of the total. *Cladonia* spp. and *Cladina mitis* were about 7% of the specimens collected; squamulose species (*Fuscopannaria, Psora, Psoroma hypnorum)* were 6%; and "pin" lichens (*Calicium, Chaenotheca, Mycocalicium)* were 2% of the total. *Cladina mitis* has been seen and collected only from certain thermal basins, and no additional locations were found in 1998.

The 1998 project concentrated more on Douglas fir and spruce/subalpine fir sites than the previous collections had. This approach resulted in the greater number of species and in finding more species and more specimens of the genus *Hypogymnia,* which is rarely found growing on lodgepole pine in Yellowstone Park. A previous study comparing lichens on three conifer

species from one site near Norris Geyser Basin (Eversman *et al.*, 1987) reported only five lichen species (*Lecanora piniperda, Melanelia exasperatula, Bryoria lanestris, Parmeliopsis ambigua,* and *Letharia,* probably *vulpina*) on lodgepole pine trunks from the base to the top, and 12 lichens (including *Hypogymnia austerodes*) on subalpine fir trunks. *Hypogymnia austerodes, H. imshaugii, H. physodes* and *H. tubulosa* were found in sites dominated by Douglas fir or Engelmann spruce, with subalpine fir present, primarily on the branches of the trees. The amount of *H. physodes* was not enough to collect for element analysis, as has been done for other parts of the world.

Some notable epiphytes missing from Yellowstone National Park were species from the genera *Alectora*, *Ramalina,* and *Lobaria* Species in these genera are common in the Pacific Northwest (McCune & Geiser, 1997), in Glacier National Park (DeBolt & McCune, 1993) about 300 miles northwest of Yellowstone Park, and in western Montana (McCune, 1982, 1984; Eversman, personal collections). Most of Yellowstone National Park is east of the Continental Divide and has a cool continental climate, with forests much drier than those west of the Continental Divide which receive more moisture from the Pacific Ocean. The atmospheric moisture requirement of these lichens is apparently greater than what is available in Yellowstone National Park.

In two sites, 34 (Avalanche Peak Trail) and 45 (ridge near the South Entrance), most of the *Bryoria fremontii* was too high in the trees to reach, and at site 34 only small nubs of the bases of *Letharia vulpina* were on fallen decorticated trees, a common substrate of the species. It appeared to us that the two species were being eaten, probably by elk which are very abundant in the park. While no direct evidence, such as stomach contents or scat analysis, of elk eating these species has been observed, hunters, wildlife biologists, and loggers have reported seeing elk eat these lichens (and *Usnea*) from trees. A wildlife biologist from northwest Montana has reported seeing elk struggle through deep snow to get to windblown *Bryoria fremontii,* and, according to observations in western Montana by Ward (1999), deer and elk used 8.24 kg/ha and 6.55 kg/ha of lichen litterfall in 1996-97 and 1997-98, respectively. More than 99% of the lichen litterfall was *Bryoria* spp.

Very little epiphytic growth was observed near thermal areas. Most of the trees in and near the active thermal areas are lodgepole pine, and wind and steam from the thermal areas probably carry mineral deposits that adversely affect lichen growth. *Rhizocarpon geographicum* grew around the openings of some of the fumaroles, indicating that the major sulfur compound, hydrogen sulfide, may not have adverse effects on lichen growth. An examination of enzyme systems of such lichens would be an interesting study of adaptations for survival in such a habitat.

Vagrant forms (Rosentreter, 1993) of lichens, forms unattached to any substrate and subject to transport by wind, seemed to be more characteristic of grasslands or alpine meadows than of forested habitats. *Xanthoparmelia chlorochroa,* common in relatively undisturbed Montana grasslands, formed a thick carpet on the soil inside an exclosure (site 15) in the dry grasslands near Gardiner, Montana. Outside the exclosure, very few thalli were seen. This is an area of heavy winter use by elk and pronghorn antelope. *Agrestia hispida* also seemed to grow only in lower elevation grassland sites (15, 55). At higher elevations, *X. wyomingica* was fairly common on relatively dry slopes. *Aspicilia filiformis* was found in one location (site 43), a high-elevation (2545 m) ridge under lodgepole and whitebark pine, a relatively dry forest type. A vagrant form of *Dermatocarpon reticulatum*, formerly named *D. vagans* Imsh., was collected from site 19, a basaltic outcrop in an alpine meadow on Mt. Washburn. Forms of *Aspicilia* transitional to vagrant forms, identified from alpine meadows on the Beartooth Plateau east of Yellowstone Park (Eversman, 1995; Weber, 1977), have not been observed in the park. Glew identified a vagrant form of *Rhizoplaca melanophthalma* from the east-southeast slopes of Mt. Washburn, similar to the vagrant forms of that species occurring on Beartooth Pass on the Beartooth Plateau (Weber, 1977).

On Mt. Sheridan (Site 53), Glew collected 37 lichen species from the windward west side and 14 from the lee east-southeast side. This may reflect different amounts of snow pack, where wind-swept rocks and soil have a longer growing season, thus more lichens, than those buried by snow for most of the year. Lichen growth in alpine areas is greatest where surfaces are free of snow more than 200 days per year (Benedict, 1990; Walker, *et al.,* 1993).

Characteristic arctic-alpine species on soil such as *Cetraria ericetorum, C. islandica,* and *C. nivalis*, common in alpine meadows on the Beartooth Plateau (Eversman, 1995) have not been collected from Yellowstone Park. *Dactylina madreporiformis* was collected from one alpine meadow, Electric Peak (site 83). As previously discussed, the only species of *Cladina, C. mitis,* grew exclusively on soils in three thermal areas. *Thamnolia subuliformis* and *T. vermicularis* were collected only on Mt. Washburn (sites 18, 19) and no *Brodoa oroarctica*, fairly common in high elevation sites outside Yellowstone Park, has been observed in the park. Glew reported no *Umbilicaria hyperborea* or species of *Caloplaca* from Mt. Sheridan. Reasons for these distributions are unknown.

Recolonization of Burned Sites

Two burned sites (20 and 21) observed in 1998 were along the road between Tower Junction and Mammoth Hot Springs in the Douglas fir zone. Site 20 was a steep north-facing slope with completely blackened trees and evidence that the rock and soil had also been burned. The species recolonizing the rock were *Acarospora veronensis, Xanthoria fulva,* and a species of *Aspicilia.* Terricolous species were *Peltigera canina, P. didactyla* var. *didactyla, P. didactyla* var. *extenuata,* and *P. rufescens.* Specimens mature enough to be identified to species on burned wood were *Cladonia fimbriata, Melanelia elegantula, M. exasperatula, Physcia adscendens,* and *Xanthoria fulva.* The largest thalli were about 2.0 x 2.5 mm. Tiny immature thalli of the genera *Bryoria, Physcia,* and *Usnea* were also present.

Nearby site 21, primarily basaltic outcrops surrounded by Douglas fir, was near the road to Blacktail Plateau Drive. The fire was not as intense here, leaving unburned rock surfaces; it was difficult to discern if saxicolous specimens present had survived the fire or had recolonized. *Peltigera didactyla* var. *didactyla* and *P. rufescens* were the only terricolous species definitely recolonizing burned soil.

A dry lodgepole pine site near Grayling Creek in the northwest corner of the park was monitored annually between 1989 and 1995 for terricolous lichen recolonization; at that time, there was none. A continuing project is to visit different locations of burns – grasslands, dry lodgepole pine, Douglas fir, subalpine fir-spruce, subalpine whitebark pine stands – to specifically target recolonization under various moisture regimes.

Degree of Completion of Lichen Flora of Yellowstone National Park

A relatively small area of this large park has been surveyed for lichen flora, although most of the major types of vegetation have been visited. The major missing areas are remote, accessible only by extensive hiking or horseback: the western flanks of the Absaroka Mountains, which form the eastern boundary of the park; the southeast corner surrounding Yellowstone Lake; and most of the western part (Figure 1). Alpine peaks in the Gallatin and Absaroka ranges are also probably undercollected. The current estimate is that about 85 to 90% of the lichen flora has been collected and identified.

Lichens and Air Quality

It is generally believed that fruticose and foliose epiphytic lichens are the most sensitive to air pollution. Fruticose species on trees are exposed to the atmosphere on all sides, and foliose epiphytes on tree trunks and branches and species on exposed rocks are also subject to pollution deposition. McCune and Geiser (1997) name the following species, present in Yellowstone National Park, to be sensitive to air pollution: *Bryoria fremontii, Cladonia fimbriata, Cladonia squamosa, Leptogium saturninum, Melanelia subelegantula, Nephroma parile, Nodobryoria abbreviata, Peltigera collina, Peltigera didactyla, P. membranacea, Physicia adscendens, P. aipolia, Physconia enteroxantha, Rhizoplaca chrysoleuca, R. melanophthalma* and *Xanthoparmelia cumberlandia.* They report five other species to be sensitive to intermediate: *Bryoria fuscescens, Cladina mitis, Parmeliopsis hyperopta, Peltigera rufescens* and *Vulpicida pinastri.* It is interesting to note that the only locations from which *Cladinia mitis* has been collected are thermal basins with an obvious presence of hydrogen sulfide. St. Clair and

Newberry (1993a, b) report six species to be sensitive to ozone: *Bryoria fremontii, Nodobryoria abbreviata, Peltigera canina, Platismatia glauca, Peltigera canina, Xanthoria candelaria*); six species sensitive to SO_2 (*Acarospora chlorophana [Pleopsidium flavum?], Cladonia fimbriata, Ochrolechia androgyna, Rhizoplaca chrysoleuca, R. melanophthalma, Tuckermannopsis chlorophylla*); four species sensitive to fluoride (*Parmelia saxatilis, Physcia dubia, Parmelia sulcata, Rhizocarpon geographicum*); two species senstive to NO_x and PAN (*Rhizoplaca chrysoleuca, Xanthoria fallax*); seven species intermediately sensitive to ozone (*Hypogymnia imshaugii, Leptochidium albociliatum, Letharia columbiana, L. vulpina, Peltigera rufescens, Pseudephebe minuscula, P. pubescens*); and 15 species intermediately sensitive to SO_2 (*Bryoria fuscescens, Caloplaca cerina, Cladonia coniocraea, Hypocenomyce scalaris, Hypogymnia physodes, Lecanora saligna, Parmelia saxatilis, P. sulcata, Parmeliopsis ambigua, P. hyperopta, Physcia caesia, Physconia detersa, Platismatia glauca, Xanthoria candelaria, X. fallax*).

Many species in the above lists designated sensitive to air pollutants that grow on the soil or bases of trees, *e.g.*, *Cladonia fimbriata* or *Peltigera didactyla,* are difficult to use for tissue analysis for air quality monitoring because of impurities from their substrates; they are also protected from exposure to pollutants. Others (*Nodobryoria abbreviata, Peltigera collina)* are relatively scarce (Table 2).

Microhabitat of the lichens is considered more important to their value as pollution indicators and atmospheric element analysis than thallus morphology (Wirth and Tuerk, 1974, 1975 in Ahmadjian, 1993). For this reason, distribution and health of epiphytes are considered key in assessing the air quality of a site. On the other hand, climate also plays a role, with epiphytes less abundant in drier areas. Yellowstone National Park has a relatively dry, cool continental climate and the vast forests of lodgepole pine do not support as much growth of fruticose and foliose epiphytes as do more moist stands of Douglas fir and Engelmann spruce. With one exception (site 45), the major trees in the sites from which adequate accessible *Bryoria fremontii* and *Letharia vulpina* were available for analysis were Douglas fir or Engelmann spruce.

Air Quality of the Region

It has generally been assumed that the atmosphere of northwest Wyoming and adjacent areas is relatively pristine. Boehm (1991) reported that the states of Utah, Idaho and Wyoming produced 0.06, 0.05, and 0.21 Tg, respectively, of sulfur dioxide emissions in 1985 [1Tg = 1 million metric tons]. Most of the production of sulfur dioxide in Wyoming was east, or downwind, of Yellowstone Park. Across the west, sulfur dioxide concentrations have generally been below 40 ppb. Utah, Idaho and Wyoming produced 0.13, 0.08, and 0.25 Tg of nitrogen oxides, respectively, in 1985. Mean annual sulfate deposition in Grand Teton National Park was 2.9 kg/ha in 1985-1988, and mean annual nitrate deposition in Grand Teton was 2.6 kg/ha. In the western states, the range of sulfate deposition was 1.3 to 8.3 kg/ha, and the range of nitrate deposition was 1.0 to 5.1 kg/ha. Salt Lake City, Utah, about 300 miles southwest of Yellowstone, produced 23-24 ppb of ozone in 1990-1998, but it is not known how much is transported to the park. Ozone levels in the park are low, but measurable (Boehm, 1991).

With regard to the sites from which *Bryoria fremontii* and *Letharia vulpina* were collected for this study, one of the collection sites (1, Divide Lake) is adjacent to U.S. Highway 191, which has car and truck traffic all year. Sites 22 (Dunraven Picnic Area), 36 (picnic area along Yellowstone Lake) and 45 (a ridge near the South Entrance) are adjacent to park roads that are open only when the snow has been plowed, roughly from the middle of May until November. However, there is some snowmobile traffic during the winter, December to March. Site 30 (Pebble Creek) is considered back country and is a few kilometers from road traffic. Site 37 (Lake Butte) faces away from a road and is around a hill from a parking lot.

Elemental Analyses of Lichens from Yellowstone National Park

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Introduction

Lichens are useful plants for biomonitoring of air quality because they depend entirely on the atmosphere for their nutrition and lack a cuticle-type barrier to stop surface deposition of chemicals. Species that grow on trees are the best to use for this purpose because they are exposed to the atmosphere more than species that grow on rocks or on the ground, and are less likely to reflect soil and rock conditions. Typically, species are sampled in areas where the air quality is suspected of being polluted and compared with samples from areas thought to be pristine. Yellowstone National Park is commonly thought to be pristine because it is remote and wild, but may not be because of high traffic densities during the summer and the geothermal features throughout the park. Automobile traffic may be sources of oxidants, sulfur oxides, and heavy metals, while geothermal features are known to emit sulfur compounds and heavy metals, including mercury. The objective of this study was to establish a biomonitoring baseline of air quality for the park using lichens.

Materials and Methods

During late July and early August of 1998, four species of lichens were sampled by C. M. Wetmore at a total of eight localities in the park, as shown in Table 1 and Figure 1.

Table 1. Dates of four lichen species collections at eight localities in Yellowstone National Park, 1998.

Locality	Bryoria fremontii	Cladina mitis	Letharia vulpina	Xanthoparmelia chlorochroa
Biscuit Basin		August 4		
Divide Lake	July 15		July 15	
Dunraven	July 24		July 24	
Gardiner				July 21
Lake Butte	August 6		August 6	
Pebble Creek	July 27		July 27	
Snake River	August 12			
Yellowstone Lake	August 6		August 6	

Bryoria was collected at six localities, *Letharia* at five, and *Cladina* and *Xanthoparmelia* at one each. Both the *Bryoria* and *Letharia* are fruticose, epiphytic species, while the *Cladina* and *Xanthoparmelia* are fruiticose and foliose ground-dwellers. The *Cladina* was collected within 100 feet of a geothermal vent, while the *Xanthoparmelia* was collected to compare it to samples collected at Theodore Roosevelt National Park. The other two species were collected from evergreen, coniferous species of trees (lodgepole pine, Douglas fir) in wooded areas not proximate to geothermal features.

Sufficient thalli of *Bryoria* and *Letharia* were collected to allow analyses of three samples to measure variability at each locality, thus giving a sample size of 18 for *Bryoria* and 15 for *Letharia*. The samples were delivered to Madison, Wisconsin, cleaned of debris, ground in a Wiley stainless steel mill, wet digested, and

analyzed by ICP at the University of Wisconsin Soil and Plant Analysis Laboratory for 22 elements: Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Ti, V and Zn. All data were analyzed statistically using Systat. The total potential data set consisted of 39 localities and replicates x 22 elements = 858, but four samples were below the detection limit of 0.01 ppm for Hg so the actual total was 854 data points. The raw elemental data, including locational data, are tabulated in Appendix 1.

Results and Discussion

A statistical summary of the 22 elements for *Bryoria* and *Letharia* is shown in Table 2. The summary was calculated only for these two species because there was an adequate number of samples for them. The summary contains the minimum, lower 95% confidence interval of the mean, median, mean, upper 95% confidence interval of the mean, maximum, and coefficient of variation for each element. The baseline for each element is the range defined by the 95% confidence interval. The coefficient of variation for almost all elements is equal to or less than 50%, indicating the values are fairly constant. The exceptions are Ni in both species, and Hg in *Letharia*. These are due to some extreme values at Divide Lake and Pebble Creek. For these elements, the 95% confidence interval for the median is the preferred baseline range.

Table 2. Chemical element concentrations (ppm) for two lichen species from Yellowstone National Park. Because of high coefficients of variation, three baselines are set to the 95% confidence level of the median instead of the mean, with the median shown in bold print, and the confidence intervals in italics.

Element	Minimum	95% CI Lower	Median	Mean	95% CI Upper	Maximum	C.V.
			Bryoria fremontii (N = 18)				
Al	105.47	128.35	141.15	143.56	158.77	224.71	0.21
As	0.41	0.59	0.62	0.69	0.79	1.17	0.30
B	15.15	18.43	19.89	20.69	22.95	29.23	0.22
Ca	1151.14	1404.68	1492.29	1584.91	1765.15	2597.14	0.23
Cd	0.11	0.18	0.22	0.23	0.28	0.41	0.44
Co	0.09	0.12	0.13	0.14	0.15	0.23	0.23
Cr	0.35	0.46	0.50	0.59	0.72	1.43	0.45
Cu	1.50	1.88	2.04	2.09	2.30	3.11	0.20
Fe	126.70	152.64	168.94	168.32	184.01	251.00	0.19
Hg	0.07	0.12	0.14	0.14	0.17	0.29	0.35
K	2632.00	2958.95	3068.64	3183.36	3407.77	4144.29	0.14
Mg	324.20	403.57	429.90	440.77	477.96	617.86	0.17
Mn	23.74	40.27	46.25	51.53	62.79	104.99	0.44
Mo	0.04	0.07	0.08	0.09	0.10	0.17	0.41
Na	22.15	31.94	35.59	36.25	40.55	58.81	0.24
Ni	0.34	*0.44*	**0.52**	0.94	*1.04*	3.63	0.94
P	626.60	831.09	933.96	937.08	1043.06	1352.00	0.23
Pb	0.68	2.00	2.85	2.66	3.32	5.21	0.50
S	718.80	917.93	978.71	1004.47	1091.02	1371.86	0.17
Ti	6.98	9.71	9.99	12.04	14.37	22.03	0.39
V	0.13	0.22	0.26	0.29	0.35	0.58	0.43
Zn	16.08	21.52	23.20	23.99	26.46	35.24	0.21
			Letharia vulpina (N= 15)				
Al	106.20	207.10	259.20	267.23	327.36	471.70	0.41
As	0.36	0.55	0.62	0.69	0.83	1.16	0.37

B	1.67	3.79	4.35	4.82	5.85	7.68	0.38
Ca	2428.00	3215.84	3718.00	3726.69	4237.54	5899.29	0.25
Cd	0.24	0.29	0.31	0.36	0.42	0.62	0.34
Co	0.14	0.19	0.21	0.21	0.24	0.30	0.22
Cr	0.28	0.46	0.54	0.57	0.67	0.92	0.35
Cu	1.11	1.54	1.74	1.74	1.94	2.35	0.21
Fe	93.17	174.75	225.60	231.50	288.25	444.30	0.44
Hg	0.01	*0.03*	**0.10**	0.11	*0.18*	0.24	0.75
K	1895.00	2522.94	2793.00	2860.76	3198.57	3950.18	0.21
Mg	505.00	629.65	658.30	692.71	755.77	908.02	0.16
Mn	35.26	75.15	95.12	93.22	111.28	136.04	0.35
Mo	0.03	0.05	0.06	0.05	0.06	0.09	0.31
Na	22.76	27.69	31.60	30.85	34.00	42.79	0.18
Ni	0.51	*0.64*	**0.79**	1.00	*0.90*	4.13	0.88
P	429.20	653.89	806.00	756.35	858.80	974.81	0.24
Pb	1.16	2.28	2.86	3.10	3.92	5.74	0.47
S	635.00	771.91	802.58	862.21	952.51	1162.79	0.19
Ti	8.27	13.48	16.11	16.52	19.56	25.84	0.33
V	0.14	0.33	0.43	0.44	0.54	0.81	0.45
Zn	21.56	24.69	25.68	27.01	29.33	37.81	0.15

Mean differences between species were significant ($P < 0.05$) for 13 elements: Al, B, Ca, Cd, Co, Fe, Mg, Mn, Mo, P, Ti, V and Zn. Re-sampling for these elements in the future must be species-specific; while for the other elements either species may be used. Neither species consistently had higher levels than the other.

Mean differences between localities were significant ($P < 0.05$) for 14 elements: As, Cd, Co, Cu, Fe, Hg, K, Na, P, Pb, S, Ti, V, and Zn. Re-sampling for these elements in the future must be locality specific, while for the other elements any locality may be used. Divide Lake, which is proximate to a major highway, appeared to have the highest concentrations of anthropogenic elements.

Cr and Ni were not significantly different between species or localities and can be sampled anywhere or with either species in the future.

The six localities sampled with *Bryoria* and *Letharia* were insufficient to determine geographic patterns of elements. However, they were grouped roughly three north (Divide Lake, Pebble Creek and Dunraven) and three south (Lake Butte, Yellowstone Lake and Snake River). Elements that were significantly different between north and south across both species were As, B, Ca, Cu, Mg, Mn, Mo, Na, Ti, V, and Zn. As, B, Cu, Mn, Mo, Na, Ti and V were all higher in the south, while Ca, Mg and Zn were higher in the north. Cd, Mo and Ti were higher in the south for *Bryoria*, but in *Letharia* Cd was higher in the north, while Mo and Ti were equal. Re-sampling these elements in the future may have to be stratified by north-south sampling and by species depending on the element.

Both *Bryoria* and *Letharia* species have been studied either at Grand Teton, Olympic, or Sequoia National Parks or other wilderness areas in southwestern Montana (Schanz, 1996; Schubloom, 1995; Wetmore, 1985; Rhoades, 1988). For *Bryoria*, the Yellowstone concentrations of Cd, Cr, Cu, K, Pb, S, Ti and Zn were comparable, but Al, Ca, Co, Fe, K, Mg, Mn, Mo, Na and V were somewhat lower, while As, B and Ni appeared higher than the other areas. Hg was not measured anywhere else previously. For *Letharia*, the Yellowstone concentrations of B, Cr, Mg, Mn, Ni, and S were comparable, but Al, Cu, K, Na, P, Pb, and Ti were lower, while Ca and Zn were higher than the other areas. The remaining elements were not measured in the other studies. Only a few elements follow a consistent pattern for both species. Cr and S were comparable in both species, while only Al and Na were lower in Yellowstone in both species. No elements were higher in both species. Sources of variation between studies include years sampled, sampling techniques, and laboratory methods.

The concentrations of the 22 elements in both *Bryoria* and *Letharia* were similar and closely related (r =

0.88). None of the elements is at significantly elevated levels for lichens in general, except for Hg. The highest concentrations of 291 and 243 ppb for each species, respectively, are unusual and probably reflect the emissions of Hg from geothermal features in the Yellowstone area (Phelps and Buseck, 1980). Even the means, while similar to the background value of 155 ppb for *Hypogymnia physodes* (Makholm and Bennett, 1998), are comparable to values seen in other lichen species near Italian geothermal areas (Loppi and Bargagli, 1996; Bargagli and Barghigiani, 1991). The mercury concentrations were also highly correlated with the sulfur concentrations for both species ($r = 0.712$, $P < 0.000$, Fig. 2), which is also emitted by geothermal features. It is important to note that these levels were observed in lichens collected far away from specific geothermal features, suggesting that mercury and sulfur are elevated throughout the park.

The averages of three replicates of one sample each of *Xanthoparmelia chlorochroa* and *Cladina mitis* are shown in Table 3. With only one locality for each species, it is difficult to generalize about the meaning of these data. Both are ground dwellers, but were collected from very different areas. The *Xanthoparmelia* was collected near Gardiner, while the *Cladina* was collected near a geothermal feature in the center of the park. Data for these elements in these species is available for Theodore Roosevelt National Park in North Dakota, and for northern Minnesota bogs, respectively, but neither of these is comparable to Yellowstone. Some of the elements for the *Xanthoparmelia* are unusually high, which may be an indication of contamination from soil. For the *Cladina* there is no indication of any elevated elements related to geothermal emissions. The means are presented for future reference in the event these species are sampled again.

Table 3. Chemical element concentrations (ppm) of two lichen species from Yellowstone National Park, n = 3. Mercury was not measurable in *Cladina.*

Element	*Xanthoparmelia chlorochroa*	*Cladina mitis*	
Al	5,574.33	1,266.67	
As	1.71		0.85
B	20.56		6.09
Ca	35,926.67	917.83	
Cd	0.46	0.16	
Co	2.68	0.32	
Cr	7.87	1.44	
Cu	6.92	2.24	
Fe	5,956.33	1,185.00	
Hg	0.04		
K	3,439.67	1,369.33	
Mg	1,659.33	506.33	
Mn	139.77	57.99	
Mo	0.21		0.15
Na	274.00	31.89	
Ni	6.64	0.92	
P	1,389.67	608.10	
Pb	5.56	1.62	
S	806.17	387.20	
Ti	156.21	49.78	
V	10.95	2.01	
Zn	196.90	19.12	

Conclusions

Two common, easy-to-find species of tree-dwelling lichens, *Bryoria fremontii* and *Letharia vulpina,* were collected at six localities in Yellowstone National Park in the summer of 1998 and measured for concentrations of 22 chemical elements for biomonitoring purposes. A sufficient number of samples was collected to calculate statistical baseline ranges for all the elements, which can be used for comparisons in the future. There were significant differences between species for 13 elements and between localities for 14. Some elements were higher in the south while others were higher in the north. Levels of most elements were comparable to other national parks and wilderness areas in the region, except Hg, which was unusually high. This element is known to be emitted by geothermal features in the park and is therefore the most likely source.

Recommendations

In order to track time trends, samples should be taken every five years and analyzed for comparison with the baseline ranges presented in this paper. Attention should be given to the sampling protocols mentioned in the report with regard to elements, species and localities.

In order to determine sources of elevated mercury and sulfur in these lichens, a more detailed, site-specific study should be conducted once.

In order to determine the impacts of summer traffic emissions on lichens, a more detailed, site-specific study should be conducted once.

References Cited

Ahmadjian, V. 1993. The lichen symbiosis. John Wiley & Sons, Inc., New York. 250 pp.

Bargagli, R. & Barghigiani, C. 1991. Lichen biomonitoring of mercury emission and deposition in mining, geothermal and volcanic areas of Italy. Env. Mon. Assess. 16: 265-275.

Benedict, J. B. 1990. Lichen mortality due to late-lying snow: results of a transplant study. Arctic and Alpine Research 22: 81-89.

Boehm, M. 1991. Air quality and deposition. *In:* Binkely, D., Olson, R. K. and Boehm, M. (Eds.). Air pollution and western forests. Springer-Verlag.

Brodo, I. M. 1991. Lichens of the Ottawa region. Syllogeus No. 29, National Museum of Natural Sciences, National Museums of Canada, Ottawa. 137 pp.

Culberson, C. F. 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. J. of Chromatography 72: 113-125.

DeBolt, A. & B. McCune. 1993. Lichens of Glacier National Park. The Bryologist 96: 192-204.

DeSpain, D. G. 1990. Yellowstone vegetation: consequences of environment and history in a natural setting. Roberts Rinehart Publishers, Boulder. 239 pp.

Esslinger, T. L. 1975. A chemosystematic revision of the brown Parmeliae. Dissertation, Duke University. Xerox University Microfilms, Ann Arbor,Michigan.

Esslinger, T. L. 1998. A cumulative checklist for the lichen-forming lichenicolous and allied fungi of the continental United States and Canada. North Dakota State University: http://www.ndsu.nodak.edu/instruct/esslinge/chcklst/chcklst7.htm

Eversman, S. 1990. Lichens of Yellowstone National Park. The Bryologist 93: 197-205.

------. 1995. Lichens of alpine meadows on the Beartooth Plateau, Montana and Wyoming, U.S.A. Arctic and Alpine Research 27: 400-406.

------. 1998. Lichens of Grand Teton National Park. In: Glenn, M.G., R.C. Harris, R. Dirig & M.S. Cole (eds). *Lichenographia Thomsoniana: North American Lichenology in honor of John W. Thomson.* Mycotaxon Ltd., Ithaca, NY. pp. 295-308

------, C. Johnson & D. Gustafson. 1987. Vertical distribution of epiphytic lichens on three tree species in Yellowstone National Park. The Bryologist 90: 212-216.

Goffinet, B. & R. I. Hastings. 1994. The lichen genus *Peltigera* (lichenized Ascomycetes) in Alberta. Provincial Museum of Alberta Natural History Occasional Paper No. 21. 54 pp.

Gries, C. 1996. Lichens as indicators of air pollution. *In:* Nash, T. H. III. (Ed). Lichen biology. Cambridge University Press, Cambridge. pp. 240-254.

Hale, M.E. 1983. The biology of lichens. 3rd edition. Edward Arnold, Baltimore. 190 pp.

Imshaug, H. A. 1951. The lichen-forming species of the genus *Buellia* occurring in the United States and Canada. Dissertation, University of Michigan. University Microfilms, Ann Arbor, Michigan.

Ladyman, J.A.R. & E. Muldavin. 1996. Terrestrial cryptograms of pinyon-juniper woodlands in the southwestern United States: a review. General Technical Report RM-GTR-280. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado

Laundon, J. R. 1989. The species of *Leproloma* – the name for the *Lepraria membranacea* group. Lichenologist 21: 1-22.

------ 1992. *Lepraria* in the British Isles. Lichenologist 24: 315-350.

Lindblom, L. 1997. The genus *Xanthoria* (Fr.) Th.Fr. in North America. J. Hattori Bot. Lab. No. 83: 75-172.

Loppi, S. & Bargagli, R. 1996. Lichen biomonitoring of trace elements in a geothermal area (central Italy). Water, Air Soil Pollut. 88: 177-187.

Makholm, M.M. & Bennet, J.P. 1998. Mercury accumulation in transplanted *Hypogymnia physodes* lichens downwind of a Wisconsin chlor-alkali plant. Water, Air Soil Pollut. 102: 427-436.

McCune, B. 1982. Lichens of the Swan Valley, Montana. The Bryologist 85: 1-12

------. 1984. Lichens with oceanic affinities in the Bitterroot Mountains of Montana and Idaho. The Bryologist 87: 44-50.

------ & L. Geiser. 1997. Macrolichens of the Pacific Northwest. Oregon State University Press, Corvallis. Co-published with the U.S.D.A. Forest Service.

------ & T. Goward. 1995. Macrolichens of the northern Rocky Mountains. Mad River Press, Eureka, CA. 208 pp.

Nash, T. III., C. Wetmore, W. Anderson, C. Bratt, W. Denison, S. Eversman, B. Murray, and L. St. Clair. 1993. Floristics. *In*: Stolte, K., et al. (Eds). Lichens as bioindicators of air quality. USDA Forest Service General Technical Report RM-224. Rocky Mountain Forest and Range Experiment Station, Forest Service, USDA, Fort Collins, Colorado

Nash, T. H. III. 1996. Nutrients, elemental accumulation and mineral cycling. *In*: Nash, T. H. III. (Ed.) Lichen biology. Cambridge University Press, Cambridge. pp. 136-153.

Nieboer, E., D. H. S. Richardson & F. D. Tomassini. 1978. Mineral uptake and release by lichens: an overview. The Bryologist 81: 226-246.

Phelps, D. & Buseck, P.R. 1980. Distribution of soil mercury and the development of soil mercury anomalies in the Yellowstone geothermal area, Wyoming. Econ. Geo. 75: 730-741.

Rhoades, R.M. 1988. Re-examination of baseline plots to determine effects of air quality on lichens and bryophytes in Olympic National Park. Report No. SP-4450-88-13. National Park Service, Air Quality Division, Denver, Colorado.

Rosentreter, R. 1993. Vagrant lichens in North America. The Bryologist 96: 333-338.

Ryan, B. D. & T. H. Nash III. 1991. *Lecanora* sect. Perasterion (lichenized Ascomycotina) in North America: notes on the *L. novomexicana* complex (subsect. Pseudocorticatae). Mycotaxon XLI: 57-65.

------ & ------ 1993. *Lecanora* section *Placodium* (lichenized Ascomycotina) in North America: new taxa in the *L. garovaglii* group. The Bryologist 96: 288-298.

Schanz, R. 1996. Chemical concentrations in the fruticose lichens *Bryoria* spp. and *Usnea* spp. collected in Grand Teton National Park. Unpublished manuscript.

Schubloom, L.A. 1995. Lichens as air quality indicators in three areas of southwestern Montana: lichen floristics and elemental analysis. Unpublished M.S. Thesis, Montana State University, Bozeman.

St. Clair, L.L. & C.C. Newberry. 1993a. Establishment of a lichen biomonitoring program and air quality baseline in the Anaconda-Pintler Wilderness Area and adjacent areas west of the Anaconda copper smelter. Report to the U.S. Forest Service, Northern Region.

------ & ------. 1993b. Establishment of a lichen biomonitoring program and air quality baseline in the Cabinet Mountains Wilderness Area. Report to the U.S. Forest Service, Northern Region.

Thomson, J.W. 1967. The lichen genus *Cladonia* in North America. University of Toronto Press. 172 pp.

------ 1979. Lichens of the Alaskan Arctic slope. University of Toronto Press, Toronto. 314 pp.

------ 1984. American Arctic lichens. 1. The macrolichens. Columbia University Press, New York. 504 pp.

------ 1997. American Arctic lichens. 2. The microlichens. The University of Wisconsin Press, Madison. 675 pp.

Timdal, E. 1986. A revision of *Psora* (Lecideaceae) in North America. The Bryologist 89: 253-275.

Walker, D. A., J. C. Halfpenny, M. D. Walker & C. A. Wessman. 1993. Long-term studies of snow-vegetation interactions. Bioscience 43: 287-301.

Ward, Richard L. 1999. The occurrence of two genera of arboreal lichens and their utilization by deer and elk on selected winter ranges in west-central Montana. Unpublished M.S. Thesis, University of Montana, Missoula.

Weber, W.A. 1977. Environmental modification and lichen taxonomy. *In*: Seaward, M.R.D. (Ed.): Lichen Ecology. Academic Press, New York. pp. 9-29.

Wetmore, C.M. 1985. Lichens and air quality in Sequoia National Park. Final Report to the National Park Service. Botany Department, University of Minnesota, St. Paul. 33 pp.

------ 1995. Lichens and air quality in Lye Brook Wilderness of the Green Mountain National Forest. Final Report for U.S.D.A. Forest Service, Green Mountain National Forest and Northeastern Area State and Private Forestry Forest Health Protection. Contract 42-649. 43 pp.

------ & J.P. Bennett. 1996. NPLICHEN: A National Park Service Lichen Database. http://www.ies.wisc.edu/brd/nplichen/nplichen.htm

------ & E. I. Karnefelt. 1998. The lobate and subfruticose species of *Caloplaca* in North and Central America. The Bryologist 101: 230-255.

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APPENDIX 1: LICHENS COLLECTED FROM YELLOWSTONE NATIONAL PARK PRIOR TO 1990 AND DURING 1998 BY SHARON EVERSMAN. SITES NUMBERED 1-54 ARE FROM 1998; SITES NUMBERED 55-84 ARE SITES FROM WHICH COLLECTIONS WERE REPORTED BY EVERSMAN, 1990 (TABLE 1). SITES DUPLICATED IN 1998 ARE NOTED IN TABLE 1; COLLECTIONS FROM SITE 21 WERE MADE IN 1996 AND 1998.

Acarospora glaucocarpa (Ach.) Koerber: 13, 25
Acarospora schleicheri (Ach.) A. Massal.: 19, 61, 62
Acarospora veronensis A. Massal.: 15, 20, 45
Agrestia hispida (Mereschk.) Hale & Culb.: 15, 55
Amandinea (Buellia) punctata (Hoffm.) Coppins & Scheid.: 11, 24, 26, 28, 35
Aspicilia caesiocinerea (Nyl. *ex* Mahlbr.) Arnold: 2, 7, 15, 19, 22, 24, 45, 46, 55, 61, 62, 64, 66, 69, 70, 74, 76, 77, 78, 79, 84
Aspicilia candida (Anzi) Hue: 84
Aspicilia cinerea (L.) Koerber: 2, 8, 16, 21, 24, 33, 44, 45, 46, 49, 50, 61, 71, 72, 74, 76, 79
Aspicilia contorta (Hoffm.) Kremp.: 2, 15, 24, 29, 42, 44, 46
Aspicilia filiformis Rosentreter: 43
Aspicilia laevata (Ach.) Arnold: 7, 20, 21, 42, 45, 46
Bellemerea alpina (Sommerf.) Clauzade & Roux: 8, 22, 42, 57, 64, 67, 74, 75
Bellemerea cinereorufescens (Ach.) Clauzade & Roux: 22, 35, 42, 45
Bryoria fremontii (Tuck.) Brodo & D. Hawksw.: 17, 22, 23, 30, 39, 40, 45, 60, 74, 75
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.: 5, 14, 16, 17, 21, 22, 37, 39, 45, 62, 63, 66, 67, 68, 69, 70
Bryoria lanestris (Ach.) Brodo & D. Hawskw.: 20, 39, 46, 49, 54, 56, 57, 58, 59, 60, 61, 62, 64, 65, 69, 72, 73, 75, 76, 78, 82
Buellia erubescens Arnold: 35, 43, 67, 68
Buellia griseovirens (Turner & Borrer *ex* Sm.) Almb.: 17
Buellia leptocline (Flotow) A. Massal.: 30
Buellia papillata (Sommerf.) Tuck.: 11, 18, 19, 21, 24, 49, 67, 69
Calicium viride Pers.: 4, 28, 37
Caloplaca adnexa Vezda: 8, 12, 15, 18
Caloplaca arenaria (Pers.) Muell. Arg.: 46, 67
Caloplaca cerina (Ahrh. *ex* Hedwig): Th. Fr.: 15, 27, 67
Caloplaca citrina (Hoffm.) Th. Fr : 7, 14, 65, 70
Caloplaca cladodes (Tuck.) Zahlbr.: 7, 19, 33
Caloplaca decipiens (Arnold) Blomb. & Forss.: 27
Caloplaca epithallina Lynge: 2, 7, 18, 19, 24, 33, 37, 45, 68, 70, 83
Caloplaca ferruginea (Hudson) Th.Fr.: 69
Caloplaca holocarpa (Hoffm. *ex* Ach.) M. Wade.: 3, 4, 27, 28, 44, 46
Caloplaca jungermanniae (Vahl) Th. Fr.: 24
Caloplaca modesta (Zahlbr.) Fink: 57
Caloplaca saxicola (Hoffm.) Nordin: 7, 13
Caloplaca sinapisperma (Lam. & DC.) Mahrer & A. Gillet: 43, 45, 73
Caloplaca tiroliensis Zahlbr.: 7, 19, 21, 24, 63, 83
Caloplaca trachyphylla (Tuck.) Zahlbr.: 15
Candelaria concolor (Dickson) Stein: 69
Candelariella aurella (Hoffm.) Zahlbr.: 19, 26, 61, 68, 69, 77, 81, 83, 84
Candelariella dispersa (Rasanen) Hakul: 2

APPENDIX 2.: LICHENS COLLECTED AND IDENTIFIED FROM YELLOWSTONE NATIONAL PARK IN 1998 BY KATHERINE GLEW. SITE DESCRIPTIONS ARE IN TABLE 1.

Acarospora fuscata (Schrader) Arnold: 1, 2, 40, 46, 47
Acarospora glaucocarpa (Ach.) Koerber: 13, 14, 15
Acarospora veronensis A. Massal.: 2, 8, 9, 51
Agrestia hispida (Merschk.) Hale & Culb.): 15
Aspicilia caesiocinerea (Nyl. *ex* Mahlbr.) Arnold: 9, 10, 18, 40, 47, 49, 53
Aspicilia cinerea (L.) Koerber: 33, 40
Bellemerea alpina (Sommerf.) Clauzade & Roux: 8, 52
Bellemerea cinereorufescens (Ach.) Clauzade & Roux: 9, 40, 49
Bryoria fremontii (Tuck.) Brodo & D. Hawksw.: 1, 30, 36, 40, 41, 48
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.: 1, 16, 22, 24, 30, 33, 36, 37, 41, 48
Bryoria lanestris (Ach.) Brodo & D. Hawskw.: 23, 24, 33, 40, 46, 54
Buellia papillata (Sommerf.) Tuck.: 18
Calicium glaucellum Ach.: 48
Calicium viride Pers.: 37
Caloplaca arenaria (Pers.) Muell. Arg.: 36
Caloplaca cerina (Ahrh. *ex* Hedwig): Th. Fr. 2
Caloplaca cladodes (Tuck.) Zahlbr.: 33
Caloplaca decipiens (Arnold) Blomb. & Forss.: 27
Caloplaca epithallina Lynge: 2, 4, 8, 12, 15, 16, 18, 19, 24, 33, 37, 45, 47, 51, 68, 70, 83
Caloplaca grimmiae (Nyl.) H. Olivier: 47
Caloplaca saxicola (Hoffm.) Nordin: 52
Caloplaca sinapisperma (Lam. & DC.) Mahrer & A. Gillet: 39, 46
Caloplaca trachyphylla (Tuck.) Zahlbr.: 9, 15
Candelariella aurella (Hoffm.) Zahlbr.: 9, 52
Candelariella rosulans (Muell. Arg.) Zahlbr.: 16, 24, 53
Candelariella terrigena Rasanen: 8
Candelariella vitellina (Hoffm.) Muell. Arg.: 9, 10, 16, 18, 21, 33, 36, 37, 46, 47, 49
Candelariella xanthostigma (Ach.) Lettau: 10
Cetraria aculeata (Schreber) Fr.: 50
Cetraria muricata (Ach.) Eckfeldt: 18
Chaenotheca furfuracea (L.) Tibell: 37
Cladina mitis (Sandst.) Hustich: 49, 50
Cladonia borealis S. Stenroos: 16
Cladonia cariosa (Ach.) Sprengel: 30
Cladonia carneola (Fr.) Fr.: 39
Cladonia cenotea (Ach.) Schaerer: 31
Cladonia cervicornis subsp. *verticillata* (Hoffm.) Ahti: 5, 10, 22, 23, 46
Cladonia chlorophaea (Floerke *ex* Sommerf.) Sprengel: 5, 11, 40, 41, 47, 48, 54
Cladonia coniocraea (Floerke) Sprengel: 36
Cladonia cornuta (L.) Hoffm.: 5, 30, 40
Cladonia deformis (L.) Hoffm.: 22, 23, 30
Cladonia ecmocyna Leighton: 5, 23, 40, 41, 48, 49
Cladonia fimbriata (L.) Fr.: 11, 25, 30, 36, 37, 46
Cladonia norvegica Tonsberg & Holien: 31, 36
Cladonia ochrochlora Floerke: 37, 40
Cladonia pyxidata (L.) Hoffm.: 11, 40

Letharia vulpina (L.) Hue: 1, 13, 22, 24, 30, 36, 37, 40, 41, 46, 48, 52 (treeline below summit), 53 (krummholz on east side), 54
Melanelia disjuncta (Erichsen) Essl.: 16, 24
Melanelia elegantula: (Zahlbr.) Essl.: 11, 19
Melanelia exasperatula (Nyl.) Essl.: 1, 13, 17, 30, 37, 40, 46, 48, 49, 54
Melanelia infumata (Nyl.) Essl.: 9, 24
Melanelia subelegantula (Essl.) Essl.: 1, 9, 22, 36, 37, 41
Melanelia subolivacea (Nyl.) Essl.: 17
Melanelia tominii (Oksner) Essl.: 24
Mycobilimbia berengeriana (A. Massal.) Hafellner & V. Wirth: 38
Mycobilimbia sabuletorum (Schreber) Hafellner: 7
Nephroma parile (Ach.) Ach.: 38
Ochrolechia androgyna (Hoffm.) Arnold: 17, 40, 46
Ochrolechia upsaliensis (L.) A. Massal.: 2, 18, 51
Parmelia fraudans (Nyl.) Nyl.: 11, 17
Parmelia hygrophila Goward & Ahti: 46
Parmelia saxatilis (L.) Ach.: 11, 16
Parmelia sulcata Taylor: 25, 32
Parmeliopsis ambigua (L.) Willd.: 1, 10, 14, 23, 24, 30, 31, 36, 37, 40, 46, 48, 49, 53, 54
Parmeliopsis hyperopta (Ach.) Arnold: 1, 6, 31, 36, 37, 40, 48
Peltigera aphthosa (L.) Willd.: 6, 9, 25, 37, 40, 46, 48, 49
Peltigera canina (L.) Willd.: 6, 11, 16, 30, 36, 37, 46, 48, 49
Peltigera collina (Ach.) Schrader: 20
Peltigera didactyla (With.) J. R. Laundon: 17, 20, 21, 49
Peltigera elisabethae Gyelnik: 25
Peltigera leucophlebia (Nyl.) Gyelnik: 30, 36, 48
Peltigera malacea (Ach.) Funck: 11, 16, 23, 40, 46, 49
Peltigera membranacea (Ach.) Nyl.: 9 (along trail below summit)
Peltigera ponojensis Gyelnik: 20, 36, 37
Peltigera praetextata (Floerke) *ex* Sommerfeld) Zopf: 7, 48
Peltigera retifoveata Vitik: 20, 40
Peltigera rufescens (Weiss) Humb.: 2, 5, 9, 10, 16, 18, 20, 21, 22, 23, 24, 25, 30, 36, 38, 39, 46, 49, 51
Peltigera venosa (L.) Hoffm.: 5, 25, 31, 48
Phaeophyscia decolor (Kashiw.) Essl.: 7, 10, 12, 14, 21, 24, 37, 46
Phaeophyscia sciastra (Ach.) Moberg: 33
Physcia adscendens (Fr.) H. Olivier: 46
Physcia aipolia (Ehrh. *ex* Humb) Fuernr.: 24
Physcia caesia (Hoffm.) Fuernr.: 7, 8, 9, 15, 21, 24
Physcia dubia (Hoffm.) Lettau: 37, 46
Physcia phaea incl. *callosa* (Tuck.) J. W. Thomson: 21, 38, 46
Physcia wainioi Rasanen: 53
Physconia isidiigera (Zahlbr.) Essl.: 11
Physconia muscigena (Ach.) Poelt: 11, 15, 18, 24
Physconia perisidiosa (Erichsen) Moberg: 11
Placynthiella oligotropha (J. R. Laundon) Coppins & P. James: 23
Placynthiella uliginosa (Schrader) Coppins & P. James: 46, 47
Placynthium nigrum: (Hudson) Gray: 25, 81
Platismatia glauca (L.) Culb. & C. Culb.: 16, 17
Pleopsidium flavum (Bellardi) Koerber: 9, 12, 15, 18, 47, 51, 52
Polychidium muscicola (Sw.) Gray: 11

APPENDIX 3. LICHENS COLLECTED BY CLIFFORD WETMORE FROM YELLOWSTONE NATIONAL PARK, 1998. COLLECTION SITES ARE DESCRIBED IN TABLE 1.

Acarospora glaucocarpa (Ach.) Koerber: 8, 13, 14, 25
Acarospora stapfiana (Muell.Arg.) Hue: 15
Acarospora strigata (Nyl.) Jatta: 8
Agrestia hispida (Merschk.) Hale & Culb.): 15
Amandinea (Buellia) punctata (Hoffm.) Coppins & Scheid.: 3, 11, 15, 24
Arthonia mediella Nyl.: 4
Aspicilia caesiocinerea (Nyl. *ex* Mahlbr.) Arnold: 2, 8, 12, 15, 18, 44, 45
Aspicilia candida (Anzi) Hue: 25
Aspicilia cinerea (L.) Koerber: 10, 11, 16, 21, 24, 42
Aspicilia contorta (Hoffm.) Kremp.: 15, 33, 47
Aspicilia filiformis Rosentreter: 43
Aspicilia laevata (Ach.) Arnold: 5, 49
Baeomyces rufus (Hudson) Rebent.: 40
Bellemerea alpina (Sommerf.) Clauzade & Roux: 34, 35, 42, 49
Bellemerea cinereorufescens (Ach.) Clauzade & Roux: 2
Biatora albohyalina (Nyl.) Bagl. & Carestia: 48
Biatora turgidula (Fr.) Nyl.: 11, 28
Biatoropsis usnearum Rasanen: 28
Bryoria fremontii (Tuck.) Brodo & D. Hawksw.: 1, 5, 22, 23, 28, 30, 31, 36, 37, 39, 40, 41, 44, 45
Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.: 3, 5, 10, 14, 16, 17, 21, 22, 24, 28, 30, 31, 36, 37, 39, 44, 45, 48, 49
Bryoria lanestris (Ach.) Brodo & D. Hawskw.: 37, 40
Buellia erubescens Arnold: 3, 5, 10, 11, 17, 22, 31, 35, 36, 42, 49
Buellia griseovirens (Turner & Borrer *ex* Sm.) Almb.: 17
Buellia papillata (Sommerf.) Tuck.: 18, 24, 40
Buellia triphragmioides Anzi: 27
Buellia turgescens Tuck.: 4
Calicium viride Pers.: 4, 37, 48
Caloplaca adnexa Vezda: 2, 8, 12, 18, 33, 38, 47
Caloplaca arenaria (Pers.) Muell. Arg.: 1, 10, 16, 24, 36, 37, 43, 45, 47
Caloplaca cerina (Ahrh. *ex* Hedwig): Th. Fr.: 47
Caloplaca chrysodeta (Vainio *ex* Rasanen) Dombr.: 11, 25, 44
Caloplaca chrysophthalma Degel: 14, 26
Caloplaca citrina (Hoffm.) Th. Fr : 2, 15
Caloplaca cladodes (Tuck.) Zahlbr.: 7, 8, 33
Caloplaca epithallina Lynge: 2, 4, 8, 12, 15, 16, 18, 33, 45, 47
Caloplaca furfuracea: 3, 10, 17, 28, 32, 36, 38
Caloplaca grimmiae (Nyl.) H. Olivier: 47
Caloplaca holocarpa (Hoffm. *ex* Ach.) M. Wade.: 4, 5, 14, 18, 24, 26, 41, 42, 44, 49
Caloplaca lactea (A. Massal.) Zahlbr.: 14
Caloplaca saxicola (Hoffm.) Nordin: 7, 11, 14, 16, 25, 42, 44
Caloplaca sinapisperma (Lam. & DC.) Mahrer & A. Gillet: 38, 39, 42, 44, 45
Caloplaca tiroliensis Zahlbr.: 8, 18, 46
Caloplaca trachyphylla (Tuck.) Zahlbr.: 12, 15
Candelaria concolor (Dickson) Stein: 5, 18, 27
Candelariella aurella (Hoffm.) Zahlbr.: 7, 18, 24, 26, 47