Biological soil crust distribution on the Boardman Conservation Area: Results from 2009 monitoring

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Introduction

Biological soil crusts are an important component of biological diversity in semi-arid and arid ecosystems. Composed of algae, fungi, cyanobacteria, lichens, and bryophytes, biological soil crusts contribute to nutrient cycling, regulation of water flow, improved soil stability and structure, and provide safe sites for vascular plant establishment (Eldridge and Rosentreter 1999, Belnap et al. 2001). Biological soil crusts are also important indicators of ecological condition because they are sensitive to disturbances such as grazing and other forms of trampling (Anderson et al. 1982, Marble and Harper 1989, Ponzetti and McCune 2001) and fire (Callison et al. 1985, Eldridge and Bradstock 1994, Johansen et al. 1993). They are also ideal indicators for evaluating long-term ecological change because unlike vascular plants, they are not greatly influenced by short-term climatic conditions (Belnap et al. 2001).

In spring 2009, we initiated a biological soil crust monitoring program on the Boardman Conservation Area. The main objective of monitoring biological soil crusts was to provide an additional measure of ecological condition that complements the on-going vegetation monitoring program. Results from monitoring will be used to evaluate ecological change resulting from management actions and natural disturbances such as fire. This report describes the first year results from biological soil crust monitoring, and provides an assessment of potential factors influencing biological soil crust distribution on the Conservation Area.

Methods

Data collection

Biological soil crusts were monitored at all 57 long-term vegetation monitoring plots (Figure 1) at the same time vegetation monitoring plots were sampled (see Elseroad et al. 2010 for vegetation monitoring results). At each vegetation monitoring plot, a 50m biological soil crust monitoring transect was run 135° from the 50m end of the vegetation monitoring plot baseline transect (Figure 2). The end of the crust transect was marked with rebar and tagged, and the location was recorded with a Juno GPS unit.

Starting at a random number between 3m and 4m along the biological soil crust transect, a quadrat frame was placed every 3m for a total of 15 quadrats per transect. The first 3m along the transect was not sampled to avoid soil disturbance created by establishing the transect or from vegetation monitoring plot sampling. The quadrat frame was always placed on the inside of the transect (the side facing the vegetation plot), and the observer walked only on the outside of the transect, also to avoid sampling disturbed soil.

The quadrat consisted of a 25cm x 25cm frame with 20 points (Figure 3). After the quadrat was placed on the ground, the ground underneath the quadrat was sprayed with water to increase the visibility of the crust. At each of the 20 points on the frame, a pin flag was dropped and the soil surface type intercepted was viewed with a hand lens and recorded as one of the following soil surface types: bare soil, litter, rock, plant base, or one of the following biological soil crust morphological groups: cyanobacteria, moss, crustose lichen, squamulose lichen, foliose lichen, and fruiticose lichen (Appendix A). Morphological groups are a modified version of those provided in Belnap et al. (2001). Initally, liverworts and gelatinous lichens were also included as morphological groups, but these groups were eliminated due to difficulties positively identifying them in the field. Liverworts were never positively identified as such, but if they were unknowingly sampled, they were recorded as a morphologically similar lichen group. Gelatinous lichen species were categorized based on their morphology rather than their gelatinous nature (i.e. *Leptochidium albociliatum*, a gelatinous, foliose lichen, was categorized as foliose rather than gelatinous).

Future biological soil crust sampling is planned to occur during the first year of each long-term vegetation monitoring plot sampling cycle. Long-term vegetation monitoring plots are generally sampled for three years in a row every 5 years. Since 2009 was the beginning of a vegetation monitoring plot sampling cycle, biological soil crust transects will be sampled next in 2017.

Data analysis

Cover of surface types in each quadrat was calculated as: (the number of points intercepted / 20) *100. Average cover of each soil surface type was then calculated for each transect. To evaluate factors influencing the distribution of biological soil crust across the Boardman Conservation Area, average crust cover was calculated by soil texture class, vegetation condition class, and whether or not the transects burned in the 2008 wildfires. The Morrow County soil survey (Holser 1983) was used to classify soils into three general soil texture classes: silt loams, sandy loams, and loamy sands. Vegetation condition classes were assigned during vegetation mapping in 2002, and are a qualitative assessment of overall ecological condition based on the abundance of cheatgrass and native perennial bunchgrasses (Elseroad 2002). The 2008 wildfires burned approximately 14,000 acres in July and August 2008, in the eastern portion of the Boardman Conservation Area and most of the adjacent Boardman Bombing Range (Nelson 2009).

Results

The morphological groups used in this study were a relatively simple method for monitoring biological soil crust. The soil surface components that were most difficult to distinguish in the field were bare ground vs. cyanobacteria, and crustose lichens vs. squamulose lichens. With careful examination, cyanobacteria crust could be distinguished from bare ground by its structured appearance, and by noting the slight resistance felt when pushed with a finger. When lichens were encountered that were difficult to categorize easily as either crustose or squamulose, the photos provided in Appendix A were consulted. In most cases, the lichens were probably categorized consistently, but because of potential differences in categorizing between observers, evaluating total lichen cover rather than by morphological group may be a more accurate way to assess future changes over time.

Biological soil crust cover across all transects

Biological soil crust was the dominant soil surface category encountered on the transects (Figure 4, Table 1). Cover of all biological soil crust morphological groups combined averaged 56%. Bare soil averaged 22%, plant base averaged 7%, and litter averaged 14%. Rock cover averaged only 0.2%, and was found in only 3 of the 57 transects.

Moss and cyanobacteria were the dominant biological soil crust morphological groups (Figure 5). Moss cover averaged 25% and cyanobacteria cover averaged 24%. Total lichen cover averaged 7% and was dominated by crustose lichens (Figure 4). Crustose lichen cover averaged 5%, compared to 1% cover for squamulose lichens, 0.75% cover for foliose lichens, and 0.02% cover for fruiticose lichens.

Biological soil crust cover stratified by soil texture

Biological soil crust cover and composition appeared to be strongly influenced by soil texture (Figure 6). Total biological soil crust cover was greater on sandy loams (average cover 61%) and silt loams (average cover 58%) compared to loamy sands (average cover 46%). Total lichen cover declined with increasing sandiness (silt loams< sandy loams<loamy sands). Total lichen cover averaged 11% in silt loams, 6% in sandy loams, and 0.6% in loamy sands. The proportion of the more morphologically complex lichens (e.g. squamulose, foliose, and fruiticose lichens) also declined with increasing sandiness (Figure 6).

Biological soil crust cover stratified by vegetative condition class

The cover of each biological soil crust morphological group varied considerably when stratified by vegetation condition class (Figure 7). Total biological soil crust cover declined as vegetation condition declined from “high” to “low”. Total biological soil crust averaged 79% in high condition classes, 69% in medium-high condition classes, 54% in medium condition classes, 48% in medium low condition classes, and 46% in low condition classes.

Biological soil crust composition also varied by vegetation condition class. In high condition classes, biological soil crust was dominated by moss (average cover 43%) and lichens (average cover 24%), with less cover of cyanobacteria (average cover 12%). In comparison, in the other condition classes the proportion of moss and cyanobacteria was nearly equal (Figure 7). Total lichen cover declined as vegetation condition declined from “high” to “low”. Total lichen cover averaged 24% in high condition classes, 15% in medium-high condition classes, 6% in medium condition classes, 3% in medium low condition classes, and 0.5% in low condition classes. Also, the proportion of the more morphologically complex lichens (e.g. squamulose, foliose, and fruiticose lichens) declined as vegetation condition declined (Figure 7). While crustose lichens were the most common lichens in all condition classes, in lower condition classes they were a greater proportion of the overall lichen cover.

Biological soil crust cover stratified by recent wildfire burning

Biological soil crust cover and composition differed depending on whether or not the transects burned in the 2008 wildfire (Figure 8). Total biological soil crust cover was slightly greater on unburned than burned transects (58% vs. 52%). Unburned transects had greater moss (15% vs. 7%) and lichen cover (9% vs. 3%) but less cyanobacteria cover (19% vs. 34%) than unburned transects.

Discussion

We found that biological soil crust composition and distribution on the Boardman Conservation Area was associated with soil texture, the ecological condition of the plant communities, and whether or not transects burned in the 2008 wildfire. Total crust cover and lichen cover was greater in finer textured soils (silt and sandy loams compared to loamy sands), in higher condition plant communities, and in unburned sites. Other studies have also documented increased soil crust development in finer textured soils (Anderson et al. 1982, Belnap et al. 2001). Finer textured soils may support more biological soil crust cover because they are more stable and retain soil surface moisture longer than coarser textured soils (Belnap et al. 2001).

The pattern we detected of less cover of the more morphologically complex crust components (i.e. fruiticose and foliose lichens) in areas of lower ecological condition and in burned areas follows generalized models of the susceptibility of morphological groups to disturbance. Typically as morphological complexity increases (e.g. cyanobacteria < moss, crustose, and squamulose lichens < fruiticose and foliose lichens) susceptibility to disturbance increases (Eldridge and Rosentreter 1999). Soils in the lower condition plant communities were probably more disturbed by livestock grazing and/or wildfires historically, which would have limited the development of morphologically complex lichens. In burned areas, some of the mosses and lichens were probably killed by the wildfire. Higher cyanobacteria cover in burned areas may have been a function of their high mobility, which allows rapid recolonization following disturbances (Belnap et al. 2001).

Results from this first year of biological soil crust sampling provide a baseline for evaluating recovery from a century of livestock grazing, the 2008 wildfire, as well as future management actions and natural disturbances on the Conservation Area. The removal of livestock grazing from the Conservation Area in 2005, and recovery from the 2008 wildfire should result in increased in crust morphological complexity over time. While cyanobacteria can recover in less than six months after disturbance; and moss, crustose and squamulose lichens may require six months to five years; recovery of fruiticose and foliose lichens can take five years or more (Eldridge and Rosentreter 1999).

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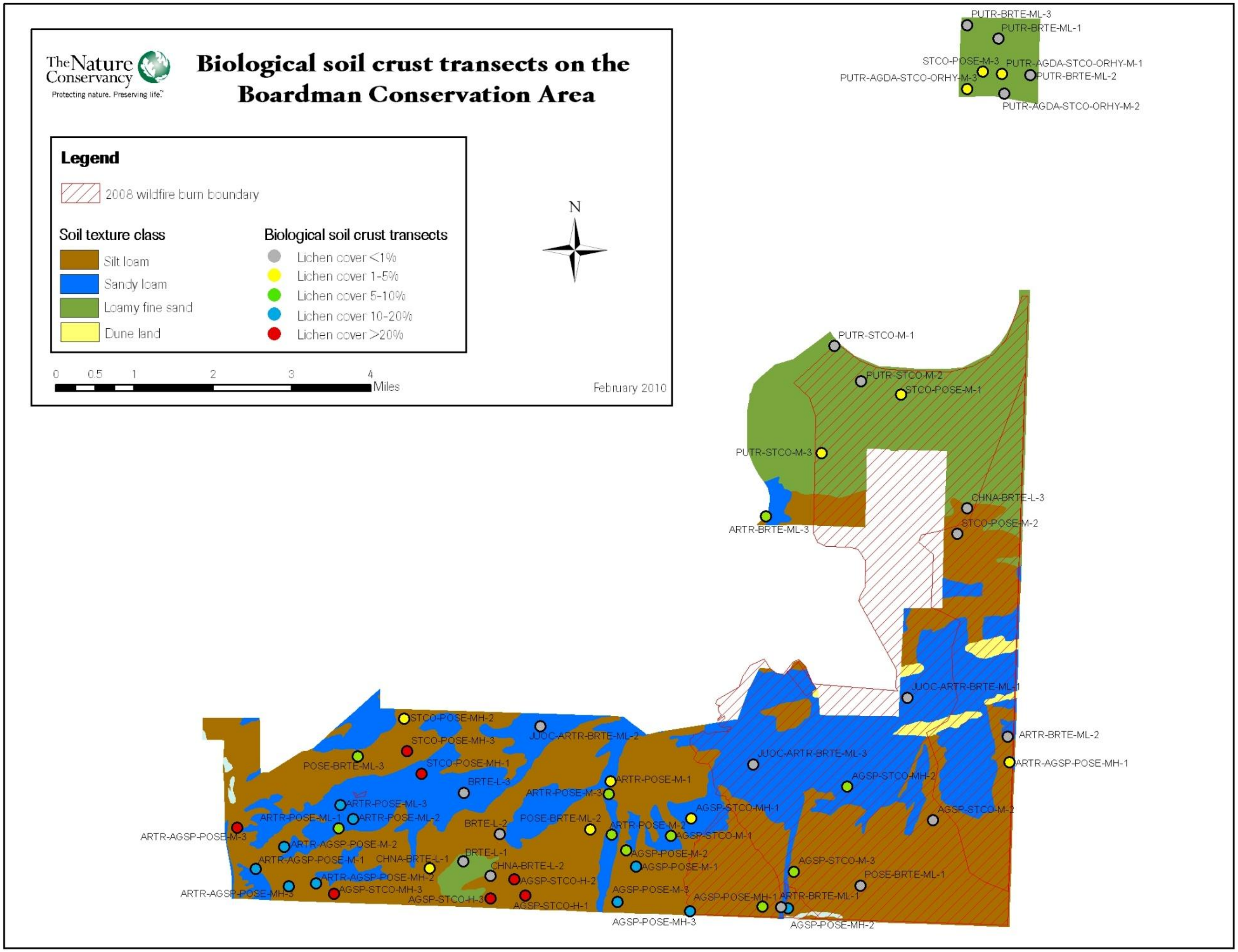
Biological soil crust transects on the Boardman Conservation Area
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Legend
2008 wildfire burn boundary
Soil texture class
Silt loam
Sandy loam
Loamy fine sand
Dune land
Biological soil crust transects
Lichen cover <1%
Lichen cover 1-5%
Lichen cover 5-10%
Lichen cover 10-20%
Lichen cover >20%
0 0.5 1 2 3 4 Miles
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Figure 1.

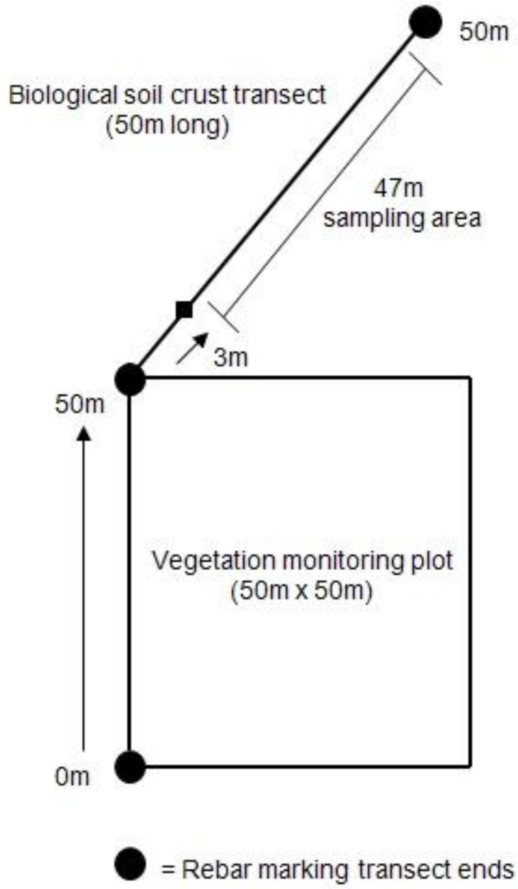


Figure 2. Location of biological soil crust transect at each vegetation monitoring plot.

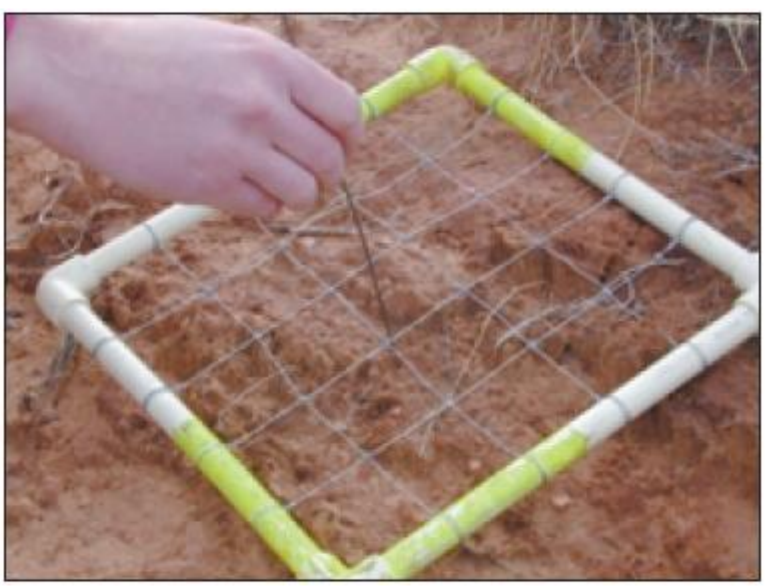


Figure 3. 25cm x 25cm quadrat frame used for point-cover estimates. Hits are determined by dropping a pin vertically from each intercept. From Belnap et al. (2001).

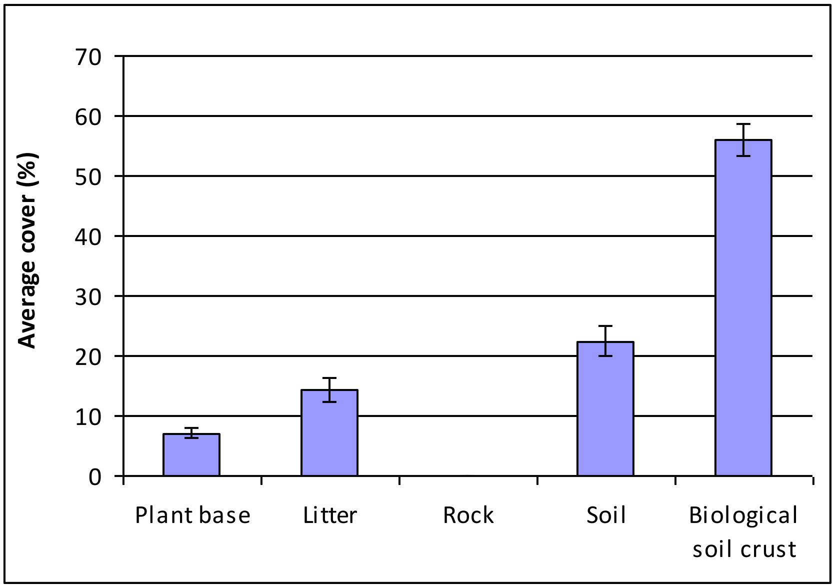


Figure 4. Cover of soil surface categories across all biological soil crust transects at the Boardman Conservation Area in 2009 (average ± 1 SE, n=57).

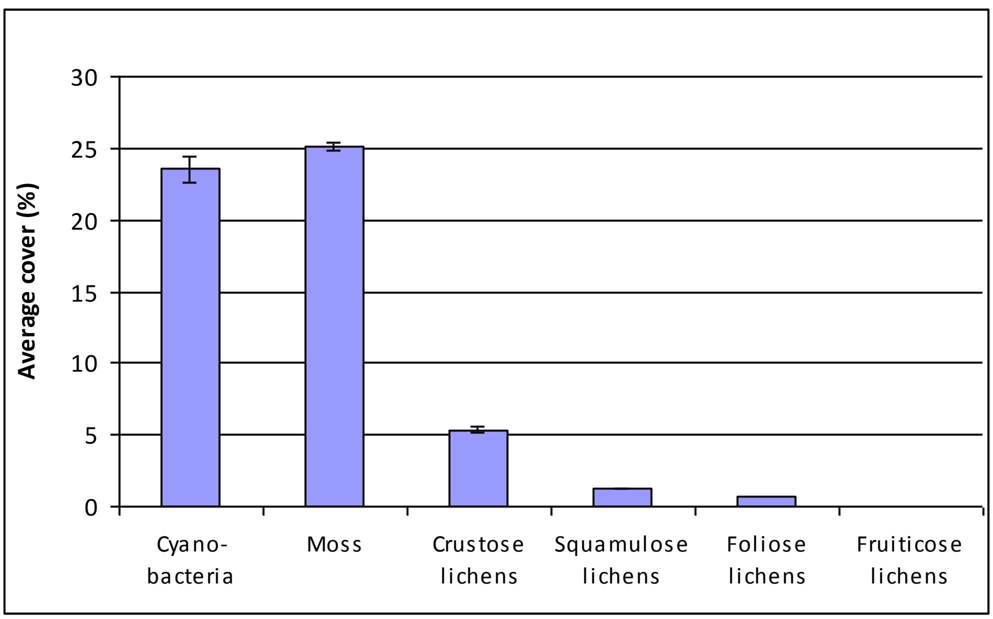


Figure 5. Cover of biological soil crust morphological groups across all biological soil crust transects at the Boardman Conservation Area in 2009 (average ± 1 SE, n=57).

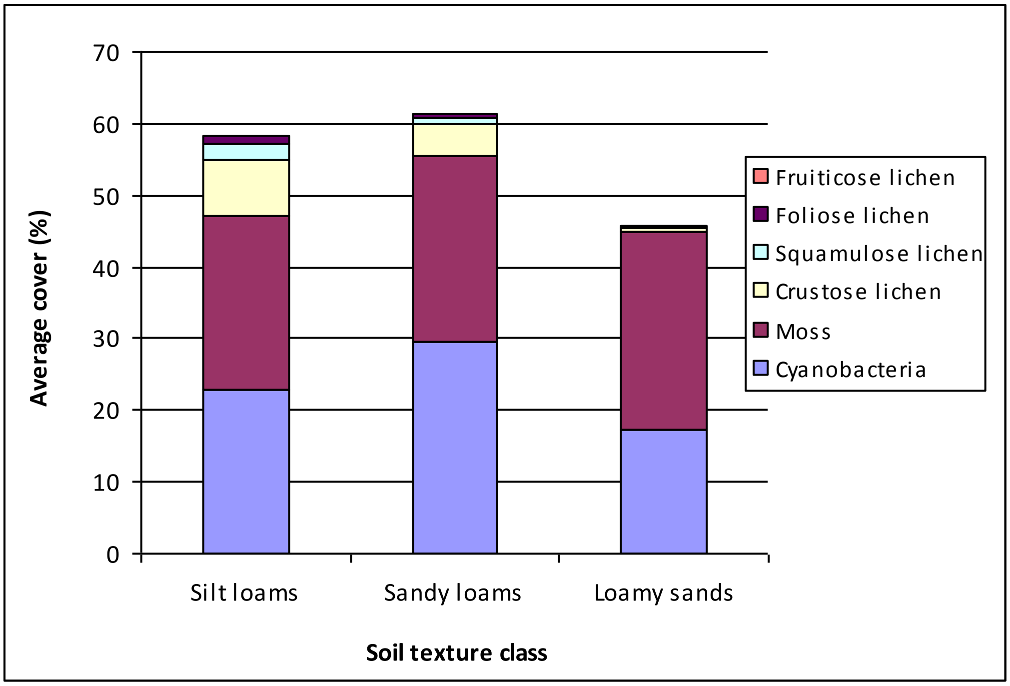


Figure 6. Cover of biological soil crust components within each soil texture class at the Boardman Conservation Area in 2009. Soil texture classes are listed in order of increasing sandiness.

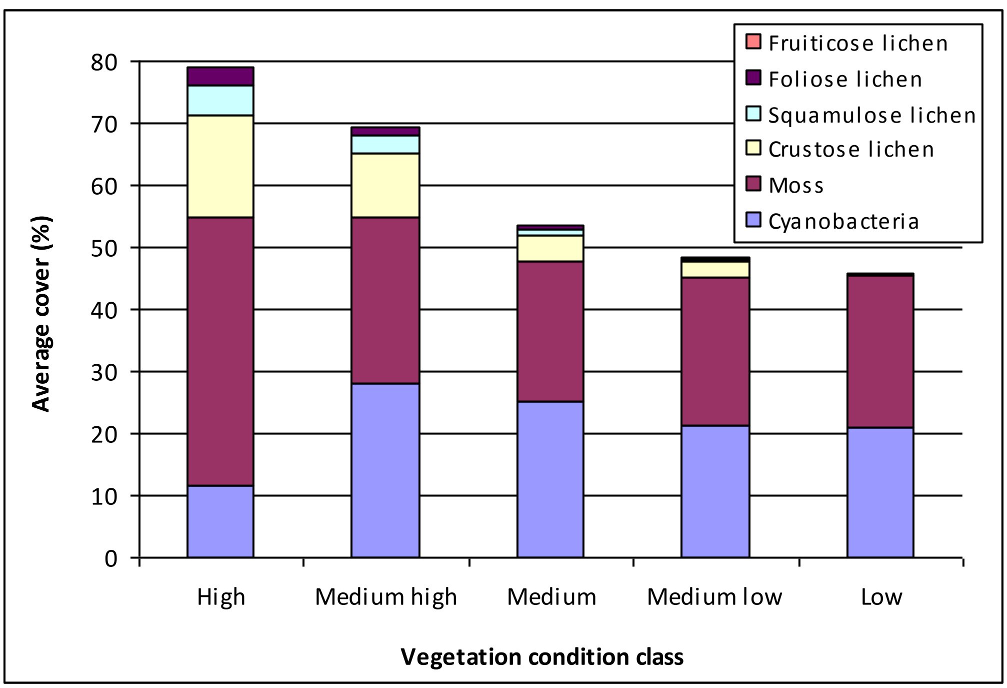


Figure 7. Cover of biological soil crust components within each of the vegetation condition class types at the Boardman Conservation Area in 2009.

Figure 8. Cover of biological soil crust components within plots burned and unburned in the 2008 wildfire at the Boardman Conservation Area in 2009.

Table 1. Cover (average ± 1 SE, n=15) of all soil surface types on biological soil crust transects at the Boardman Conservation Area in 2009.

	Non-biological soil surface type (% cover)				Biological soil crust (% cover)							
Plot name	Plant base	Litter	Rock	Soil	Cyano-bacteria	Moss	Crustose lichens	Foliose lichens	Fruit-icose lichens	Squam-ulose lichens	All lichens	All crust types
AGSP-POSE-M-1	15.3 ± 2.5	8.7 ± 2.9	0 ± 0	14 ± 2.8	12.3 ± 3.9	39.7 ± 3.1	6.7 ± 2.1	2.3 ± 1.5	0 ± 0	1 ± 0.5	10 ± 2.6	62 ± 5.1
AGSP-POSE-M-2	7 ± 1.4	0.7 ± 0.5	0 ± 0	20.7 ± 7.9	50.7 ± 6.9	13 ± 4.2	6.7 ± 2.3	1 ± 0.7	0 ± 0	0.3 ± 0.3	8 ± 2.3	71.7 ± 8.1
AGSP-POSE-M-3	12.7 ± 2	28.7 ± 4.9	0 ± 0	22 ± 4.9	4.7 ± 1.8	19.7 ± 3.6	11 ± 3.4	1.3 ± 0.8	0 ± 0	0 ± 0	12.3 ± 3.7	36.7 ± 5.5
AGSP-POSE-MH-1	13.7 ± 3.1	20.7 ± 5.3	0 ± 0	6.3 ± 3.3	8.3 ± 2.3	44.3 ± 6.5	5.7 ± 2.5	1 ± 0.7	0 ± 0	0 ± 0	6.7 ± 2.5	59.3 ± 7.2
AGSP-POSE-MH-2	2.7 ± 1	28.5 ± 5.1	0 ± 0	15.7 ± 2.3	19.7 ± 4.2	16.1 ± 4.5	10.4 ± 2.9	5.4 ± 1.7	0 ± 0	1.7 ± 0.9	17.4 ± 3.8	53.1 ± 5.4
AGSP-POSE-MH-3	13.7 ± 4.6	0.3 ± 0.3	0 ± 0	0.7 ± 0.7	36 ± 6.3	35.7 ± 5.6	12 ± 3.7	1.7 ± 0.8	0 ± 0	0 ± 0	13.7 ± 4	85.3 ± 4.8
AGSP-STCO-H-1	19 ± 6.4	2 ± 1.1	0 ± 0	0 ± 0	4 ± 1.4	51 ± 5.4	10 ± 3.1	6.3 ± 1.9	0 ± 0	7.7 ± 1.9	24 ± 4.1	79 ± 6.9
AGSP-STCO-H-2	7.2 ± 2.2	13.3 ± 3.7	0 ± 0	0.8 ± 0.6	25.6 ± 4.7	29.9 ± 5.3	22.1 ± 4.1	1.1 ± 0.6	0 ± 0	0 ± 0	23.2 ± 4.2	78.7 ± 3.7
AGSP-STCO-H-3	17.3 ± 4.7	2.3 ± 1	0 ± 0	0.7 ± 0.7	5.3 ± 1.9	48.7 ± 4.5	17.3 ± 3.1	1.3 ± 0.8	0 ± 0	7 ± 2.6	25.7 ± 4.2	79.7 ± 5.2
AGSP-STCO-M-1	21.3 ± 5	23 ± 5.4	0 ± 0	3.7 ± 1.3	35.7 ± 5.2	11 ± 3.7	5.3 ± 2.2	0 ± 0	0 ± 0	0 ± 0	5.3 ± 2.2	52 ± 5.6
AGSP-STCO-M-2	4.3 ± 1.8	27.7 ± 4.2	0 ± 0	39 ± 5.3	19 ± 5.7	9.7 ± 3.6	0 ± 0	0.3 ± 0.3	0 ± 0	0 ± 0	0.3 ± 0.3	29 ± 7.5
AGSP-STCO-M-3	9 ± 1.6	5.7 ± 1.9	0 ± 0	9.7 ± 4.3	25.3 ± 5.9	44 ± 5.3	2 ± 0.8	0.3 ± 0.3	0 ± 0	4 ± 1.8	6.3 ± 2.2	75.7 ± 4.5
AGSP-STCO-MH-1	20.3 ± 4.8	10.2 ± 3.8	0 ± 0	4 ± 1.6	20 ± 5.1	41.3 ± 6.1	3 ± 2.1	0 ± 0	0 ± 0	1.3 ± 0.6	4.3 ± 2.3	65.6 ± 5.8
AGSP-STCO-MH-2	2 ± 1.1	4 ± 1.8	0 ± 0	2.7 ± 1.6	66.3 ± 6	17.7 ± 3.4	6.3 ± 2.4	0 ± 0	0 ± 0	1 ± 0.7	7.3 ± 2.4	91.3 ± 3.3
AGSP-STCO-MH-3	14 ± 3.6	6 ± 3.6	0 ± 0	2 ± 1.7	18.7 ± 7.7	17.9 ± 5.2	34.2 ± 7.1	0 ± 0	0 ± 0	7.3 ± 3.3	41.5 ± 6.9	78.1 ± 6.5
ARTR-AGSP-POSE-M-1	8 ± 2.9	19.1 ± 6.3	0 ± 0	10.6 ± 3.8	7 ± 4.3	39.5 ± 6.7	6 ± 3.9	1 ± 0.7	0.7 ± 0.4	8.2 ± 2.8	15.8 ± 4.9	62.3 ± 9.3
ARTR-AGSP-POSE-M-2	4 ± 1.6	19.3 ± 5.2	0 ± 0	17.9 ± 6.2	9.7 ± 2.9	32.8 ± 6.6	9.7 ± 3.3	5 ± 1.5	0 ± 0	1.7 ± 1.2	16.3 ± 4.7	58.8 ± 9.4
ARTR-AGSP-POSE-M-3	8.3 ± 1.8	32 ± 8.9	0 ± 0	3.3 ± 1.7	13 ± 5.9	18 ± 5.5	25.3 ± 7.9	0 ± 0	0 ± 0	0 ± 0	25.3 ± 7.9	56.3 ± 9.3
ARTR-AGSP-POSE-MH-1	3 ± 1.4	5 ± 1.6	0 ± 0	19.3 ± 5.5	64.3 ± 7.1	6 ± 2.4	0 ± 0	2.3 ± 1.6	0 ± 0	0 ± 0	2.3 ± 1.6	72.7 ± 5.8
ARTR-AGSP-POSE-MH-2	15.4 ± 2.2	9.7 ± 3.4	0 ± 0	4 ± 1.8	15.4 ± 3.4	36.2 ± 5.4	11.8 ± 3.4	1.7 ± 1	0.3 ± 0.3	5.4 ± 2.1	19.2 ± 4.6	70.8 ± 5.2
ARTR-AGSP-POSE-MH-3	18.6 ± 4	19.3 ± 3.5	0 ± 0	4 ± 1.9	20.3 ± 3.4	18.3 ± 4.7	8.3 ± 3.2	0 ± 0	0.3 ± 0.3	10.8 ± 4.2	19.4 ± 5	58 ± 6
ARTR-BRTE-ML-1	1 ± 0.7	13.7 ± 5.2	0 ± 0	52 ± 10.5	30.3 ± 8.5	3 ± 1.6	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	33.3 ± 9.3
ARTR-BRTE-ML-2	0.7 ± 0.5	1.3 ± 0.6	0 ± 0	12.7 ± 6.2	82 ± 6.5	3.3 ± 1.7	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	85.3 ± 6.5
ARTR-BRTE-ML-3	0 ± 0	3.7 ± 1.1	0 ± 0	60.3 ± 9.2	7.3 ± 2.9	28.7 ± 8.1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	36 ± 8.9
ARTR-POSE-M-1	2 ± 1.4	3 ± 1.2	0 ± 0	23.3 ± 6.5	65.7 ± 7	5 ± 2	1 ± 0.7	0 ± 0	0 ± 0	0 ± 0	1 ± 0.7	71.7 ± 6.9
ARTR-POSE-M-2	1.7 ± 0.9	1 ± 0.7	0 ± 0	23.4 ± 8.7	54.6 ± 7.3	12.7 ± 3.5	4.3 ± 1.7	0.7 ± 0.7	0 ± 0	1.7 ± 0.8	6.7 ± 2.3	73.9 ± 8.4
ARTR-POSE-M-3	15.7 ± 2.7	11.7 ± 3.5	0 ± 0	17 ± 4.9	10.3 ± 3.5	36 ± 4.1	6 ± 2.5	3.3 ± 1.3	0 ± 0	0 ± 0	9.3 ± 2.5	55.7 ± 6.2
ARTR-POSE-ML-1	2 ± 0.8	42.9 ± 8.5	0 ± 0	20.1 ± 5.8	1.7 ± 1.1	28.3 ± 7.8	3 ± 1.9	0.7 ± 0.5	0 ± 0	1.3 ± 1.3	5 ± 3.4	35 ± 9.6
ARTR-POSE-ML-2	3.7 ± 1.6	31.1 ± 8.6	0 ± 0	15.9 ± 5	25.4 ± 5.8	8 ± 2.3	12.4 ± 3.3	3.1 ± 1.8	0 ± 0	0.3 ± 0.3	15.8 ± 4.2	49.3 ± 8.2
ARTR-POSE-ML-3	11 ± 4.6	12.3 ± 3.3	0 ± 0	17.7 ± 5.3	7.3 ± 2.8	34.7 ± 5	13.7 ± 4.5	1.7 ± 0.8	0 ± 0	1.7 ± 0.8	17 ± 5.2	59 ± 5.6
BRTE-L-1	4.6 ± 1.2	65.5 ± 5.2	0 ± 0	12.2 ± 2.8	1.3 ± 0.9	16 ± 6.3	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	17.7 ± 6.7
BRTE-L-2	0.3 ± 0.3	3 ± 1.3	0 ± 0	8.3 ± 2.7	65.3 ± 5.6	23 ± 5.1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	88.3 ± 3
BRTE-L-3	1 ± 0.5	7 ± 2.4	0 ± 0	4.3 ± 1.2	2.3 ± 1	85.3 ± 3.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	87.7 ± 3.3

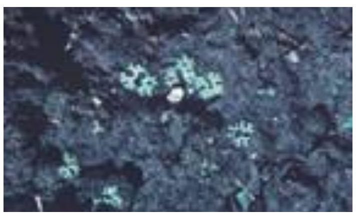
	Non-biological soil crust cover				Biological soil crust cover							
Plot name	Plant base	Litter	Rock	Soil	Cyano-bacteria	Moss	Crustose lichens	Foliose lichens	Fruit-icose lichens	Squam-ulose lichens	All lichens	All crust types
CHNA-BRTE-L-1	2.3 ± 1.2	73.7 ± 7.1	0 ± 0	17.3 ± 4.7	1.3 ± 1	3.3 ± 3	2 ± 2	0 ± 0	0 ± 0	0 ± 0	2 ± 2	6.7 ± 4.3
CHNA-BRTE-L-2	2.1 ± 0.9	51.6 ± 9.2	0 ± 0	21 ± 4.3	25 ± 7.8	0 ± 0	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	25.3 ± 7.9
CHNA-BRTE-L-3	1.3 ± 0.8	3.3 ± 2.2	0 ± 0	45.3 ± 8.5	30 ± 7.4	19.7 ± 7.2	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	50 ± 8.7
JUOC-ARTR-BRTE-ML-1	0 ± 0	0 ± 0	0 ± 0	23 ± 6.9	42.3 ± 8.2	34.3 ± 10.9	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	77 ± 6.9
JUOC-ARTR-BRTE-ML-2	0.3 ± 0.3	0 ± 0	0 ± 0	49.3 ± 10.9	26.3 ± 6.4	23.7 ± 9.4	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0.3 ± 0.3	50.3 ± 10.8
JUOC-ARTR-BRTE-ML-3	0 ± 0	1 ± 1	0.3 ± 0.3	75 ± 9.7	23.7 ± 9.5	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	23.7 ± 9.5
POSE-BRTE-ML-1	7.7 ± 1.5	36 ± 6.8	0 ± 0	37 ± 5.4	4 ± 1.9	15.3 ± 6	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	19.3 ± 6
POSE-BRTE-ML-2	7.7 ± 1.5	5.3 ± 2.1	0 ± 0	32.7 ± 6.4	39.3 ± 7.5	11.7 ± 3.6	2.7 ± 1.4	0 ± 0	0 ± 0	0.7 ± 0.7	3.3 ± 1.4	54.3 ± 7.1
POSE-BRTE-ML-3	15 ± 2.5	26.7 ± 5.6	0 ± 0	11.7 ± 3.1	4.7 ± 2.5	36.3 ± 6.6	5 ± 2.1	0 ± 0	0 ± 0	0.7 ± 0.5	5.7 ± 2.3	46.7 ± 7.4
PUTR-AGDA-STCO-ORHY-M-1	2.3 ± 1.1	8.3 ± 2.1	0 ± 0	19 ± 4.5	22.7 ± 9.3	46.7 ± 9.2	1 ± 0.7	0 ± 0	0 ± 0	0 ± 0	1 ± 0.7	70.3 ± 5.1
PUTR-AGDA-STCO-ORHY-M-2	4 ± 1.6	37 ± 4.1	0 ± 0	22 ± 4	7.3 ± 2.4	29.7 ± 3.6	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	37 ± 4.3
PUTR-AGDA-STCO-ORHY-M-3	6.7 ± 2.2	16.3 ± 4.4	0 ± 0	38.3 ± 4.7	23 ± 5.6	14.3 ± 3.7	0.7 ± 0.7	0 ± 0	0 ± 0	0.7 ± 0.7	1.3 ± 0.9	38.7 ± 5.8
PUTR-BRTE-ML-1	11.7 ± 7.7	11 ± 3	0 ± 0	21.3 ± 5	1.7 ± 0.8	54.3 ± 8.8	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	56 ± 8.8
PUTR-BRTE-ML-2	2 ± 1.7	1 ± 0.7	0 ± 0	32.7 ± 6.2	4.7 ± 2.6	59.7 ± 7.2	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	64.3 ± 6.9
PUTR-BRTE-ML-3	0.7 ± 0.5	5.4 ± 2.3	0.7 ± 0.5	57.8 ± 5.6	18.7 ± 5.7	16.8 ± 4.3	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	35.5 ± 5.6
PUTR-STCO-M-1	5 ± 2.4	20.3 ± 7.5	0 ± 0	37.7 ± 6.1	30 ± 5.1	6.3 ± 3.4	0.7 ± 0.5	0 ± 0	0 ± 0	0 ± 0	0.7 ± 0.5	37 ± 6.1
PUTR-STCO-M-2	0 ± 0	8.7 ± 4.1	0.3 ± 0.3	61.3 ± 5.5	29.3 ± 5.8	0.3 ± 0.3	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	29.7 ± 5.7
PUTR-STCO-M-3	0.7 ± 0.7	5.7 ± 1.8	0 ± 0	42.7 ± 7	29.3 ± 5.1	20.7 ± 8.6	0.3 ± 0.3	0.7 ± 0.7	0 ± 0	0 ± 0	1 ± 0.7	51 ± 7.9
STCO-POSE-M-1	8.3 ± 2.1	3.3 ± 1.9	0 ± 0	27.3 ± 2.9	43.7 ± 5.1	15.3 ± 2.9	1.7 ± 0.8	0 ± 0	0 ± 0	0.3 ± 0.3	2 ± 0.8	61 ± 4.1
STCO-POSE-M-2	1.3 ± 0.8	1.7 ± 0.8	0 ± 0	63 ± 6.5	31.7 ± 6.7	1.7 ± 0.9	0.7 ± 0.7	0 ± 0	0 ± 0	0 ± 0	0.7 ± 0.7	34 ± 6.4
STCO-POSE-M-3	6.7 ± 2.8	8.7 ± 2.2	0 ± 0	23.7 ± 4.6	1 ± 0.7	58.3 ± 5.9	1.7 ± 1.1	0 ± 0	0 ± 0	0 ± 0	1.7 ± 1.1	61 ± 5.9
STCO-POSE-MH-1	11.7 ± 2	4.7 ± 1.4	0 ± 0	10.7 ± 2.1	24 ± 3.5	29 ± 3.8	15.7 ± 3.4	0 ± 0	0 ± 0	4.3 ± 2.4	20 ± 4.3	73 ± 4.2
STCO-POSE-MH-2	10.9 ± 1.5	0 ± 0	0 ± 0	24 ± 4.5	34.6 ± 5.6	27.1 ± 7.4	3.3 ± 1.1	0 ± 0	0 ± 0	0 ± 0	3.3 ± 1.1	65.1 ± 4.3
STCO-POSE-MH-3	18.3 ± 2.5	6 ± 1.5	0 ± 0	16.6 ± 4.6	7.7 ± 2.2	32 ± 5.1	15 ± 5.2	0.3 ± 0.3	0 ± 0	4.3 ± 1.5	19.6 ± 4.8	59.2 ± 6

Appendix A:
Boardman Conservation Area biological soil crust morphological groups

Adrien Elseroad
April 2009

Cyanobacteria colonies are black to blue-green and visible primarily when moist

Moss

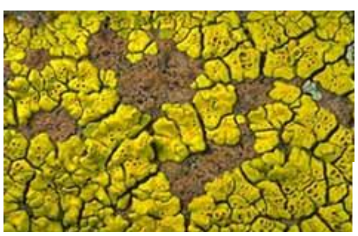


Liverwort- flat, narrow ribbon or green-black dichotomously branching material on the soil surface. Can be difficult to detect, are usually in a mosaic with other crusts. When moist, can see tiny black ribbons with hand lens.

NOT DETECTED DURING 2009 MONITORING- COMBINED WITH RELEVANT LICHEN MORPHOLOGICAL GROUP IF INTERCEPTED

Gelatinous lichens- have a single-celled structure of interwoven fungal threads with algae scattered between them and have a rubbery, jelly-like texture (*Collema tenax,* shown here, is also considered foliose.)

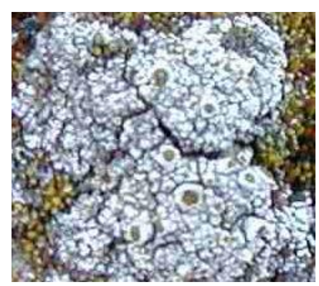
GROUP NOT USED DURING 2009 MONITORING- USED APPROPRIATE LICHEN MORPHOLOGICAL GROUP INSTEAD



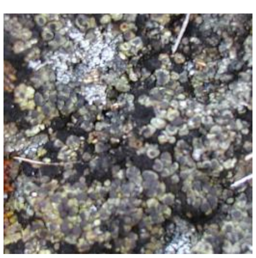
Crustose lichens- form a crust on the substrate surface that is very difficult to remove. Can be thick and granular or embedded within the substrate with the fruiting bodies rising above the surface. Can be continuous or areolate (appearing tile- or island-like and divided into small areas by cracks.)

Caloplaca tominii at BCA

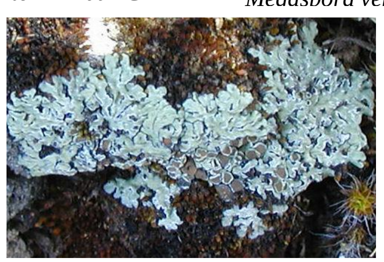
Megaspora verrucosa at BCA



Texosporium sancti-jacobi at BCA



Acarospora nodulosa at BCA

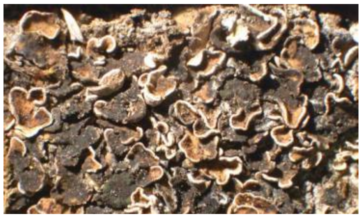


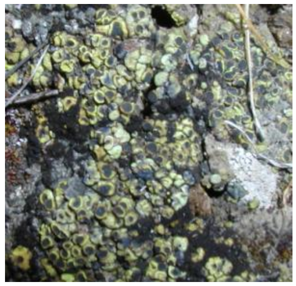
Lecanora muralis at BCA (lobate crustose)

Diploschistes muscorum at BCA

Squamulose lichens- have scale-like lobes (squamules) that are usually small and **overlapping**. Squamules can be discrete flakes that are round or ear-shaped, convex or concave, and often have lobed margins. They are otherwise similar to crustose lichens in that they possess an upper cortex but no lower cortex.

Squamules edged in white with brown fruiting bodies

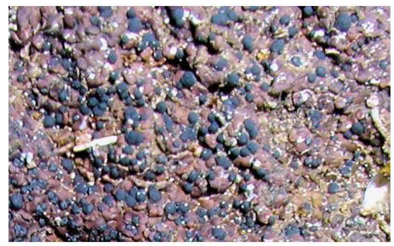




Acarospora schleicheri at BCA

Cladonia with squamulose base and fruticose fruiting structure

Trapeliopsis steppica (at BCA)



Psora globifera at BCA

Foliose lichens- are somewhat leaf-like, composed of lobes. Generally raised to some extent above the substrate, and are relatively loosely attached to their substrates, usually by means of rhizines (specialised root-like hyphae). Lobes have upper and lower sides and usually grow more-or-less parallel to the substrate. *Leptochidium albociliatum* is also gelatinous.

Leptochidium albociliatum (at BCA)

Peltigera didactyla at BCA

Fruticose lichens- are the most three-dimensional. Usually round in cross section (terete) and branched. Can be like little shrubs growing upward, or can hang down in long strands. Some foliose lichens can be shrubby like fruticose lichens, however, close examination will reveal that the algal part exists only on one side of the flattish thallus whereas in fruticose lichens it exists as a ring around the thallus, even when it is flattened.

Cladonia frimbiata at BCA