Effects of Burning on the Algal Communities of a High Desert Soil near Wallsburg, Utah

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Abstract

A recently burned area near Wallsburg, Wasatch County, Utah, was sampled to determine if differences existed between the soil algal flora of a burned area and that of an adjacent ecologically similar unburned area. Soil samples were cultured and analyzed to determine presence and relative frequency of living algae. The frequency of visible algal patches present after eight days of culturing was much higher in the unburned soil samples than in the burned samples. Percent relative frequencies and absolute densities of diatoms were also determined. Diatom floras of the two areas were very similar. However, the absolute densities of diatoms were significantly greater in the unburned samples. The major effect of the burn was to decrease algal biomass, although the flora remained remarkably similar.

Edaphic algal communities have been studied throughout the years in many parts of the world. Landmark studies include those of Bischoff and Bold (1963), Bristol-Roach (1926, 1927), Fritsch and John (1942), Moore and Carter (1926), Moore and Karrer (1919), Lowe and Moyse (1935) and Shields and Durrell (1964). Novichkova-Ivanova (1968) reviewed soil algal studies conducted in the U.S.S.R. Algal soil communities in arid regions of the world have received attention from several workers (Ali and Sandhu 1972; Anantani and Marathe 1947a, 1974b; Cameron 1964; Chantanachat and Bold 1962; Deason and Bold 1960; Durrell 1959; Fletcher and Martin 1948; Forest and Weston 1966).

Edaphic diatom communities have likewise been studied (Bristol 1920; Hayek and Hulbary 1956; Lund 1945, 1946; Petersen 1915, 1935; Reimer 1970). All of these studies deal with communities found in mesic soils and diatom studies of arid regions of the world are rare. The populations of playas and dry lakes of western North American have been studied by St. Clair and Rushforth (1978) and Van Landingham (1966). However, though such sites experience long periods of dryness and high temperature, they are occasionally flooded and thus differ from true desert soils. Anderson and Rushforth (1976) examined desert soils crusts throughout Utah and discussed the taxonomy and distribution of the diatoms as well as other cryptogamic crust components. In a more recent study conducted in Navajo National Monument, Kayenta County, Arizona (Johansen et al. in press) we found that uncrusted soils, though poor in green and blue-green algae, support a viable and occasionally rather diverse diatom community.

We had several objectives in mind at the outset of the present study. First, we wanted to learn more about algal communities in arid soils of western North America. Second, we wanted to determine absolute densities of diatoms in these soils. And third, we wished to discover if differences existed between the algal populations of recently burned soils and those of adjacent unburned soils. This could be of particular interest since burning is a commonly used technique for the management of some rangeland ecosystems of western North America.

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Site Description

The site of the present study was aproximately 5 km northwest of Wallsburg, Wasatch County, Utah. This region of Utah is subject to periodic burning from unplanned range fires. The last fire occurred in the summer of 1976. It was ignited by lightning and burned about 1,210 hectares over a 2-day period. Sampling sites were selected in an area near U.S. Highway 189 overlooking Deer Creek Reservoir.

Soils of the study site are sandy with varying amounts of silt. They are ultimately derived from the Oquirrh Formation, which has locally prominent intercalated limestone and sandstone beds with minor shales and siltstones. Average annual precipitation is approximately 30 cm. Precipitation occurs primarily as winter snow and summer thunderstorms, although gentle spring rains are not uncommon.

Vegetation of the study area is primarily comprised of shrubs and grasses. Sagebrush *(Artemisia tridentata)* and serviceberry *(Amelanchier alnifolia)* are the most abundant shrubs and are dominant in the unburned regions. Cheatgrass *(Bromus tectorum)* and several wheatgrasses (*Agropyron* species) are the most abundant grass species and are found primarily in the burned area. Shrubs in the study area provide winter browse for mule deer while domestic grazers more commonly utilize the grasses. Visible soil cryptogamic communities are rare throughout the study area and the absence of such communities is likely due to grazing (Anderson et al. 1982, Loope and Gifford 1972). However, even though crusts are absent, algae probably still bind soil particles and thus function to protect against erosion (Durrell and Shields 1961).

Materials and Methods

Fifteen paired stands were established at 30-m intervals along a 400-m section of the fireline. Each paired stand consisted of 2-m square quadrats, one in the burned area and one in the unburned area, each placed 30 m away from and perpendicular to the fireline. The slope and exposure of both members of each stand pair were required to be approximately the same. A 15-20 g soil sample, 2 cm deep, was taken randomly within each quadrat. Frequencies of visible cryptogams were recorded.

Upon returning to the laboratory 10 g of each soil sample were moistened in 10 ml of deionized water in sterilized petri dishes. After 4 days an additional 10 ml of water were added. After 8 days under continuous light, the samples were examined. Frequency of visible algal patches was determined by placing a petri dish lid which had been marked into quarters over the culture and recording the number of quarters containing algae. A subsample from each quarter was mounted on a microscope slide, the algal patches being sampled when present. Frequency of living algal species was determined by observing 20 microscope fields and recording the number of times each species was seen.

Permanent diatom slides were prepared by boiling the remaining 10 g of soil from each sample in concentrated nitric acid. After rinsing, diatoms were mounted in Naphrax diatom mountant. Through the use of quantitative dilutions, all diatom slides contained the equivalent of 2 mg of soil. Diatoms were identified and quantified by studying transects across the slide until at least 50 frustules had been observed. In most cases the completion of the transect made it necessary to count more than 50 diatoms and consequently a total of more than 2000 frustules was counted during this study.

Using the Spearman rank correlation coefficient (Siegel 1956), the frequencies of diatoms along each transect were compared with frequency of the same species along other transects taken at that sample location to determine uniformity among subsamples. By using this test, we found that our sampling methods were adequate to describe qualitatively the diatom communities.

The Spearman rank correlation coefficient (Siegel 1956) was also used to determine the similarity of living algal floras of samples from burned and unburned areas. Similarity of the diatom floras was calculated using Ruzicka's (1958) similarity index. Shannon-Wiener diversity indices (Krebs 1978) were calculated for each diatom sample.

Results and Discussion

A total of 27 algal taxa were observed during this study. Nineteen of these were diatoms (Bacillariophyta), 7 were blue-green algae (Cyanophyta), 1 was a green alga (Chlorophyta), and 1 was a *Euglena* (Euglenophyta). Fourteen taxa were observed as living specimens in the fresh mounts. Algal biomass in both burned and unburned soils was dominated by blue-green algae, primarily *Microcoleus vaginatus*. This alga and *Phormidium tenue* were the chief components of the algal patches observed after moistening. *Hantzschia amphioxys* was the most abundant diatom. It occurred together with other diatoms in the matrix of the blue-green algal patches as well as in the soil between patches. Percent frequencies of the algae observed in the fresh mounts are given in Table 1.

The diatom community was dominated by *Hantzschia amphioxys, Navicula mutica* var. *cohnii* and *Pinnularia borealis,* in that order. *Navicula mutica* and *Stauroneis kriegeri* were also important. These taxa are characteristic of arid soils throughout Utah and Arizona (Anderson and Rushforth 1976, Johansen et al. in press). Average percent relative densities as well as importance values equal to frequency times absolute density (Warner and Harper 1972) are presented in Table 2.

Statistical analyses of the data proved fruitful. Frequencies of algal patches in the samples from the unburned and burned areas were compared using a two-tailed *t*-test. They were significantly different at the $\alpha = .05$ level. The unburned area had higher frequency of such patches and greater algal biomass. Mean absolute densities for unburned and burned areas were 1850 diatoms/mg soil and 1280 diatoms/mg soil respectively. The means were significantly different ($P < .05$) in a two-tailed test. From these two tests, it appears that the algae have both higher densities and biomass in the unburned area.

Table 1. Percent relative frequencies of the algae observed in fresh mounts made from soil collected from burned and unburned soils.

Species	Unburned	Burned
Cyanophyta		
Chroococcus rufescens (Kuetz.) Naegeli	.7	.6
Chroococcus turgidus (Kuetz.) Naegeli	.2	
Microcoleus vaginatus (Vauch.) Gomont	50.1	34.7
Oscillatoria angusta Koppe	.9	1.3
Oscillatoria boryana Bory	.6	
Phormidium tenue (Menegh.) Gomont	10.2	4.5
Chlorophyta		
Unknown coccoid green algae	4.6	
Euglenophyta		
Euglena gracilis Klebs		2.9
Bacillariophyta		
Achnanthes species	.2	.3
Hantzschia amphioxys (Ehr.) Grunow	28.0	49.7
Navicula mutica Kuetzing	2.2	1.3
Navicula mutica var. *cohnii* (Hilse) Grunow	.2	
Pinnularia borealis Ehrenberg	1.1	1.6
Stauroneis kriegeri Patrick	.9	2.9

Table 2. Average percent relative densities and importance values of diatoms encountered in the study: UB = Unburned; B = Burned Area.

Species	Average percent relative dens. UB	Average percent relative dens. B	Importance values UB	Importance values B
Achnanthes species	5.67	4.11	9.20	55.2
Amphora ovalis var. *affinis* (Kuetz.) V.H. *ex* Det.		.12		.1
A. perpusilla (Grun.) Grunow	.13		.1	
Cyclotella comta (Grun.) Kuetzing	.11		.1	
C. kutzingiana Thwaites	1.77	1.97	20.0	14.0
C. ocellata Pantocsek	.11	.22	.1	3.1
Diploneis oblongella (Naeg. *ex* Kuetz.) Ross	.10		.1	
Hantzschia amphioxys (Ehr.) Grunow	33.14	37.18	574.0	468.0
Navicula excelsa Krasske	2.89	3.55	36.0	19.2
N. mutica Kuetzing	7.30	6.54	111.2	61.6
N. mutica var. *cohnii* (Hilse) Grunow	25.03	23.46	410.0	218.0
N. mutica var. *nivalis* (Ehr.) Hustedt	.76	.81	3.3	3.0
N. mutica var. *undulata* (Hilse) Grunow	5.32	7.75	109.2	85.0
N. pelliculosa (Breb. *ex* Kuetz.) Hilse	1.17	.58	2.4	1.6
N. tripunctata (O.F. Muell.) Bory	.11		.1	
Navicula species	.21	.23	1.1	.5
Pinnularia borealis Ehrenberg	13.39	10.39	278.0	145.0
Stauroneis kriegeri Patrick	3.51	2.86	57.0	20.0
Stephanodiscus species		.12		

The living algal floras of the two areas were found to be highly similar using the Spearman rank correlation coefficient ($p < .01$). The diatom floras were even more closely associted ($p < .0002$). Using average percent relative densities (Table 2), the diatom communities were calculated to be 84.9% similar using Ruzicka's similarity index. Diversities were also very similar. The mean Shannon-Wiener diversity index values for the unburned and burned areas were 1.68 and 1.63, respectively. These values are not significantly different when compared through use of a paired *t*-test. Diversity was also similar in that an average of 8.33 diatom species were found in both burned and unburned samples. Likewise, an average of 8.33 and 8.27 living algal species per sample were found in fresh mounts of burned and unburned samples.

Though differences in density and biomass were observed between the algal floras of the two areas, the causes for these differences are unknown. Several possible causes can be postulated, though more research is needed to verify any of these possibilities. (1) It may be that the algal populations were damaged by fire and have not had sufficient time to regain their former size. (2) The fire could have affected nutrients in the soil, causing differential algal growth. (3) Fire-crusting of the soil observed in the burned area increases runoff and consequently less water is absorbed into the ground. (4) Vascular plant floras are different, with shrubs dominating the unburned region and grasses dominating the burned region. Vascular plants affect soil nutrients, temperature, and water content, as well as the amount of light reaching the soil surface. (5) Allelopathic reactions may be occurring in the burned area to inhibt algal growth. (6) Livestock may preferentially graze on the burned site because of the higher amount of grass, and thus may exert more pressure on the soil communities of this area by trampling.

Our findings of nearly identical diatom floras in burned and unburned soils which differ only in their densities suggest a need for more quantitative edaphic diatom studies. Previous studies have shown that diatom communities tend to be similar throughout the world. Thus, if the effects of soil type, grazing pressure, litter, climatic conditions, etc., on such communities are to be discovered and understood, better quantitative approaches must be employed than have been used in the past.

The effects of fire on soil algal communities are important to understand since burning is a management tool for control and modification of many western North American rangelands. Since algae are important as soil stabilizing agents, it is possible that continued burning of plant communities in a given area could cause accelerated erosion and thus decreased carrying capacity for both plants and animals. This is particularly important since many soil cryptogam communities are apparently slow to recover from disturbance (Anderson et al. 1982). On the other hand, since floristic changes in the algal communities we studied were slight, and viable algae were present in the burned soil after only 3 years, it is likely that burning with rests between of several years would not significantly modify the algal communities. Further research on this issue is planned.

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