A Preliminary Report on Aerophytic Cyanoprokaryota and Chlorophyta from Rocky Mountain National Park and Fraser Experimental Forest, Colorado, USA

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Abstract: This paper reports the results of a study of the aerophytic algae from Fraser Research Forest (Fraser, Colorado) and the Loch Vale site in Rocky Mountain National Park, Colorado. Ten bark samples from two trees (Engelmann spruce and Douglas fir) were collected from both study sites. A total of 16 species of aerophytic algae were recovered from these samples. Cyanoprokaryota were the dominant group, with 13 species identified (81.2%) and green algae had three species at 18.8%. There were nine species identified from Fraser Experimental Forest and 13 from Loch Vale. There were 14 species identified on Douglas fir and 8 on Engelmann spruce. There was a slight positive trend for higher numbers of species at higher elevations.

Keywords: Aerophytic, Algae, Cyanoprokaryota, Fraser Experimental Forest, Rocky Mountain National Park, ROMO, FEF.

INTRODUCTION

Rocky Mountain National Park (ROMO) and Fraser Experimental Forest (FEF) are located in the northern portion of the Front Range of the Rocky Mountains in the state of Colorado in the western United State, approximately 86 km and 76 km respectfully, from the city of Denver (Figure **1**). Rocky Mountain National Park has a total area 107,428 ha, and the highest point in the park is Long Peak at 4346 m. The major ecological zones are montane and subalpine. The dominant vegetation in the montane zone (elevation 1,700 to 2,900 m) is a forest consisting of ponderosa pine (*Pinus ponderosa* Douglas ex Lawson), Douglas fir (*Pseudotsuga menziesii* [Mirb.] Frano), lodgepole pine (*Pinus contorta* Douglas), and quaking aspen (*Populus tremoloides* Michx.). The subalpine zone (elevation 2,700 to 3,400 m) is characterized by forests dominated by Douglas fir and Engelmann spruce (*Picea engelmanii* Parry ex Engelm.). Loch Vale is located in portion of the subalpine zone of Rocky Mountain National Park. The Fraser Experimental Forest has a total area of 9300 ha, and the highest point is 3,900 m [13]. The predominant vegetation is similar to that of Rocky Mountain National Park.

There have been a relatively few studies [2, 10, 14, 16-18] of algae in Rocky Mountain National Park, and no studies have been carried out in the Fraser Experimental Forest. Moreover, no previous study has focused on aerophytic algae in the general study area, although the algae associated with freshwater habitats have been investigated.

The purpose of the study reported herein was to document the aerophytic algae (including cyanoprokaryota) associated with samples of bark collected from living trees at the two study areas represented Loch Vale and the Fraser Experimental Forest. As the terms are used in this paper, algae are defined as eukaryotic organisms containing chlorophyll “a” in the Kingdom *Protoctista*, whereas cyanoprokaryota are prokaryotic organisms in the Kingdom *Prokaryotae* containing chlorophyll “a” and phycobilins as photosynthetic pigments.

METHODS AND MATERIALS

On 6-7 July of 2006, 20 samples of the dead outer bark were collected from individual trees of Douglas fir and Engelmann at 10 localities each in the Loch Vale study site of Rocky Mountain National Park and FEF. Both the Fraser Experimental Forest and Loch Vale study sites occur in subalpine zone. Elevations ranged from 3248 m to 3260 m at FEF, and 3215 m to 3232 m at Loch Vale (Table **1**). All of the samples were obtained from a forest habitat. At FEF, samples were collected from five Douglas fir trees and five Engelmann spruce trees. The same number and types of samples were collected at the Loch Vale study site. The bark samples from each tree were placed in small

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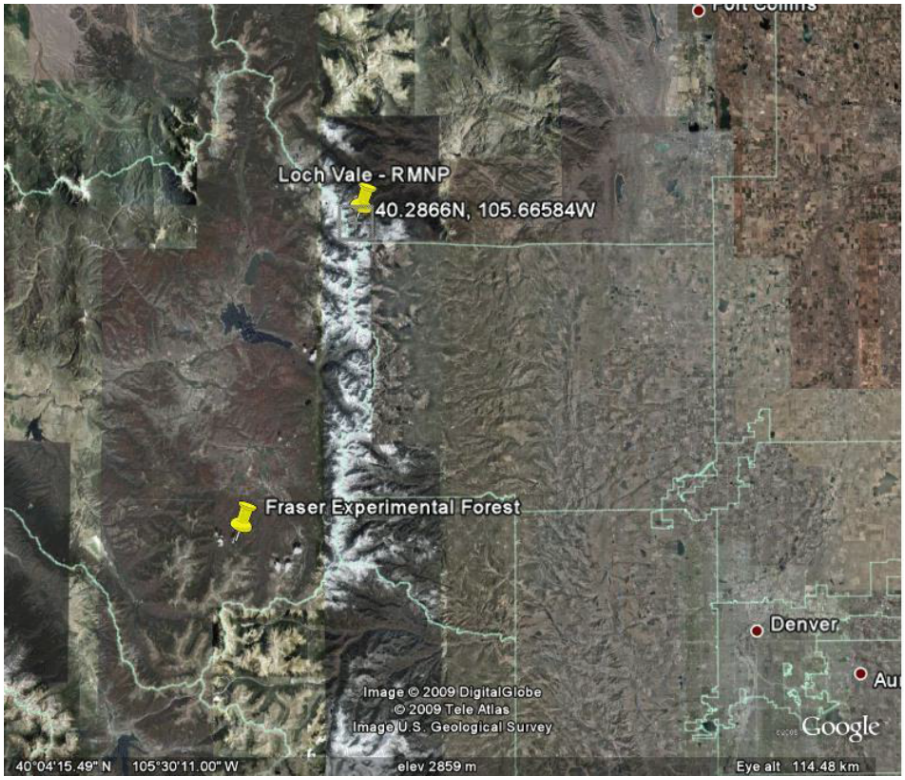

Figure 1: Colorado with study sites identified.

paper bags for drying and brought back to the laboratory.

Table 1: Study Sites and Elevations (m) on the Fraser Experimental Forest (#1-10) and at Loch Vale (Rocky Mountain National Park, #11-20)

Sample #	Locality	Tree	Elevation (m)
1	FEF	ES	3250
2	FEF	ES	3248
3	FEF	ES	3253
4	FEF	ES	3250
5	FEF	ES	3248
6	FEF	DF	3260
7	FEF	DF	3259
8	FEF	DF	3257
9	FEF	DF	3259
10	FEF	DF	3260
11	LV	ES	3215
12	LV	ES	3215
13	LV	ES	3217
14	LV	ES	3223
15	LV	ES	3222
16	LV	DF	3226
17	LV	DF	3231
18	LV	DF	3232
19	LV	DF	3229
20	LV	DF	3229

FEF – Fraser Experimental Forest; LV – Loch Vale (Rocky Mountain National Park); ES – Engelmann spruce; DF – Douglas fir.

To inoculate the Bold's Basal Medium (BBM) [1] liquid media, pieces of bark were placed into test tubes for culturing. Cultures were maintained at room temperature (22 °C). The cultures were examined after four weeks. Although BBM is the standard medium used for culturing algae, it is possible that other media might have yielded at least a few additional taxa. Semipermanent slides were prepared with distilled water and sealed with epoxy [15]. Keys used to identify species and to determine the appropriate nomenclature were used [1, 3, 4-6, 8, 9]. In order to update the nomenclature, the Algaebase.org website [7] was used. As such, all names are currently accepted taxonomically. To determine the degree of similarity between tree type and study site, the Jaccard Index was used.

RESULTS AND DISCUSSION

Sixteen species were identified from the 20 samples (Table **2**). Members of the Cyanoprokaryota were the dominant group, represented by 13 species (81.2% of

Table 2: Annotated Taxonomic list with their Locality of the Species of Algae and Cyanoprokaryota Recovered from Samples Collected from Fraser Experimental Forest and Loch Vale (Rocky Mountain National Park)

Taxon	Fraser Experimental Forest		Loch Vale (ROMO)	
	Douglas fir	Engelmann spruce	Douglas fir	Engelmann spruce
Cyanoprokaryota				
Chondrocystis dermochroa (Nägeli) Komárek & Anagnostidis			X	
Chroococcus helveticus Nägeli			X	
Cyanobacterium cedrorum (Sauvageau) Komárek, Kopecky & Cepák			X	
Cyanophanon mirabile Geitler	X		X	X
Gloeocapsopsis magma (Brébisson) Komárek & Anagnostidis	X	X	X	X
Gloeocapsopsis pleurocapsoides (Novácek) J. Komárek & K. Anagnostidis	X		X	
Hyella terrestris Chodat			X	
Onkonema compactum Geitler	X	X	X	X
Oscillatoria sancta Kützing ex Gomont	X	X		X
Pleurotaenium sceptum (Roy) West & G.S. West				X
Symploca lacrimans Claus	X	X		X
Trichormus ellipsosporus (F. E. Fritsch) Komárek & Anagnostidis	X			
Xenococcus minimus Geitler	X	X		
Chlorophyta				
Gloeocystis vesiculosa Nägeli	X			
Nannochloris bacillaris Naumann			X	
Stichococcus minutus Grintzesco & Peterfi				X

the total), while three species (18.8%) of in the Chlorophyta were identified (Table **2**). Since there have been no other studies of aerophytic or freshwater algae carried out in Rocky Mountain National Park or the Fraser Experimental Forest, there is nothing with which to compare our data.

As a general observation, the samples were not very diverse and algal species richness was low. There was an average of four species per sample identified. The Fraser Experimental Forest had the higher number of species per site at 4.1, compared to Loch Vale at 3.9.

At the Loch Vale there were 13 species identified, while at the Fraser Experimental Forest there were a total of nine species. When looking at the assemblages present on spruce and fir trees, there were 14 species identified on Douglas fir and eight on Engelmann spruce. At Loch Vale, Douglas fir yielded nine species and seven species were recorded from Engelmann spruce. For the Fraser Experimental Forest, Douglas fir produced nine species Engelmann spruce five species (all of the latter also were found on Douglas fir).

When calculating the Jaccard index, there was a 0.375 similarity between the Loch Vale and FEF study sites. When looking at the FEF site and comparing the Engelmann spruce to Douglas fir, the Jaccard index was 0.556. At the Loch Vale sites, the Jaccard index was 0.231, which is a much lower than the FEF site. When calculating the Jaccard index for Douglas fir from both sites, the index number was relatively small at 0.286, and the Engelmann spruce index number was relatively higher at 0.50. Consequently, species of Cyanoprokaryota and Chlorophyta (all species of algae recorded belong to this group) tended to be site specific and tended to be tree specific as well.

At the FEF site, there were a total of eight species identified, seven members of the Cyanoprokaryota and only a single species of green algae. When comparing both trees, the Jaccard index was 0.625 for the Cyanoprokaryota and 1.0 for green algae (since only a single species was found on Douglas fir). At the Loch Vale study site, there was a total of 12 species identified, with 10 Cyanoprokaryota and two species of green algae. Comparing both trees, the Jaccard index for the Cyanoprokaryota was 0.25, and the species of green algae were found on opposite trees.

Elevations of study sites ranged from 3248 m to 3260 m at FEF and 3215 m to 3232 m at Loch Vale. There was not a significant correlation between elevation and the total number of species at a particular study site, but there was a positive trend (Figure **2**) with respect to elevation and the total number of species. As such, there was a slightly higher number of species identified at higher elevations.

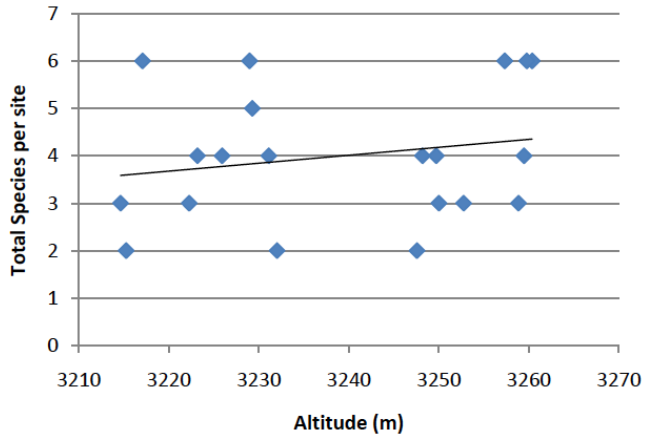

Figure 2: The total number of species identified per site and the elevation (m) with a trend line for Fraser Experimental Forest and Loch Vale (Rocky Mountain National Park).

Since only a limited number of samples were examined in the present study, both the lack of diversity and low species richness would not be unexpected. However, our data do suggest that particular species tend to be site specific and possibly substrate specific. In the future, additional samples would need to be obtained to generate a more complete annotated species list from Rocky Mountain National Park and Fraser Experimental Forest.

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