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NUTRIENTS IN *CAREX EXSERTA* SOD AND GRAVEL IN SEQUOIA NATIONAL PARK, CALIFORNIA

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Abstract.— Nutrients in soil covered by *Carex exserta* sod and in adjacent unvegetated gravel areas were compared at Siberian Outpost, Sequoia National Park, California. The comparisons were part of a study to learn if *Carex exserta* meadow can be reestablished and if herbaceous cover on gravel areas can be increased. Grazing capacity and aesthetic appeal of denuded areas would be improved by better vegetative cover. The sod had higher concentrations of calcium, copper, iron, magnesium, manganese, nitrogen, potassium, and zinc than did the gravel areas. And it had a higher soil pH and percent organic matter. Sod and gravel did not differ in concentrations of phosphorus and sulfur. The differences were as might be expected between climax and badly deteriorated (or early seral) situations, and the results suggest that fertilization may be a useful treatment.

Carex exserta (short-hair sedge) meadows are found throughout the Sierra Nevada of California. Altitudinally, they extend from the subalpine into the alpine zone (Jackson and Bliss 1982). At Siberian Outpost—an unglaciated subalpine valley in Sequoia National Park—stands of *Carex exserta* (Fig. 1) vary in form from sod steps (Klikoff 1965) to nearly continuous sod on gentle slopes. In and around Siberian Outpost are found expansive areas of coarse-grained granitic gravel. Small plants found in the gravel provide little cover.

The sod can withstand considerable use, but continued overuse or trampling will break and eventually destroy it. Sheep are known to have grazed in Sequoia National Park during the late 1800s and early 1900s (Vankat 1970). In parts of Siberian Outpost, pedestaled remnants attest to overgrazing as a cause for destruction of *Carex exserta* sod. More than 15 cm of sod and top soil have been lost in some places, and little recovery is evident. However, the sod appears to be establishing or reestablishing in other places.

Grazing may not be the only reason for the areas of gravel. Sand and gravel may have originated from debris-laden outwash below glacial moraines or may have been deposited in Pleistocene lakes (Benedict and Major 1982). Retreat of glaciers with warmer, dryer summers may have changed the vegetation the areas were capable of supporting. Rapid percolation to deep layers may make precipitation largely unavailable for on-site plant growth. High winds may keep some areas clear of snow. And gravels and sands from weathering of the granite rocks may be deposited over vegetation in some areas about as soon as it becomes established.
Thus, some of the gravel areas in and similar to those of Siberian Outpost may be completely natural—representing early seral stages.

Nevertheless, where the *Carex exserta* sod has obviously been destroyed, an eroded stretch of gravel and sand remains. That and the presence of large tree stumps in gravel and up to 290 m from the present forest border suggest that some areas of gravel, such as found in Siberian Outpost, may once have supported considerably more vegetation than now.

If the present gravel areas were largely a *Carex exserta* meadow at one time, can that vegetation be reestablished, or can cover of vegetation now occupying the gravel areas in Siberian Outpost and elsewhere be increased? Observed differences between sod and gravel areas should reveal how loss of *Carex exserta* sod alters the nutrient status and should suggest nutrients that might be added to gravel areas. On the other hand, if the gravel areas represent natural seral stages, knowledge of how they differ in nutrients will increase understanding of seral and climax communities.

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Fig. 1. Areas of gravel (upper) and pristine *Carex exserta* sod (lower), Siberian Outpost, Sequoia National Park, California.

Information on the soil texture, pH, and organic matter of *Carex exserta* sod is available (Ratliff 1982), but data on its nutrient composition and that of gravel areas are scant. Such information is needed in the selection of programs to revegetate backcountry areas that have been overused, and to rehabilitate trails and campsites.

This paper compares soil organic matter, pH, and nutrients in *Carex exserta* sod with those in gravel in Siberian Outpost, Sequoia National Park.

Methods

Siberian Outpost at 36°28′N, 118°17′W (U.S. Geological Survey 1956) lies 11.3 km south of Mount Whitney at 3293 m elevation within the "Boreal Plateau erosion surface" (Matthes 1950, 1962), between Rock Creek on the north and Big Whitney Meadow on the south. Siberian Pass Creek drains the area from east to west.

Calamagrostis breweri meadows are found at the bottom areas of Siberian Outpost. The otherwise gravelly slopes have a few species of forbs such as *Oreonana clementis*, *Calyptridium umbellatum*, *Eriogonum incanum*, and *Lupinus culbertsonii*. They have been classified as an *Eriogonum-Oreonana clementis* association (Benedict 1983). *Stipa occidentalis* and *Sitanion hystrix* are occasionally abundant.

A grid with a ground distance of 45 m between intersections (grid points) was superimposed on aerial photographs of Siberian Outpost. Fifty grid points without *Carex exserta* sod (henceforth referred to as *gravel*), and 30 grid points with *Carex exserta* sod (henceforth referred to as *sod*) were randomly selected. Fewer grid points were allocated for the sod because it occupied less area than the gravel. Three soil cores (17 cm long and 4.7 cm in diameter) were extracted at each grid point and combined to make one sample. Material larger than 2 mm was separated and discarded. The fraction less than 2 mm was kept for laboratory analysis. In addition, intact cores were collected at 15 and at 6 arbitrary grid points in the gravel and in the sod, respectively.

Acidity of each soil sample was determined with a saturated paste and an electronic pH meter. Percent soil organic matter was estimated by gravimetry and dry combustion. Bulk density and gravel content were estimated from the intact cores by gravimetry.

Available facilities and funds limited the nutrient analyses that could be made to those common for crop agriculture. Total nitrogen was determined by the ammonia electrode modification of Kjeldahl method (Page et al. 1982). Available phosphorus was determined by the sodium bicarbonate method (Page et al. 1982). Amounts of calcium, copper, iron, magnesium, manganese, potassium, sulfur, and zinc were determined at a commercial laboratory by standard procedures (Reisenauer 1976).

Parametric tests were not appropriate for the data because they either did not conform to the normal distribution, or the variances were not equal, or both. Therefore, the nonparametric rank-sum test with the normal approximation was used (Steel and Torrie 1960). The hypothesis that the sets of values from the sod and gravel belong to a common population was rejected when chance probability of the rank-sum for the sod samples was 5% or less. Presence of a common population was rejected for all the nutrients except phosphorus and sulfur (Table 1).

Because the samples were obtained at arbitrary grid points, bulk density and gravel data were not random sets. Those data, therefore, could not be statistically analyzed but are presented for reader information.

Results and Discussion

Soil from the sod samples contained more nutrients than did soil from the gravel. The natural openings in the sod were not sampled, and some of the nutrient differences between the sod and gravel may be due to concentration of nutrients in the sod at the expense of the openings within it. Therefore, on an area basis, the differences in nutrients may not be as large as indicatd by the mean values (Table 1). Nevertheless, the gravel samples were relatively low in nutrients for plant growth.

Nitrogen ordinarily ranges from 0.02% to 0.5% of soil. In prairie soils, 0.1% to 0.3% nitrogen is usual (Allison 1957). Nitrogen contents of alpine mine spoils and topsoil were

0.06% and 0.13%, respectively, on the Beartooth Plateau (Brown and Johnston 1976). Soil of the sod at Siberian Outpost, therefore, was relatively high in total nitrogen—about 0.2%. The gravel, on the other hand, had only about 0.04% nitrogen.

With 27 ppm and 24 ppm in the sod and gravel, respectively, available phosphorus (Table 1) at Siberian Outpost should be adequate for herbaceous plant growth. For pasture and range, no response to added phosphorus is likely with more than 10 ppm available phosphorus in the soil (Reisenauer 1976). High soil acidity, however, generally lowers phosphorus availability.

Ammonium acetate extractable potassium was 0.006% in the sod and 0.001% in the gravel (Table 1). Nitric acid extractable potassium in the sod (0.02%) was twice that in the gravel (0.01%). By either extraction process, exchangeable potassium content of the sod bordered on a deficiency (Reisenauer 1976). Potassium content of the gravel appeared clearly deficient and was lower than that reported for mine spoils (Brown and Johnston 1976).

Potassium is more readily released when concentrations of calcium and/or magnesium are high. The concentration of exchangeable calcium in mine spoils (Brown and Johnston 1976) was higher than that in either the gravel (0.7 meq/100 g) or the sod (1.2 meq/100 g) at Siberian Outpost. Also, although higher than in the mine spoils, magnesium concentrations in the sod (0.5 meq/100 g) and in the gravel (0.2 meq/100 g) at Siberian Outpost were lower than in topsoil on the Beartooth Plateau, Montana (Brown and Johnston 1976).

Soils in Siberian Outpost are low in sulfur content. The average concentration of sulfur (1.25 ppm or 0.0001%) in the sod and gravel is equivalent to only 1.4 $kg \cdot ha^{-1}$ to a 10-cm depth. That concentration is 100 times less than the minimum expected.

Amounts of manganese, iron, copper, and zinc in the gravel, though lower than in the sod, appeared adequate for plant growth. However, their amounts were near critical levels for agricultural crops—especially in the gravel. Critical levels suggested for these nutrients (Reisenauer 1976) were 1.0 ppm (manganese), 5.0 ppm (iron), 0.2 ppm (copper), and 0.5 ppm (zinc).

Soil organic matter and soil pH (Table 1) were higher in the sod (6.3% and pH 4.2) than in the gravel (1.7% and pH 4.0)—$P < 0.001$. *Carex exserta* sites studied earlier (Ratliff 1982) had higher values (7.3% organic matter and pH 5.1) for the top 20 cm of soil. Soil bulk density averaged 1.1 $g \cdot cm^{-3}$ in the sod and 1.7 $g \cdot cm^{-3}$ in the gravel. With the difference in organic matter contents, lower bulk density in the sod would be expected. Gravels composed 37% of the soil mass in the gravel and 24% of the soil mass in the sod.

Table 1. Soil organic matter, pH, and nutrients in *Carex exserta* sod and gravel in Siberian Outpost, Sequoia National Park, California.

	Sod			Gravel		
Variable	Low	Average	High	Low	Average	High
Organic matter (%)	4.2	6.3	9.8	1.2	1.7[a]	3.8
pH	4.0	4.2	4.5	3.6	4.0[a]	4.5
Nutrients (ppm)						
N	1258.0	2040.07	2951.0	201.0	378.52[a]	1223.0
P	6.7	27.30	56.8	13.0	24.50	37.0
K[b]	31.0	55.77	95.0	8.0	14.58[a]	35.0
K[c]	128.0	191.87	257.0	42.0	94.68[a]	179.0
Ca	160.3	241.60	140.9	40.1	143.49[a]	200.4
Mg	48.6	65.66	97.3	7.3	25.54[a]	48.6
S	0.5	1.37	3.0	0.5	1.13	2.0
Mn	5.4	12.78	26.2	0.5	1.15[a]	3.7
Fe	53.0	102.79	133.0	5.7	12.42[a]	37.0
Cu	0.4	0.74	1.4	0.1	0.31[a]	1.1
Zn	2.9	7.28	17.6	0.5	1.46[a]	6.6

[a] Average value significantly different from short-hair sedge sod ($P < 0.001$) by the rank-sum test with normal approximation.

[b] Ammonium acetate extractable

[c] Nitric acid extractable

The organic matter content of the gravel was only 0.7% lower than in alpine zone topsoil on the Beartooth Plateau (Brown and Johnston 1976) and was greater than that of most Aridisols with a high sand content (Soil Survey Staff 1975). Therefore, the sparse vegetation in the gravel was unlikely to have produced the existing level of organic matter. Denser vegetation at an earlier time could have been responsible for it, however. Loss of the sod by erosion would remove most of the organic matter built up in the soil system and leave the gravel as a pavement. Because organic matter markedly improves the cation-exchange properties of soils, nutrients also would have been removed by erosion.

CONCLUSIONS

This study found substantial differences between soils of *Carex exserta* sod and gravel in nutrient and organic matter contents and acidity. The differences were as expected between climax and badly deteriorated soils. If the gravel in Siberian Outpost once supported *Carex exserta* meadow, then loss of sod resulted in removal of 40% of the calcium, 58% of the copper, 88% of the iron, 61% of the magnesium, 91% of the manganese, 81% of the nitrogen, 74% of the potassium, and 80% of the zinc. Losses of those magnitudes can be hypothesized as a consequence of the destruction of *Carex exserta* sod. Alternatively, if the gravel represents a natural seral stage, succession to a *Carex exserta* climax would require nutrient accumulation and conservation as the sod develops.

Brown and Johnston (1979) suggested fertilization with relatively high rates of nitrogen (up to 168 $kg \cdot ha^{-1}$) for rehabilitating disturbed alpine areas. They also suggested lime applications on alpine disturbances where pH is below 5.5. Given the low pH of Siberian Outpost soils, fertilization with lime may make more phosphorus available.

To increase cover of gravel areas or to rehabilitate disturbed *Carex exserta* sites in Siberian Outpost and similar areas elsewhere (within a present rather than a successional or geological time frame), stimulation by fertilization may be a useful treatment. The differences found between sod and gravel in nutrient contents suggest including nitrogen, potassium, calcium, magnesium, and sulfur in a fertilizer mix.

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