United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

P.O. Box 245
Berkeley
California 94701

Research Note
PSW-371

April 1985

Rehabilitating Gravel Areas with Short-Hair Sedge Sod Plugs and Fertilizer

Raymond D. Ratliff

Rehabilitating plant cover on backcountry trails and campsites is a task facing many park and forest managers. Plant cover on some sites has deteriorated, leaving a pavement of gravel.

In Sequoia National Park, in central California, coarse-grained granite is the principal rock type found in and around Siberian Outpost—an unglaciated subalpine valley, where expansive areas are characterized by granitic gravel *(fig. 1)*. Similar gravel areas are found elsewhere in the Park, and in nearby Inyo and Sequoia National Forests. Although plants in the gravel may be numerous, they are small and provide little cover. And where it is biologically possible, practical, and within the scope of public policy to do so, rehabilitating the plant cover is desirable.

In some instances natural forces caused deterioration. Gravels from debris-laden glacial outwash covered previous vegetation.[1] That process continues where gravel weathered from the granite rocks is deposited, keeping vegetation from getting established. And as glaciers retreated, the vegetation that some sites could support changed.

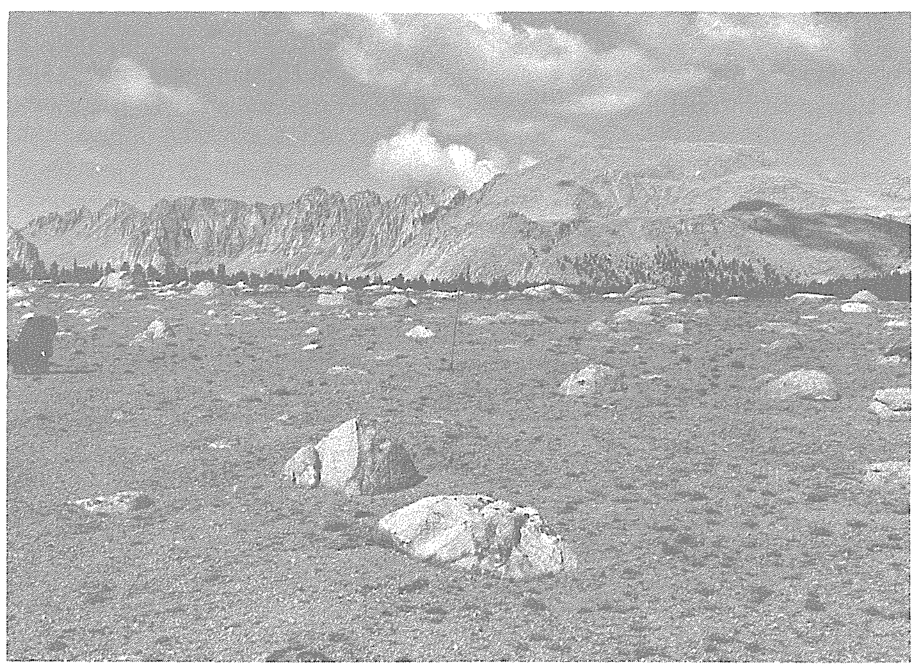

Figure 1—Granitic gravel areas are found in Siberian Outpost, Sequoia National Park, California.

Ratliff, Raymond D. *Rehabilitating gravel areas with short-hair sedge sod plugs and fertilizer.* Res. Note PSW-371. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1985. 4 p.

Tests to rehabilitate gravel areas in high-value recreation sites were carried out by transplanting short-hair sedge *(Carex exserta)* plugs. The plugs were 1.9 cm (0.75 inch) and 5.1 cm (2.0 inches) in diameter, 10 cm (4.0 inches) deep, and were transplanted in September 1981, with and without papier-mache pots. The test site was Siberian Outpost, in Sequoia National Park, California. Treatments were randomized in 40 quadrat pairs; one quadrat in each pair was fertilized. Results after 1 year showed that the most promising treatment was to transplant large-diameter sod plugs unpotted and unfertilized. Density of plants present in the gravel at the time of treatment was reduced by fertilization.

Retrieval Terms: Carex exserta, short-hair sedge, revegetation, transplanting, fertilization, ecology, Sequoia National Park, California.

In other instances over-use by domestic animals and humans caused deterioration. The presence of large tree stumps in gravel and nearly 300 m (984 ft) from the present forest border of Siberian Outpost suggest that some areas of gravel may once have supported much more vegetation than at present. Short-hair sedge *(Carex exserta)* meadows, which are common in subalpine and alpine gravelly sites throughout the Sierra Nevada of California, may have comprised a large part of that vegetation.[2] At Siberian Outpost, short-hair sedge meadows vary in form from sod steps to nearly continuous sod on gentle slopes.[3] In places more that 15 cm (6 inches) of sod and top soil have been lost, and pedestaled remnants attest to overgrazing by sheep in the late 1800's and early 1900's.[4] Short-hair sedge can withstand considerable use, but continued improper grazing or trampling will break and eventually destroy it.

Transplanting short-hair sedge plugs to subalpine gravel areas may be a way to increase plant cover. And fertilization may improve chances of plug survival or stimulate present vegetation or both. Fertilizer was essential for plant growth on alpine disturbances.[5] Relatively high rates of fertilizer were applied, and lime application was suggested on soils with pH below 5.5. Soils of gravel areas in Siberian Outpost are lower in pH and in organic matter content, and more deficient in plant nutrients than are soils of short-hair sedge sod.[6]

To find out if short-hair sedge meadows can be reestablished in areas of gravel, I transplanted sod plugs with and without papier-mache pots in gravel areas of Siberian Outpost in September 1981. In addition, as parts of these tests, I tried out treatments with and without fertilizers.

This note reports first-year (1981 to 1982) results of a study in which short-hair sedge sod plugs and fertilization are being tried as a means of rehabilitating plant cover. Preliminary results suggest that in gravel areas of Siberian Outpost, the most promising treatment consists of transplanting large-diameter plugs unpotted and unfertilized.

METHODS

Siberian Outpost lies 11.3 km (7 miles) south of Mount Whitney at 3293-m (10,800-ft) elevation within the "Boreal Plateau erosion surface,"[7] between Rock Creek on the north and Big Whitney Meadow on the south. Parts of Siberian Outpost are remnants of the younger "Chagoopa erosion surface," which is best represented by the Chagoopa Plateau to the west. Siberian Pass Creek drains the area from east to west.

Shorthair *(Calamagrostis breweri)* meadows are found at the bottom areas of Siberian Outpost. The otherwise bare slopes have a few species of forbs, such as Clement's mountain-parsley *(Oreonana clementis)*, pussy paws *(Calyptridium umbellatum)*, Sierra wildbuckwheat *(Eriogonum incanum)*, and Hockett meadows lupine *(Lupinus culbertsonii)*. They have been classified as an *Eriogonum-Oreonana clementis* association.[8] Western needlegrass *(Stipa occidentalis)* and bottlebrush squirreltail *(Sitanion hystrix)* are occasionally abundant.

Snow accumulation and water content were greater in 1982 than in 1981 in Siberian Outpost *(table 1)*.[9] Early May snow depths in 1981 were 46 percent of the average, and in 1982 were 142 percent of the average. Snow water contents were 45 percent of the average in 1981, and 133 percent of the average in 1982. Probably, in 1982. the snowpack lasted considerably longer, soil water was available for plant growth later into the summer, and air temperatures were cooler.

Experimental Design

From a grid (ground distance between grid points = 45 m [148 ft]) superimposed on aerial photographs, 40 points (about a 5 percent sample) falling in gravel areas were randomly selected. Two quadrats, each 1 m^2 (10.75 ft^2), were placed 1 m (3.28 ft) apart on the counter at each grid point.

For analyses, the quadrats were treated as pairs. The quadrat pair locations were not picked so as to control specific sources of error. Effects of slope, aspect, and slope position, therefore, could not be accounted for in the analyses.

Treatments

The treatments selected were designed to test the survival of short-hair sedge sod plugs and the effects of fertilization on current vegetation. Treatment design included a 2^3 factorial consisting of two sizes (levels) of short-hair sedge plugs, two transplanting methods, and two fertilizer regimes *(fig. 2)*. The plugs were 1.9 cm (0.75 inch) and 5.1 cm (2.0 inches) in diameter and 10 cm (4.0 inches) deep. All plugs were extracted from a single site in Siberian Outpost. Two plugs of each size were transplanted into each quadrat. One plug of each size was potted in a 10 cm (4.0 inch) (depth and diameter) papier-mache pot with soil from the quadrat. The plugs were set in the soil so their tops were at ground level, and they were centered 24 cm (9.5 inches) in and at 45° from the quadrat corners. Plug size and transplanting method were randomly selected. After the plugs were transplanted, a randomly chosen quadrat in each pair was fertilized with a mix of ammonium nitrate, 1319 kg/ha (1175 lb/acre); potassium nitrate, 145 kg/ha (129 lb/acre); elemental sulfur, 11 kg/ha (10 lb/acre); and dolomite, 359 kg/ha

Table 1—*Snow depth and snow water contents in Siberian Outpost, Sequoia National Park, California, averages and in 1981-1982*

Month	Average			1981		1982	
	Record years	Snow depth	Water content	Snow depth	Water content	Snow depth	Water content
		Centimeters					
February	20	100.2	29.8	32.5	4.6	147.8	37.8
March	24	118.3	37.2	70.6	18.8	130.8	41.2
April	34	132.2	45.8	110.7	33.0	190.0	62.5
May	15	141.5	59.6	65.0	26.7	202.2	79.5

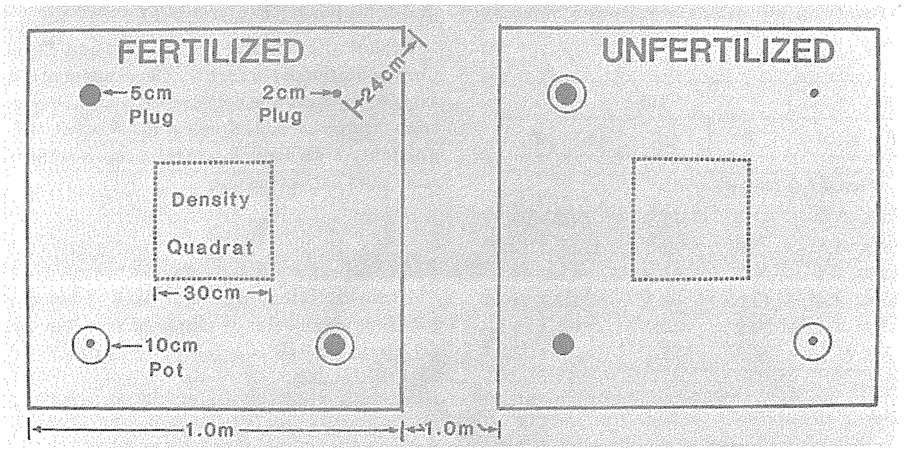

Figure 2—Quadrat pairs, on which short-hair sedge sod plugs were transplanted and fertilized or left unfertilized, formed the experimental design.

(320 lb/acre). The fertilizer components used were suggested by comparing nutrients in native short-hair sedge sod with those in areas of gravel.[6]

In September 1982, each plug transplanted in September 1981 was examined and evaluated as either alive or dead. A plug was considered alive if it had produced a single leaf in the current growing season.

In the center of each 1 m^2-quadrat (10.75 ft^2-quadrat) a 30 cm by 30 cm (1 ft^2) "density quadrat" was used to study fertilizer effects on current vegetation. Treatments were either fertilized as described earlier or left unfertilized. Plants rooted in the density quadrats were counted by species before treatment in 1981 and recounted in 1982.

Statistical Analysis

To test the hypothesis that the probability of survival for a plug was the same under all treatments I used Cochran's Q-test.[10] Q has a Chi-square distribution, and with eight treatment combinations there were $t - 1 = 7$ degrees of freedom (df). H_0 was to be rejected if $Q > \chi^2_{.95}$ with 7 df.

To locate important differences between treatments, each single factor effect—plug size, transplanting method, and fertilization—was tested with levels of the other factors held constant. I hypothesized that the proportion of plugs for which level 1 (e.g., large plugs) was favorable was the same as the proportion of plugs for which level 2 (e.g., small plugs) was favorable. The hypothesis was to be rejected if the 95 percent confidence interval for the difference [(proportion of quadrat pairs with plugs alive under level 1 but dead under level 2) - (proportion of quadrat pairs with plugs dead under level 1 but alive under level 2)] covered zero.[11]

Paired "t" tests were used to examine the hypothesis that the mean difference in plant density between treatments within year was zero, and the hypothesis that the mean difference in plant density between years within treatment was zero. Either hypothesis was rejected when t exceeded $t_{\alpha/2}$ with $\alpha = 0.05$ and df = 39. Total density was analyzed as well as the density of pussy paws, Sierra wildbuckwheat, Hockett meadows lupine, Clement's mountain-parsley, and western needlegrass.

RESULTS AND DISCUSSION

Plug Survival

Not all of the eight plug size, transplanting, and fertilization combinations had equal effects on plug survival the first year *(table 2)*. The test value (Q) was 142.5, far exceeding the χ^2 value required for statistical significance at the 5 percent level.

In tests in which the transplanting and fertilizer treatments were held constant, the large plugs survived better than the small ones *(table 2)*. The effect was least when the plugs were potted and fertilized both.

Potting did not affect small plug survival or survival of large, unfertilized plugs. But potting nearly eliminated large, fertilized plugs.

Regardless of the plug size and transplanting method used, the fertilizer had decided negative effects on plug survival.

These initial results suggest that for short-hair sedge establishment in gravel areas at Siberian Outpost the most promising treatment is large-diameter plugs, unpotted, and unfertilized. Whether the plugs continue to survive and whether new growth extends into

Table 2—*First year survival of short-hair sedge* (Carex exserta) *sod plugs in gravel and effects of plug size, potting, and fertilizer treatments at Siberian Outpost, Sequoia National Park, California*

Treatments[1]				Single treatment effects[3]		
Plug size	Pot	Fertilization	Survival[2] (pct)	Plug size	Potting	Fertilizer
L	N	U	90.0	a	a	a
L	N	F	50.0	c	b	a*
L	P	U	90.0	b	a	b
L	P	F	10.0	d	b*	b*
S	N	U	42.5	a*	c	c
S	N	F	5.0	c*	d	c*
S	P	U	40.0	b*	c	d
S	P	F	0.0	d*	d	d*

[1]L = large; S = small; N = Unpotted; P = Potted; U = unfertilized; F = fertilized.

[2]Percent of plugs surviving out of 40.

[3]Within columns, treatments with the same letter were tested for differences. Those with an asterisk differ significantly from other treatments with same letter ($p < 0.05$).

Table 3—*Density responses of five species to fertilizer and year effects in gravel areas of Siberian Outpost, Sequoia National Park, California, 1981-1982*

Species	1981			1982		
	F[1]	UF[2]	(F - UF)[3]	F	UF	(F - UF)
	Density (number/m²)					
Calyptridium umbellatum	11.7	13.1	-1.4 ± 7.9	33.1	13.9	19.2 ± 22.6
Eriogonum incanum	14.7	13.6	1.1 ± 8.5	5.9⁺	19.8	-13.9 ± 12.6*
Lupinus culbertsonii	9.8	16.7	-6.9 ± 7.4	6.7	13.3	-6.7 ± 10.1
Oreonana clementis	3.6	1.1	2.5 ± 2.4*	13.6⁺	42.5⁺	-28.0 ± 17.8*
Stipa occidentalis	0.6	2.2	-1.7 ± 2.1	0.9	2.0	-1.1 ± 1.8
Total	44.2	47.8	-3.6 ± 13.6	73.3	113.6⁺	-40.3 ± 41.1

[1]F = Fertilized
[2]UF = Unfertilized
[3]F - UF = difference in plant densities with 95 pct confidence intervals.
⁺ = Between year difference for same treatment significant by paired "t" test ($p < 0.05$).
* = Between treatment difference for same year significant by paired "t" test ($p < 0.05$).

the surrounding soil is, of course, the final test of treatment success.

Use of pots does not appear viable. They are expensive, take added field time, and offer no advantage. Also, as suggested by results with the large size plugs, pots may slow disperison of and thereby amplify fertilizer effects.

Present Vegetation

Differences in total plant densities between fertilized and unfertilized quadrats were not statistically significant in either 1981 or 1982 *(table 3).* However, compared with plant densities 1981, the wetter weather in 1982 produced an increase in plant density on the unfertilized quadrats ($\bar{d}$ = 65.8 ± 26.0 plants/m²) but not on the fertilized quadrats ($\bar{d}$ = 29.2 ± 32.8 plants/m²). Because the quadrats in each pair were 1 m (3.28 ft) apart, effects of weather or other abiotic factors should have been the same. Therefore, the lack of increase in total plant density was the result of fertilization.

There was no difference in density of Sierra wildbuckwheat between unfertilized and fertilized quadrats in 1981, but the density was lower on the fertilized quadrats in 1982. And between 1981 and 1982, density of Sierra wildbuckwheat on the fertilized quadrats decreased ($\bar{d}$ = 8.9 ± 7.3 plants/m²).

In 1981, the quadrats to be fertilized had more plants of Clement's mountain-parsley than on those which were not to be fertilized. In 1982, the density of that species was significantly greater on the unfertilized quadrats. Between 1981 and 1982, however, density increased ($\bar{d}$ = 10.0 ± 7.9 plants/m²) on the fertilized quadrats as well as increasing ($\bar{d}$ = 41.2 ± 22.7 plants/m²) on the unfertilized quadrats. As with total density, better moisture conditions explain these differences. the lesser increase in Clement's mountain-parsley density on the fertilized quadrats and the difference between fertilized and unfertilized quadrats in 1982 can be attributed to fertilization.

Two other species—Hockett meadow lupine and western needlegrass—appear to have been little affected by either fertilizer or the weather. While not statistically significant, pussy paws density appears to have increased in response to the fertilization. That response, if real, would account for the lack of a significant difference in total density in 1982.

Except for the possible stimulation of pussy paws, the fertilizer mix was detrimental to the present vegetation. Ammonium nitrate at the high rate applied may "burn" plants of most species in gravel. These preliminary results suggest that before fertilizer is used to rehabilitate gravel areas—with or without short-hair sedge sod plugs—more studies are needed. Specifically needed are studies of the nutrient requirements of Sierra wildbuckwheat and Clement's mountain-parsley.

ACKNOWLEDGMENTS:

I thank the staffs of the Sequoia and Kings Canyon National Parks, U.S. Department of the Interior, for granting permission to work in Siberian Outpost; and Stanley E. Westfall, for assistance with field logistics, study establishment, and data collection.

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The Author:

RAYMOND D. RATLIFF, a range scientist, is assigned to the Station's unit studying range management in California, headquarted in Fresno, Calif. He earned degrees in range management at the University of California (B.S., 1959; M.S., 1961) and at New Mexico State University (Ph.D., 1979). He joined the Station's staff in 1961.