SURVEY OF DISTURBANCE TO ALPINE TUNDRA IN ATIGUN GORGE FROM SNOW-VEHICLE TRAFFIC IN NOVEMBER 2003

Arctic National Wildlife Refuge
Janet C. Jorgenson, Botanist, Arctic NWR
March 30, 2005

INTRODUCTION

Snow vehicles operated by Alyeska Pipeline Service Company (Alyeska) traveled from the Dalton Highway into Atigun Gorge in the Arctic National Wildlife Refuge in November, 2003, creating a highly-visible trail of crushed vegetation and disrupted soil. The trail is in one of the most commonly visited areas of the Refuge. This report describes the results of our initial assessment of impacts conducted in August 2004.

Alyeska contracts with Air Logistics Co. to fly regular helicopter surveys over the Trans-Alaska Pipeline. On November 22, 2003, a helicopter was forced to land in Atigun Gorge due to bad weather, approximately 4.3 km (2.7 miles) east of the pipeline and Dalton Highway and 3 km (2 miles) inside the Arctic Refuge. The helicopter was about 7 km (4.5 miles) from Alyeska Pump Station #4 and a Tucker 1644-E Snow Cat was sent from the station to retrieve the pilot. The Tucker traveled on the frozen Atigun River, but on the return trip it was disabled when it broke through the river ice and sustained damaged. A second Tucker was then dispatched to the site. It traveled on the river for the first 1.6 km (1 mile) and then crossed tundra for at least 1.6 km (1 mile) to avoid the river ice. The first Tucker was repaired and both vehicles then returned to Pump Station #4 following the tundra route. Alyeska Incident Report #2003-IR-5550 (Attachment 1) was filed internally and the Joint Pipeline Office was notified, but the incident was not reported to the U.S. Fish and Wildlife Service (USFWS).

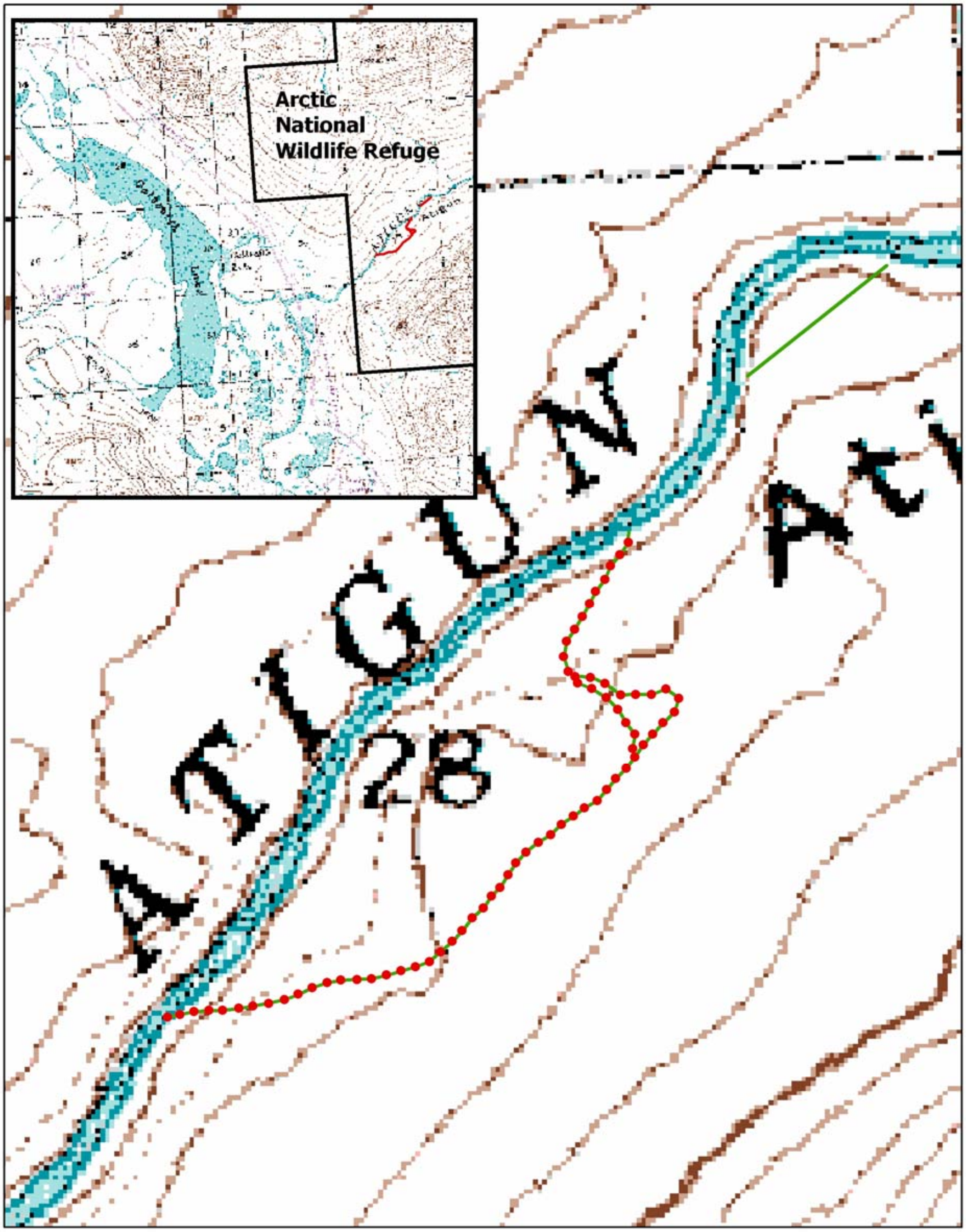
On June 9, 2004, two USFWS biologists hiked into Atigun Gorge to conduct a Dall Sheep survey and discovered the obvious trail left by the Tuckers. On June 16 two other USFWS personnel visited the site and determined that the tracks were clearly from a vehicle too large to have been a recreational vehicle. In conducting an investigation of the incident, USFWS contacted Alyeska and received a copy of the incident report.

USFWS biologists visited the site on August 10 – 11, 2004 to assess impacts to Refuge resources. Sampling was conducted in August when vegetation had reached peak biomass and greenness to facilitate future monitoring of recovery. Vegetation cover changes too rapidly in early summer to allow year to year comparisons.

Impacts to vegetation and soils were assessed using two approaches. First, a rapid semi-quantitative assessment was conducted over the entire known trail to quantify the overall level of inpact. Second, permanent intensive plots were established to better quantify changes in plant species composition and to provide baseline data for monitoring recovery. We plan to repeat the sampling in 2005 and then at two or three year intervals to track recovery over time. This report presents the results of the first year's sampling.

Figure 1. Western end of snow-vehicle trail made on November 22, 2003, and photographed on June 9, 2004, in Atigun Gorge, Arctic NWR.

Figure 2. Aerial view of trail on June 9, 2004.



Atigun VehicleTrail

0 100 200 400 Meters

Plots

Trail

METHODS

Evaluation of vehicle impacts

To document the amount of stress applied to the tundra in the affected areas, we requested information from Alyeska personnel on the types and weights of the vehicles used and depth of snow observed by the vehicle passengers. Snow depths are not monitored in Atigun Gorge, but are recorded at nearby automated weather stations (http://www.uaf.edu/water/projects/NorthSlope). Snow depth records for the day of the incident were acquired from two stations near Atigun Gorge that have ultrasonic snow depth sensors.

Systematic sampling to document overall disturbance levels

To document the amount of disturbance to vegetation and soils, plots were sampled systematically every 20 meters on the trail as determined by GPS, for a total of 67 plots (Figure 3). At each plot, we recorded vegetation type and assigned a disturbance rating using the semi-quantitative scheme in Table 1, developed for monitoring disturbance and recovery of winter trails from seismic exploration in the Arctic Refuge (Emers and Jorgenson 1997). A more detailed table with descriptions of four disturbance levels in eight different types of tundra vegetation can be found in Raynolds and Felix (1989).

Table 1. Scheme for rating disturbance on winter vehicle trails, Arctic National Wildlife Refuge, Alaska.

Disturbance Level	Description
0 – Little or None	No impact to slight scuffing of higher microsites.
1 - Low	Less than 25% decrease in vegetation or shrub cover; less than 5% soil exposed. Compression of standing litter and slight scuffing in wet graminoid and moist sedge-shrub tundra. Tussocks or hummocks scuffed. Trail evident only within tracks on Dryas terrace sites.
2 -Medium	Vegetation or shrub cover decrease 25-50%; exposed soil 5-15%. Compression of mosses and standing litter in wet graminoid and moist sedge-shrub tundra; may have increase in aquatic sedges. Tussocks or hummocks crushed but show regrowth. Portions of trail may appear wetter than surrounding area. Some disruption of vegetative mat within tracks of riparian shrubland and Dryas terrace. May be some change in vegetative composition.
3 - High	Over 50% decrease in vegetation cover or shrub cover; over 15% soil exposed. Obvious track depression in wet graminoid and moist sedge-shrub tundra; standing water is apparent on trail that is not present in adjacent area in wet years; moist sedge-shrub tundra changing to wet graminoid. Crushed tussocks or hummocks nearly continuous; general depression of the trail is evident; change in vegetative composition. In riparian shrub and Dryas terrace, vegetative mat and ground cover substantially disrupted.

Figure 4. Scuffed vegetation and bare soil on moist alpine tundra, June 9, 2004.

Figure 5. Cleat marks in feathermoss in riparian shrublands, June 9, 2004.

Permanent vegetation plots

To document the effects of high-level disturbance on the vegetation and to track recovery over time, we chose three sites to collect detailed plant composition data. We chose sites that sustained high-level disturbance and were in large areas of homogeneous vegetation so that unaffected control plots could be established adjacent to the trail.

Each site consisted of a plot on the trail and a control plot in the adjacent undisturbed tundra. Control plots were located approximately two meters uphill from the disturbed plots, in the same vegetation type. Each plot was 10.5 m long and 3 m wide. Within the plot we established four transects. For plots on the trail, there were 2 transects in each of the 2 main tracks. Ground cover was quantified by point sampling at 40 points per transect, resulting in 160 points per plot. Details of the plot lay-out and point sampling methods are presented in Appendix I. The percent cover of each plant species and other ground cover (e.g. bare soil, dead moss, leaf litter) was tallied by species and by plant lifeform. Plots were photographed and marked with wooden stakes, and will be revisited to monitor recovery over time. T-tests were performed to evaluate differences between disturbed and control plots for all lifeforms and for individual plant species that had at least 5% cover in either plot. For the T-tests, the transect was the sampling unit.

RESULTS

Evaluation of vehicle impacts

The trail was created by rubber-tracked Tucker Snow Cats. The second vehicle dispatched drove on the trail round trip. It was a Tucker 1700 series Cat that weighed 8500 lbs with a ground pressure (unloaded) of 0.89 lbs/square inch (psi). Loaded, ground pressure was probably just over 1 psi. The first vehicle, a Tucker 1644 Snow Cat, traveled over the tundra only on the return trip. It weighed 9000 lbs and had an unloaded ground pressure of 1.16 psi. Loaded, ground pressure was probably less than 2 psi.

The vehicles traveled on a single narrow trail across slopes that ranged from flat to fairly steep on an alpine mountainside in early winter when snow depth was low. Passengers reported that snow depth was variable, ranging from a few inches to several feet. An automatic weather station about 8 km (5 miles) north-west of the trail, near Galbraith Lake, recorded 8 to 10 cm of snow on the ground on the date the trail was made. A station 21 km (13 miles) to the north by the Kuparuk River recorded 46 cm snow depth on that date. Atigun Gorge probably had snow depths intermediate between those two stations, because the former is in an area with high wind scouring in the winter and the latter is in a much less windy area. There is no nearby data available on snow density, but it is likely that in November the snow was less dense than it is later in the winter, affording less protection to the vegetation and soil.

Systematic sampling to document disturbance levels

Sixty-seven plots were sampled on the trail, one every 20 meters (Figure 3). Results are presented in Table 2, summarized as percents of all plots at each disturbance level in each of four vegetation types. Appendix II presents the actual numbers of plots at each disturbance level. Nine percent of the plots were rated as little or no disturbance, 43% as low-level, 42% as medium-level, and 6% as high-level disturbance according to the rating scheme in Table 1. The length of trail sampled was 1.4 km, which translates to approximately 0.1 km of little or no disturbance, 0.6 km each of low and medium-level disturbance, and 0.1 km of high-level disturbance. We discovered later from an aerial photo, however, that the trail did not end where it returned to the river and we stopped sampling. After going on river ice past a steep bluff it climbed a bank and crossed another length of about 0.25 km of tundra before returning to the river. Therefore, the total length of known trail is about 1.65 km (1 mile).

Table 2. Percentages of four disturbance levels within four vegetation types on a snow-vehicle trail created during November 2003 in Atigun Gorge, Arctic NWR.

	Disturbance Level				
	No	Low	Med	High	Overall
All Vegetation Types	9	43	42	6	100
By Vegetation Type:					
Dry Tundra	0	6	12	1	19
Moist Tundra	3	28	15	3	49
Riparian shrublands	6	3	4	1	15
Wet Graminoid Tundra	0	6	10	0	16

The trail was visible for most of its length. Two tracks were usually visible, often with undisturbed vegetation between the tracks. Some stretches of trail had four or more tracks visible and some sites, particularly dry areas, had general scuffing over a width of at least 3 m.

The trail crossed over colluvial slopes below limestone mountains. Vegetation varies due to differences in soil moisture and amount of protective snow cover in the winter. Four main vegetation types were found. One half of the plots were on Moist Dwarf Shrub Tundra with moderately well-drained, loamy soils with abundant rocks. Nineteen percent of the plots were on Dry Dwarf Shrub Tundra where the trail crossed raised areas with rocky well-drained soils. Sixteen percent of the plots were on Wet Graminoid Tundra in gently-sloping, poorly-drained meadows. Fifteen percent of the plots were in Riparian Willow Shrublands in small side drainages or along the Atigun River. The willows grow taller in these areas due to plentiful water and protection from winter wind by deeper snow.

The kind of damage caused by the vehicles was determined mainly by the topography and vegetation types. On the portions of the trail that crossed Moist Dwarf Shrub Tundra, most plots sustained low-level damage. The disturbance consisted of cleat marks in the moss and scuffing of the ground, which exposed bare soil and removed some dwarf shrubs and mosses. At some sites with taller shrubs, the shrubs were broken. Many moist sites had hummocky topography. Hummocks were often compressed and scuffed. At the most-disturbed sites, all tops were scraped off the hummocks. Cottongrass tussocks were smashed in the few areas where they occurred.

Medium to high-level disturbance was more frequent on the Dry Dwarf Shrub Tundra and Wet Graminoid Tundra. Damage on dry sites consisted of extensive scuffing that exposed bare soil and compressed raised hummocks. Most wet sites had distinct cleat marks in the thick moss mat and the more disturbed wet sites had patches of bare ground. Riparian Willow Shrublands in small drainages had little or no damage, probably because the drainages collect adequate snow to protect the willows and ground cover. Riparian Willow Shrublands on open slopes along the river at both ends of the trail sustained higher damage. Willows were broken and moss areas had distinct cleat marks. The most disturbed riparian plot had continuous cleat marks and all of the 6-ft-tall willows were broken off at ground level. By August 10, some of these tall willows were already resprouting at the base, although no resprouting was noted for other damaged shrub species along the trail.

<u>Permanent vegetation plots</u>

Highly-disturbed areas were chosen for the three permanent plots to track recovery over time, so there were numerous statistically significant differences between the disturbed plots and adjacent controls (Tables 3-5, Figures 6-11). All three disturbed plots showed large decreases in live plant cover and large increases in bare ground on the trail as compared to the control plots. Cover of vascular plants decreased at all plots. Cover of non-vascular plants (mosses, liverworts, and lichens) decreased at all plots, but the difference was not statistically significant at Plot #3. Sedges, grasses, and horsetails were the only plant lifeforms that did not tend to decrease after disturbance. The plant species that showed the largest decreases were the dominant dwarf shrubs Mountain Avens (*Dryas octopetala*) and Net-leaf Willow (*Salix reticulata*) and all of the dominant feathermosses.

Table 3. Mean plant cover (%) on a disturbed snow-vehicle trail on Moist Dwarf Shrub-Sedge-Moss Tundra (Site #1), in comparison to an adjacent undisturbed control plot in Atigun Gorge, Arctic National Wildlife Refuge, 2004.

	PLANT COVER (%)		
	DISTURBED	CONTROL	P-VALUE*
LIFEFORM			
Algae	0	1	
Deciduous shrubs	3	8	**0.03**
Evergreen shrubs	6	11	0.2
Forbs	1	3	
Grasses	0	1	
Horsetails	6	9	0.3
Lichens	1	4	
Mosses and liverworts	19	59	**0.001**
Non-vegetated	66	18	**<0.001**
Sedges	8	9	0.8
TOTAL PLANT COVER	45	105	**0.001**
Total vascular plants	25	41	**0.03**
Total non-vascular plants	20	64	**0.001**
SPECIES WITH >3% COVER			
SHRUBS			
Dryas octopetala	6	11	0.2
Salix reticulata	1	5	**0.03**
MOSSES			
Tomenthypnum nitens	15	34	**0.03**
Hypnum cf bambergeri	3	13	**0.04**
Hylocomium splendens	0	4	0.6
Rhytidium rugosum	0	3	
Orthothecium chryseum	1	4	
LICHENS			
Cetraria nivalis	1	3	
NON-VEGETATED			
Dead moss	28	2	**0.004**
Leaf litter	9	8	0.7
Bare soil	27	1	**0.003**
Water	4	7	**0.03**

* P-value from T-test of difference in plant cover between control and disturbed plots, for cover types with >5% cover. P-values in bold indicate a significant difference ($P \leq 0.05$).

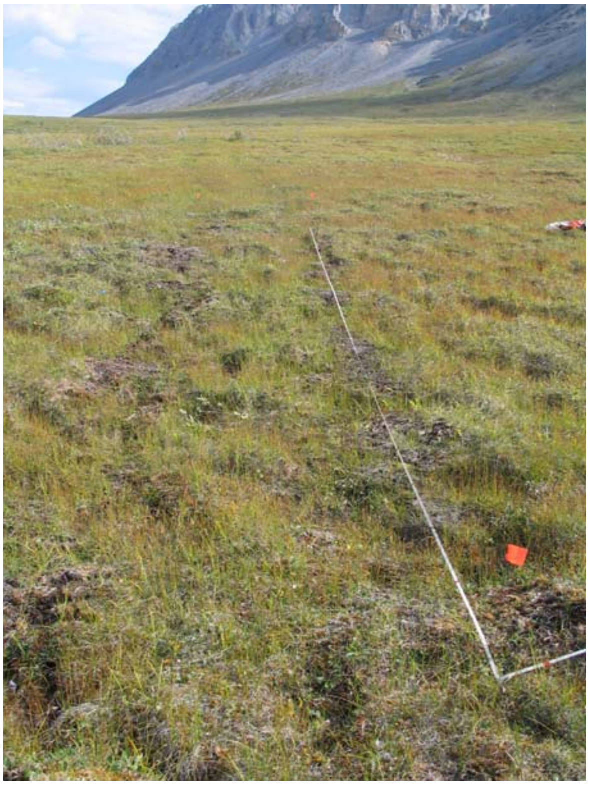


Figure 6. Disturbed plot on trail at Site #1, August 10, 2004.

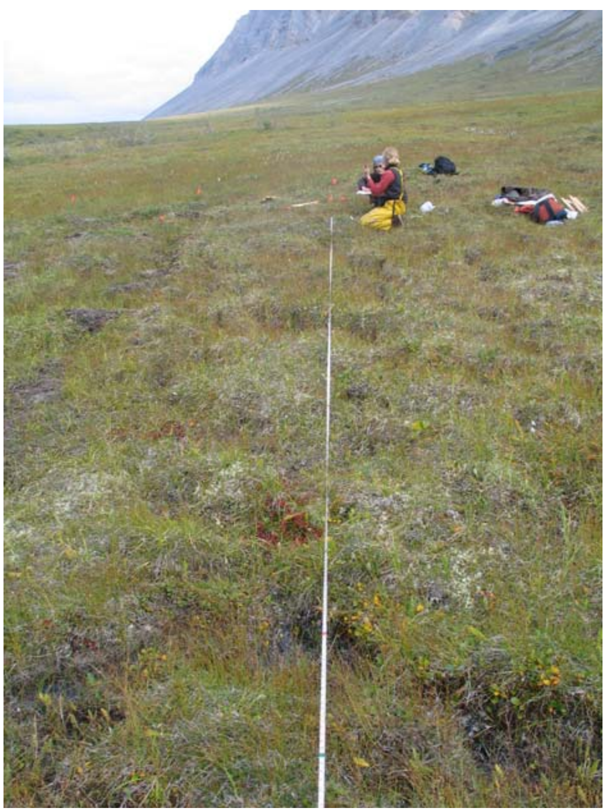


Figure 7. Control plot at Site #1, August 10, 2004. Note trail on left.

Table 4. Mean plant cover (%) on a disturbed snow-vehicle trail on Dry Dwarf Shrub-Moss-Lichen Tundra (Site #2), in comparison to an adjacent undisturbed control plot in Atigun Gorge, Arctic National Wildlife Refuge, 2004.

	PLANT COVER (%)		
	DISTURBED	CONTROL	P-VALUE*
LIFEFORM			
Deciduous shrubs	2	13	**0.002**
Evergreen shrubs	7	31	**0.01**
Forbs	1	3	
Horsetails	1	0	
Lichens	5	9	0.07
Mosses and liverworts	6	28	**0.02**
Non-vegetated	74	28	**<0.001**
Sedges	5	2	0.8
TOTAL PLANT COVER	27	86	**<0.001**
Total vascular plants	16	49	**0.001**
Total non-vascular plants	11	37	**0.02**
SPECIES WITH >3% COVER			
SHRUBS			
Dryas octopetala	7	31	**0.01**
Salix reticulata	0	10	**0.009**
Salix glauca	1	3	
MOSSES			
Rhytidium rugosum	1	15	**0.01**
Ditrichaceae	2	3	
LICHENS			
Crustose lichens	3	3	
Cetraria cucullata	1	3	
Cetraria nivalis	1	3	
NON-VEGETATED			
Dead moss	4	0	
Leaf litter	44	19	**0.003**
Bare soil	21	7	0.1
Bare rock	4	3	

* P-value from T-test of difference in plant cover between control and disturbed plots, for cover types with >5% cover. P-values in bold indicate a significant difference ($P \leq 0.05$).

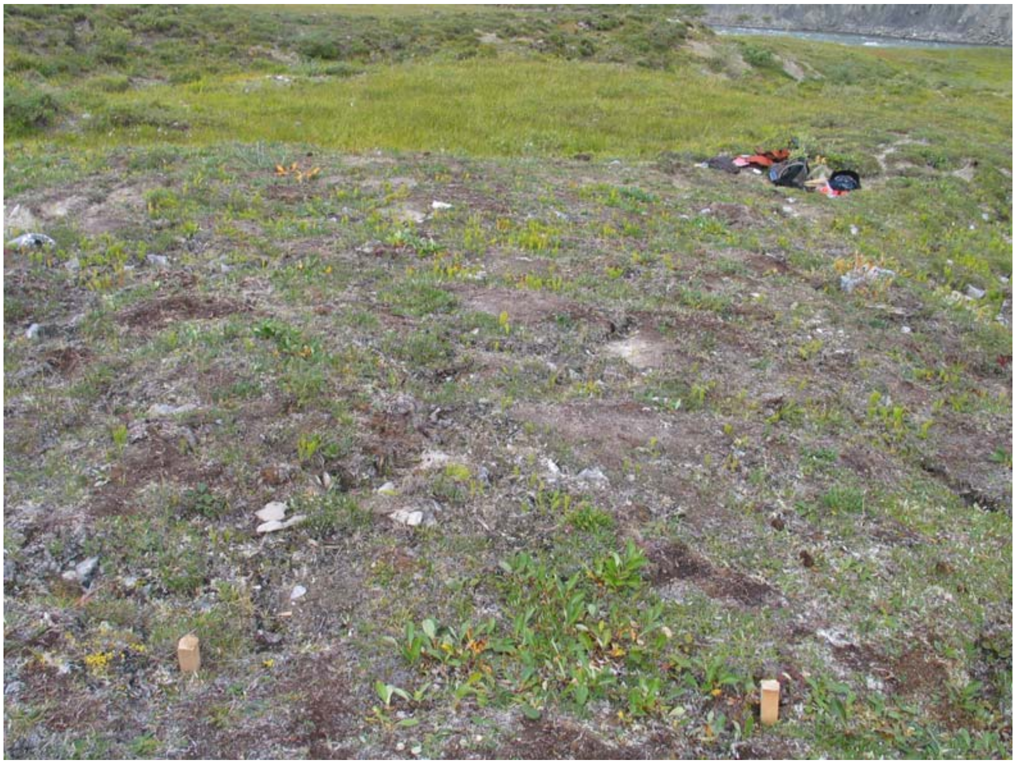


Figure 8. Disturbed plot on trail at Site #2, August 10, 2004.

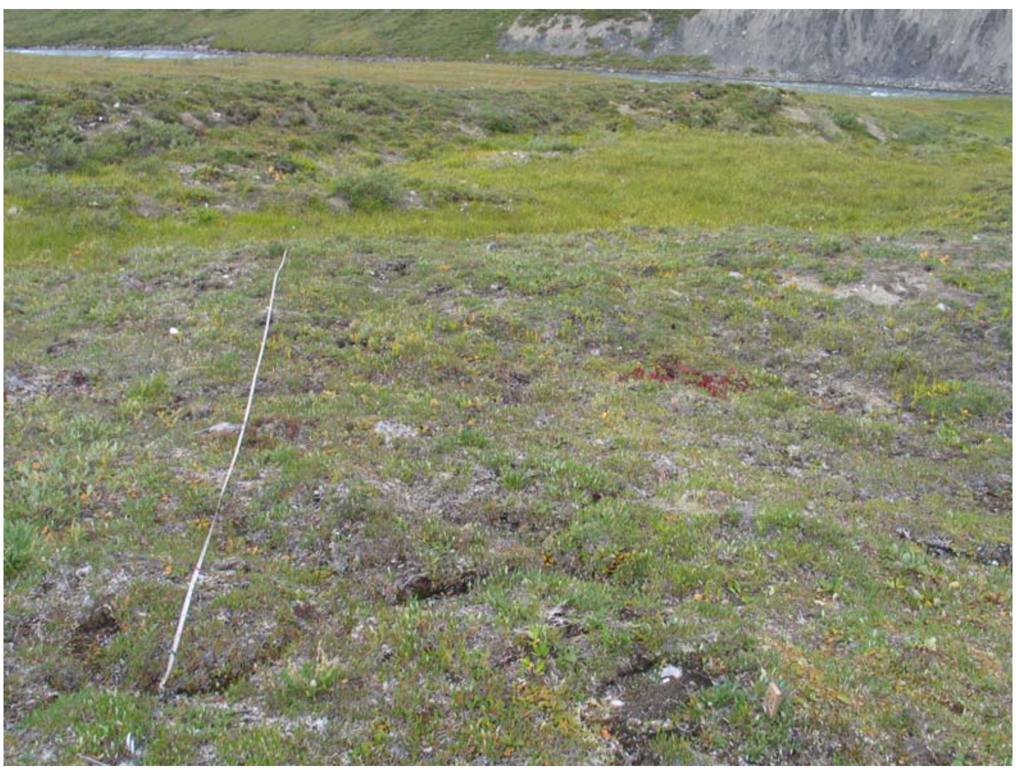


Figure 9. Control plot at Site #2, August 10, 2004.

Table 5. Mean plant cover (%) on a disturbed snow-vehicle trail on Dry Dwarf Shrub-Moss-Lichen Tundra (Site #3), in comparison to the adjacent undisturbed control plot in Atigun Gorge, Arctic National Wildlife Refuge, 2004.

	PLANT COVER (%)		
	DISTURBED	CONTROL	P-VALUE*
LIFEFORM			
Deciduous Shrubs	6	8	0.6
Evergreen Shrubs	16	43	**<0.001**
Horsetails	1	1	
Forbs	3	4	
Grasses	1	1	
Lichens	3	19	**0.03**
Mosses	26	19	0.1
Non-vegetated	53	19	**<0.001**
Sedges	4	3	0.7
TOTAL PLANT COVER	60	98	**<0.001**
Total vascular plants	31	60	**<0.001**
Total non-vascular plants	29	38	0.1
SPECIES WITH >3% COVER			
SHRUBS			
Dryas octopetala	16	43	**<0.001**
Salix reticulata	4	6	0.5
SEDGES & GRASSES			
Carex scirpoidea	3	3	
MOSSES			
Rhytidium rugosum	13	8	0.4
Tomenthypnum nitens	2	3	
LICHENS			
Cetraria cucullata	2	8	0.2
Cetraria nivalis	1	3	
NON-VEGETATED			
Dead moss	11	0	**0.009**
Leaf litter	15	15	0.6
Bare soil	24	3	**0.01**

* P-value from T-test of difference in plant cover between control and disturbed plots, for cover types with >5% cover. P-values in bold indicate a significant difference ($P \leq 0.05$).

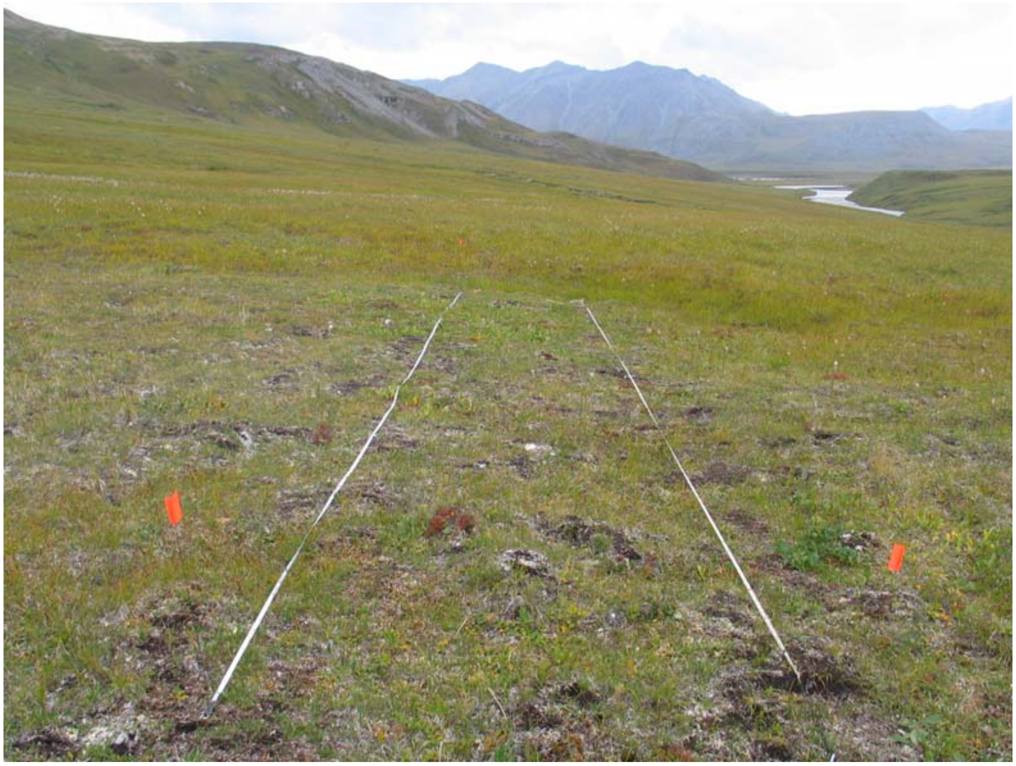


Figure 10. Disturbed plot on trail at Site #3, August 11, 2004.


Figure 11. Control plot at Site #3, August 11, 2004.

DISCUSSION

The snow-vehicle trail created on November 22, 2003 extends approximately 1.65 km (1 mile) into the Arctic National Wildlife Refuge. It is along a hiking route to a waterfall in Atigun Gorge that is the most frequented hike in the Refuge due to easy access from the Dalton Highway and spectacular scenery. In June 2004, before the vegetation was fully greened up the first summer after the trail was made, the trail was highly visible. On August 10 - 11, 2004, the trail was still easy to follow, but seemed to be less visible than in June. Another biologist reported that on August 22 it was again highly visible, perhaps because the Fall colors highlighted the decreases in live shrubs on the trail.

To estimate time to recovery of vegetation and soils, we compared the data to that from vehicle trails made during winter seismic exploration on the Refuge in 1984 and 1985. These provide the most comparable data for predicting the future rate of recovery for this trail. The seismic exploration occurred on the coastal plain tundra and the Atigun trail is on alpine tundra, so there are some differences. The coastal plain is much wetter and the vegetation is often dominated by sedges, which are more resistant and resilient to damage than the shrubs and mosses that dominate in the alpine vegetation of Atigun Gorge. Much of the trail in the gorge is on steeper slopes than the coastal plain, which may increase erosion. The trail in the gorge is on well-drained rocky colluvium which does not have the large amounts of ground ice that caused trail subsidence on the fine-grained soils of the coastal plain. Wet tundra on the flat coastal plain was very resistant to damage in winter because the saturated, fine-grained soils froze solid. In contrast, the wet sites in the gorge were substantially damaged, probably because the substrate was rocky, not saturated, and therefore loose even if frozen. Also, wet tundra in the gorge has thick feathermoss which is easily damaged, while wet tundra on the coastal plain has little moss.

The overall level of disturbance on this trail was higher than that of the seismic trails, although the vehicles were lighter. Ground pressure of the vehicles for the seismic exploration ranged from 1 to 10 psi, while the vehicles in Atigun Gorge had only 1 to 2 psi. The greater initial disturbance may be because of lower snow cover, steeper slopes, and loose rocky soils. The Atigun trail was rated as 42% medium-level disturbance and 6% as high-level. Using the same rating scheme the first summer after disturbance on the seismic trails, 26% had medium-level disturbance, 2% high, and the rest had low or no disturbance.

The dry tundra and riparian shrublands in the gorge have similar substrates to their counterparts on the coastal plain, so we expect that changes in species composition and rate of recovery over time will be similar to what was seen after seismic exploration. Dry sites will recover very slowly and riparian shrublands will recover rapidly. Recovery in moist and wet tundra is less predictable because of the steeper slopes in Atigun Gorge.

We will continue monitoring both the systematic and permanent plots. The moss mat was either scuffed or dying at many sites in 2004, and we cannot predict how much of it will recover or die in the next few years. Cover of live moss continued to decrease on plots on the seismic trails for three years after disturbance. We recommend that the monitoring done this year be repeated next year and then every two or three years thereafter until about 90% of the systematic plots recover to low disturbance levels. After that, problem areas should be monitored periodically. We will allow natural recovery to proceed rather than attempting interventions, unless monitoring reveals that erosion during spring run-off is a problem.

LITERATURE

Emers, M., J. C. Jorgenson, and M. K. Raynolds. 1995. Response of Arctic plant communities to winter vehicle disturbance. Can. J. Botany 73: 905-919.

Emers M. and J. C. Jorgenson. 1997. Effects of winter seismic exploration on the vegetation and soil thermal regime of the Arctic National Wildlife Refuge. *In* Crawford, R. M. M. Ed., 1997. Disturbance and recovery in Arctic lands: an ecological perspective. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Raynolds, M. K. and N. A. Felix. 1989. Airphoto analysis of winter seismic disturbance in northeastern Alaska. Arctic 42:(4)362-367.

Appendix I. Detailed methods for point sampling of percent plant cover.

The percent of the plot area covered by each plant species was quantified by point sampling at 160 points. The sampling equipment was a vertical rod with a sighting device attached on a horizontal arm. The device consisted of an eye tube with a cross hair mounted in it. Each of the four sampling units per plot was 4.5 m X 0.5 m, centered on one of the two main tracks through the plot. Units were 1.5 m apart. In each unit, points were spread in a closely-spaced web by placing the rod every 0.5 m along a measuring tape through the center of the unit. The horizontal arm on the sighting device was rotated to four positions, along the measuring tape and perpendicular to it, yielding 40 points per sampling unit. The result was a web of points with each point 15 and 30 cm from its nearest neighbors. All plant species that were intersected by the cross-hair when the observer's eye socket rested on the top of the tube were recorded.

For each plot, percent plant cover by species was calculated as: (number of occurrences/160)*100. Because layers of vegetation can overlap, the total plant cover is usually more than 100%.

Appendix II. Results of a systematic sample of 67 plots along the vehicle tracks in Atigun Gorge, showing numbers of plots at each disturbance level in each of four vegetation types.

	Disturbance Level				
	No	Low	Med	High	All Levels
All Vegetation Types	6	29	28	4	67
Dry	0	4	8	1	13
Moist	2	19	10	2	33
Riparian shrub	4	2	3	1	10
Wet Graminoid	0	4	7	0	11