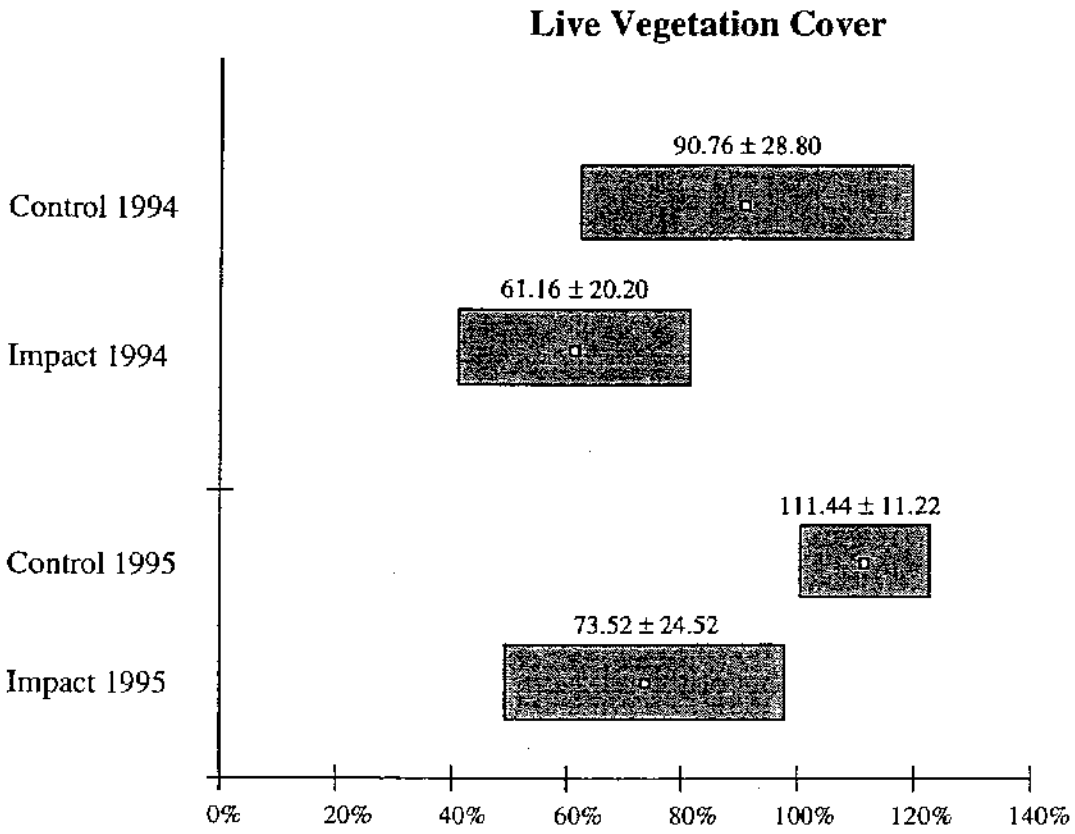


Figure 10. Comaprison of means and standard deviations for 1994 and 1995 percent live vegetation cover at the Yukon Gold site, Alaska.

Eriophorum angustifolium and *Carex aquatilis* dominated the graminoid vegetation at both control and impact plots in 1994 and 1995 (Table 2, and Table 3), although *E. angustifolium* was reduced on impact plots In contrast, forbs and shrubs were not numerous, contributing 10% of live cover at control sites and 4% live cover on impact sites in 1995 (Table 1). Mosses dominated the non-vascular plant cover, specifically *Scorpidium scorpioides* and *Tomenthypnum nitens* (Table 2 and Table 3). Mean cover values from 1993 through 1995 are presented in Table 4. Data for 1994 and 1995 are normalized to a total 100% maximum cover for comparison with 1993 data. The extent of live vegetation recovery within the pad footprint on 29 July 1995 is illustrated in Figure 11.

Paired Plot Analyses

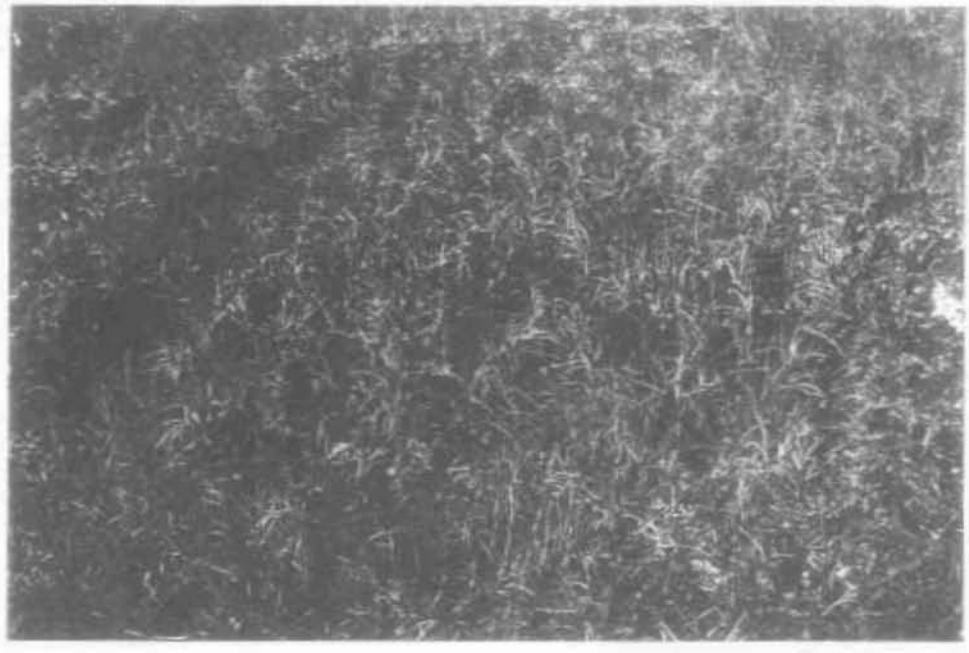
Paired sample *t* tests were conducted on both natural vegetation groupings in 1994 and 1995 (Table 5) and individual plant taxa (Table 6 and Table 7). Total live vegetation, graminoids and shrubs were significantly lower at impact plots ($P < 0.0001$), while barren ground was significantly higher at impact plots ($P < 0.0001$) for both 1994 and 1995. The cover of dead plant material, and non-vascular plants did not differ between control and impact plots ($P > 0.18$) for 1994 and 1995. The null hypothesis is rejected for all live cover categories except forbs in 1995 and non-vascular plants in both 1994 and 1995 (Table 5).

E. angustifolium, C. aquatilis and *Carex saxatilis* dominated graminoid cover. *E. angustifolium,* and *C. saxatilis* were significantly more abundant at control plots in both 1994 and 1995 ($P<0.05$, Table 6 and Table 7). The forb *Pedicularis sudetica,* and the shrubs *Salix arctica, Salix reticulata,* and *Dryas integrifolia* were significantly more abundant on control plots in both 1994 and 1995 ($P<0.05$, Table 6 and Table 7). Non-vascular plants were not significantly different between control and impact plots in either 1994 or 1995 ($P>0.05$). The null hypothesis is rejected for *E. angustifolium, P. sudetica, D. integrifolia, S. arctica,* and *S. reticulata* for 1994 and 1995 (Table 5 and Table 6).

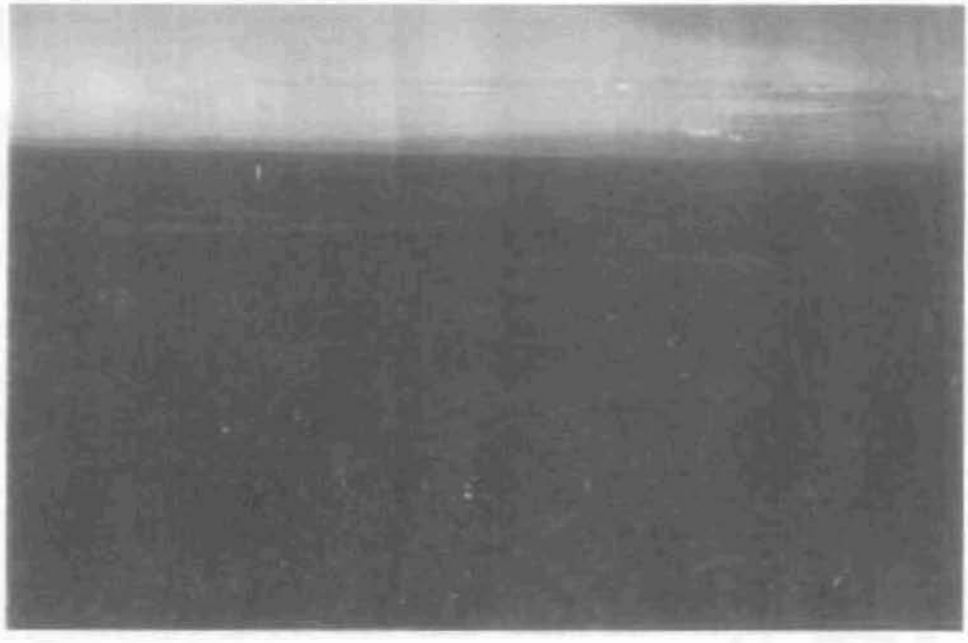
Paired plot comparisons for 1993 through 1995 data are presented for live vegetation and graminoid cover in Figure 12, Tables 8 and 9. The mean difference between paired control plots for 1993 data was near zero. Post-impact 1994 and 1995 data illustrate the decrease in live vegetation and graminoid cover at impact plots as a negative mean difference between paired impact and control plots. There was a slight decrease in the mean difference (greater difference between impact and control plots) from 1994 to 1995 for both live cover and graminoid vegetation; however 95% confidence intervals overlap, so this decrease was not significant (Fig. 12, Tables 8 and 9).

Table 4. Mean number of hits and percent cover by vegetation category for impact and control plots at the Yukon Gold site, Alaska, for data collected 13–16 July 1993, 2–4 August 1994, and 27–29 July 1995. Data for 1993 include only one hit at each data point, while data for 1994 and 1995 include two hits per data point, one at canopy level and one at ground level. Canopy and ground level cover are combined for 1994 and 1995 and are divided by the total 100 points for comparison with 1993 data, yielding a theoretical maximum of 100 percent cover. Standard deviation is abbreviated SD.

	1993 Data		1994 Data				1995 Data			
	Control (n=50)		Impact (n=24)		Control (n=24)		Impact (n=25)		Control (n=25)	
	Mean No. Hits (±SD)	Mean % Cover (±SD)	Mean No. Hits (±SD)	Mean % Cover (±SD)	Mean No. Hits (±SD)	Mean % Cover (±SD)	Mean No. Hits (±SD)	Mean % Cover (±SD)	Mean No. Hits (±SD)	Mean % Cover (±SD)
Live Vegetation	17.0 ±5.7	34.0% ±11.4%	30.6 ±12.3	30.6% ±12.3%	45.4 ±5.6	45.4% ±5.6%	36.8 ±12.3	36.8% ±12.3%	55.7 ±5.6	55.7% ±5.6%
Dead Plant Material	29.3 ±4.9	58.6% ±9.8%	36.1 ±7.7	36.1% ±7.7%	33.4 ±6.6	33.4% ±6.6%	40.5 ±7.7	40.5% ±7.7%	40.0 ±6.6	40.0% ±6.6%
Barren	3.7 ±4.0	7.4% ±8.0%	33.3 ±13.6	33.3% ±13.6%	21.3 ±2.7	21.3% ±2.7%	22.8 ±13.6	22.8% ±13.6%	4.3 ±2.7	4.3% ±2.7%
Graminoids	9.7 ±3.7	19.4% ±7.4%	9.1 ±13.1	9.1% ±13.1%	17.0 ±3.1	17.0% ±3.1%	26.4 ±13.1	26.4% ±13.1%	42.4 ±3.1	42.4% ±3.1%
Forbs	0.2 ±0.5	0.4% ±0.9%	0.2 ±1.2	0.2% ±1.2%	0.8 ±1.1	0.8% ±1.1%	1.1 ±1.2	1.1% ±1.2%	1.3 ±1.1	1.3% ±1.1%
Shrubs	2.2 ±2.6	4.3% ±5.1%	0.0 ±1.2	0.0% ±1.2%	2.5 ±3.7	2.5% ±3.7%	0.9 ±1.2	0.9% ±1.2%	4.2 ±3.7	4.2% ±3.7%
All Vascular	12.1 ±3.6	24.2% ±7.2%	9.3 ±12.7	9.3% ±12.7%	20.3 ±3.4	20.3% ±3.4%	28.4 ±12.7	28.4% ±12.7%	47.8 ±3.4	47.8% ±3.4%
All Non-Vascular	4.9 ±5.2	9.9% ±10.3%	21.3 ±7.5	21.3% ±7.5%	25.1 ±6.4	25.1% ±6.4%	8.4 ±7.5	8.4% ±7.5%	7.9 ±6.4	7.9% ±6.4%



A.



B.

Figure 11. Vegetation cover within the Yukon Gold site, Alaska, showing vegetation recovery after two growing seasons, photo 29 July 1995. A.—close view of vegetation cover within ice pad footprint. B.—view to west from within ice pad footprint, right stake is within footprint, left stake is outside footprint.

Table 5. Results of paired-sample t tests comparing impact and control plots by category for data collected 2-4 August 1994 and 27–29 July 1995 at the Yukon Gold site, Alaska. Data for canopy level and ground level are combined, yielding a theoretical maximum of 200 percent cover. Standard deviation is abbreviated SD.

	Impact (n=25)	Control (n=25)			Accept Null Hypothesis
	Mean No. Hits (±SD)	Mean No. Hits (±SD)	t Value	P Value (two tailed)	(α=0.05)
	1994 Data				
	Impact (n=24)	Control (n=24)			
Live Vegetation	30.58 ±10.10	45.38 ±14.40	4.703	<0.0001	No
Dead Plant Material	36.08 ±12.65	33.38 ±18.01	-0.735	0.4695	Yes
Barren	33.33 ±8.52	21.25 ±7.77	-5.464	<0.0001	No
Graminoids	9.08 ±6.35	16.96 ±6.49	4.998	<0.0001	No
Forbs	0.21 ±0.41	0.75 ±0.90	2.716	0.0123	No
Shrubs	0.04 ±0.20	2.54 ±2.54	4.733	<0.0001	No
All Vascular	9.33 ±6.36	20.25 ±5.53	7.564	<0.0001	No
All Non-Vascular	21.25 ±12.21	25.13 ±15.68	1.377	0.1817	Yes
	1995 Data				
	Impact (n=25)	Control (n=25)			
Live Vegetation	36.76 ±12.26	55.72 ±5.61	6.801	<0.0001	No
Dead Plant Material	40.48 ±7.65	40.00 ±6.64	-0.213	0.8333	Yes
Barren	22.76 ±13.64	4.28 ±2.72	-6.927	<0.0001	No
Graminoids	26.44 ±13.11	42.36 ±3.05	6.062	<0.0001	No
Forbs	1.08 ±1.22	1.32 ±1.14	0.796	0.4339	Yes
Shrubs	0.88 ±1.17	4.16 ±3.74	4.709	<0.0001	No
All Vascular	28.40 ±12.68	47.84 ±3.44	8.234	<0.0001	No
All Non-Vascular	8.36 ±7.47	7.88 ±6.44	-0.223	0.8256	Yes

Table 6. Results of paired-sample t tests comparing impact and control plots by plant taxa for data collected 2–4 August 1994, at the Yukon Gold site, Alaska. Data are organized with two hits recorded, one at canopy level and one at ground level, yielding a theoretical maximum of 200 percent cover. Standard deviation is abbreviated SD.

	Impact (n=24)	Control (n=24)			Accept Null Hypothesis (α=0.05)
	Mean No. Hits (±SD)	Mean No Hits (±SD)	t Value	P Value (two tailed)	
Barren					
No Canopy or Bare Ground	32.38 ±8.95	21.25 ±7.77	-5.188	<0.0001	No
Gravel	0.96 ±2.44	0.00 ±0.00	-1.924	0.0668	Yes
Graminoids					
Carex aquatilis	1.33 ±1.40	3.75 ±2.27	4.306	0.0003	No
Carex atrofusca	0.08 ±0.41	0.21 ±0.59	0.827	0.4170	Yes
Carex bigelowii	0.00 ±0.00	0.42 ±1.84	1.110	0.2786	Yes
Carex saxatilis	1.00 ±1.44	1.96 ±2.44	1.638	0.1150	Yes
Eriophorum angustifolium	6.58 ±5.12	10.46 ±5.26	2.896	0.0082	No
Juncus biglumis	0.00 ±0.00	0.04 ±0.20	1.000	0.3277	Yes
Forbs					
Equisetum variegatum	0.13 ±0.34	0.25 ±0.68	0.768	0.4503	Yes
Pedicularis sudetica	0.08 ±0.28	0.46 ±0.66	2.584	0.0166	No
Polygonum viviparum	0.00 ±0.00	0.04 ±0.20	1.000	0.3277	Yes
Shrubs					
Dryas integrifolia	0.00 ±0.00	1.13 ±2.23	2.469	0.0214	No
Salix arctica	0.00 ±0.00	0.58 ±0.72	3.984	0.0006	No
Salix lanata	0.00 ±0.00	0.33 ±0.92	1.781	0.0881	Yes
Salis reticulata	0.04 ±0.20	0.50 ±0.66	3.114	0.0049	No
Non Vascular Plants					
Lichens	0.04 ±0.20	0.13 ±0.61	0.624	0.5385	Yes
Liverworts	0.04 ±0.20	0.08 ±0.28	0.569	0.5747	Yes
Mosses	21.17 ±12.11	24.92 ±15.58	1.344	0.1921	Yes
Bryum pseudotriquetrum	0.63 ±1.13	0.88 ±1.23	0.710	0.4850	Yes
Hypnum bambergeri	1.38 ±2.22	2.04 ±4.29	0.725	0.4760	Yes
Oncophorus wahlenbergii	0.13 ±0.45	0.29 ±0.75	0.941	0.3567	Yes
Scorpidium scorpioides	13.88 ±9.67	13.88 ±11.54	0.000	2.0686	Yes
Tomenthypnum nitens	5.17 ±8.25	7.79 ±11.59	1.124	0.2727	Yes

Table 7. Results of paired-sample t tests comparing impact and control plots by plant taxa for data collected 27–29 July 1995 at the Yukon Gold site, Alaska. Standard deviation is abbreviated SD.

	Impact (n=25)	Control (n=25)			Accept Null Hypothesis
	Mean No. Hits (±SD)	Mean No. Hits (±SD)	t Value	P Value (two tailed)	(α=0.05)
Barren					
Bare Canopy or Ground	22.76 ±13.64	4.28 ±2.72	-6.927	<0.0001	No
Dead Plant Material					
Litter	39.88 ±7.74	39.48 ±6.50	-0.178	2.0639	Yes
Standing Dead	0.60 ±1.00	0.52 ±0.65	-0.371	0.7136	Yes
Graminoids					
Carex aquatilis	6.04 ±3.86	6.28 ±3.40	0.248	0.8063	Yes
Carex atrofusca	0.00 ±0.00	0.36 ±1.60	1.122	0.2729	Yes
Carex bigelowii	0.08 ±0.40	0.68 ±2.43	1.208	0.2388	Yes
Carex misandra	0.00 ±0.00	0.44 ±0.87	2.529	0.0184	No
Carex saxatilis	1.44 ±2.22	4.28 ±4.71	2.528	0.0185	No
Eriophorum angustifolium	18.72 ±11.87	29.08 ±5.28	3.809	0.0008	No
Juncus biglumis	0.00 ±0.00	0.04 ±0.20	1.000	0.3273	Yes
Forbs					
Caltha palustris arctica	0.00 ±0.00	0.04 ±0.20	1.000	0.3273	Yes
Equisetum variegatum	0.84 ±1.14	0.40 ±0.71	-1.701	0.1019	Yes
Pedicularis sudetica	0.04 ±0.20	0.48 ±0.65	3.381	0.0025	No
Polygonum viviparum	0.16 ±0.47	0.32 ±0.63	0.941	0.3563	Yes
Saxifraga hirculus	0.04 ±0.20	0.08 ±0.28	1.000	0.3273	Yes
Shrubs					
Dryas integrifolia	0.00 ±0.00	1.44 ±1.61	4.474	0.0001	No
Salix arctica	0.68 ±1.03	1.52 ±1.64	2.201	0.0376	No
Salix lanata	0.00 ±0.00	0.32 ±0.90	1.778	0.0881	Yes
Salix reticulata	0.16 ±0.37	0.76 ±1.51	2.268	0.0326	No
Salix rotundifolia	0.04 ±0.20	0.12 ±0.44	0.811	0.4254	Yes
Non-Vascular Plants					
Liverworts	0.00 ±0.00	0.04 ±0.20	1.000	0.3273	Yes
Mosses					
Bryum pseudotriquetrum	0.48 ±0.92	0.60 ±0.87	0.499	0.6220	Yes
Distichium sp.	0.00 ±0.00	0.36 ±0.76	2.377	0.0258	No
Funaria hygrometrica	0.04 ±0.20	0.04 ±0.20	0.000	1.0000	Yes
Hypnum bambergeri	1.32 ±5.19	0.96 ±2.82	-0.308	0.7607	Yes
Oncophorus wahlenbergii	0.00 ±0.00	0.20 ±1.00	1.000	0.3273	Yes
Scorpidium scorpioides	3.16 ±4.20	3.52 ±3.56	0.327	0.7463	Yes
Tomenthypnum nitens	3.20 ±4.99	1.68 ±1.99	-1.415	0.1699	Yes

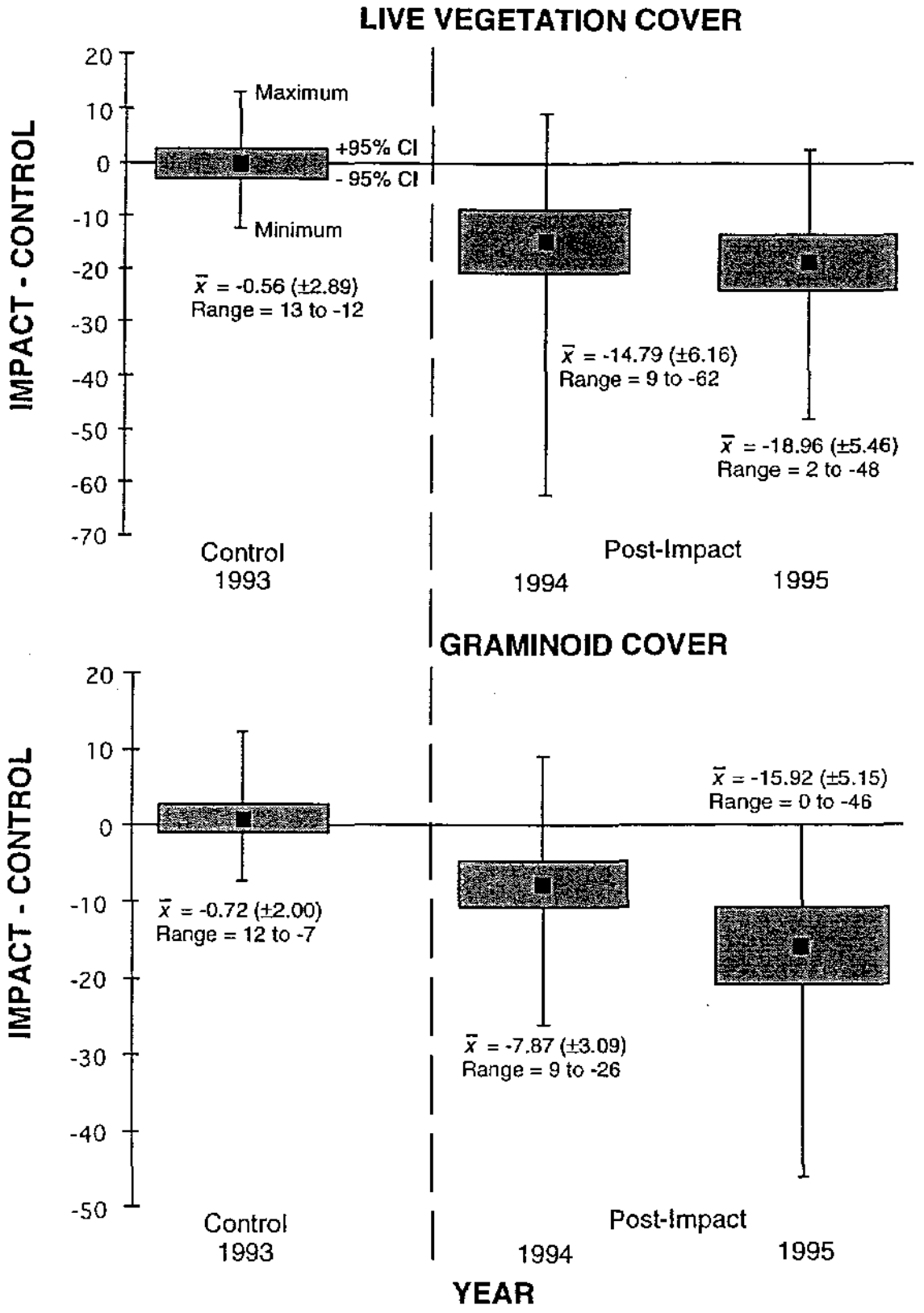


Figure 12. Mean differences (±95 % Confidence Interval) between members of individual plot pairs for control (1993, n=25) and post-impact (1994, n=24; 1995, n=25) live vegetation and graminoid cover at the Yukon Gold site, Alaska. Data for live vegetation and graminoid cover at paired plots are presented in Tables 8 and 9.

Table 8. Number of hits for live vegetation cover data from 1993, 1994, and 1995 Yukon Gold site, Alaska, monitoring data used in Before-After-Control-Impact (BACI) analysis in Figure 12.

	Live Vegetation 1993			Live Vegetation 1994			Live Vegetation 1995		
Plot Pair	Control (a)	Control (b)	Difference	Impact	Control	Difference	Impact	Control	Difference
1	24	11	13	38	64	-26	44	62	-18
2	9	13	-4	23	31	-8	54	52	2
3	34	23	11	38	51	-13	41	61	-20
4	24	23	1	12	74	-62	47	53	-6
5	12	19	-7	26	50	-24	41	48	-7
6	14	22	-8	19	35	-16	44	54	-10
7	13	25	-12	25	37	-12	43	56	-13
8	8	16	-8	39	65	-26	20	56	-36
9	22	10	12				22	70	-48
10	18	11	7	27	37	-10	46	49	-3
11	31	21	10	27	18	9	39	59	-20
12	13	21	-8	19	46	-27	32	53	-21
13	19	19	0	26	30	-4	34	49	-15
14	12	18	-6	11	41	-30	39	57	-18
15	10	14	-4	41	35	6	16	48	-32
16	12	16	-4	41	56	-15	11	55	-44
17	8	13	-5	41	51	-10	44	57	-13
18	20	15	5	34	31	3	31	52	-21
19	16	25	-9	19	44	-25	49	50	-1
20	13	11	2	37	55	-18	34	60	-26
21	14	18	-4	31	26	5	50	67	-17
22	24	19	5	50	62	-12	17	56	-39
23	12	19	-7	37	33	4	23	61	-38
24	21	15	6	34	58	-24	47	55	-8
25	16	16	0	39	59	-20	51	53	-2
Mean			-0.56			-14.79			-18.96
SD			7.38			15.41			13.94
95% CI			2.89			6.16			5.46
Max			13			9			2
Min			-12			-62			-48

Table 9. Number of hits for graminoid vegetation cover data from 1993, 1994, and 1995 Yukon Gold site, Alaska, monitoring data used in Before-After-Control-Impact (BACI) analysis in Figure 12.

	Graminoids 1993			Graminoids 1994			Graminoids 1995		
Plot Pair	Control (a)	Control (b)	Difference	Impact	Control	Difference	Impact	Control	Difference
1	23	11	12	18	24	-6	42	45	-3
2	8	12	-4	11	17	-6	42	44	-2
3	9	11	-2	6	16	-10	39	39	0
4	10	9	1	9	21	-12	40	42	-2
5	9	3	6	12	27	-15	38	41	-3
6	13	12	1	11	23	-12	35	40	-5
7	11	8	3	16	16	0	38	42	-4
8	8	13	-5	2	14	-12	13	35	-22
9	15	6	9				13	38	-25
10	16	10	6	12	17	-5	11	45	-34
11	2	6	-4	14	14	0	35	41	-6
12	6	13	-7	9	22	-13	13	46	-33
13	10	14	-4	8	17	-9	26	44	-18
14	12	9	3	1	14	-13	33	45	-12
15	6	13	-7	4	23	-19	1	47	-46
16	12	10	2	0	11	-11	2	39	-37
17	6	7	-1	12	20	-8	17	44	-27
18	7	11	-4	16	21	-5	22	42	-20
19	13	11	2	2	28	-26	35	48	-13
20	8	3	5	5	15	-10	31	43	-12
21	9	7	2	13	19	-6	32	39	-7
22	10	10	0	1	5	-4	8	41	-33
23	11	4	7	24	15	9	23	41	-18
24	6	12	-6	0	5	-5	31	43	-12
25	12	9	3	12	3	9	41	45	-4
Mean			0.72			-7.88			-15.92
SD			5.11			7.72			13.13
95% CI			2.00			3.09			5.15
Max			12			9			0
Min			-7			-26			-46

Vegetation Monitoring Requirements

Table 10 includes live cover data and calculations for determining the percent of control live cover value for compliance with the vegetation monitoring program (Appendix E). Table 10 includes 1994 and 1995 impact and control plot pooled mean live cover data derived from vegetation plots. Percent of control live vegetation cover within the pad footprint was 67% in 1994 and 66% in 1995. This represents a net decrease in live vegetation cover from 1994 to 1995 of 1%. If the base condition is calculated, with the addition of 50% of the control group standard deviation, the percent of control live vegetation cover within the pad footprint was 53% in 1994 and 58% in 1995. This represents a net increase in live vegetation cover from 1994 to 1995 of 5%. Because the impact to live cover was greater within the edge zone, the overall recovery within the pad footprint may be more accurately described by omitting the edge plots within the affected areas at 1 m and 2 m intervals. For plots within the footprint excluding the 1 m edge zone (n=22), which represents 92% of the pad area, percent of control live cover was 70% in 1995. For plots within the footprint excluding the 2 m edge zone (n=19), which represents 84% of the pad area, percent of control live cover was 75% in 1995.

DISCUSSION

The paired *t* tests indicate that measurable and significant reductions in live vegetation and graminoid cover in the pad area remain (Table 5). This is consistent with visual evaluation of the ice pad site. Live cover at control sites has apparently increased during sampling: 1993, 34%; 1994, 45%; and 1995, 56% (Table 3). This may be due in part to the later sampling periods in 1994 (early August) and 1995 (late July) compared to mid-July in 1993. Other factors potentially influencing live cover measures are variation in precipitation and snow-melt timing, or differences in observer techniques. Variability in observer techniques may be responsible for the apparent increase in graminoid cover and decrease in barren and non-vascular cover from 1994 to 1995. Because the impact of the ice pad was not uniform within the pad footprint, higher variability in the impact plots was expected. The similarity in variance between impact and control plots in 1994 suggests there was either some inconsistency in recording point contacts, or that due to random selection more patchy control areas were sampled. In contrast, the variance for control plots was less than that for impact plots in 1995. Environmental conditions that also may have contributed to differences in cover measures between years were standing water, saturated soils and breezy conditions during 1995. Differences in annual phenology and observers are controlled for by using paired plot comparisons within years and by using the percent of control value to normalize the live vegetation cover measure.

Table 10. Percent of control live vegetation cover at impact and control plots for 1994 and 1995 at the Yukon gold site, Alaska. Data were collected 2-4 August 1994 and 26–29 July 1995, at the Yukon Gold ice pad, Alaska. Standard deviation is abbreviated SD.

	1994 Mean % Cover (±SD)		1995 Mean % Cover (±SD)	
	Impact (n=24)	Control (n=24)	Impact (n=25)	Control (n=25)
Live Vegetation	61.16 ±20.20	90.76 ±28.80	73.52 ±24.52	111.44 ±11.22
Graminoids		33.92 ±12.98		84.72 ±6.10
Forbs		1.50 ±1.79		2.64 ±2.28
Shrubs		5.08 ±5.07		8.32 ±7.48
All Non-Vascular		50.26 ±31.36		15.76 ±12.88
Cumulative SD		±51.20		±28.74
50% of Cumulative SD		±25.60		±14.37
Percent of Control Live Vegetation Cover	61.16% + 90.76% = 67.39%		73.52% ÷ 111.44% = 65.97%	
Recovery Rate (% of Control) (Percent of Control Live Cover 1995 - Percent of Control Live Cover 1994)			66% - 67% = -1%	
Base Cover Condition (Mean Control Cover + 50% Cumulative SD)	90.76% + 25.60% = 116.39%		111.44% + 14.37% = 125.81%	
Percent of Base Condition	61.16% ÷ 116.39% = 52.55%		73.52% ÷ 125.81% = 58.43%	
Recovery Rate (% of Base Condition) (Percent of Base Condition 1995 - Percent of Base Condition 1994)			58% - 53% = 5%	

Live vascular plant cover, primarily graminoids, was significantly reduced (34% decrease) on impact plots in 1995, as in 1994 results (33% decrease). Non-vascular plants appeared to be largely unaffected by the ice pad. The large standard deviation for impact plots compared to control plots (roughly four times larger for impact vascular plant cover) indicated patchiness in the recovery which is consistent with visual observations. While some areas appear to be near normal, other areas show decreased live cover. Even though some areas remain visibly damaged, especially strangmoor ridges, 76% of the impact plots were within 75% of the mean control plot live cover.

No thaw depths have been recorded during monitoring, and the only areas of obvious thermokarst were near the well head and the trench. The southeast corner of the pad appears to be low, but this low area extends beyond the footprint edge heading northeast and appears to be a normal depression. Rains prior to monitoring on 27–29 July caused extensive areas of standing water and saturated soils within and around the pad footprint. This flooding also appeared normal. There was no obvious increase in ponding or subsidence of the tundra surface within the pad footprint, which would indicate an increased thaw depth. Standing water was more visible within the impact area because of the decreased live vegetation cover and increased barren cover.

The percent of the control live vegetation cover base condition for impact plots (Table 10) meets the 30% to 69% of control live vegetation cover criterion, as stipulated in the Yukon Gold Monitoring Plan (Appendix E). Specifically, impact live cover was 58% of control live cover. Changes in the degree of variability for control plot taxa from 1994 to 1995, complicate use of the base condition. Without the addition of variance to the percent of control, live vegetation cover was 66% in 1995. When the edge zone impact is excluded, percent of control live vegetation increases to 75%.

Reported effects of winter ice roads, winter seismic trails, and snow pads are summarized in Table 11. The most long-lasting effect of these disturbances appears to be increased thaw depth and the flattening of local micro-topography due to compaction. Although thaw depths have not been monitored at the Yukon Gold site, there was no noticeable visual indication that thaw depths have increased. However, the effect of compression on strangmoor ridges remains. These physical changes can result in changes in plant composition due to increased wetness (Walker and Webber 1980). The effects of such changes are apparently more severe in areas with pronounced micro-topography (Brown and Berg 1980).

A second effect of ice road, winter seismic trail, and snow pad construction is direct damage to individual plants, which vary in susceptibility to disturbance (Walker et al. 1987;

Table 11. Reported effects of winter ice roads, winter seismic trails, and snow pads on tundra vegetation at sites in arctic Alaska and Canada.*

Type of Disturbance	Microtopography	Depth of Thaw	Microenvironment	Vegetation Cover	Upright Shrubs (e.g., willows)	Lichens/ Mosses	*C. aquatilis/ E. angustifolium*
Winter Ice Roads	Decrease due to compaction (4)	Increase (5)	Increase in wetness due to compression of microtopography (4); Tussocks compressed and sheared, 4 years recovery, some still dead and damaged (1)	Decrease (5)	Decrease due to broken or abraded terminal stems and wetter microenvironment (1)	Decrease due to compression and wetter microenvironment in tussock tundra, impact expressed 2nd summer post-impact (1)	Little effect or increase due to wetter microenvironment (4)
		Return to preimpact after several years (1)					
Winter Seismic Trails	Trampling and Compaction (1)	Increase (5)	Increase in wetness due to compression of microtopography (3)	With little snow up to 85% cover destroyed (1)	Decrease due to broken terminal stems (3,6)	Decrease due to crushing (3,6)	Little effect or increase due to wetter microenvironment (3)
				Decrease (5)	Moist graminoid sedge/barren complex: Decrease, significant--1 site, Decrease, non-significant--1 site. Regrowth 2 summers after disturbance (3)	Moist graminoid sedge/barren complex: Decrease significant--2 sites (3)	
				Moist Sedge, Control 73-110%, Impact 78-68% (3)			
Snow Pads	Decrease due to abrasion (2)	Increase (1,2)		1st Summer decreased, recover after 3 years (1)	Decrease due to broken terminal stems (1,2)	Decrease due to compression (1)	
				Moist sedge/shrub tundra, 10-20 cm snow depth, 22.7% cover decrease (6)	Moist sedge/shrub tundra, 10-20 cm snow depth, 55.5% shrub cover decrease (6)		

*Sources of information are coded by number: 1. Walker et al. 1987; 2. Brown and Berg 1980; 3. Felix and Raynolds 1989a; 4. Walker and Webber 1980; 5. Brown and Grave 1979; 6. Felix and Raynolds 1989b

Felix and Raynolds 1989a, b). The plants most susceptible to damage are willows and other upright shrubs (Brown and Berg 1980; Walker et al. 1987; Felix and Raynolds 1989a, b), and lichens and mosses (Walker et al. 1987; Felix and Raynolds 1989a, b). Lichens and mosses are apparently very susceptible to compression when frozen (Walker et al. 1987). Vascular plants, such a *C. aquatilis* and *E. angustifolium*, are least affected by compression (Walker et al. 1987; Felix and Raynolds 1989a). Walker et al. (1987) reported that vascular plant cover was reduced during the first growing season following snow pad construction, but had largely recovered after three years. Cover by mosses and lichens was still reduced after three years compared to control plots (Walker et al. 1987).

In contrast to Walker et al.'s (1987) findings for snow pads, the multi-season Yukon Gold ice pad has primarily affected vascular plant cover. Although reduction in vascular plant cover was still apparent at this site two years after the ice pad had melted, new *Eriophorum* and *Carex* seedling growth was evident at impact sites. However, it may take several more years for these seedlings to contribute significantly to live vegetation cover. Forb species had returned to normal levels since 1994, when there were significantly less forbs on impact plots. Shrub vegetation was still significantly reduced on impact plots, especially *D. integrifolia*, which was most often located on strangmoor ridges. We suspect that by the third year, recovery of vascular plants on the Yukon Gold site may not be as complete as observed by Walker et al. (1987) for snow pads, probably due to the impact of the loss of a growing season. Even though no measurable decrease in non-vascular plant cover has been measured at the Yukon Gold site, the visible damage to strangmoor ridges (especially to the mosses) will probably require more than three years for recovery. In contrast to the visible damage to mosses on strangmoor ridges, *S. scorpioides* within the trough areas appeared normal.

CONCLUSIONS

Live vegetation cover, composed primarily of graminoid vegetation, at the Yukon Gold site remained visibly and measurably decreased compared to the surrounding tundra in 1995. The most obvious ice pad impacts were to strangmoor ridges, and at the pad edges. Other impacts from drilling operations effected approximately 9 to 10% of the footprint area. The only obvious increases in thaw depths were associated with the well head and trench. Changes in the degree of variability for control plot taxa from 1994 to 1995, complicate use of the base condition. Without the addition of variance to the percent of control, live vegetation cover was 66% in 1995. When the edge zone impact is excluded, percent of control live vegetation increased to 75%.

New seedling graminoid growth was observed, but these small plants may require a fourth or fifth year to reach a crown size that will contribute to cover density. Forbs have apparently already returned to normal levels within the impact area. Strangmoor ridges may be visibly impacted for a much longer period. In summary, besides the lack of decrease in non-vascular plant cover and lack of evidence for an increased thaw depth found in studies of ice roads, seismic trails and snow pads, the effects of the multi-year Yukon Gold ice pad appear to be similar. In addition, we expect recovery will also be similar, although perhaps requiring several additional years for a comparable recovery, to compensate for the loss of a growing season.

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APPENDIX A. SPECIES LIST FOR YUKON GOLD SITE MONITORING

Table A-1. Plant taxa identified at the Yukon Gold ice pad, Alaska, during vegetation studies conducted summer 1994 and summer 1995. Codes appear in Appendix A and Appendix B tables and were also used during field data collection.

Species or Category	Code
Barren	
Bare Canopy of Ground	BARE
Gravel	GRAV
Dead Plant Material	
Litter	LITT
Standing Dead	STDE
Graminoids	
Carex aquatilis	CAAQ
Carex atrofusca	CAAT
Carex bigelowii	CABI
Carex misandra	CAMI
Carex saxatilis	CASA
Carex sp.	CASP
Eriophorum angustifolium	ERAN
Juncus biglumis	JUBI
Forbs	
Caltha palustris arctica	CAPA
Equisetum variegatum	EQVA
Pedicularis sudetica	PESU
Polygonum viviparum	POVI
Saxifraga hirculus	SAHI
Shrubs	
Dryas integrifolia	DRIN
Salix arctica	SAAR
Salix lanata	SALA
Salix reticulata	SARE
Salix rotundifolia	SARO
Non-Vascular Plants	
Lichens	LICH
Liverworts	LIVE
Mosses	
Bryum pseudotriquetrum	BRPS
Distichium sp.	DISP
Funaria hygrometrica	FUHY
Hypnum bambergeri	HYBA
Oncophorus wahlenbergii	ONWA
Scorpidium scorpioides	SCSC
Tomenthypnum nitens	TONI
Mixture of species	MOMX

APPENDIX B. 1993 YUKON GOLD VEGETATION DATA

Table B-1. Numbers of hits by category for pooled plot comparison (based on a total of 50 hits/plot) for 1993 Yukon Gold site, Alaska.

Plot No.	Carex spp./ Eriophorum angustifolium	Moss spp.	Salix spp.*	Dryas integrifolia	Lichen spp.	Pedicularis sudetica	Potentilla spp.	Polygonum viviparum	Total Living Vegetation	Dead Plant Material	Barren Ground
1a	23	1	0	0	0	0	0	0	24	26	0
2a	8	1	0	0	0	0	0	0	9	32	9
3a	9	9	0	3	13	0	0	0	34	16	0
4a	10	9	0	5	0	0	0	0	24	24	2
5a	9	0	1	0	0	2	0	0	12	29	9
6a	13	0	0	0	0	1	0	0	14	27	9
7a	11	0	2	0	0	0	0	0	13	29	8
8a	8	0	0	0	0	0	0	0	8	35	7
9a	15	2	5	0	0	0	0	0	22	26	2
10a	16	1	0	1	0	0	0	0	18	32	0
11a	2	17	1	8	0	0	2	0	31	14	5
12a	6	4	3	0	0	0	0	0	13	37	0
13a	10	6	3	0	0	0	0	0	19	29	2
14a	12	0	0	0	0	0	0	0	12	26	12
15a	6	4	0	0	0	0	0	0	10	33	7
16a	12	0	0	0	0	0	0	0	12	34	4
17a	6	2	0	0	0	0	0	0	8	28	14
18a	7	7	4	2	0	0	0	0	20	30	0
19a	13	3	0	0	0	0	0	0	16	32	2
20a	8	3	2	0	0	0	0	0	13	37	0
21a	9	3	1	1	0	0	0	0	14	35	1
22a	10	12	1	1	0	0	0	0	24	26	0
23a	11	0	1	0	0	0	0	0	12	36	2
24a	6	15	0	0	0	0	0	0	21	27	2
25a	12	0	3	0	1	0	0	0	16	32	2

*Salix reticulata, S. arctica, S. planifolia pulchra, S. lanata richardsoni

Table B-1. Continued.

Plot No.	Carex spp./ Eriophorum angustifolium	Moss spp.	Salix spp.*	Dryas integrifolia	Lichen spp.	Pedicularis sudetica	Potentilla spp.	Polygonum viviparum	Total Living Vegetation	Dead Plant Material	Barren Ground
1b	11	0	0	0	0	0	0	0	11	38	1
2b	12	0	0	0	0	1	0	0	13	29	8
3b	11	6	3	3	0	0	0	0	23	26	1
4b	9	10	2	2	0	0	0	0	23	27	0
5b	3	13	3	0	0	0	0	0	19	31	0
6b	12	9	0	0	0	1	0	0	22	28	0
7b	8	7	9	1	0	0	0	0	25	25	0
8b	13	0	1	2	0	0	0	0	16	29	5
9b	6	1	1	1	0	1	0	0	10	31	9
10b	10	0	0	0	0	1	0	0	11	33	6
11b	6	9	5	1	0	0	0	0	21	28	1
12b	13	8	0	0	0	0	0	0	21	24	5
13b	14	4	1	0	0	0	0	0	19	31	0
14b	9	6	3	0	0	0	0	0	18	32	0
15b	13	0	0	0	0	1	0	0	14	33	3
16b	10	3	1	2	0	0	0	0	16	27	7
17b	7	5	1	0	0	0	0	0	13	21	16
18b	11	3	0	0	1	0	0	0	15	31	4
19b	11	12	0	0	2	0	0	0	25	20	5
20b	3	6	1	0	0	1	0	0	11	35	4
21b	7	7	0	3	0	0	0	1	18	29	3
22b	10	3	2	4	0	0	0	0	19	29	2
23b	4	12	3	0	0	0	0	0	19	31	0
24b	12	2	1	0	0	0	0	0	15	34	1
25b	9	5	1	1	0	0	0	0	16	30	4

*Salix reticulata, S. arctica, S. planifolia pulchra, S. lanata richardsoni

Table B-2. Numbers of hits by category for paired plot comparison (based on a total of 50 hits/plot) for 1993 Yukon Gold site, Alaska.

Plot No.	Carex spp./ Eriophorum angustifolium	Salix spp.*	Forbs**	Moss spp./ Lichen spp.	Total Living Vegetaton	Dead Plant Material	Barren Ground
1a	23	0	0	1	24	26	0
2a	8	0	0	1	9	32	9
3a	9	0	3	22	34	16	0
4a	10	0	5	9	24	24	2
5a	9	1	2	0	12	29	9
6a	13	0	1	0	14	27	9
7a	11	2	0	0	13	29	8
8a	8	0	0	0	8	35	7
9a	15	5	0	2	22	26	2
10a	16	0	1	1	18	32	0
11a	2	1	11	17	31	14	5
12a	6	3	0	4	13	37	0
13a	10	3	0	6	19	29	2
14a	12	0	0	0	12	26	12
15a	6	0	0	4	10	33	7
16a	12	0	0	0	12	34	4
17a	6	0	0	2	8	28	14
18a	7	4	2	7	20	30	0
19a	13	0	0	3	16	32	2
20a	8	2	0	3	13	37	0
21a	9	1	1	3	14	35	1
22a	10	1	1	12	24	26	0
23a	11	1	0	0	12	36	2
24a	6	0	0	15	21	27	2
25a	12	3	0	1	16	32	2

*Salix reticulata, S. arctica, S. planifolia pulchra, S. lanata richardsoni

**Pedicularis sudetica, Dryas integrifolia, Potentilla spp., Polygonum viviparum

Table B-2. Continued.

Plot No.	Carex spp./ Eriophorum angustifolium	Salix spp.**	Forbs**	Moss spp./ Lichen spp.	Total Living Vegetation	Dead Plant Material	Barren Ground
1b	11	0	0	0	11	38	1
2b	12	0	1	0	13	29	8
3b	11	3	3	6	23	26	1
4b	9	2	2	10	23	27	0
5b	3	3	0	13	19	31	0
6b	12	0	1	9	22	28	0
7b	8	9	1	7	25	25	0
8b	13	1	2	0	16	29	5
9b	6	1	2	1	10	31	9
10b	10	0	1	0	11	33	6
11b	6	5	1	9	21	28	1
12b	13	0	0	8	21	24	5
13b	14	1	0	4	19	31	0
14b	9	3	0	6	18	32	0
15b	13	0	1	0	14	33	3
16b	10	1	2	3	16	27	7
17b	7	1	0	5	13	21	16
18b	11	0	0	4	15	31	4
19b	11	0	0	14	25	20	5
20b	3	1	1	6	11	35	4
21b	7	0	4	7	18	29	3
22b	10	2	4	3	19	29	2
23b	4	3	0	12	19	31	0
24b	12	1	0	2	15	34	1
25b	9	1	1	5	16	30	4

*Salix reticulata, S. arctica, S. planifolia pulchra, S. lanata richardsoni

**Pedicularis sudetica, Dryas integrifolia, Potentilla spp., Polygonum viviparum, Saxifraga hirculus