

Recovery of Tundra Vegetation Three Decades after Hydrocarbon Drilling with and without Seeding of Non-Native Grasses

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APPENDIX 1. List of species observed in our study, organized by family, genus, and species. Average species frequencies for each zone (% occurrence by terrain type and seeding treatment) are given along with the correlations to each NMDS axis (NMDS using both terrain types). An ‘x’ in the NMDS column indicates a species that was removed from this analysis.

	Lowland						Upland						NMDS axes	
	Seeded			Unseeded			Seeded			Unseeded			1	2
	C	P	U	C	P	U	C	P	U	C	P	U		
Equisetopsida														
Equisetaceae														
<i>Equisetum arvense</i> L.	43	58	62	10	17	13	21	25	25	50	58	21	0.01	0.38
<i>E. palustre</i> L.	0	4	0	0	0	0	0	0	0	0	0	0	x	x
<i>E. variegatum</i> Schleich. ex F. Weber & D.M.H. Mohr	0	2	4	3	10	27	0	0	4	4	4	21	-0.2	-0.46
Dicotyledons														
Asteraceae														
<i>Artemisia tilesii</i> Ledeb	25	10	4	13	0	0	29	13	0	8	4	0	0.15	0.41
<i>Aster sibiricus</i> L.	2	10	6	0	0	0	0	0	0	0	0	0	-0.04	0.38
<i>Petasites frigidus</i> (L.) Fries	0	0	0	0	0	0	25	29	4	8	4	25	0.50	-0.34
<i>P. sagittatus</i> (Banks ex Pursh) Gray	0	0	0	0	0	0	0	0	0	0	4	0	x	x
<i>Saussurea angustifolia</i> (Willd.) DC.	0	2	0	3	0	0	0	0	0	0	0	0	-0.05	0.27
<i>Senecio lugens</i> Richards	0	0	0	0	0	0	0	13	13	0	0	0	0.14	-0.22
<i>Tephrosieris atropurpurea</i> (Ledeb.) Holub	0	0	0	0	0	0	0	0	0	0	0	0	x	x
<i>Tripleurospermum maritima</i> (L.) W.D.J. Koch subsp. <i>phaeocephala</i> (Rupr.) Hamet-Ahti	0	0	0	3	3	0	0	0	0	0	0	0	0.09	0.29
Betulaceae														
<i>Alnus viridis</i> (Vill.) Lam. & DC. subsp. <i>crispa</i> (Ait.) Turrill	2	0	0	0	0	0	4	17	4	29	13	63	0.34	-0.43
<i>Betula nana</i> L.	0	2	0	2	0	0	25	46	54	8	17	38	0.59	-0.51
Brassicaceae														
<i>Cardamine digitata</i> Richards	0	0	0	0	2	0	0	0	13	0	0	0	0.06	-0.22
<i>C. pratensis</i> L.	0	0	0	0	22	0	0	0	0	0	0	0	x	x
Caryophyllaceae														
<i>Stellaria longipes</i> Goldie	0	6	2	0	0	0	12	8	21	21	4	4	0.41	-0.44
Empetraceae														
<i>Empetrum nigrum</i> L.	0	0	0	0	0	0	4	33	58	4	8	46	0.50	-0.54
Ericaceae														
<i>Arctostaphylos rubra</i> (Rehd. & Wilson) Fern.	2	0	0	5	0	0	4	4	63	8	13	50	0.39	-0.45
<i>Cassiope tetragona</i> (L.) D. Don	0	0	0	0	0	0	0	0	21	0	0	8	0.18	-0.30
<i>Chamedaphne calyculata</i> (L.) Moench	0	0	0	0	0	0	0	0	4	0	0	4	0.18	-0.35
<i>Ledum palustre</i> L. subsp. <i>decumbens</i> (Ait.) Hultén	0	0	0	0	0	0	0	21	38	0	4	96	0.40	-0.52
<i>Rhododendron lapponicum</i> (L.) Wahlenb.	0	0	0	0	0	0	0	0	4	0	0	0	x	x
<i>Vaccinium uliginosum</i> L.	0	0	0	0	2	0	0	0	38	8	8	50	0.22	-0.40
<i>V. vitis-idaea</i> L.	0	0	2	0	0	0	0	21	58	0	8	46	0.44	-0.47
Fabaceae														
<i>Astragalus alpinus</i> L.	8	0	0	3	0	2	0	0	0	8	17	0	0.12	0.01
<i>Hedysarum alpinum</i> L.	38	23	35	0	2	0	0	0	0	0	0	0	-0.07	0.54
<i>Lupinus arcticus</i> S. Wats.	0	0	0	0	0	0	0	0	13	0	0	4	0.18	-0.29
<i>Oxytropis deflexa</i> (Pallas) DC.	2	0	0	13	0	0	29	0	0	21	21	13	0.54	0.10
Gentianaceae														
<i>Lomatogonium rotatum</i> (L.) Fries ex Fern.	4	2	0	38	5	0	0	0	0	0	0	0	0.15	0.44
Hippuridaceae														
<i>Hippuris vulgaris</i> L.	0	0	0	2	3	8	0	0	0	0	0	0	-0.26	0
Lentibulariaceae														
<i>Pinguicula vulgaris</i> L.	0	0	0	0	0	2	0	0	0	0	4	0	-0.06	-0.30
Onagraceae														
<i>Epilobium angustifolium</i> L. subsp. <i>angustifolium</i>	4	0	2	0	8	10	50	4	0	67	29	8	0.25	-0.36
Polygonaceae														
<i>Polygonum viviparum</i> L.	10	0	2	0	2	10	0	0	21	0	4	33	0.10	-0.42
Pyrolaceae														
<i>Orthilia secunda</i> (L.) House	0	0	0	0	0	0	8	0	13	0	4	4	0.31	-0.23
<i>Pyrola grandiflora</i> Radius	23	6	2	8	2	0	8	0	17	13	8	17	0.35	0.22

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	Lowland						Upland						NMDS axes	
	Seeded			Unseeded			Seeded			Unseeded				
	C	P	U	C	P	U	C	P	U	C	P	U	1	2
Ranunculaceae														
<i>Caltha palustris</i> L.	0	10	0	0	7	3	0	0	0	0	0	0	-0.38	-0.11
<i>Ranunculus cymbalaria</i> Pursh	0	0	0	2	12	7	0	0	0	0	0	0	x	x
Rosaceae														
<i>Dryas integrifolia</i> Vahl.	0	0	0	0	0	0	0	0	34	0	0	34	0.18	-0.35
<i>Rubus chamaemorus</i> L.	4	0	0	0	0	0	0	0	29	0	0	13	0.24	-0.4
Salicaceae														
<i>Salix alaxensis</i> (Anderss.) Coville	46	25	15	42	0	0	8	0	0	13	0	4	0.04	0.68
<i>S. arbusculoides</i> Anderss.	0	0	0	0	2	0	4	0	0	13	17	13	0.24	-0.27
<i>S. arctophila</i> Cockerell ex Heller	2	0	0	15	5	10	0	0	0	0	0	0	-0.14	0.06
<i>S. bebbiana</i> Sarg.	0	4	0	0	0	0	0	0	0	0	0	0	x	x
<i>S. boothii</i> Dorn	0	0	0	2	0	0	0	0	0	0	0	0	x	x
<i>S. fuscescens</i> Anderss.	0	0	0	0	0	0	0	8	4	0	0	0	0.33	-0.33
<i>S. glauca</i> L.	8	4	4	20	10	0	38	13	8	33	33	33	0.56	0.23
<i>S. hastata</i> L.	0	0	0	2	0	0	0	0	0	0	0	0	x	x
<i>S. niphoclada</i> Rydb.	15	2	0	25	5	2	0	0	0	0	0	0	-0.01	0.32
<i>S. planifolia</i> Pursh	0	4	13	0	2	0	33	8	4	0	0	0	0.11	0.11
<i>S. pulchra</i> Cham.	0	0	0	2	0	2	0	8	4	0	8	0	0.31	-0.27
<i>S. reticulata</i> Hook.	0	0	0	0	0	0	0	0	4	0	0	0	x	x
<i>S. richardsonii</i> L.	29	27	35	18	20	60	0	4	4	8	17	29	x	x
Saxifragaceae														
<i>Parnassia palustris</i> L.	48	23	4	37	2	3	25	4	0	0	13	0	0.06	0.48
<i>Saxifraga hirculus</i> L.	0	0	0	0	0	0	4	0	0	4	4	0	0.35	-0.12
Scrophulariaceae														
<i>Castilleja elegans</i> Malte	2	0	0	22	2	0	0	0	0	0	4	0	0.07	0.40
<i>C. raupii</i> Pennell	0	0	0	3	0	0	0	0	0	0	0	0	x	x
<i>Pedicularis capitata</i> M.F. Adams	0	0	0	0	0	0	0	0	8	0	0	0	x	
<i>P. lanata</i> Cham. & Schlecht. subsp. <i>lanata</i>	0	0	0	0	0	0	4	0	13	0	0	4	0.27	-0.25
<i>P. langsdorffii</i> Fisch. ex Stev.	10	8	0	8	10	15	0	0	13	0	0	17	-0.11	-0.23
<i>P. verticillata</i> L.	4	0	0	0	0	0	0	0	0	0	0	0	x	x
Monocotyledons														
Cyperaceae														
<i>Carex aquatilis</i> Wahlenb.	38	52	46	5	68	80	0	21	0	8	46	4	-0.81	-0.42
<i>C. bigelowii</i> Torr. ex Schwein.	0	0	0	5	0	0	25	50	46	4	17	67	0.50	-0.53
<i>C. capillaris</i> L.	4	2	0	5	0	5	0	0	0	0	0	0	-0.07	0.08
<i>C. lugens</i> Holm	0	0	0	0	0	0	0	0	0	8	0	0	x	x
<i>C. microchaeta</i> Holm	0	0	0	0	0	0	0	0	17	0	0	17	0.24	-0.42
<i>Eriophorum angustifolium</i> Honckeney	8	38	42	0	40	52	0	0	0	0	4	13	-0.72	-0.40
<i>E. vaginatum</i> L.	0	0	0	0	0	0	0	0	0	0	0	13	x	x
<i>Kobresia myosuroides</i> (Vill.) Fiori	0	0	0	0	0	0	0	0	13	0	0	0	x	x
Juncaceae														
<i>Juncus arcticus</i> Willd.	0	2	0	0	0	0	0	0	0	13	13	0	0.11	-0.15
<i>J. balticus</i> var. <i>littoralis</i> Engelm.	0	0	0	0	0	2	0	0	0	0	0	0	x	x
Juncaginaceae														
<i>Triglochin palustre</i> L.	0	0	0	0	0	0	8	0	0	0	0	0	x	x
Liliaceae														
<i>Tofieldia pusilla</i> (Michx.) Pers.	0	0	0	0	2	2	0	0	8	0	8	8	0.13	-0.39
Orchidaceae														
<i>Platanthera obtusata</i> (Banks ex Pursh) Lindl.	2	0	0	0	0	0	0	0	0	0	8	8	0.13	-0.22
Poaceae														
<i>Alopecurus pratensis</i> L.	0	0	0	0	7	5	0	0	0	0	0	0	x	x
<i>Arctagrostis latifolia</i> (R. Br.) Griseb.	77	21	13	62	13	3	67	21	29	58	38	13	0.47	0.60
<i>Arctophila fulva</i> (Trin.) Rupr. ex Anderss.	15	2	0	0	0	10	0	0	0	0	0	0	-0.13	0.04
<i>Calamagrostis lapponica</i> (Wahlenb.) Hartman	0	0	0	18	8	3	0	0	0	0	8	0	-0.3	-0.22
<i>C. stricta</i> (Timm) Koel	25	25	19	38	22	10	8	4	0	0	0	0	-0.05	0.53
<i>Deschampsia caespitosa</i> (L.) Beauv.	0	2	4	0	5	2	0	0	0	0	0	0	x	x
<i>Dupontia fisheri</i> R. Br.	0	0	0	0	0	2	0	0	0	0	0	0	x	x
<i>Festuca lenensis</i> Drobow	0	0	0	2	0	0	0	0	0	0	0	0	x	x
<i>F. richardsonii</i> Hook.	44	23	4	35	7	8	8	0	0	0	8	0	x	x
<i>F. rubra</i> L. ¹	8	17	0	2	0	0	21	0	0	4	0	0	0.08	0.13
<i>F. trachyphylla</i> (Hack.) Krajina ¹	2	0	0	0	0	0	0	0	0	0	0	0	x	x
<i>Poa arctica</i> R. Br.	0	0	0	0	0	0	4	4	8	21	13	0	0.29	-0.26
<i>P. glauca</i> Vahl.	4	4	0	0	0	2	0	0	0	17	4	25	0.28	-0.22
<i>P. palustris</i> L.	0	0	0	5	0	2	0	0	0	0	0	0	-0.07	0.24
<i>P. pratensis</i> L. ¹	0	2	0	0	7	0	8	0	0	0	0	0	-0.21	-0.09
<i>P. pseudoabbreviata</i> Rosh.	0	2	0	0	0	0	0	0	0	0	0	0	x	x
<i>Puccinellia agrostidea</i> Sorensen	0	0	0	3	2	0	0	0	0	0	0	0	x	x
<i>P. angustata</i> (R. Br.) Rand & Redf.	0	0	0	0	0	0	0	0	0	0	0	0	x	x
<i>P. arctica</i> (Hook.) Fern. & Weatherby	0	0	0	3	7	7	0	0	0	0	0	0	0	0.21
<i>P. nutkaensis</i> (J. Presl) Fern. & Weatherby	0	0	0	2	5	0	0	0	0	0	0	0	x	x
<i>Trisetum spicatum</i> (L.) Richter	0	0	0	0	0	0	0	0	0	4	8	0	0.12	-0.16

¹ Non-native species.

APPENDIX 2. Axis loadings of environmental and surface cover variables on NMDS 1 and NMDS 2. The r^2 values are Pearson correlation coefficients obtained after 999 permutations. Significance codes: $p < 0.05^*$, $p < 0.01^{**}$.

	Lowlands + Uplands			Lowlands			Uplands		
	NMDS1	NMDS2	r^2	NMDS1	NMDS2	r^2	NMDS1	NMDS2	r^2
Environmental variables:									
Relative elevation	0.56	-0.02	0.31**	0.38	-0.37	0.28*	-0.51	0.14	0.28
Active layer depth	-0.14	-0.43	0.21*	0.08	-0.48	0.23	-0.62	0.41	0.55*
Salinity	-0.05	-0.26	0.07	0.10	-0.32	0.11	-0.46	0.39	0.36
Organic layer depth	0.12	-0.13	0.03	0.18	0.53	0.31**	0.70	-0.27	0.56*
Canopy height	0.24	-0.11	0.07	0.12	-0.46	0.23	-0.23	0.23	0.10
Surface cover variables:									
Total vegetation	-0.13	0.33	0.13	-0.31	-0.22	0.14	0.20	-0.40	0.20
Lichen	0.32	0.53	0.38**	-0.11	-0.27	0.09	0.53	0.20	0.32
Litter	0.12	0.20	0.06	-0.01	-0.31	0.10	0.22	-0.23	0.10
Water	-0.10	0.13	0.03	-0.13	-0.16	0.05	-0.31	0.29	0.18
Bare soil	-0.33	-0.12	0.12	-0.20	0.14	0.06	-0.32	-0.20	0.14
Moss	0.13	-0.41	0.18*	0.34	0.53	0.40**	-0.25	0.04	0.07