Explanation for the maps of the Toolik Lake Area and the Toolik Lake Grid

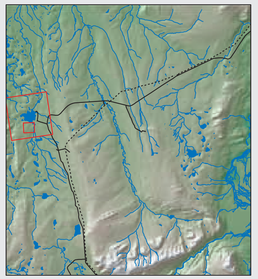


Figure 1. Location of the Toolik Lake Area (large red rectangle) and Toolik Lake Grid (small red rectangle) within the upper Kuparuk River region.

Vegetation of the Toolik Lake Area

Map F is located near the western boundary of Map A (displayed on front) and encloses a 20-km^2 area surrounding Toolik Lake that stretches from the Dalton Highway on the east to Jade Mountain on the west (large red rectangle in Fig. 1). It includes the Toolik Field Station, the old Toolik Lake pipeline construction camp gravel pad and airstrip on the northeast side of the lake and the primary terrestrial research areas on the south, west and east sides of the lake, as well as several smaller research lakes in the immediate vicinity of Toolik Lake. The area contains surfaces with irregular topography that were glaciated during the Late Pleistocene (Fig. 2 and 3).

Map F portrays the physiognomy of the dominant plant communities in each mapped polygon. Fifty-one landcover types (GIS codes are in parentheses in the second column of the legend) were recognized in the field (minimum mapping unit approximately 250 m^2). These were later grouped into the 14 physiognomic vegetation units on the map, which correspond to the same units on the 1:63,360-scale map of the upper Kuparuk River region (Map A).

Vegetation of the Toolik Lake Grid

Map G focuses on the 1.2-km^2 research grid on the south side of Toolik Lake (red rectangle on Map F and small red rectangle in Fig. 1). This area is one of the principal intensive research areas at the Toolik Lake Field Station. It includes many experimental research sites where long-term observations and experiments are being conducted, including the greenhouse and snow-fence experiments (Fig. 6-9). The grid was constructed in 1989 to provide geographic referencing for experimental plots and to provide a sampling scheme for periodic measurements of snow, active layer and plant communities.

Sixty-five plant communities were recognized (minimum mapping unit approximately 2.5 m^2) in the field (GIS codes are in the second column of the legend) and were then grouped into the 24 units appearing on the map. The vegetation units are primarily at the plant-community level (compared to the physiognomic level for the maps of the Upper Kuparuk River Region and the Toolik Lake Area). Several of the dominant plant communities in the Toolik Lake area are shown in the photos (Fig. 10-16). Details of the methods for both maps, sources for aerial photos, orthophoto topographic map, cross-reference to the Braun-Blanquet syntaxonomic plant community names (Walker et al. 1994) and other information are on the Arctic Geobotanical Atlas website, http://www.arcticatlas.org/.

Typical Plant Communities

Figure 10. Sagavanirktok-age glacial surface near Imnavait Creek. The vegetation is tussock tundra (*Eriophorum vaginatum-Sphagnum* spp.), the most common plant community on old, stable, acidic landscapes in the region. This is the dominant plant community in unit four on Maps A, F and G.

Figure 11. Blockfield with *Cetraria nigricans-Rhizocarpon geographicum*, unit two on Map A, F and G.

Figure 12. Close-up of *Carex bigelowii-Dryas integrifolia*, the dominant vegetation on mesic non-acidic tundra sites on Itkillik-age glacial surfaces, unit five on maps A, F and G.

Figure 13. Fen with *Carex aquatilis-C. chordorrhiza*, a major component of unit seven on Map A and F, and unit nine on Map G.

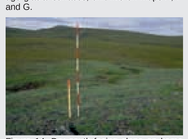


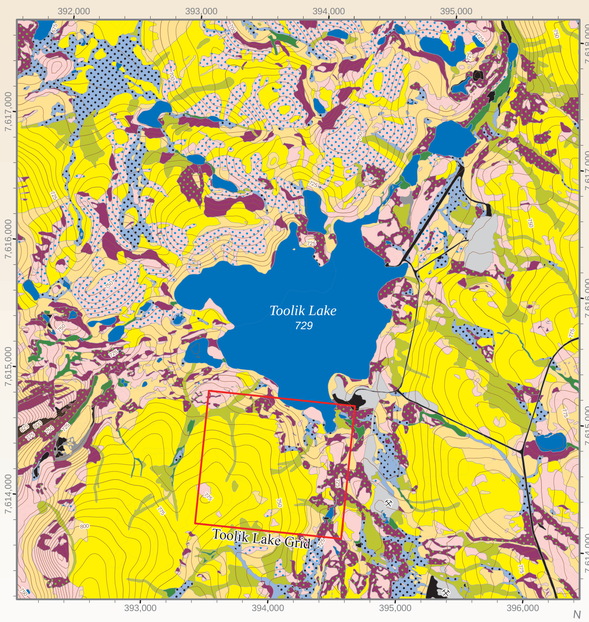
Figure 14. Dry south-facing slope on kame with *Dryas octopetala-Selaginella sibirica*, unit nine on Map A, F, and unit 13 on Map G.

Figure 15. Deep, late-melting snowbed with *Salix rotundifolia* (at stake). Dark-colored vegetation above the stake is *Cassiope tetragona-Dryas integrifolia*, a common component of unit 11 on Map A and F and unit 17 on Map G.

Figure 16. Well-developed water track with *Salix pulchra-Eriophorum angustifolium*, a common component of map unit 14 on Map A and Map F and unit 23 on map G.

All photos are by D.A. Walker except figures 6 and 7 which are courtesy of the Arctic LTER website (http://ecosystems.mbl.edu/ARC/terrest/maps_photos/index.html).

F: Toolik Lake Area Vegetation



Vegetation mapping was performed in 1991 at 1:5,000 scale from 1:5,000 scale base photography acquired in 1990. The map is displayed at 1:20,000 scale.

Physiognomy	Plant Communities (GIS codes)	Typical Microsites	Area (ha)	% of Map
Barren				
1. Barren	Unvegetated (91, 101).	Unvegetated natural and anthropogenic barrens.	23.8	1.2
2. Lichens on rocks	Lichen communities on rocks, including *Cetraria nigricans-Rhizocarpon geographicum* (92).	Xeric blockfields, glacial erratics.	3.9	0.2
3. Partially vegetated barrens and revegetated disturbed areas	Revegetated gravel pads (e.g., *Festuca rubra* or *Salix alaxensis* 102).	Partially vegetated disturbed barrens on gravel pads, abandoned roads, bulldozed areas.	24.9	1.2
Moist graminoid tundra				
4. Tussock sedge, dwarf-shrub, moss tundra	Moist acidic tussock tundra complexes dominated by graminoids. Dominant plant communities include: *Eriophorum vaginatum-Sphagnum* (41) and *Carex bigelowii-Sphagnum* (no code).	Mesic to subhygric, acidic, shallow to moderate snow. Stable slopes. Some areas on steeper slopes with solifluction are dominated by Bigelow sedge (*Carex bigelowii*) (no code).	605.1	29.8
5. Nontussock sedge, dwarf-shrub, moss tundra	Moist nonacidic tundra complexes. Dominant plant communities include: *Carex bigelowii-Dryas integrifolia* (42) and other subtypes of this unit (e.g., *Salix glauca* (33), *Equisetum arvense* and *Cassiope tetragona* (no codes)). Includes some miscellaneous graminoid communities mostly on disturbed areas, such as *Deschampsia caespitosa* (45); *Rumex arcticus-Carex saxatilis* (75) *Salix chamissonis-Carex aquatilis* (65); *Ranunculus pedatifidus-Poa glauca* (104).	Mesic to subhygric, circumneutral, shallow to moderate snow. Solifluction areas and somewhat unstable slopes (42), mainly on Itkillik II glacial surfaces. Some south-facing slopes have scattered glaucous willow (*Salix glauca*) (33). Also includes some miscellaneous graminoid-dominated sites: deep-snow stream margins (65), landslides, some rocky drained lake basins (45, 75) and animal dens (104).	306.8	15.1
Wet graminoid tundra and water				
6. Sedge, moss tundra (poor fens)	Nutrient-poor fen wetland complexes. Dominant plant communities include: Lower microsites: *Eriophorum scheuchzeri-Carex rotundata* (72). Raised microsites: *Sphagnum lenense-Salix fuscescens* (71).	Subhydric to hydric, acidic (pH < 4.5). Wet meadows, poor fens in colluvial basins – mainly on older (Itkillik I) glacial surfaces.	7.8	0.4
7. Sedge, moss tundra (fens)	Nutrient-rich fen wetland complexes. Dominant plant communities include: Lower microsites: *Carex aquatilis-Carex chordorrhiza* (no code); *Eriophorum angustifolium-Carex aquatilis* (82), *Carex aquatilis-Scorpidium scorpioides* (74). Raised microsites: *Trichophorum caespitosum-Tomentypnum nitens* (73) and *Carex bigelowii-Dryas integrifolia* (42). Includes a few other miscellaneous wetland types.	Subhydric to hydric, minerotrophic (pH > 4.5). Water tracks, stream margins, fens, flarks on solifluction slopes – mainly on younger (Itkillik II) glacial surfaces.	105.6	5.2
8. Water and herbaceous marsh	Unvegetated water (84); graminoid marsh *Arctophila fulva* (81) and *Sparganium hyperboreus-Hippuris vulgaris* (83).	Lakes, ponds and streams; aquatic vegetation in some protected sites.	196.5	9.7
Prostrate-shrub tundra				
9. Prostrate dwarf-shrub, fruticose-lichen tundra.	Dry acidic tundra complexes. Dominant plant communities include *Dryas octopetala-Selaginella sibirica* (12), *Arctous alpina-Hierochloë alpina*, typical subtype (14), *Salix phlebophylla* subtype (no code) or *Vaccinium vitis-idaea* subtype (17).	Xeric to xeromesic, acidic, shallow snow. Exposed sites on glacial till, outwash, ridge tops, exposed slopes, dry river terraces.	232.2	11.5
10. Prostrate dwarf-shrub, sedge, forb, fruticose-lichen tundra (nonacidic)	Dry nonacidic tundra complexes. Dominant plant communities include *Dryas integrifolia-Oxytropis nigrescens* (13), *Dryas integrifolia-O. maydelliana* (no code), *Dryas integrifolia-Astragalus umbellatus* (16), *Dryas integrifolia-Dicranum elongatum* (18) and undifferentiated *Dryas* communities (11).	Xeromesic to mesic, nonacidic with shallow snow cover. Exposed sites on dry river terraces, recent alluvium (13); dry microsites in nonsorted-stripe complexes (16, 18). Dominated by *Dryas integrifolia*.	159.5	7.9
11. Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra	Snowbed communities dominated by either *Cassiope tetragona* or *Salix rotundifolia* (20). These communities are not differentiated at this scale, but include *Cassiope tetragona-Carex microchaeta* (acidic sites); *Cassiope tetragona-Dryas integrifolia* (nonacidic sites); *Salix rotundifolia-Scnionia uncinata* (deep snowbeds).	Includes all snowbed types.	93.0	4.6
12. Hemi-prostrate dwarf-shrub, fruticose-lichen tundra	Dry or moist shrublands with very low-growing or creeping dwarf-shrubs. Dominant plant communities include *Betula nana-Hierochloë alpina* (23); *Salix pulchra-Hierochloë alpina* (24); and those dominated by *Ledum palustre* ssp. *decumbens*, *Empetrum nigrum* or *Vaccinium uliginosum* (no codes).	Subxeric to mesic, acidic, with shallow snow. Shallow depressions on dry glacial till or outwash.	121.0	6.0
Erect-shrub tundra				
13. Dwarf-shrub or low-shrub, sedge, moss tundra	Moist acidic tundra complexes dominated by shrubs, including shrubby tussock tundra. Dominant plant communities include *Betula nana-Eriophorum vaginatum* (43) and *Salix pulchra-Carex bigelowii* (44). Also dwarf-shrub tundra dominated by dwarf birch or willows. Dominant plant communities include *Betula nana-Rubus chamaemorus* (51) and *Salix pulchra-Sphagnum* (52).	Mesic to subhygric, moderate snow. Lower slopes and upland water-track margins (43, 52), often with solifluction (44). Or palsas and high-centered polygons (51).	124.3	6.1
14. Low and tall shrublands	A wide variety of low to tall shrublands. Dominant plant communities include those growing in upland water tracks such as *Salix pulchra-Eriophorum angustifolium* (67) and *Eriophorum angustifolium-Sphagnum squarrosum* (66); those growing along streams such as *Salix pulchra-Dasiphora fruticosa* (61) and other low (5122) and tall shrublands (5121); upland shrublands dominated by *Salix glauca* (33) and/or *Alnus crispa* (52) or *Populus balsamifera* (34) and shrublands on river gravels dominated by feltleaf willow (*S. alaxensis*) (63) or lanate willow (*S. richardsonii*) (62).	Low shrubs in upland water tracks (66, 67), streamsides (61, 62, 63) and south facing slopes (52, 34), mesic to subhydric, often with deep snow.	23.2	1.1
		Total	2027.6 ha	100%

Typical landscapes in the Upper Kuparuk River region:

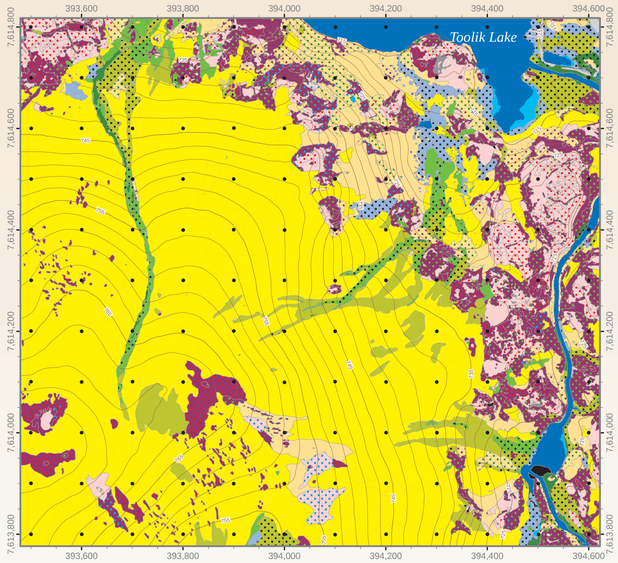
Figure 2. View looking northeast from Jade Mountain across an Itkillik II glacial landscape with numerous glacial lakes, kames and kettles.This landscape is much more vegetatively complex than the Sagavanirktok-age glacial surfaces (Fig. 3).

Figure 3. View looking southeast across the headwaters of Imnavait Creek into the Philip Smith Mountains of the Brooks Range. Vegetation is typical of the Sagavanirktok-age glacial surfaces, which cover large portions of Map A but do not occur on the terrain shown in Maps F and G.

Figure 4. Alpine area on limestone on Peak 1376 in the southeast corner of Map A, looking south into the valley of the Sagavanirktok River. The dominant vegetation is *Dryas integrifolia-Oxytropis nigrescens* (unit 10 on Map A).

Figure 5. Streamside vegetation along the inlet stream to Toolik Lake. The tallest shrubs are *Salix alaxensis*. Low shrubs along the far bank are a mix of *Betula nana* and *Salix pulchra*. The dominant vegetation unit along the stream is low to tall shrublands, unit 14 on Maps A and F, and unit 24 on Map G.

G: Toolik Lake Grid Vegetation



Vegetation mapping was performed in 1991 at 1:500 scale from 1:1,000 scale base photography acquired in 1990. The map is displayed at 1:5,000 scale. The map is presented in the NAD 1927 datum so that the map coordinates will match the labels on the original

Plant Communities (GIS codes)	Description (physiognomy and typical microsite)	Area (ha)	% of Map
Barren			
1. Barren (901)	Unvegetated natural and anthropogenic barrens.	0.16	0.1
2. *Cetraria nigricans-Rhizocarpon geographicum* (902)	Lichen communities on rocks. Xeric blockfields, glacial erratics.	0.11	0.1
3. *Festuca rubra* (903); *Salix alaxensis* (904); *Epilobium latifolium* (905); *Juncus biglumis-Luzula arctica* (no code)	Partially revegetated areas. Gravel pads (903), river gravels (904, 905) and nonsorted circles (no code).	0.23	0.2
Moist graminoid tundra			
4. *Eriophorum veginatum-Sphagnum* (406,407); *Carex bigelowii-Sphagnum* (404, 405)	Tussock sedge, dwarf-shrub, moss tundra (tussock tundra, moist acidic tundra). Mesic to subhygric, acidic, shallow to moderate snow, stable. This unit is the zonal vegetation on fine-grained substrates with ice-rich permafrost (406, 407). Some areas on steeper slopes with solifluction are dominated by Bigelow sedge (*Carex bigelowii*) (404, 405).	65.92	54.2
5. *Carex bigelowii-Dryas integrifolia*, typical subtype (401, 403); *Tomentypnum nitens-Carex bigelowii*, *Salix glauca* subtype (320)	Nontussock sedge, dwarf-shrub, moss tundra (moist nonacidic tundra). Mesic to subhygric, nonacidic (pH > 5.5), shallow to moderate snow. Solifluction areas and somewhat unstable slopes (401,403). Some south-facing slopes have scattered glaucous willow (*Salix glauca*) (320).	7.04	5.8
6. *Carex bigelowii-Dryas integrifolia*, *Equisetum arvense* subtype (402); *Tomentypnum nitens-Carex bigelowii*, *Carex aquatilis* subtype (410)	Nontussock sedge, prostrate dwarf-shrub, horsetail, moss tundra (wetter subtypes of moist nonacidic tundra, often with abundant horsetails). Mesic to subhygric, nonacidic, moderate snow. Seepage areas below snowbeds with abundant horsetails (*Equisetum arvense*) (402) or aquatic sedge (*C. aquatilis*) in wetter areas (410).	2.22	1.8
7. *Carex bigelowii-Dryas integrifolia*, *Cassiope tetragona subtype (208);* or other miscellaneous graminoid plant communities, including *Ranunculus pedatifidus-Poa glauca* (106); *Salix chamissonis-Carex podocarpa* (408); *Festuca altaica-Artemisia arctica* (412); *Poa glauca-Epilobium latifolium* (109)	Sedge, hemi-prostrate dwarf shrub, moss tundra (moist nonacidic tundra in snow accumulation areas). Mesic to subhygric, mostly nonacidic, moderate to deep snow. Inter-stripe areas in nonsorted stripe complexes on upper hill-slopes with moderate to deep snow and abundant Lapland heather (*Cassiope tetragona*). This unit also includes several miscellaneous graminoid, dwarf-shrub, forb communities that cover small areas, including animal dens (106), deep-snow stream and lake margins (106), dry snow accumulation areas (412) and stream banks (109).	1.64	1.3
Wet graminoid tundra and water			
8. *Tricophorum caespitosum-Tomentypnum nitens* (409), *Salix fuscescens-Sphagnum lenense* (411,508), *Carex aquatilis-Sphagnum warnstorfii* (506)	Sedge, prostrate dwarf-shrub, moss tundra. Hygric to subhydric. Hummocks, strangs and raised microsites in fens (409) and poor fens in wet meadows and colluvial-basins (411, 508) and mossy colluvial basin margins (506).	0.32	0.3
9. *Eriophorum angustifolium-Carex aquatilis*, typical subtype (501), *Carex chodorrhiza* subtype (502, 505), *Drepanocladus revolvens* subtype (503); *Carex saxatilis-Carex aquatilis* (504) and *Calliergon giganteum-Drepanocladus revolvens* (507)	Sedge, moss tundra in fens with flowing water. Subhydric to hydric. Lower microsites in colluvial basins, water tracks and stream margins (501, 502, 503, 505), wet pools on solifluction slopes (507).	2.30	1.9
10. Unvegetated water (602)	Hydric. Streams, lakes, ponds.	5.34	4.4
11. *Sparganium hyperboreum-Hippuris vulgaris* (603, 604); *Arctophila fulva* (601)	Herbaceous marsh. Hydric. Water to 1-m deep in lakes and ponds.	0.33	0.3

Plant Communities (GIS codes)	Description (physiognomy and typical microsite)	Area (ha)	% of Map
Prostrate- and hemi-prostrate dwarf-shrub tundra			
12. *Arctous alpina-Hierochloë alpina*, typical subtype (105), *Salix phlebophylla* subtype or *Vaccinium vitis-idaea* subtype (103)	Prostrate dwarf-shrub, fruticose-lichen tundra. Xeric, acidic, shallow snow. Dry acidic tundra on well-drained glacial till, outwash and exposed sites.	5.14	4.2
13. *Dryas octopetala-Selaginella sibirica* (101), *Dryas octopetala-Salix glauca* (102)	Prostrate dwarf-shrub, forb, fruticose-lichen tundra. Xeric, acidic, wind blown or shallow winter snow cover, stony or with considerable bare soil. Ridge crests, dry river terraces. Dominated by *Dryas octopetala* (101), occasionally with *Salix glauca* (102).	3.71	3.1
14. *Dryas integrifolia-Oxytropis maydelliana* (108)	Prostrate dwarf-shrub, forb, fruticose-lichen tundra. Xeromesic to mesic, nonacidic, wind-blown to shallow winter snow cover. Dry slopes, river terraces, drier microsites in nonsorted stripe complexes, dominated by *Dryas integrifolia*.	0.72	0.6
15. *Cassiope tetragona-Carex microchaeta*, typical subtype (202), *Salix glauca* subtype (203)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, acidic, moderately deep snow. Acidic snowbeds (50-150 cm snow).	2.35	1.9
16. *Cassiope tetragona-Calamagrostis inexpansa*, typical subtype (104) or *Vaccinium vitis-idaea* subtype (111); *Cassiope tetragona-Racomitrium lanuginosum* (112)	Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra. Subxeric to mesic, acidic, shallow to moderately deep snow (<1 m deep). Nonsorted stripe complexes with shallow to moderately deep snow (104, 111).	3.54	2.9
17. *Cassiope tetragona-Dryas integrifolia*, typical subtype (113, 204, 205)or *Boykinia richardsonii* subtype (206). Includes *Salix rotundifolia-Sanionia uncinata* (207)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, nonacidic, moderately deep snow. Nonacidic snowbeds (50-150 cm snow) (113, 204, 205). Also includes deep (>3 m snow) well-drained snow-beds with *Salix rotundifolia* (207).	1.39	1.1
18. *Betula nana-Hierochloë alpina* (302, 303), *Vaccinium uliginosum-Arctous alpina* (110); or *Ledum palustre* ssp. *decumbens-Empetrum nigrum* (201)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, acidic, moderately deep snow. Depressions on glacial till or outwash (302, 303); warm snowbeds (201). Very low-growing hemi-prostrate dwarf-birch (*Betula nana*) (302, 303) or erect dwarf blueberry (*Vaccinium uliginosum* ssp. *microphyllum*) (110) or Labrador tea (*Ledum palustre* ssp. *decumbens*) (201).	7.47	6.1
Erect-shrub tundra			
19. *Betula nana-Eriophorum vaginatum* (308)	Dwarf-shrub, sedge, moss tundra (shrubby tussock tundra dominated by dwarf birch, *Betula nana*). Mesic to subhygric, acidic, moderate snow. Lower slopes and water-track margins. Mostly on Itkillik I surfaces.	3.75	3.1
20. *Salix pulchra-Carex bigelowii* (312, 325)	Dwarf-shrub, sedge, moss tundra (shrubby tussock tundra dominated by diamond-leaf willow, *Salix pulchra*). Subhygric, moderate snow, lower slopes with solifluction.	3.59	3.0
21. *Betula nana-Rubus chamaemorus*, dwarf-shrub variant (306, 307) and *Cladonia arbuscula* variant (304)	Dwarf-shrub, moss tundra dominated by dwarf birch (*Betula nana*). Subhygric to hygric, acidic, moderate to moderately deep snow. Upland water tracks, margins of water tracks and lower slope areas (306, 307). Somewhat drier areas have abundant lichens (304).	2.08	1.7
22. *Salix pulchra-Sphagnum warnstorfii* (310, 311)	Dwarf-shrub or low-shrub tundra dominated by willows (*Salix pulchra*). Subhygric, acidic, moderate to moderately deep snow. Margins of upland water tracks, palsas and high-centered polygons.	1.36	1.1
23. *Salix pulchra-Eriophorum angustifolium* (314, 315, 318); or *Salix pulchra-Calamagrostis canadensis* (316)	Low shrublands (generally 40-100 cm tall). Subhydric to mesic, moderate to deep snow. Deeper upland water tracks with flowing water (314, 315) or riparian areas along major streams (316).	0.74	0.6
24. *Salix alaxensis* (323, 324) or *S. richardsonii* (319) (tall shrubs)	Tall shrublands (> 2 m tall). Subhydric to mesic, nonacidic, moderate to deep snow. Stream margins dominated by tall willows, *Salix alaxensis* (323, 324) and/or *S. richardsonii* (319).	0.21	0.2
	Total	121.66 ha	100%

Research within the Toolik Lake Grid:

Figure 6. Long-term experiments within the Toolik Lake grid, aerial view showing boardwalks, greenhouses (white structures) and shadehouses (black structures).

Figure 7. Experimental greenhouse with the side and top opened to show enhanced growth due to added warmth. Pre-treatment shrubs were same height as vegetation in the foreground.

Figure 8. Snowfence experiment within the Toolik Lake Grid, summer view showing fence, snow-depth monitoring stakes, and small open-top greenhouses.

Figure 9. Winter view of snowfence experimental area showing the drift that forms behind the fence. Tall stakes are the same as striped stakes in Figure 8.

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