2016 Habitat Monitoring and Assessment
CD5 Development Project

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Prepared for
ConocoPhillips Alaska, Inc.
Anchorage, Alaska

Prepared by
ABR, Inc.—Environmental Research & Services
Fairbanks and Anchorage, Alaska

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EXECUTIVE SUMMARY

This report presents the results of the 2016 CD5 Habitat Monitoring Study, a long-term monitoring study designed to monitor and assess potential changes in habitat related to the CD5 Development Project on a portion of the Colville River Delta (CRD) in northern Alaska. The CD5 Habitat Monitoring Study is one component of a broader long-term Monitoring Plan with an adaptive management strategy that is being implemented by ConocoPhillips Alaska, Inc. (CPAI) as a condition on their CD5 development permit, USACE Permit POA-2005-1576. The specific objectives of the 2016 CD5 Habitat Monitoring Study were to: 1) conduct the first year of post-construction data collection and monitoring of climate and habitat in the CD5 Habitat Monitoring Study Area; 2) analyze and summarize 2016 field data with respect to the 2013 baseline data; 3) update the Integrated Terrain Unit (ITU) mapping in the CD5 Habitat Monitoring Study Area, based on 2015 high-resolution aerial imagery and 2016 field data; and 4) prepare a summary report and present findings at an agency and stakeholder meeting in February 2017.

The 2016 CD5 Habitat Monitoring Study includes two components: local climate monitoring and habitat monitoring. For each of these components, ABR collected and assessed the first year of post-construction data and compared these data with the baseline data collected in 2013 to assess potential ecosystem changes associated with the CD5 Project. For climate monitoring, the Alpine weather station was installed on 10 May 2013 by Polar Alpine, Inc. Climate parameters monitored include wind speed and direction, incoming solar radiation, air temperature, snow depth, precipitation, and barometric pressure. ABR summarized the climate data collected from May through September, 2013–2016, as these are the months during which the habitat monitoring field work occurred. Snowfall and snow depth data was also summarized for the winter months preceding field work.

For the habitat monitoring component, ABR completed several tasks. Habitat-monitoring field surveys were conducted 16 July–7 August 2016 during which habitat-monitoring locations were accessed via helicopter, inflatable boat, and by foot. ABR located the permanent Integrated Monitoring plots, originally established in 2013, and 1) sampled the vegetation at each plot using the point-intercept method, and 2) measured soil and environmental parameters. Elevation and thaw depth surveys were conducted during the second and third weeks of July 2016 to assess potential changes in thaw depth and ground surface elevation through time, as per the Monitoring Plan.

The baseline map Integrated Terrain Unit (ITU) mapping was updated using high-resolution imagery acquired 3–5 July 2015. The updated mapping was then used to perform a landscape change analysis as indicated in the Monitoring Plan. This first ecosystem map update and associated landscape change analysis showed that, apart from the expected landscape changes related to the direct placement of the CD5 development infrastructure, the changes documented were localized and consistent with the natural changes known to occur in deltaic environments elsewhere on the CRD.

ABR performed a wildlife habitat analysis, as per the Monitoring Plan, that generated mean, 75%, and 95% confidence intervals for percent cover of wildlife habitat structure classes in the CD5 Study Area. The cover data were generated for 2013 and 2016 in both Test and Reference Areas, and a repeated measures analysis was performed to test for interaction effects of year and Area on cover percentage. The habitat assessment showed a decrease in percent cover of standing water and an increase in mineral soil and mosses in 2016 when compared to 2013 in both Reference and Test Areas. The observed differences in standing water and water table depth between 2013 and 2016 are attributed to the warmer temperatures, a shallower snowpack, earlier snow melt, higher evapotranspiration, and lower July precipitation in 2016 when compared to 2013. In addition, the break-up flooding in spring 2016 was relatively benign, resulting in the majority of the CD5 Study Area not flooding.

The vegetation plot assessment data analysis methods follow directly from the Monitoring Plan. Specifically, vegetation data from both Test and References Areas in 2016 were ordinated with the 2013 data to determine if a shift in species composition had occurred in the intervening time period. The vegetation assessment found that 96%

of Vegetation Plots (171 plots) had not changed in species composition between 2013 and 2016, with the remaining 4% of the Vegetation Plots (8 plots total) showing a change between years. Of the 8 plots that showed changes in species composition, the change at the 2 plots located in the Reference Areas was attributed to natural changes in species composition. The changes at 3 plots in the Test Area were attributable to increases in the cover of sedges in 2016, an indicator of increased productivity. The changes at the remaining 3 plots were related to either increases or decreases in willow (*Salix* sp.) and sedge (*Carex* sp. and *Eriophorum* sp.) and increases and decreases in the number species detected at the plots. In summary, the total number of Vegetation Plots identified as having changed in species composition between 2013 and 2016 is very small (<5% of the total plots), the plots were located in both the Test and Reference Areas, and the plots were not specific to any single plot ecotype.

Changes in species richness between ecotypes, years, and Areas were relatively small and within the range of variability, based on the standard deviation. Changes in vegetation structure classes were also generally consistent between ecotypes, Areas, and years. In general, total live cover increased between 2013 and 2016, a change driven largely by an increase in the cover of mosses and sedges in several ecotypes.

To assess sedimentation and erosion rates along Monitoring Transects, we calculated the average and 95% confidence intervals (CI) for surface organic thickness in the Test and Reference Areas by year for the most common surface terrain units and used these data to compare changes in surface organic thickness through time, as per the Monitoring Plan. Average surface organic thickness was greatest in Delta Abandoned Overbank Deposits, moderately thick in Delta Inactive Overbank Deposits, and thinnest in Delta Active Overbank Deposits. This pattern held true for Reference and Test Areas in both study years. For surface terrain units Delta Abandoned Overbank Deposit and Delta Active Overbank Deposit in the Test Area, average surface organic thickness overlapped the 95% confidence intervals of the corresponding surface terrain unit in the Reference Area in both years.

The results of the 2016 Habitat Monitoring effort showed very little ecosystem change between 2013 and 2016. Broad-scale changes that were significant between years, including the decrease of standing water cover and increase in mineral soil cover, were observed in both Reference and Test Areas and hence not attributable to the CD5 Road. Rather, differences in broad-scale climatic factors and break-up flooding between 2013 and 2016 are the primary causal factors leading to the differences observed.

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ACKNOWLEDGMENTS

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1.0 INTRODUCTION

1.1 BACKGROUND

As a condition of the permit to develop CD5 in the Northeast National Petroleum Reserve-Alaska (NE NPRA) and associated infrastructure on the Colville River Delta, the U.S. Army Corp of Engineers (USACE) stipulated that ConocoPhillips Alaska, Inc. (CPAI) implement a monitoring plan with an adaptive management strategy (POA-2005-1576). The monitoring plan with an adaptive management strategy (Monitoring Plan) was developed to monitor changes in site conditions and the efficacy of the proposed mitigation measures (ABR and Baker 2013). The Monitoring Plan commits CPAI to 1) develop a monitoring program prior to construction; 2) prepare monitoring reports on a variety of monitoring components (see below) for review by key stakeholders; and 3) meet with federal agencies annually to review the monitoring reports and the effectiveness of current mitigation measures.

1.2 MONITORING PROGRAM GOALS AND OBJECTIVES

As a result of 4 decades of development activities in North Slope wetlands, rivers, and streams, and more than 10 years of oil and gas extraction in the Colville River Delta, impacts resulting from gravel placement on tundra and in the Colville River Delta and bridges across rivers and streams are well understood. Those impacts have prompted CPAI operations to implement mitigation measures for the CD5 Project in consultation with federal agencies.

The goals and objectives presented here follow the Monitoring Plan with an Adaptive Management Strategy for the CD5 Development Project, dated March 2013 (ABR and Baker 2013). The CD5 Monitoring Plan's goal is to monitor for changes in site conditions and selected resources and to modify, if appropriate, operational practices to minimize impacts on the hydrologic function of the Colville River Delta as a result of road, bridge, and pad construction. As discussed with federal agencies in meetings during 2011, an outline of the Monitoring Plan and a table summarizing the Plan's monitoring components were provided to the USACE in a letter dated 23 November 2011. Subsequent discussions and correspondence through 30 August 2012 resulted in the following list of studies to be included in the Monitoring Plan:

- Habitat Monitoring (climate, vegetation, geomorphology, sedimentation, and permafrost)
- Hydrology Monitoring
- Erosion-Control Monitoring
- Culvert Monitoring
- Bridge Monitoring (Niġliq and Niġliagvik Bridges)

This report presents the results of the habitat monitoring component (herein, CD5 Habitat Monitoring Study) of the overall CD5 Monitoring Plan. As described in the CD5 Monitoring Plan (ABR and Baker 2013), the overall goals of the CD5 Habitat Monitoring Study include 1) determine if placement of gravel results in alteration to wildlife habitat upstream and/or downstream of the CD5 road; 2) quantify vegetation communities and habitat in permanent plots established upstream and downstream of the road to identify changes through time based on comparison to baseline data; 3) monitor permanent plots beginning the year before and immediately following construction and every 5 years thereafter to evaluate and identify changes in vegetation, wildlife habitat, geomorphology (soils, permafrost, thaw depth), and sedimentation/ erosion over time; and 4) through periodic monitoring of vegetation and hydrology, identify intermediate trends of change that corroborate sedimentation and erosion predictions, to the extent possible.

The 2016 effort was focused on collecting the first year of post-construction data, and comparing these data with the baseline data collected in 2013 to assess potential ecosystem changes associated with the CD5 Project. The specific objectives of the 2016 CD5 Habitat Monitoring Study were to:

1. Conduct the first year of post-construction data collection and monitoring of climate and habitat in the CD5 Habitat Monitoring Study Area;

2. Analyze and summarize 2016 field data with respect to the 2013 baseline data, update the Integrated Terrain Unit (ITU) mapping in the CD5 Habitat Monitoring Study Area, based on 2015 high-resolution aerial imagery and 2016 field data; and prepare summary reports and maps; and
3. Present findings at an agency and stake-holder meeting in February 2017.

1.3 CD5 HABITAT MONITORING STUDY AREA

1.3.1 DESCRIPTION

This study focuses on the CD5 Habitat Monitoring Study Area, which is located along the Niġliq Channel in the southwestern portion of the Colville River Delta (CRD) on the North Slope of Alaska (Figures 1.1 and 1.2). The Alpine Oil Facilities are located directly east of the CD5 Habitat Monitoring Study Area, and the village of Nuiqsut, established in 1971, is located several kilometers to the south of the CD5 Habitat Monitoring Study Area. For a detailed description of the climate and environment of the CRD, see Wells et al. (2014).

The CD5 Habitat Monitoring Study Area has been partitioned into 4 subareas, including Test and Reference Areas (Figure 1.2). The "Test" Areas include the general area directly upstream along the Niġliq Channel (Test Area South) and downstream along the Niġliq Channel (Test Area North) with the CD5 road as the dividing line (within approximately 1.9 km). ABR and Baker (2011) predicted this area could be affected by moderate and high changes in sedimentation and erosion regime during a 200-year flood. The "Reference" Areas were located approximately 3–5 km upstream (Reference Area South) and downstream along the Niġliq Channel (Reference Area North) from the proposed CD5 road and were predicted by ABR and Baker (2011) to be unaffected by the proposed development.

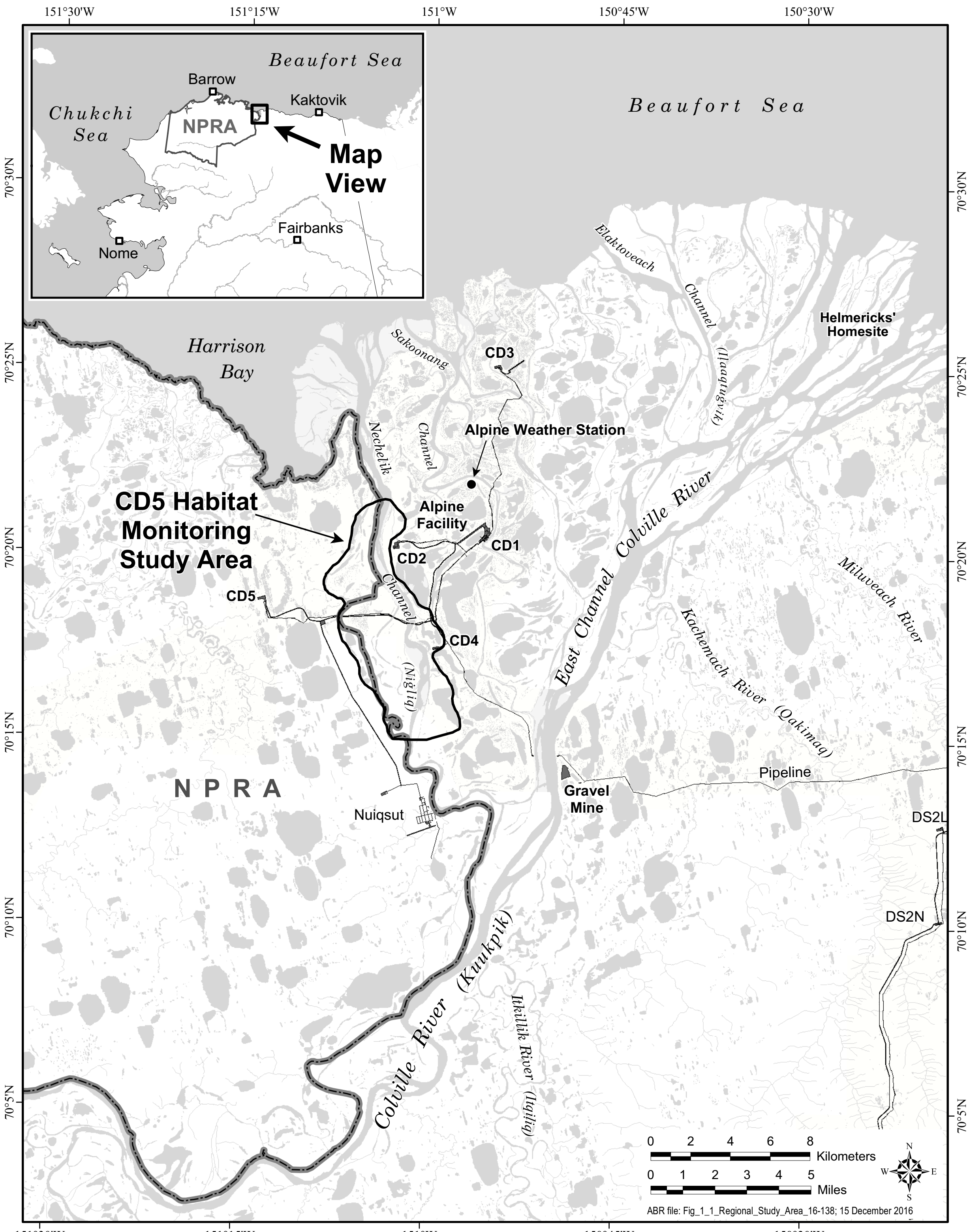

Figure 1.1. Overview map showing the location of the CD5 Habitat Monitoring Study area on the Colville River Delta, northern Alaska, 2013 and 2016.

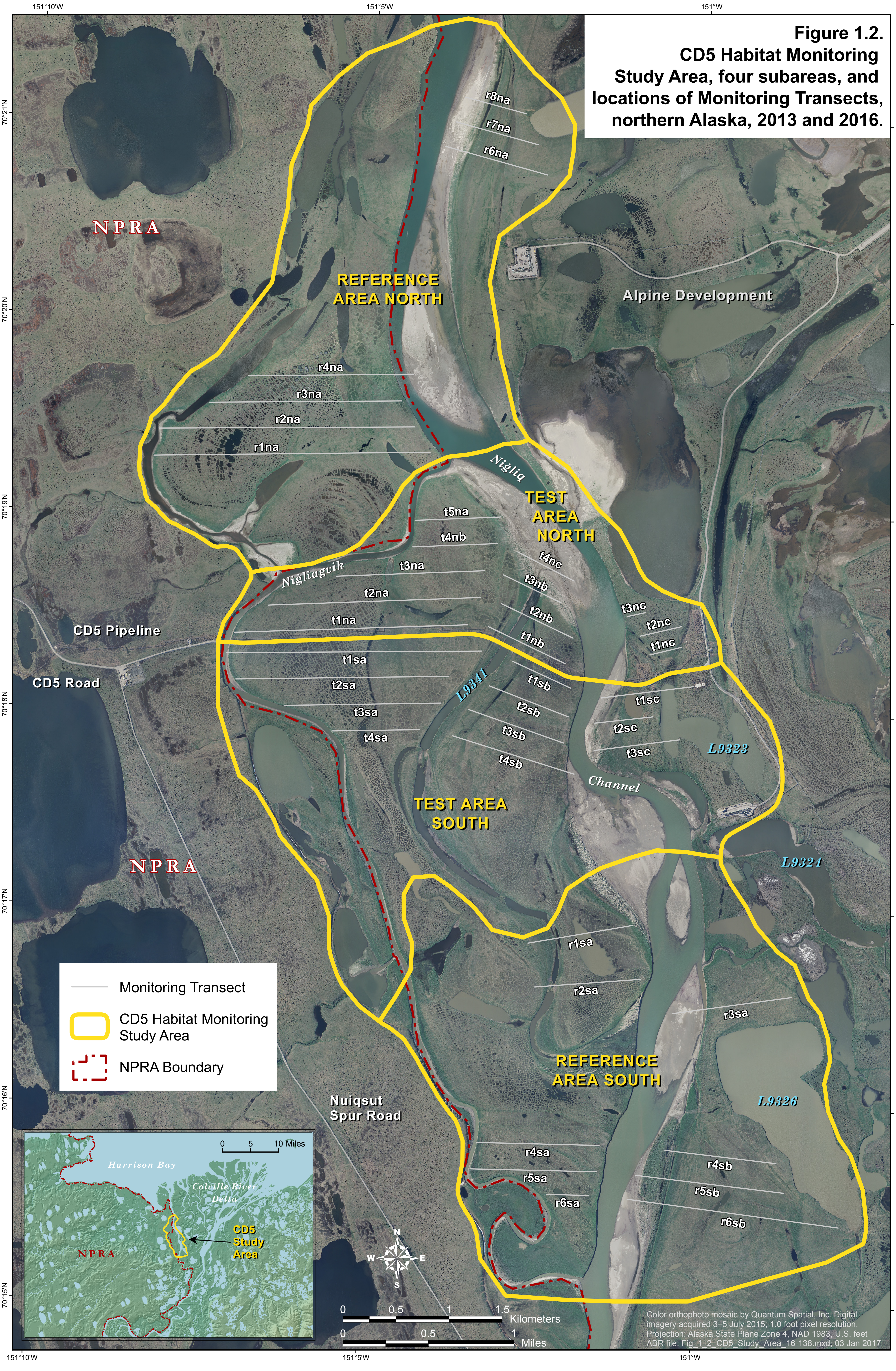

Figure 1.2.
CD5 Habitat Monitoring Study Area, four subareas, and locations of Monitoring Transects, northern Alaska, 2013 and 2016.
151°10'W
151°5'W
151°W
70°21'N
70°20'N
70°19'N
70°18'N
70°17'N
70°16'N
70°15'N
NPRA
REFERENCE AREA NORTH
TEST AREA NORTH
TEST AREA SOUTH
REFERENCE AREA SOUTH
Alpine Development
Nigliq
Nigliagvik
Channel
CD5 Pipeline
CD5 Road
Nuiqsut Spur Road
L9341
L9323
L9324
L9326
r8na
r7na
r6na
r4na
r3na
r2na
r1na
t5na
t4nb
t4nc
t3na
t3nb
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t2nb
t1na
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t2sa
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t4sa
t4sb
r1sa
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r3sa
r4sa
r5sa
r6sa
r4sb
r5sb
r6sb
Monitoring Transect
CD5 Habitat Monitoring Study Area
NPRA Boundary
Harrison Bay
Colville River Delta
CD5 Study Area
0 5 10 Miles
N
S
E
W
0 0.5 1 1.5 Kilometers
0 0.5 1 Miles
Color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 3–5 July 2015; 1.0 foot pixel resolution.
Projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet
ABR file: Fig_1_2_CD5_Study_Area_16-138.mxd; 03 Jan 2017

2.0 CLIMATE MONITORING

2.1 RATIONALE

Weather and climate are strongly linked to several components of the CD5 monitoring effort, including the timing and magnitude of spring breakup flooding, groundwater and surface water levels, annual vegetation cover, permafrost active-layer thickness, and soil temperature. Also, given the long-term timeframe of the Habitat Monitoring study, naturally occurring climate variability may play a role in the outcome of monitoring efforts.

2.2 METHODS

2.2.1 DATA ANALYSIS

Climate data from the Alpine Weather Station (Wells et al. 2014) were summarized for May through September, 2013–2016, as these are the months during which the Habitat Monitoring field work occurred. Snowfall and snow depth data was also summarized for the winter months preceding field work. Hourly data were tabulated and summarized using R, an open-source language and environment for statistical computing (R Core Team 2016). Before producing daily summaries, hourly data were checked to confirm that each day had 24 valid observations for the parameters of interest and that there were the correct number of days when aggregating to the month. The station was not installed until 10 May 2013, so the May data are incomplete for the first year of the study.

Hourly temperature observations were aggregated to daily minimum, maximum and average temperatures. Hourly wind measurements were categorized as calm (wind speed <1 meter per second [mps]), low (1–5 mps), moderate (5–10 mps), or high (>10 mps), and placed into 22.5 degree directional bins for analysis. Hourly precipitation was aggregated to daily precipitation by calculating daily sums. The first snow-free date in spring was estimated by finding the first day of the year where the recorded snow depth was zero or negative. Because of the relatively low quality of the snow depth data, these values were compared with snow depth data at nearby stations (see below). Finally, daily data were broken down into monthly periods for analysis.

Winter snowpack was estimated by finding the 95th percentile of snow depth data during the winter months prior to the 2016 field season and compared with similarly aggregated snow depth and cumulative snowfall data from nearby stations. The 95th percentile for snow depth was chosen in order to get a maximum winter-season value that compensates for the rapid settling of fresh snow after a storm.

We also examined daily temperature, precipitation, snowfall, and snow depth data for nearby weather stations from the Global Historical Climatology Network (NCEI 2016), including the Alpine Airport (7 km northeast of the CD5 Study Area), Nuiqsut Airport (10 km south), and the station at Colville Village (28 km northeast). To help place the observed conditions in context, we compared these data with 1981–2010 climate normals (Arguez et al. 2010) calculated for Colville Village (NCEI 2010).

Moisture conditions during the growing season are influenced both by precipitation and evaporative demand. Therefore, Reference Evapotranspiration was estimated using the Penman–Monteith equation (Allen et al. 1998). Daily minimum and maximum temperature, wind speed, and solar radiation data from the Alpine Weather Station were used in the calculation. Actual vapor pressure was estimated for each day using the minimum daily temperature because relative humidity and dewpoint data are not collected at the site.

2.3 RESULTS AND DISCUSSION

2.3.1 TEMPERATURE AND PRECIPITATION

Daily temperature and precipitation for the 2013 and 2016 summer are presented in Figure 2.1. The 2016 thaw-season started in early May with a week of above average, and above freezing temperatures that resulted in an early melt-off of the snowpack. The Alpine Weather Station was snow-free by 11 May 2016, more than two weeks earlier than in 2013 (Table 2.1). This was also the earliest snow-free date ever recorded at the Colville Village station, which has snow-depth records going back to 1997. Despite the early warming, late May and early June temperatures in 2016 were close to normal; the average May temperature was comparable to 2013 as well as the

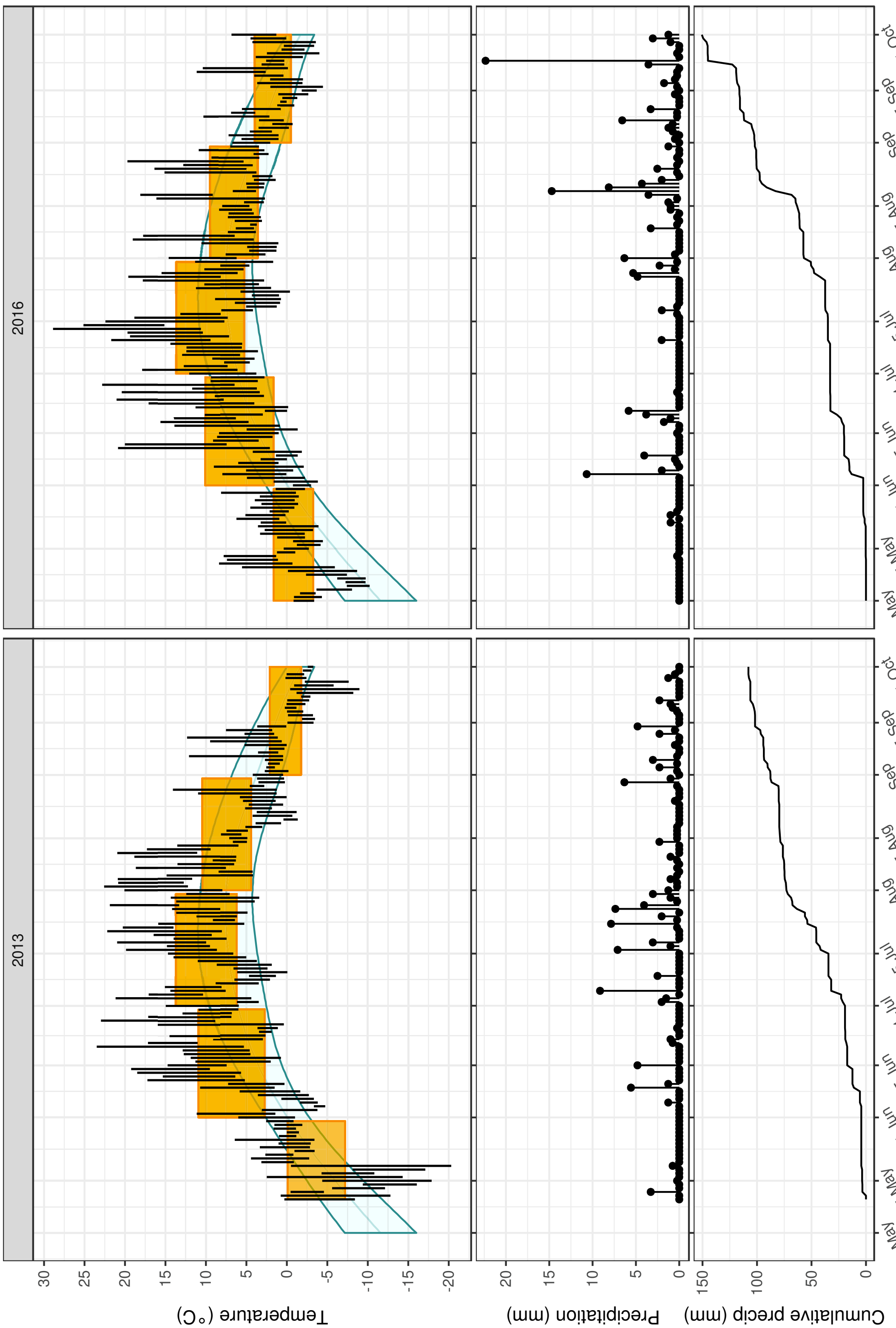


Figure 2.1. Charts summarizing temperature and precipitation data from the Alpine weather station, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. (Top) daily minimum and maximum temperature (black bars), monthly average high and low temperature (orange boxes), and 1981–2010 Climate Normal temperatures for the Colville River weather station (light blue). (Middle) Daily precipitation (mm). (Bottom) Cumulative precipitation from 1 May–1 October.

Table 2.1. Spring snow free date at the Alpine Weather Station and two other long term stations, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2016.

Year	Alpine Weather Station	Alpine	Colville Village
2013	2013-05-28	2013-06-08	2013-06-05
2014	2014-06-10	2014-06-06	2014-06-01
2015	2015-05-24	2015-05-26	2015-05-22
2016	2016-05-11	2016-05-10	2016-05-14

four-year average (Figure 2.2). Daily maximum temperatures were above 20° C for 9 days in 2016 (12 days in 2013), and reached 28.9° C on 13 July, three degrees higher than the next highest maximum at the site (data collected 2013–2016). This was also the warmest date on record at the three nearest stations with longer records: 28.9° C at Alpine Airport (2011–2016), 28.9° C at Nuiqsut Airport (1998–2016), and 28.3° C at Colville Village (1996–2016). August temperatures were close to normal in 2016 and September was slightly warmer than normal. Freeze-up in 2016 was 28 days later than in 2013, when there was a sharp drop in temperature on 15 September. Average temperatures in 2016 remained above freezing into October.

Total summer rainfall in 2016 was 150.6 mm, significantly higher than the 107.9 mm that fell in 2013 and exceeding the four-year average of 112.4 mm (Table 2.2). July was the driest of the summer months in 2016; most of the precipitation came in August and September. In contrast, the monthly pattern in 2013 was almost the opposite of 2016; almost half the summer precipitation fell in July. The 1981–2010 climate normal summer precipitation total for the Colville Village station is 84.1 mm; totals observed at this station in 2013 and 2016 were 125.5 mm and 147.1 mm, respectively.

2.3.2 WIND

Winds in the CD5 Study Area are predominantly east-north-easterly for all of the summer, except in September when winds also come from the west-southwest (Figure 2.3). Winds in 2016 mostly followed this pattern except in June, when the wind was often north-westerly, and in September when the prevailing winds were from the southwest and west-southwest. Wind speeds in 2016 were usually in the low category, with well over half of all observations between 1–5 mps (Table 2.3). In May, however, the frequency of medium wind speeds was slightly higher than normal.

2.3.3 WINTER SNOWPACK

The 2015–2016 winter snowpack depth in the CD5 Study Area was lower than in any other year of the study (2013–2016) (Table 2.4); snowpack depth and cumulative snowfall during the winter season at the Colville Village station were also significantly lower. The 1981–2010 climate normal cumulative winter snowfall at Colville Village is 1,453 mm, and 967 mm was observed during the 2015–2016 winter. In contrast, 2012–2013 cumulative winter snowfall was above normal at 1,878 mm.

2.3.4 WATER BALANCE

Evapotranspiration rates in 2016 were near average for all summer months except July, when the Reference Evapotranspiration rate was 2.81 mm per day compared with a four-year average rate of 2.41 mm per day (Table 2.5). Overall evapotranspiration rates for May–August were slightly lower in 2016 (2.03 mm per day) than in 2013 (2.17 mm per day).

The combination of a shallow snowpack, early snowmelt, lower than normal precipitation through July, extreme high temperatures in mid-July, and relatively higher July evapotranspiration rates likely contributed to drier soil moisture conditions in 2016 compared with 2013. These instrumental measurements were corroborated by field observations made during the habitat monitoring field effort in July and August 2016.

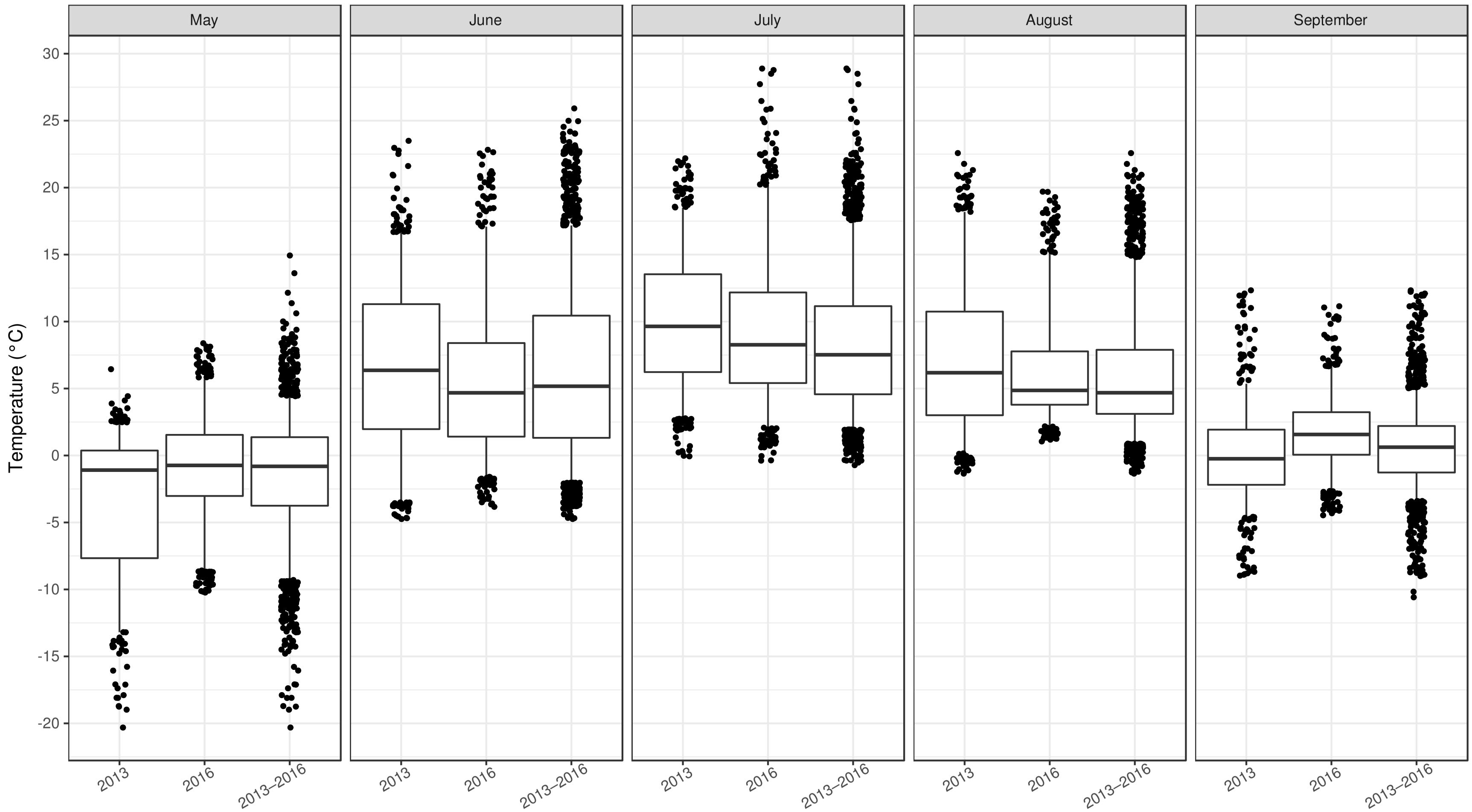


Figure 2.2. Boxplots summarizing monthly temperature distribution for the months May through September, 2013, 2016 and all years, Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2016. Boxes represent the 25%–75% quartiles, the horizontal line through each box is the mean value, lines above and below the boxes extend to 5% and 95%, and the dots represent the remaining extreme temperatures.

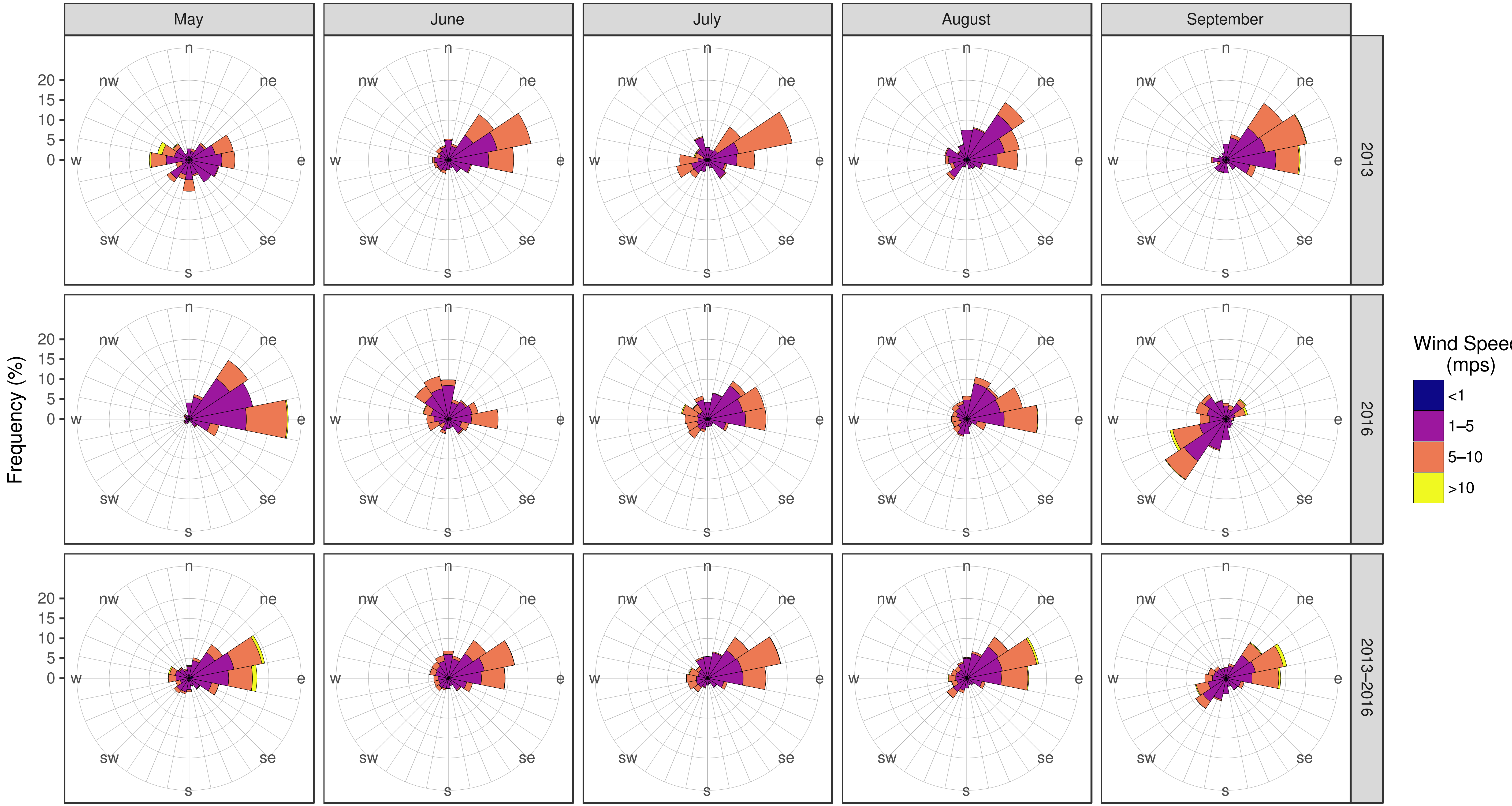


Figure 2.3. Charts summarizing monthly wind speed and direction for the months May through September, 2013, 2016, and all years, Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Table 2.2. Monthly summer precipitation totals in mm for 2013 and 2016 and average monthly totals (2013–2016), Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Period	2013	2016	2013–2016
May	4.3	2.5	5.2
June	15.0	30.4	20.0
July	52.5	17.7	25.1
August	15.9	51.4	36.7
September	20.2	48.6	25.4
TOTAL	107.9	150.6	112.4

Table 2.3. Categorized wind speed frequency (%) by month for 2013, 2016, and average for 2013–2016, Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Period	Calm (<1 mps)	Low (1–5 mps)	Medium (5–10 mps)	High (>10 mps)
May 2013	3.1	71.1	24.1	1.7
May 2016	1.9	66.9	30.4	0.8
May 2013–2016	4.7	67.5	25.5	2.3
June 2013	4.2	69.2	26.7	0.0
June 2016	1.9	70.3	27.6	0.1
June 2013–2016	3.3	67.7	28.9	0.1
July 2013	2.8	58.7	38.2	0.3
July 2016	3.8	66.8	29.0	0.4
July 2013–2016	3.3	66.1	30.2	0.4
August 2013	6.6	76.9	16.5	0.0
August 2016	3.8	67.7	28.1	0.4
August 2013–2016	4.0	66.9	28.2	1.0
September 2013	4.4	67.9	27.2	0.4
September 2016	4.4	68.5	25.3	1.8
September 2013–2016	5.0	64.5	28.7	1.8

Table 2.4. Maximum snow depth (95th percentile, mm) at the Alpine Weather station and the Colville Village station, cumulative winter snowfall (mm) and 1981–2010 climate normal cumulative winter snowfall at Colville Village, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2016.

	Alpine Weather Station	Colville Village Station		
Winter Year	Snowpack (mm)	Snowpack (mm)	Cumulative Snowfall (mm)	Climate Normal Cumulative Snowfall (mm)
2012–2013		305	1878	1453
2013–2014	415	305	1362	1453
2014–2015	352	279	1765	1453
2015–2016	156	203	967	1453

Table 2.5. Average daily reference evapotranspiration (mm per day) by month for 2013, 2016, and average for 2013–2016, Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Period	2013	2016	2013–2016
May	1.51	1.26	1.37
June	2.73	2.60	2.58
July	2.54	2.81	2.41
August	1.89	1.46	1.48
Average	2.17	2.03	1.96

3.0 HABITAT MONITORING

3.1 RATIONALE

Habitat can be described as the ecological space occupied or potentially occupied by animals that includes both physical and biological features. ABR uses the term wildlife habitat to refer to the classification system that summarizes vegetation, surface forms, and geomorphology into useful categories when applied to birds and mammals (Jorgenson et al. 1997). The CRD features a complex environment with many interacting biotic and abiotic landscape elements (Wells et al. 2014), which makes long-term habitat monitoring in this environment particularly challenging. Consequently, ABR has incorporated a broad array of biotic and abiotic features into the habitat-monitoring program, including vegetation, soils, geomorphology, permafrost, and climate. Further confounding the challenges to implementing a monitoring program in this environment, is that deltaic landscapes are highly dynamic and undergo natural landscape change through time. This makes it difficult to differentiate potential changes in sedimentation and erosion associated with the CD5 Project from natural change. Reference Areas with similar environmental conditions to those areas directly upstream and downstream of the CD5 Project road have been selected for monitoring in an attempt to account for natural landscape change through time.

3.2 HABITAT MONITORING COMPONENTS

Habitat Monitoring includes several components as detailed in the Monitoring Plan. Detailed descriptions of each component and associated subcomponents are provided in the following sections. The outline below provides a guide to each of the Habitat Monitoring components and associated subcomponents.

- Spring Breakup Surveys
- Monitoring Transects
    - ◦ Integrated Habitat Monitoring Plots
        - *Vegetation Plots*
            - –Vegetation Plot Photograph
        - *Vegetation Lines*
            - –Vegetation Plot Sample Points
        - *General environment data*
        - *Soils*
    - ◦ Habitat Plots
        - *Habitat Plot Line*
            - –Habitat Plot Line Photographs
            - –Habitat Plot Points
        - *Map Verification Plots*
- Real Time Kinematic Surveys
    - ◦ Integrated Habitat Monitoring Plots
    - ◦ Thaw Depth/Elevation Points
- Broad-scale Monitoring of Geomorphology
    - ◦ Marker Horizons
    - ◦ Drift Lines
    - ◦ Geomorphology Monitoring Photography Points

3.3 METHODS

3.3.1 OVERALL STUDY DESIGN

The overall study design fits generally into the category of environmental impact analysis called BACI or before-after-control-impact (Stewart-Oaten et al. 1986). Sites in Reference Areas and impact areas (here referred to as "Test" Areas) are sampled before an impact occurs and resampled after the impact to compare conditions. The study design also incorporates elements of a gradient-oriented design (Ellis and Schneider 1997) in which data are collected across a range of potential impact levels, close to the development and far enough from the development that impacts are not anticipated.

3.3.1.A Permanent Habitat Monitoring Transects

Permanent Habitat Monitoring Transects (referred to herein as 'Monitoring Transects') were established in 2013 in both upstream and downstream Test and Reference Areas (Figure 1.2). Monitoring Transects in the Test Areas were oriented parallel with the proposed CD5 road (east-west) primarily between the Niġliagvik and Niġliq channels. The Monitoring Transects serve as the sampling framework for habitat monitoring. Monitoring Transect orientation and placement were a function of stratification along two gradients, including distance from the CD5 road, and distance (both vertical and horizontal) from active river channels. Monitoring Transects in the Test Areas were located 100 m from the proposed CD5 road alignment to evaluate potential direct and indirect road effects (dust, gravel spray, thermokarst, impoundments, disturbance) on soils, vegetation, and habitat. Subsequent Monitoring Transects were spaced 250 m apart. In the Test Areas, Monitoring Transect length ranged between 180 m and 2,401 m. In the Reference Areas, Monitoring Transects were placed perpendicular to the Niġliq channel, were spaced at least 250 m apart, and ranged in length from 400 m to 2,600 m.

To link this report with the project database and other analytical products for the CD5 monitoring effort, the text uses the actual table and field names from the database. Database table names are written in bold and italics (e.g., ***veg_cover***) and database table field names are written in italics (e.g., *plot_id*). Dot notation is used to specify a field name in a specific table, e.g., **veg_cover**.*plot_id*, refers to the *plot_id* field in the **veg_cover** table. Values contained in text fields are enclosed in double quotes (e.g., the plot_id was "t1sa-0200-veg").

Naming conventions to identify transects (transect_id) were the same as those used in 2013:

1. Test or Reference using a "t" or "r".
2. Sequential numbering starting with 1 for the first transect north or south of the road, and then 2, 3, 4, etc. for transects farther north and south, respectively.
3. North or South using an "n" or "s".
4. Alpha-character labels for different segments along the same transect, starting with "a" for the westernmost transect segment, and then "b", "c", etc. from west to east.

For example, Monitoring Transect "t1na" would be the westernmost segment of the first transect north of the road in Test Area North. The transect segment east of the Niġliq channel in the furthest south Monitoring Transect in the southern Reference Area would be "r6sb" (Figure 1.2).

Permanent Integrated Habitat Monitoring Plots (herein 'Integrated Plots') were re-established at approximately 200-m increments along each transect for the first set of transects north and south of the road (i.e., t1na, t1nb, t1nc, t1sa, t1sb, and t1sb), and at approximately 400-m increments along all other transects (Figure 3.1). Integrated plots consisted of a co-located Vegetation Plot and Habitat Plot (Figure 3.2). A Soil Pit was associated with each Vegetation Plot and a Mapping Verification Plot was associated with Habitat Plots that included more than one geomorphic surface, surface form, and/or vegetation type (Figure 3.2). The Integrated Plots were designed to monitor for changes in habitat at two spatial scales, including 1) the vegetation community scale using data from the Vegetation Plots, and 2) the landscape scale using data from the Habitat Plots in combination with a habitat map.

The following naming conventions were used to identify Integrated Plots (herein, superplot_id):

- The associated transect_id; i.e., "t1na".
- Distance of the Vegetation Plot from the start of the transect in meters, zero-padded to 4 digits to ensure proper sorting; e.g., distance 0 became 0000, 200 became 0200, 2000 remained 2000.
- For plots nested in the Integrated Plot, a plot-type code was tagged onto the end of the site_id resulting in a plot_id:
- "-veg" was appended to site_id for Vegetation Plots and the associated Soil Pit.
- "-hab" was appended to site_id for Habitat Plots.
- "-v" was appended to site_id for Mapping Verification Plots.

For example, the superplot_id for the Integrated Plot at distance 0 along transect "t1na" would be "t1na-0000" and the Vegetation Plot plot_id would be "t1na-0000-veg".

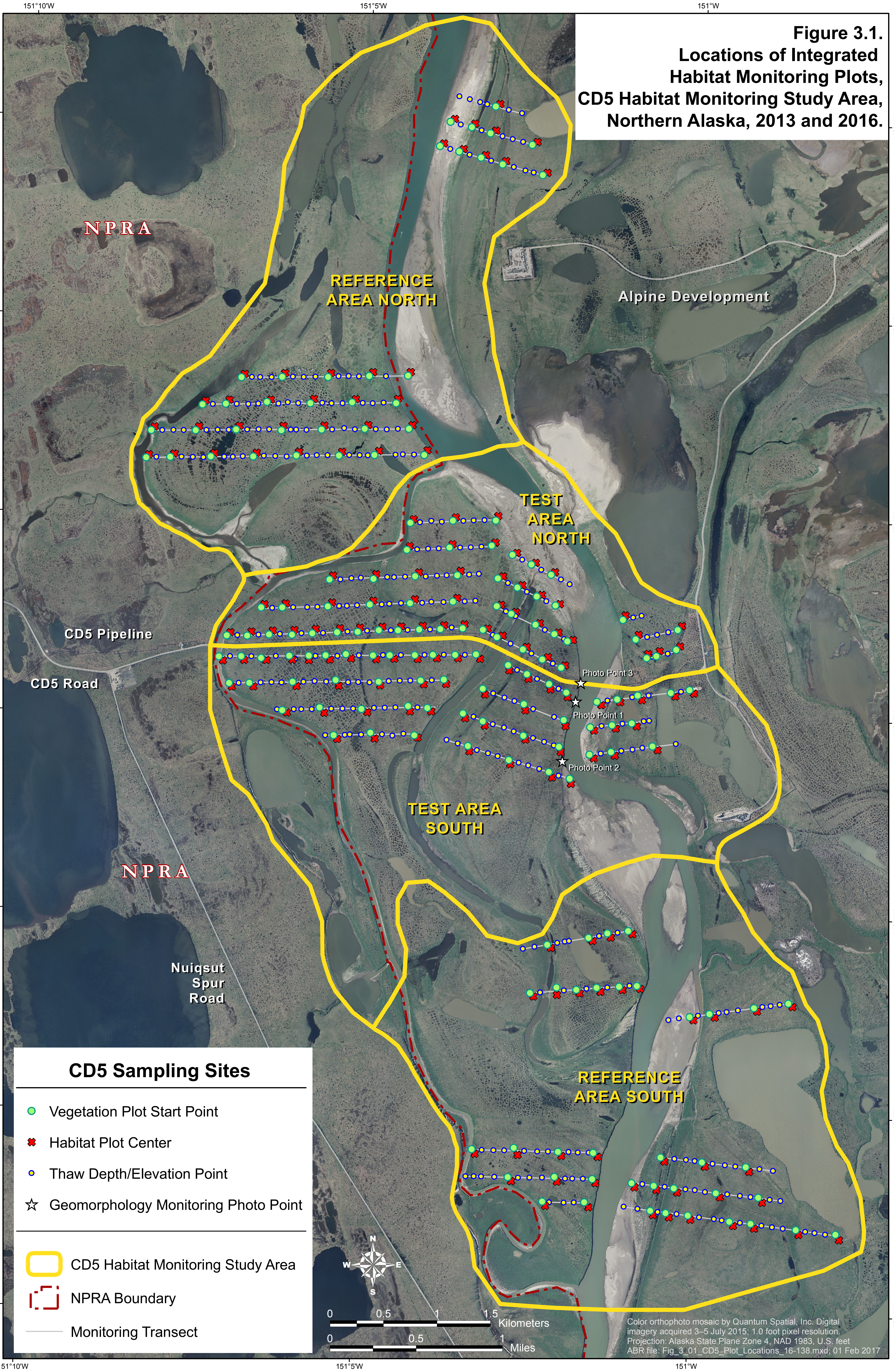


Figure 3.1. Locations of Integrated Habitat Monitoring Plots, CD5 Habitat Monitoring Study Area, Northern Alaska, 2013 and 2016.

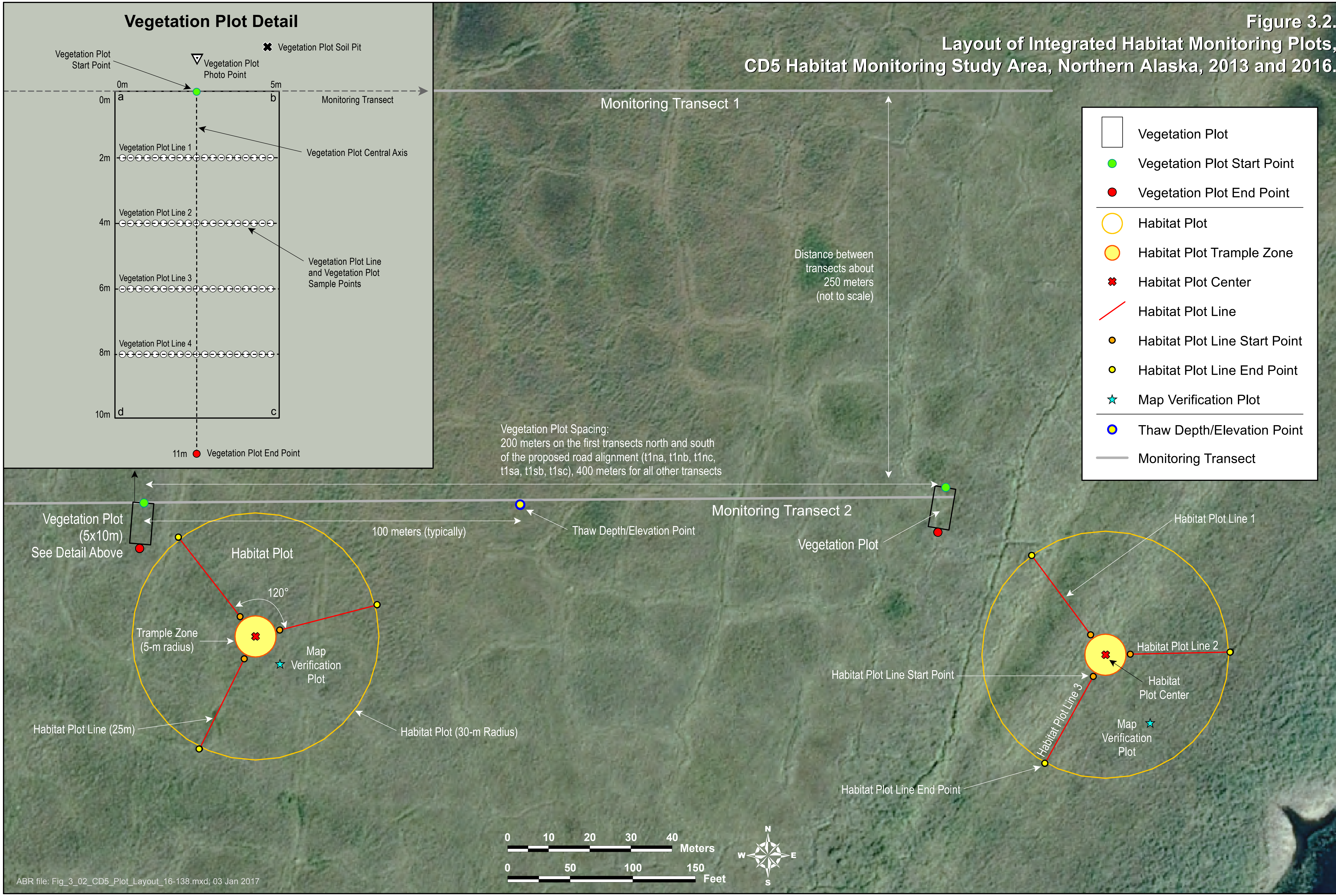


Figure 3.2.
Layout of Integrated Habitat Monitoring Plots,
CD5 Habitat Monitoring Study Area, Northern Alaska, 2013 and 2016.
Vegetation Plot Detail
Vegetation Plot Soil Pit
Vegetation Plot Start Point
Vegetation Plot Photo Point
0m
5m
a
b
Monitoring Transect
Vegetation Plot Line 1
Vegetation Plot Central Axis
2m
Vegetation Plot Line 2
4m
Vegetation Plot Line and Vegetation Plot Sample Points
Vegetation Plot Line 3
6m
Vegetation Plot Line 4
8m
10m
d
c
11m
Vegetation Plot End Point
Monitoring Transect 1
Distance between transects about 250 meters (not to scale)
Vegetation Plot Spacing:
200 meters on the first transects north and south of the proposed road alignment (t1na, t1nb, t1nc, t1sa, t1sb, t1sc), 400 meters for all other transects
Vegetation Plot (5x10m) See Detail Above
100 meters (typically)
Thaw Depth/Elevation Point
Monitoring Transect 2
Vegetation Plot
Habitat Plot
120°
Trample Zone (5-m radius)
Map Verification Plot
Habitat Plot Line (25m)
Habitat Plot (30-m Radius)
Habitat Plot Line 1
Habitat Plot Line 2
Habitat Plot Line Start Point
Habitat Plot Center
Habitat Plot Line 3
Map Verification Plot
Habitat Plot Line End Point
Vegetation Plot
Vegetation Plot Start Point
Vegetation Plot End Point
Habitat Plot
Habitat Plot Trample Zone
Habitat Plot Center
Habitat Plot Line
Habitat Plot Line Start Point
Habitat Plot Line End Point
Map Verification Plot
Thaw Depth/Elevation Point
Monitoring Transect
0 10 20 30 40 Meters
0 50 100 150 Feet
N
W
E
S
ABR file: Fig_3_02_CD5_Plot_Layout_16-138.mxd; 03 Jan 2017

3.3.2 FIELD SURVEYS

3.3.2.A Spring Breakup

ABR joined Michael Baker International field crews during their annual spring-breakup surveys on the Colville River Delta 13–22 May 2016. ABR staff participated in aerial and gage surveys and assisted with preparations for discharge measurements. During the daily aerial surveys, ABR field staff recorded observations and photo documented breakup activities. Photographs were taken using a 12.1 megapixel Ricoh G700SE GPS Camera System with 5–25 focal length, and 1:3.5–5.5 lens ratio, and 5x optical zoom. Field notes were digitized and archived with spring breakup photos.

3.3.2.B Habitat Monitoring

Habitat-monitoring field surveys were conducted 16 July–7 August 2016. Three crews of 3 people, each crew consisting of 2 botanists and 1 soil scientist, completed the habitat-monitoring fieldwork based out of the Alpine Oil Facilities on the Colville River Delta. Habitat-monitoring locations were accessed via helicopter, inflatable boat, and by foot.

Habitat-monitoring field crews (herein "Habitat Crews") worked with LCMF Engineering (LCMF) to precisely locate the Integrated Plots established in 2013 (Figure 3.1). To facilitate locating the Habitat Plots, ABR supplied LCMF with the GPS locations for all Vegetation Plot Start Points, Habitat Plot Centers, and Habitat Plot Line End Points before surveying began. Habitat crews met with LCMF before they began field surveys to review the layout of the Integrated Plots (Figure 3.2) and to discuss how best to avoid trampling vegetation in the plots. Working ahead of the habitat-monitoring field crews, LCMF walked the Monitoring Transects using Real Time Kinematic (RTK) satellite navigation to locate the Vegetation Plot Start Point, Vegetation Plot End Point, Habitat Plot Center, and Habitat Plot Line End Points at each Integrated Habitat Monitoring plot. Pin flags placed at each of the above locations served as temporary markers for the Habitat Crews.

<u>3.2.2.B.i. Vegetation Plots</u>

Field-crew leaders used handheld Global Positioning System (GPS) units to navigate to the Vegetation Plot Start Points. As Habitat Crews approached the Vegetation Plots, they slowed their pace of travel and looked for the temporary pin flag marking the Vegetation Plot Start point. Once the pin flag was located, backpacks and other sampling gear were placed well away from the plot to avoid trampling in the plot area.

Monumentation

In 2013, Vegetation Plot Start Points were permanently monumented by burying a Surv-Kap® magnetic marker 20 cm below the soil surface at the Vegetation Plot Start Point by removing a small (10 × 10 × 20 cm) soil plug, which was subsequently replaced. In addition, a survey nail with bright pink survey whiskers and an aluminum tag labeled with the plot_id (e.g., "t1na-0000-veg") was inserted into the soil plug above the magnet placed at the Vegetation Plot Start Point. In 2016, Habitat Crews relocated the survey pin marking the Vegetation Plot Start Point and used this as the starting point for setting up the vegetation plot. In most cases, LCMF had placed the temporary pin flags at the survey pin. At a few plots, the survey pin was not found, having been buried by sediment or otherwise removed (e.g., ice gouging). In these cases, a new survey pin with bright pink whiskers and an aluminum tag with *plot_id* label was prepared and placed at the location of the temporary pin flag. A wooden lath with florescent orange-painted tip was temporarily inserted into the ground directly next to the survey nail for use in photograph documentation of the Vegetation Plot. A 30 m tape (herein, "meter tape") was used to temporarily establish the Vegetation Plot Central Axis as a reference for plot layout and for repeat photographs. The meter tape was extended 11 m from the Vegetation Plot Start Point to the Vegetation Plot End Point (marked with another temporary pin flag) while avoiding trampling of the plot area. A second wooden lath with florescent orange-painted tip or survey nail was used to hold the meter tape temporarily in place for the Vegetation Plot Start Point Photo. After the Vegetation Plot Start Point Photo was taken (see below) a survey nail with bright blue whiskers and an aluminum tab with *plot_id* + "END" (e.g., "t1na-0000-veg END") was placed at the Vegetation Plot End Point. The addition of this nail will aid in relocating the Vegetation Plot End Point in future monitoring years.

Vegetation Plot Photographs

Photographs were taken of the Vegetation Plot for use in future repeat photograph monitoring (Figure 3.3, upper left). The photographs were taken using a 23 megapixel SONY Xperia Z5, Model E6603, phone camera with 2–24 mm focal length. All photographs were taken without zoom and photograph file-size was standardized to 23MB. All equipment, packs, and humans were moved from the Vegetation Plot Start Point Photo frame before the photograph was taken. Vegetation Plot Start Point Photos were photographed in landscape position and centered on the meter tape that was laid out and oriented along the Vegetation Plot Central Axis during monumentation. The wooden lath placed at the Vegetation Plot Start Point was used to orient the photograph vertically, i.e., the photograph was framed with the bottom of the wooden lath at the bottom center (Figure 3.3, upper left). We used an internally developed Android application running on the cameras that allowed the photographer to record plot information about each photo, including Plot ID, location code, GPS location, timestamp, and notes (Figure 3.3, middle right). These attributes were stored in a local database on the device along with the photo, and synchronized to our server database at the end of each field day. The application also renamed each photo to include the information necessary to identify where it was taken, when, and the subject matter of the photo.

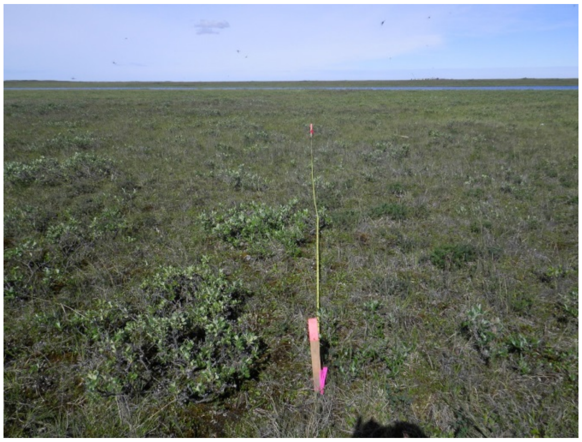
Vegetation Plot Setup

The Vegetation Plot was set up using a "box plot" design (Figures 3.2 and 3.3, middle left). Care was taken during plot setup to avoid vegetation trampling within the plot boundaries. The first plot corner was established by placing a wooden stake (30 × 5 × 2.5 cm) in the ground 2.5 m from the Vegetation Plot Start Point towards the zero (western) end of the Monitoring Transect and securing the start of the meter tape on the stake (Figure 3.2 inset, corner "a"). Second, the first plot edge was established by extending the meter tape perpendicular across the Vegetation Plot Central Axis (over the Vegetation Plot Start Point and along the Monitoring Transect) to the 5 m mark on the meter tape. The second plot corner was established at this mark by placing a second wooden stake (Figure 3.2 inset, corner "b"). The second wooden stake was used to secure the meter tape, which was then extended parallel to the Vegetation Plot Central Axis, to the 15-m mark on the meter tape. The third plot corner was established at this mark by placing a third wooden stake around which the meter tape was secured (Figure 3.2 inset, corner "c"). The tape was then extended perpendicular across the Vegetation Plot Central Axis to 20 m and the fourth plot corner was established similar to above with the "tape box" meter tape at the 15-m mark (Figure 3.2 inset, corner "d"). These corners were adjusted to ensure that the "tape box" meter tape crossed the 10 m mark on the Vegetation Plot Central Axis at exactly 17.5 m. Lastly, the tape was extended to the 30-m mark back towards the first plot corner ("a"). The fourth plot corner ("d") was adjusted as needed such that it fell on the 20-m mark when the 30-m mark on the meter tape was at the first plot corner ("a").

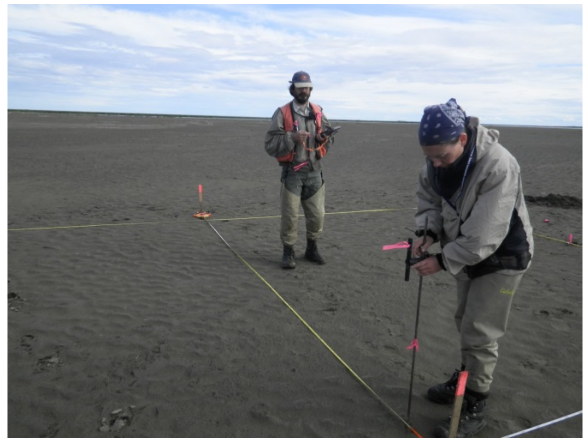
Vegetation Plot Lines

Once photographs and plot "tape box" setup were complete, the meter tape demarcating the Vegetation Plot Central Axis and wooden lath were removed in preparation for sampling-line setup. Four Vegetation Plot Lines were sampled at each Vegetation Plot using the point-intercept method (NARSC 1999). In the point-intercept method vegetation sampling occurs by systematically sampling at discrete points in space, typically along a sampling line. At each point a very thin (2−3 mm) metal rod or, in this study, a laser beam are held stationary above the vegetation. All instances in which the rod or laser beam intersected with a live or dead plant part or ground cover class (e.g., bare soil) are recorded. The process of conducting vegetation sampling using the point-intercept method is referred to as "point-intercept sampling" and the associated data is referred to as "point-intercept data." For reference, a schematic layout of the Vegetation Plot Lines is provided in the inset on Figure 3.2, and example photographs are shown in Figure 3.3, upper right, lower left, and lower right.

A meter tape was used to establish the Vegetation Plot Lines at 2-m increments along the long axis of the Vegetation Plots, starting at 2 m and ending at 8 m (Figure 3.2). The Vegetation Plot Lines were set up perpendicular to the Central Axis



Vegetation Plot photograph with tape marking Vegetation Plot Central Axis.



Vegetation Plot Line layout.

Vegetation Plot "box plot" layout.

Data was collected on handheld tablet computers.

Typical team configuration, included botanist (foreground) and data entry technician (background).

Botanist using a laser pointer mounted on a frost probe to conduct point counts along a vegetation sampling line.

Figure 3.3. Examples of data collection using the point intercept method in a vegetation Plot, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. Photographs are from sample year 2013.

of the Vegetation Plot using meter marks on the "tape box," and were used as the framework for point-intercept sampling. Point-intercept sampling was conducted along sampling lines using a laser pointer (GreenBeam 50) mounted on a frost probe (a 1.3-m tile probe) that was self-supporting after being pushed into the ground vertically. To ensure repeatability in the future, laser specifications are as follows: Class III A, 532 nm wavelength, lithium batteries, and 2–3-mm wide beam when held at 1 m above soil surface. Point-intercept sampling occurred along each sampling line at 0.25-m increments, beginning at 0.25 m and ending at 4.75 m, for a total of 19 points per sampling line, and 76 points per plot (Figure 3.2 inset, Vegetation Plot Line and Vegetation Plot Sample Points).

Point-intercept Sampling

All field data were recorded digitally in the field (Figure 3.3, middle right) using a standardized data entry form on an Android tablet computer designed to upload data to a relational database (PostgreSQL). Point-intercept protocols for Vegetation Plots were as follows:

At each sampling point:

- The laser point was oriented towards the Vegetation Plot End Point.
- Canopy Hits

    ◦ All hits were recorded beginning at the highest hit and proceeding downward to the ground cover (last hit).

    ◦ In plots with vegetation >1.0 m in height, point-intercept sampling began with the laser pointing up, starting with highest hit and working downward to the laser. The laser was then pointed down and hits were recorded downward to ground cover.

    ◦ Multiple hits of a single species were allowed.

    ◦ If a dead portion of attached current annual growth was hit, it was recorded as a live hit. This was most often encountered with dead graminoid leaf tips or senescing shrub leaves.

    ◦ Hits are counted if any portion (i.e., partial hits) of the laser beam intercepts a plant part (either live or dead). For the last hit at a point, priority is given to partial hits of live non-vasculars over partial hits of non-vegetated classes (e.g., mineral soil).

- Standing Dead

    ◦ Standing dead included dead vascular plants attached at the base.

    ◦ Hits of standing dead vascular plants were recorded using the "dead" modifier up to a maximum of 3 dead hits for a given standing-dead lifeform.

    ◦ Standing-dead hits of graminoids were recorded as lifeform only ("graminoid").

    ◦ Standing-dead hits of forbs and shrubs were recorded to species or genus when obvious; otherwise these were recorded as lifeform (forb, dwarf shrub, low shrub, etc.).

- Mineral vs. Organic Soil

    ◦ Mineral soil hits include hits of silt and sand

    ◦ Organic soil hits included most commonly "limnic materials" which are defined as reddish, iron-rich organic materials originally deposited in water and typically found exposed in wet sedge meadows and low-center polygons.

- Litter

    ◦ Litter included any detached dead organic material.

    ◦ Dead non-vascular plants were recorded as "litter" with no modifier.

    ◦ Dead plants that were attached but compressed and appressed to the soil surface were also considered litter.

    ◦ Only live non-vascular hits of vegetation were recorded below litter.

- Heights

    ◦ ABR recorded heights following the Bureau of Land Management Assessment, Inventory & Monitoring (BLM AIM) protocol (Toevs et al. 2011), with modifications from NPRA (BLM 2013).

◦ Height measurements were collected at every fifth sample point (starting with the first point on each line).

◦ The tallest attached herbaceous and woody plant element that intersected a cylinder of 15-cm diameter placed around the laser point was recorded.

◦ The height was measured from where the laser intersected the ground.

–Heights were recorded in cm, to the nearest integer.

–The species were also recorded for the tallest woody and herbaceous vegetation at each point.

–Plant-height minimum (when a plant was present) was set at 1 cm.

–When water was present at the point, the plant heights were measured from the soil surface beneath the water.

- Water Depths

◦ Water depth was recorded from the point on water surface intersected by the laser, to the ground surface directly beneath.

◦ When water was measurable or visible beneath the last (non-soil) hit, a water hit was recorded as the final hit, unless live material was found below.

◦ "Measurable" water was defined as water depth that could be measured using the measuring tape with a slight downward pressure to compress loose materials.

◦ Water depth was measured with gentle pressure on the substratum or floc until slightly firm resistance was encountered.

◦ Only live hits of vegetation (including moss, when visible) were recorded below water.

◦ Depths were recorded in cm, to the nearest integer.

◦ Minimum water depth (when water was present) was recorded as 1 cm.

- In Vegetation Plots, non-vascular plants were recorded to the species level for common species that were readily and consistently identifiable (e.g., *Hylocomium splendens*, *Dactylina arctica*). For all other non-vasculars, hits were recorded in broad categories (e.g., fruticose lichen, foliose lichen, Sphagnum, other mosses, etc.).
- In Habitat Plots (see below, "Habitat Plots"), hits of non-vasculars were recorded using broad categories (e.g., fruticose lichen, foliose lichen, Sphagnum, other mosses, etc.) and voucher specimens were not collected.

Vegetation Plot Trace Search

A trace search was conducted in vegetation plots upon completion of the sampling lines. All vascular species that were not hit along the sampling lines were recorded as occurring in the plot as a "trace" with a cover value of 0.1%. For non-vasculars, 3–5 of the most common mosses and lichens in each plot were collected as vouchers and recorded as "trace". All voucher specimens were collected from outside the plot area.The trace search was considered complete once 10–15 minutes had past since a new species was encountered.

General Environment Data

Soil scientists on each crew were responsible for collecting general site data at each Vegetation Plot. Geomorphic, topographic, and vegetation variables recorded included physiography (e.g., Riverine), surface geomorphology separated into terrestrial (Table 3.1) and aquatic (Table 3.2) units, slope, aspect, surface form (Table 3.3), vegetation structure (e.g., Low Shrub), Viereck et al. (1992) Level IV vegetation class (Table 3.4), and recent disturbance (Table 3.5).

Soils

Soil scientists described soils and hydrology from a Vegetation Plot Soil Pit at each Vegetation Plot. The Vegetation Plot Soil Pit consisted of a shallow soil plug or soil pit at least 40 cm deep (Figure 3.4), located outside the Vegetation Plot and within 3 m of the Vegetation Plot Start Point (Figure 3.3, middle left). Efforts were made to locate and excavate the 2013 soil plugs for documenting sedimentation or erosion for the

Table 3.1. Standard classification system developed for classifying and mapping terrestrial geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2016. Classes modified from Jorgenson et al. (1997, 2003), Roth et al. (2007), Carter and Galloway (1985), and Kreig and Reger (1982).

Code	Geomorphic unit
Cs	Solifluction Deposit
Esa	Eolian Active Sand Deposit
Esda	Eolian Active Sand Dune
Esdi	Eolian Inactive Sand Dune
Esi	Eolian Inactive Sand Deposit
Fdoa	Delta Active Overbank Deposit
Fdob	Delta Abandoned Overbank Deposit
Fdoi	Delta Inactive Overbank Deposit
Fdra	Delta Active Channel Deposit
Fdri	Delta Inactive Channel Deposit
Fto	Old Alluvial Terrace
Ftr	Recent Alluvial Terrace
Hfg	Gravel Fill
Ltdi	Delta Thaw Basin, Ice-rich
Ltdn	Delta Thaw Basin, Ice-poor
Ltic	Ice-rich Thaw Basin Center
Ltim	Ice-rich Thaw Basin Margin
Ltiu	Undifferentiated Ice-rich Thaw Basin

Table 3.2. Standard classification system developed for classifying and mapping aquatic geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2016. Classes modified from Jorgenson et al. (1997, 2003), Roth et al. (2007), Carter and Galloway (1985), and Kreig and Reger (1982). Geomorphic units that were identified in the field but not mapped are identified with an asterisk.

Code	Geomorphic unit
Weldc	Brackish Deep Tapped Lake, Connected
Wert	Tidal River
Wldcrh	Deep Tapped Riverine Lake, High-water Connection
Wldir	Deep Isolated Riverine Lake
Wldit	Deep Isolated Thaw Lake
Wlscr*	Shallow Connected Riverine Lake
Wlsir	Shallow Isolated Riverine Lake
Wlsit	Shallow Isolated Thaw Lake

Table 3.3. Standard classification system developed for classifying and mapping surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2016. Classes modified from Jorgenson et al. (1997, 2003) and Roth et al. (2007). Surface form types that were identified in the field but not mapped are identified with an asterisk.

Code	Surface form
Dr*	Ripples
Dt	Water Tracks
Ek	Streaked Dune
Es	Small Dune
Hm	Human Modified
N	Nonpatterned
Pc*	Polygon Center
Pd	Disjunct Polygon Rims
Phh	High-centered, High-relief Polygons
Phl	High-centered, Low-relief Polygons
Plhh	Low-centered, High-relief, High-density Polygons
Plhl	Low-centered, High-relief, Low-density Polygons
Pllh	Low-centered, Low-relief, High-density Polygons
Plll	Low-centered, Low-relief, Low-density Polygons
Pm	Mixed High and Low-centered Polygons
Pr*	Polygon Rims
Sb	Bluffs or Banks
Tm	Mixed Thermokarst Pits and Polygons
Tt*	Troughs (Degraded ice-wedges)
W	Water
Wi	Lake with Islands

Table 3.4. Standard classification system developed for classifying and mapping vegetation in the CD5 Habitat Monitoring Study Area, northern Alaska, 2016. Classes adapted from Viereck et al. (1992). Vegetation classes that were identified in the field but not mapped are identified with an asterisk.

Code	Vegetation
Bbg	Barrens
Bpv	Partially Vegetated
Hfds	Seral Herbs
Hfmm*	Mixed Herbs
Hgdl	*Elymus*
Hgmss	Moist Sedge-Shrub Tundra
Hgmswt*	Moist Sedge-Willow Tundra
Hgmt	Tussock Tundra
Hgwfg	Fresh Grass Marsh
Hgwfs	Fresh Sedge Marsh
Hgwst	Wet Sedge Meadow Tundra
Hgwswt	Wet Sedge–Willow Tundra
Sddf*	*Dryas*–Forb Dwarf Shrub Tundra
Sdds*	*Dryas*–Sedge Dwarf Shrub Tundra
Sddt	*Dryas* Dwarf Shrub Tundra
Sdec	*Cassiope* Dwarf Shrub Tundra
Sdwgh	Halophytic Willow–Graminoid Dwarf Shrub Tundra
Sdwh*	Halophytic Willow Dwarf Shrub
Sdwt*	Willow Dwarf Shrub Tundra
Slcw	Closed Low Willow
Slott*	Open Mixed Low Shrub-Sedge Tussock Tundra
Slow	Open Low Willow
Slows	Open Low Willow-Sedge Shrub Tundra
Stow	Open Tall Willow
Wb	Brackish Water
Wf	Fresh Water
Xp	Deep Polygon Complex

Table 3.5. Standard classification system developed for classifying and mapping disturbances in the CD5 Habitat Monitoring Study area, northern Alaska, 2016. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2007). Disturbance classes that were identified in the field but not mapped are identified with an asterisk.

Code	Disturbance
A	Absent, none (mature vegetation)
Hfgp	Gravel Pad
Hfgr	Gravel Road
Hseb	Bridge
Hsep	Elevated Pipeline
Hti	Snow/Ice pads and roads
Nge	Eolian (Wind)
Ngf*	Fluvial
Ngfd	Fluvial Deposition
Ngfe	Fluvial Erosion/channel migration
Ngt	Thermokarst
Nsk*	Salt killed vegetation

broad-scale monitoring of geomorphology. The 5-gauge nails that had been placed in the soil profile to serve as marker horizons for monitoring sedimentation and erosion in 2013 were not reliably found. Instead, the 2013 Vegetation Plot Soil Pit plug or pit material was temporarily extracted and a new plug or pit face adjacent to the plug described (Figure 3.4). This method ensured sedimentation and surface organic thickness would be described from an undisturbed, soil profile plug or pit in 2016. Soil plugs and excavated soil material were placed on tarps to protect the ground surface during sampling. A measuring tape was placed next to the soil plug or, in the case of soil pits, oriented vertically along the pit face. The soil plug or pit was then photographed using the same camera as described for the Vegetation Plot photographs.

The following data were collected at the Vegetation Plot Soil Pit in the upper 40 cm of the soil plug or pit:

- Detailed soil descriptions including horizons, soil texture, boundary topography and distinctness,
- Soil taxonomic classification to the subgroup level (Soil Survey Staff 2014),
- Type and percentage of, and depth to >15 % coarse fragments,
- Minimum depth to coarse fragments (>15% by volume),
- pH and electrical conductivity (EC),
- Dominant soil texture in the upper 40 cm,
- Soil moisture,
- Depth to saturated soil,
- Depth to water table above or below ground surface,
- Thickness of surface organic matter,
- Depth to and type of restrictive layer (e.g., permafrost and thaw depth),
- Maximum observation depth, and
- Alaska Vegetation Classification (Viereck et al. 1992) Level IV vegetation class.

Electrical conductivity and pH were measured in groundwater within the pit using Oakton® EC and pH meters. When water was not present in the soil pit, EC and pH were measured in a saturated soil paste using distilled water mixed with several grams of soil. A small amount of soil from a depth of 10 cm was used to measure EC and pH at each soil pit. Soil texture was assessed by estimating the percent of sand, silt, and clay using the hand-texturing method. A single simplified texture (e.g., organic-rich) was assigned to characterize the dominant texture in the top 40 cm at each plot. Once soil descriptions were complete, the site was restored by placing the soil plug back into the ground or backfilling the pit with excavated soil. A survey nail, with blue survey whiskers, was prepared with an aluminum tag labeled with the *plot_id*-soil (e.g., t1na-000-veg-soil) and placed on the surface of the rehabilitated 2016 Vegetation Plot Soil Pit. The cardinal direction of the 2016 Vegetation Plot Soil Pit in relation to the 2013 Vegetation Plot Soil pit was recorded in the notes when the exact location of the 2013 Vegetation Plot Soil Pit could be determined.

Figure 3.4. Example of a soil pit demonstrating the temporary removal of the 2013 soil plug, and the shovel slice for the 2016 soil plug, used to describe soil at vegetation plots, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

3.2.2.B.ii. Habitat Plots

Field-crew leaders used hand-held GPS units to navigate to pre-established Habitat Plot Center Points. As Habitat Crews approached the Plots, they slowed their pace of travel and looked for the temporary pin flags marking the Habitat Plot Center and Habitat Plot Line End Points (Figure 3.2). Once the pin flags were located, backpacks and other sampling gear were placed in the Trample Zone (see below "Habitat Plot Setup") to avoid trampling in the Habitat Plot Lines. Whereas the location of the Vegetation Plots was adjusted to fit the entire plot into a discrete vegetation community and ecotype, the Habitat Plot Center Points were not adjusted in the field unless they fell in a river channel or lake (in which case the location was moved to the nearest adjacent shore). The circular Habitat Plots (30-m radius) were based on the BLM AIM sample plot layout for NPRA (Figure 3.2; Toevs et al. 2011 and BLM 2013).

Monumentation

In 2013, Habitat Plot Center Points were permanently monumented by burying a Surv-Kap® magnetic marker 8 in (20 cm) below the soil surface at the Habitat Plot Center Point (Figure 3.2) by removing a small (10 × 10 × 20 cm) soil plug (subsequently replaced). Bright pink survey whiskers and an aluminum tag labeled with the plot_id (e.g., "t1na-0000-hab") were then attached to a survey nail. In 2016, Habitat Crews relocated the survey pin marking the Habitat Plot Center and used this as the starting point for setting up the Habitat Plot Lines. In most cases, LCMF had placed the temporary pin flags at the survey pin. At a few plots the survey pin was not found, having been buried by sediment or otherwise removed (e.g., ice gouging). In these cases a new survey pin with bright pink whiskers and an aluminum tag with *plot_id* label was placed at the location of the temporary pin flag. After the Habitat Plot Lines were laid out and the Habitat Plot Line Photos were taken (see below), a survey nail with bright blue whiskers and an aluminum tab with plot_id + "E" (e.g., "t1na-0000-hab E") was placed at each of the three Habitat Plot Line End Points. The addition of these nails will aid in relocating the Habitat Plot Line End Points in future monitoring years.

Habitat Plot Setup

A 5-m radius trample zone surrounding the Habitat Plot Center Point was established using a meter tape and wooden lath (Figure 3.2). The trample zone provided space for field staff and gear while preventing the trampling of vegetation along the Habitat Plot Lines. Three Habitat Plot Lines were sampled in each Habitat Plot using the point-intercept method. The first Habitat Plot Line was established using a compass (declination set to 0 degrees) to strike the predetermined azimuth and extending a meter tape out to 30 m from the Habitat Plot Center Point to the temporary pin flag marking the Habitat Plot Line End Point. The tape was then adjusted such that the zero end was moved to the Habitat Plot Line Start Point at the edge of the trample zone (i.e., 5 m from the Habitat Plot Center Point) and the end of the tape was at 25.5 m (offset 0.5 m from the actual Habitat Plot Line End Point to avoid trampling). A wooden lath labeled with the line number (Figure 3.5) was placed at the Habitat Plot Line Start Point, to which the meter tape was secured. The tape was then pulled tight thus aligning it between the Habitat Line Start and End Points. Once the alignment of the tape was satisfactory (i.e., straight and taut) the tape was secured at 25.5 m) using a second wooden lath labeled with the line number and the letter “E” (i.e., End; Figure 3.5). The second and third habitat lines were set up as above.

Habitat Plot Line Photographs

Upon completing the layout of each Habitat Plot Line and before point-intercept sampling, photographs were taken of each Habitat Plot Line from the Habitat Plot Line Start Point (i.e., center photograph) and Habitat Plot Line End Point (i.e. line end photograph) for use in future repeat photograph monitoring (Figure 3.5). Photographs were taken using the same 23 megapixel SONY Xperia Z5, Model E6603, phone camera used for Vegetation Plot photographs (see above for detailed specifications). The built-in form recorded the plot_id, Habitat Plot Line number and photo element (center photograph vs. line end photograph). All photographs were taken without zoom and photograph file-size was standardized to 23MP. For center photographs, all equipment, packs, and humans were moved from the photograph frame, while equipment, packs, and humans may be present in line end photographs. Photographs were oriented for a landscape view. The meter tape oriented along the Habitat Plot Line during monumentation was used to center the photograph horizontally. The wooden laths placed at the Habitat Line Start and End Points were used to orient the Habitat Plot Line photographs vertically, i.e., the photograph was framed with the bottom of the wooden lath at the bottom center.

Figure 3.5. Examples of Habitat Plot Line Start Point and Habitat Plot Line End Point photographs, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Habitat Plot Lines

Point-intercept sampling was conducted along Habitat Plot Lines using a laser pointer (see "Vegetation Plot Lines" above for specifications) mounted on a frost probe. Point-intercept sampling occurred along each sampling line at 1-m increments, beginning at 1 m and ending at 25 m for a total of 25 points per Habitat Plot Line, and 75 points per Habitat Plot. Point-intercept sampling followed the same protocols as the Vegetation Plots with few exceptions (see above, "Point-Intercept Sampling"). While traversing each Habitat Plot Line the botanist and data entry technician stood on the left of the meter tape (i.e., when looking out from the Habitat Plot Center Point) and the laser was oriented toward the right side of the meter tape.

Three Habitat Plots were selected as "calibration plots" for assessing the sampling error associated with point-intercept sampling. The *plot_id* for Habitat Plots selected as calibration plot were r6na-0400-hab, r6na-1000-hab, and t2nc-0400-hab. At these 3 plots all 6 botanists took turns conducting the point-intercept sampling along each of the 3 Habitat Plot Lines. At each point along the lines each botanist placed the thaw probe with the laser mount in the same hole that was created by the first botanist to sample the line. Once the thaw probe was placed the laser was oriented at 90 degrees to the habitat line. Each unique line × user combination was considered the sampling unit for assessing sampling error.

Map Verification Plots

Map Verification Plots collected basic landscape variables and photographs to inform photo-interpretation of Integrated Terrain Units (ITUs). Map Verification Plots were sampled within the Habitat-Plot boundary when the environment or vegetation differed from the Vegetation Plot in all or part of the Habitat Plot (Figure 3.2). Data collected at Map Verification Plots include only those variables pertinent to the ITU mapping, including geomorphic unit, surface form, Viereck Level IV vegetation class, and disturbance. If a Habitat Plot encompassed more than one wildlife habitat (geomorphic units, surface forms, and vegetation types), only one Map Verification Plot was sampled in the dominant wildlife habitat class in the Habitat Plot. Two landscape and two ground-cover photographs were taken from the Map Verification Plot Center. The photographs were taken of representative views of the habitat.

<u>3.2.2.B.iii. Real Time Kinematic (RTK) Surveys</u>

Survey Preparation

LCMF used RTK satellite navigation for conducting thaw-depth and elevation surveys while walking the Monitoring Transect to relocate the Vegetation and Habitat Plots as described in section "3.3.2.B Habitat Monitoring", above. RTK satellite navigation is a technique used to enhance the precision and accuracy of position (location) data without post-processing using a satellite-based GPS. Accuracy of the RTK surveys is in the range of 3–5 cm horizontally (i.e., x/y coordinate plane) and 7–8 cm vertically (z coordinate) (pers. comm. T. Bass).

Prior to conducting surveys, LCMF used a combination of conventional leveling and static GPS techniques to establish a broad control network that encompassed the entire CD5 Habitat Monitoring Study Area. The static survey was then processed using GPS software and the OPUS network to derive the NAD83 (2011) coordinates. Leveled elevations from local benchmarks were used to bring the vertical datum to the standard British Petroleum mean sea level (BPMSL). The strategically placed control points allowed LCMF to use GPS RTK surveying techniques and maintain the stringent horizontal and vertical tolerances required for the project. The careful planning put forth in preparing the 2016 survey will allow LCMF to duplicate similar results over the life of the project.

Elevation and Thaw Depth Survey

To assess potential changes in thaw depth and ground surface elevation through time, as per the Monitoring Plan (ABR and Baker 2013), LCMF conducted the surveys during the second and third weeks of July 2016 (note that the RTK surveys were conducted in the first and second weeks of August in 2013). While traversing each monitoring transect, LCMF stopped at each Integrated Plot (see section "3.3.2.B Habitat Monitoring," above) and Thaw Depth/Elevation Points, spaced at 100-m intervals between each Vegetation Plot Start Point. Three-dimensional GPS locations (latitude, longitude, elevation) and thaw depths were collected at each Vegetation Plot Start Point and Thaw Depth/ Elevation Point. Thaw depth (i.e., the depth from the ground surface to frozen ground) was measured by plunging a 6.4-mm diameter steel rod into the ground until it hit frozen ground. A survey nail with florescent pink whiskers was placed at each Thaw Depth/Elevation Point to permanently monument the location. LCMF also collected GPS points at Monitoring Transect Transition Points, including the edge of large waterbodies (e.g., riverine lakes, Niġliq channel) that occurred along transects (**monitoring_ locations**.*point_type* = "Water Edge"), grade breaks (**monitoring_locations**.*point_type* = "Grade Break", and the top of the cut bank along the Niġliq channel (**monitoring_locations**.*point_type* = "Cut Bank"). Results from 2016 were compared with baseline conditions established in 2013.

3.2.2.B.iv. Broad-scale Monitoring of Geomorphology

Geomorphology monitoring in 2016 consisted of three tasks. First, ABR staff described an undisturbed soil plug or profile adjacent to the 2013 Vegetation Plot Soil Pit. Detailed soil descriptions, including surface organic horizon thickness, were recorded for sedimentation and erosion monitoring. As described in section 3.2.2.B.i. Vegetation Plots/Soils, the study design was modified to measure changes in horizon profile thickness using a marker horizon, due to the unreliable nature of finding the 5-gauge nail in the field. Second, as ABR staff traversed monitoring transects, the location of drift lines was recorded as photo observations opportunistically in the Integrated Monitoring Plots. Third, geomorphology monitoring repeat photography points (herein, Geomorphology Monitoring Photo Points) were photographed near the proposed CD5 road alignment (Figures 3.6–3.7). ABR staff monumented each photograph-point location by placing a survey nail with florescent pink whiskers and an aluminum tag labeled with the photograph-point name in the ground and recorded GPS locations. For each geomorphology photograph, ABR staff recorded the compass direction (degrees) in which the photograph was taken relative to the survey nail. Photographs were taken while standing on the head of the survey nail. In 2013, two Geomorphology Monitoring Photo Points were established (Figure 3.1) on the west side of the Niġliq channel in Test Area South. In 2016 it was found that the more northerly of these two points, which was placed near a cut-bank, was at risk of erosion in the near future. In the event that this Geomorphology Monitoring Photo Point erodes away we established a new Geomorphology Monitoring Photo Point located on the Niġliq Channel Bridge looking south (Figure 3.1).

3.3.3 OFFICE METHODS

3.3.3.A Data Management

Habitat Monitoring data were collected in the field using internally developed forms and mobile applications deployed on a fleet of ruggedized Android tablet computers. Data collected on each form were inserted into a local database on each tablet that mirrors the project database structure on ABR's servers in Fairbanks and Anchorage. To ensure data quality and consistency throughout the long-term monitoring effort, entries to each field were validated against a data dictionary that was customized for the CD5 Habitat Monitoring Study. For example, when entering data for a categorical variable (e.g., geomorphic unit), field observers selected from "pick lists" that were populated with values relevant to the variable. Similarly, apps were designed to accept only numeric entries for quantitative variables (e.g., soil pH). These validation rules enforced attribute domains and database integrity, both of which are essential to long-term monitoring. Field teams carried paper forms in case any issues arose with the tablets during fieldwork. Backups of the data in the database were copied to removable media after completion of each plot in order to ensure the data are retrievable even if a tablet were to fail.

At the end of each field day, teams backed up all data from tablets to hard drives and conducted an initial data review by inspecting raw data tables and running data-proofing queries. After review, field data were uploaded to ABR's servers using the Wi-Fi connection at Alpine Camp.

Field data were stored in a project-specific PostgreSQL database created using a common template database shared by all ELS and Wetlands projects. This template database includes all the necessary reference tables for the categorical fields

2013

2016

2013 Photo Point 1 at 110º

2016 Photo Point 1 at 110º

2013 Photo Point 1 at 190º

2016 Photo Point 1 at 190º

2013 Photo Point 2 at 154º

2016 Photo Point 2 at 154º

Figure 3.6. Photographs from the Geomorphology Monitoring Photo Points 1 and 2, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. Photographs include Photo Point 1 at 110º in 1.a) 2013, and 1.b) 2016; Photo Point 1 at 190º in 2.a) 2013, and 2.b) 2016; Photo Point 2 at 154º degrees in 3.a) 2013, and 3.b) 2016.

Figure 3.7. Photographs from Geomorphology Monitoring Photo Point 3, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. This point was added in 2016 to monitor for landscape change from the Niġliq channel bridge (left) NNW at 329º and (right) SSE at 149º.

in our field forms, an existing data table structure, and views designed to streamline data review, analysis, and reporting tasks. The template is partitioned into several "schemas" that are used for database organization and each can independently contain tables, views, functions, and other database objects.

All databases are backed up to disk (nightly) and also to tape (approximately weekly), and these backups are rotated such that we maintain older copies of the databases for up to several months.

3.3.3.A.i Data Quality Assurance and Control

After the field effort, we performed a sequence of quality assurance and quality control (QAQC) routines on the Habitat Monitoring data. The QAQC procedures were designed to ensure that only the highest quality data were used for analysis. Vegetation point-intercept, environmental, and GPS Survey data and photographs were reviewed to ensure that data were collected in accordance with the overall study design, and consistently across the 3 field teams.

The first stage of QAQC occurred after the field data were uploaded from the Android tablets directly to the "field" schema of the project database on ABR servers. After reviewing the primary identifiers in all tables to ensure referential integrity between the data collected with different mobile applications at the same locations, the data were copied to the "public" schema where subsequent data review would take place. The original field data, with only primary key adjustments, were preserved in the field schema.

Once the data were copied to the "public" schema, SQL queries and a series of pre-written database views were used to perform logical checks on the data. For instance, *water_depth_cm* was checked against the *water_above_below_surf_code* field to ensure that water depths were recorded with the correct sign depending on if the water table was above (positive) or below (negative) the soil surface. When errors were encountered, updates were made using web-based review forms. The review forms communicated with the server database, integrating the data from each field form, photograph, and field into a single interface that allowed users to review and correct the data simultaneously. All updates were logged in the database and read/write access to the form was restricted by login.

Next, the data were checked for consistency with relevant classification systems using database views that aggregated and ordered the data to facilitate such review. For instance, the point-intercept data were aggregated to percent-cover values for each Vegetation Plot and these quantitative values were then used to confirm that an appropriate AVC vegetation class (Viereck et al. 1992) was assigned to each plot in the field.

Plot photographs were reviewed using a form that organized all photos by plot_id and sample year. The form facilitated review by allowing reviewers to 1) confirm that the photographs were correctly assigned to the correct *plot_id* and *photo_plot_element_code* (e.g., Vegetation Plot Start Point, Habitat Plot Line, Soil Pit); 2) select the best photographs among the duplicates in each category; and 3) identify any missing photographs. Photographs were also reviewed spatially using the GPS coordinates embedded in the Exif (exchangeable image file format) metadata to display the photos in a GIS. The photo locations were then compared to the location of each Integrated Habitat Plot to ensure that each photo was assigned to the correct plot.

Plant voucher specimens were sent for verification to Carolyn Parker at the University of Alaska Anchorage Herbarium (vascular plants) and Brian Heitz at the University of Alaska Anchorage (non-vasculars). A subset of non-vascular specimens were sent to Dr. Lars Hedenäs at the Swedish Museum of Natural History in Stockholm. The species determinations were used in the PostgreSQL database to update the preliminary species codes assigned to voucher specimens in the field.

3.3.3.A.ii Plant Taxonomy Revisions

The scientific names of plants are continuously being revised to reflect new information concerning phylogenetic relationships within and among different groups of plants. For example, genetic and morphological studies often indicate that what was previously considered one species is actually two or more closely related species. In other cases, new information leads to the regrouping and renaming of existing taxa. Because the taxonomy of plants is under constant revision, it can be challenging for botanists to keep track of the current plant nomenclature, and many times well known older names remain in use. Therefore, taxonomic changes can complicate long-term monitoring efforts such as those reported on here for the CD5 Study Area.

To address this issue, plant observations recorded at field plots in 2013 were reviewed and names were updated as needed to match more current, published taxonomic nomenclature. We updated species names according to Viereck and Little (2007) for shrubs and Skinner et al. (2014) for grasses; the taxonomy used for all other vascular plants followed Hultén (1968) and thus remained unchanged from 2013. For non-vascular plants (i.e., mosses, liverworts, and lichens), we attempted to use the taxonomy preferred by the U.S. Department of Agriculture (USDA). The USDA maintains an online database—USDA PLANTS—which provides up-to-date taxonomic information for most non-vascular plants in Alaska (USDA 2017). If the nonvascular species name used in 2013 was not found in USDA PLANTS, the name provided in the Flora of North America was used instead (Flora of North America Editorial Committee 2007, 2014). In addition to revision of species names prompted by taxonomic changes, we also revised records of one common moss species—*Calliergon giganteum*—after an expert review of voucher specimens revealed that all observations instead pertained to the closely related *Calliergon richardsonii*.

3.3.3.B Integrated Terrain Unit (ITU) Mapping

ABR performed baseline ecological mapping for the CD5 Study Area in 2013. This mapping applied an existing ecological classification system that was developed for the Central Beaufort Coastal Plain (CBCP; see below) and described landscape conditions photo-interpreted using high-resolution imagery from 25 July 2012. However, the deltaic ecosystems of the CRD are shaped by numerous natural disturbance and successional processes that change ecosystem conditions over time. For example, river channel migration results in predictable patterns of erosion along cutbanks, and deposition of new sediment on point bars that are gradually colonized by vegetation. As a result, the baseline maps for the CD5 Study Area represent a "snapshot" of ecosystem conditions that existed when the imagery used for mapping was acquired in 2012. Since then, the construction of CD5 infrastructure and ice roads have caused local-scale changes to ecosystem conditions, and the exceptional spring breakup floods of 2013 and 2015 resulted in extensive flooding, ice scour, and sedimentation along the Niġliq Channel and other distributaries of the CRD. Thus, as per the

Monitoring Plan the mapping was updated by overlaying the baseline map units onto high-resolution imagery acquired 3–5 July 2015. The updated mapping was then used to perform a landscape change analysis as indicated in the Monitoring Plan (ABR and Baker 2013).

As part of the landscape change assessment, the Monitoring Plan specified the following criteria:

> For each of the ITU components or wildlife habitat, if the average percent change in spatial area in the Test Area is greater than or less than the 95% confidence interval of the corresponding aggregated ITU components or wildlife habitat classes in the Reference Area, this will trigger a review of the hydrology model and resulting design criteria.

However, confidence intervals are used in statistics to describe the amount of uncertainty associated with a sample estimate of a population parameter. After reviewing the Monitoring Plan guidelines for the landscape change analysis, it was unclear what confidence intervals of the average percent change in spatial area would represent with respect to uncertainty in the ITU mapping. Uncertainty in mapping is more commonly expressed by a formal accuracy assessment using an independent field verification dataset, rather than confidence intervals. An accuracy assessment of the ITU mapping was not conducted as part of the CD5 Monitoring Study because an independent verification dataset was not available. Due to the unclear nature of applying confidence intervals to the ITU mapping we developed a new objective criteria for assessing landscape changes in the Test Areas with respect to the Reference Areas. The criteria are as follows:

> A review of the hydrology model will be triggered if any one or more ITU component classes or habitat classes in the Test Areas changes in area between 2012 and future years mapping (in this case the 2015 mapping). The change in area must be greater than or equal to 5% of the total area of that component across the entire CD5 Study Area AND the difference in percent of area changed for said component class or habitat between Test and Reference Areas is >5%.

The above criteria is highly applicable, and readily applied to the ITU mapping. The above criteria was applied to the landscape change analysis performed in this report.

For wildlife management purposes, ITU map updates can be used to quantify changes in the areal extent and landscape arrangement of habitat types for species of interest over time, and to determine if changes are extensive enough to necessitate adaptive management in the CD5 Study Area. In addition, habitat monitoring provides a tool to evaluate landscape alterations resulting from factors beyond the direct control of CPAI, such as climate change and landscape-scale disturbances such as river channel migration.

All mapping efforts used an Ecological Land Survey (ELS) ITU mapping approach in which 4 ecosystem parameters were assigned to each landscape “patch” (hereafter, map unit) delineated in the map: geomorphic unit, surface form, vegetation, and disturbance class. These parameters describe ecosystem properties that are relevant to land management applications, including wildlife habitat assessment and monitoring, landscape trafficability assessment, and contingency planning. Each unique combination of parameters constitutes an Integrated Terrain Unit (ITU; e.g., Delta Active Overbank Deposit/High-center Low-relief Polygons/Open Low Willow Shrub/Fluvial Sedimentation). The mapping classification was applied using a standard coding system (Tables 3.1–3.5) and all map units in the baseline map were delineated at a scale of 1:1,500, for a final map scale of 1:3,000 (i.e., the scale at which the mapping is valid for landscape analysis). For baseline mapping, the minimum map unit size was 0.1 hectare (ha) for waterbodies, 1.0 ha for complexes, and 0.3 ha for all other classes. For the map update effort, we adjusted map units as needed to reflect changes in landscape conditions evident in 2015 imagery, even if the portion of map units affected by change did not meet the minimum map unit criteria used in construction of the baseline map.

The high-resolution imagery acquired 3–5 July 2015 was compared with 2012 imagery using the “swipe” tool in ArcMap GIS software, and the baseline map units were edited to reflect changes evident in the recent imagery. These edits included spatial adjustment of map unit boundaries, change to one or more ecosystem parameters assigned to a map unit, or both. Our image review first focused on landscape positions that are known to be highly dynamic, such as shorelines of the Niqliq Channel and tapped lakes such as Nanuk Lake. Tapped lakes are waterbodies that have been partially drained through erosion of banks by adjacent river channels; they are connected to rivers by distinct, permanently flooded channels. We also reviewed all map units for which a disturbance class had been assigned during baseline mapping to assess whether the disturbed area had changed in size, or if vegetation had recovered from the historical disturbance. We used existing “as-builts” in the form of GIS shapefiles to delineate the boundaries of the newly constructed CD5 road, bridges, and pipelines. We ultimately developed a simple classification of natural and anthropogenic mechanisms potentially responsible for landscape change in the CD5 Study Area, and assigned a mechanism class to each updated map unit (Table 3.6). The landscape change mechanisms identify the suspected cause of landscape changes that occurred between 2012 and 2015.

Throughout this report, the term *map update* refers to ITU map changes that pertain to actual changes in the ecological conditions of a map unit that occurred since the baseline mapping effort. The emphasis of the map updates was on changes that could be interpreted unequivocally from high-resolution imagery and involved a transition from one ITU to another. In addition to map updates, we performed a small number of *map revisions* to the 2012 baseline mapping where 2016

Table 3.6. Standard classification system developed for classifying and mapping landscape change mechanisms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2012–2015.

Disturbance regime	Description
Absent	No detectable change in ecosystem conditions during the 2012–2015 monitoring interval.
Anthropogenic–bridge	Bridge construction over distributaries of the Colville River Delta associated with the CD5 Road in 2013.
Anthropogenic–gravel road	Emplacement of gravel fill for roads and pads in 2013.
Anthropogenic–ice road or pad	Disturbance and/or mortality of vegetation due to ice roads and pads on tundra during 2012–2015.
Anthropogenic–pipeline	Construction of elevated pipelines in 2013.
Fluvial Erosion	Former terrestrial areas that were disturbed or destroyed by channel migration and cutbank erosion from 2012–2015.
Fluvial Sedimentation	Former stream channels that were filled with sediment, or vegetated areas that experienced partial or complete plant mortality due to sediment deposition during 2012–2015, usually associated with flood events.
Succession	Increases in vegetation density and/or changes in vegetation structure associated with ecological succession after historical disturbance.
Thermokarst (Ngt)	The processes associated with the thawing permafrost that leads to local or widespread collapse, subsidence, erosion and instability of the ground surface.

field observations indicated that the original ITU assigned to a map unit was inaccurate. Map revisions of inaccurancies are depicted in the updated mapping, but they were not included in assessments of ecosystem change in the Test and Reference Areas (see Landscape Change Analysis section, below).

Updated maps were produced for each of the 4 ecosystem parameters used to create the ITUs: geomorphic unit, surface form, vegetation, and disturbance. Geomorphic units were separated into terrestrial and aquatic maps to better display waterbodies. The 4 ITU component codes were concatenated for each map unit, and the resultant ITU code combinations (herein, ITU codes; e.g., Fdoi/Phl/Slow/Ngfd) were aggregated into map ecotypes (e.g., Riverine Moist Low Willow Shrub) and wildlife habitats (e.g., Moist Low Shrub) based on the CBCP classification.

Ecotype and Wildlife Habitat Classification

The Central Beaufort Coastal Plain (CBCP) classification and mapping represents nearly 20 years of ELS classification and mapping efforts in northern Alaska, including the Colville River Delta (Jorgenson et al. 1997) and northeastern NPRA (Jorgenson 2003; Jorgenson et al. 2002). The CBCP classification includes map ecotypes and wildlife habitats that were developed, and have been continually refined, from field data collected as part of these studies and others performed in the greater western Kuparuk oilfield. The CBCP classification also provides a framework for cross-referencing between ITUs identified in new or updated mapping and the map ecotype and wildlife habitat classifications (Appendix A).

Map ecotypes represent local-scale ecosystems that are classified by aggregating ITUs with similar geomorphology, surface form, vegetation, and disturbance regime. The overarching goal of the aggregation is to identify strong relationships that are useful for land management and mapping, while avoiding the creation of extraneous classes that would lead to confusion and decreased map accuracy. In developing the CBCP ecotype classification, we attempted to use ecological characteristics that could be interpreted from high-resolution imagery. A nomenclature for ecotypes was also developed that translated fundamental ecological characteristics, including physiography, soil moisture, vegetation structure, and dominant species into intuitive and easily understood classes (e.g., Riverine Moist Low Willow Shrub). The number of potential ecotype classes was reduced by aggregating the field data for individual ecological characteristics (e.g., soil stratigraphy and vegetation composition) using a hierarchical approach. For geomorphology, near-surface soil classes, textures, and layers were aggregated into geomorphic units using the approaches of Miall (1985) and Brown et al. (1997). Geomorphic units were assigned to physiographic settings based on their primary erosional or depositional processes. Surface forms were aggregated into a reduced set of classes (primarily driven by degree of ground-ice development, e.g., ice-wedge polygons). For vegetation, the structural levels of the AVC (Viereck et al. 1992) were used because they are readily identifiable in high-resolution imagery. Some classes were grouped (e.g., open and closed shrub) because species composition was similar.

We updated the baseline map ecotype and wildlife habitat maps by recoding the updated ITU map, using a cross-reference table between ITU code, map ecotype, and wildlife habitat. During the 2016 CD5 ITU map update, a few new ITUs were encountered that were not present in the existing CBCP; in these cases, map-ecotype and wildlife-habitat classes were assigned based on the classification of the most similar existing ITU(s) (Appendix A).

The CBCP wildlife habitat classification was based on landscape properties considered most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, plant species composition, surface form, soils, hydrology, and microclimate. Wildlife habitats are not equivalent to vegetation types; for example, dissimilar vegetation types may be combined into the same wildlife habitat because selected wildlife species use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of relief, soil characteristics, prey availability, or other factors not reflected in plant-species composition. Habitat classifications for the same region may also differ, depending on the wildlife species or species groups being considered. For the CBCP classification, the focus of the habitat classification was on (1) breeding waterbirds that use waterbodies and wet and moist tundra types, and (2) mammals and upland birds that use shrublands and drier tundra types. Wildlife-habitat classes were assigned to the ITUs according to the CBCP classification scheme that was developed following bird-habitat studies conducted in the Prudhoe Bay, Kuparuk, and Alpine oilfields and in northeastern NPRA (Anderson et al. 2001; Burgess et al. 2003; Johnson et al. 1990, 1997; Jorgenson et al. 1989; Murphy and Anderson 1993; Murphy et al. 1989).

3.3.3.C Data Analysis

3.3.3.C.i Vegetation Plot Analysis

Point-intercept Data Summaries

Raw point-intercept data does not correspond directly to percent cover of plant species or ground cover classes. Therefore, for each Vegetation Plot, point-intercept data were summarized to produce estimates of plant cover and to characterize woody and herbaceous vegetation height. The data for all the points sampled at each plot were aggregated to calculate the cover metrics by species and by vegetation-structure class for each plot. Vegetation-structure class was assigned based on lifeform for herbaceous and non-vascular vegetation (sedge, grass, forb, lichen, and moss). For woody vegetation, structure class was based on the Viereck and Little (1992) shrub species size class descriptions (e.g., low shrub). For analysis, low and tall shrubs were combined as "low and tall shrubs," and dwarf and prostrate shrubs were grouped as "dwarf shrubs."

Water, bare soil, and litter (including standing dead vegetation) were each summarized as separate classes in this analysis. Cover data were then summarized in four ways: 1) hit density (hit_density)—all hits by species and structure class at each point, 2) cover (cover)—first hit of each species and structure class at each point, 3) top cover (top_cover), and 4) bottom cover (bottom_cover)—last hit at each point.

Following the BLM AIM protocol (Toevs et al. 2011, BLM 2013), we used shrub- and herbaceous-height data collected at every fifth point along each line to calculate average woody and herbaceous vegetation height (the mean height for all sampled points at which shrubs or herbaceous vegetation were present) and frequency (the percentage of sampled points where woody or herbaceous vegetation was present).

Vegetation Plot Assessment

The vegetation plot assessment data analysis methods follow directly from the Monitoring Plan (ABR and Baker 2013), which specified the following:

> Vegetation data from both Test and References Areas from post-construction monitoring years will be ordinated with the pre-construction data to determine if a shift in species composition has occurred over time. Generalized regressions will be fit to the ordination axes scores for each continuous environmental variable. The direction along each axis to which plots may have shifted will be compared to the results of the generalized regressions to draw inferences regarding changes in environment associated with the shift in species composition.

Several data transformations were performed following the aggregation of the Vegetation Plot point-intercept data to cover values. First, vascular and non-vascular subspecies and varieties were aggregated to the species level. In addition, vascular species that were easily confused in the field were aggregated to genus level for the analysis. These two transformations were completed using a cross-reference table (**ref_ssp_var_xwalk**) stored in the project schema of the project data (Table 3.7). Both transformations were required to harmonize the 2013 and 2016 datasets and reduce differences between the years related to misidentification or taxonomic resolution. Second, unknown species codes, ground cover classes, non-vascular taxa, and vascular taxa identified to genus level only (with the exception of those discussed above) were excluded from the analysis. Third, plots where the floristic_analysis_ynna_code field in the veg table is equal to "no" (n) were withheld from the analysis. This field was used to exclude water plots (i.e., plots representing waterbodies) and barrens (<5% live cover). Fourth, all trace species (i.e., cover of 0.1%) were withheld from the analysis.

Table 3.7 Cross-reference table between original species codes and scientific names and species codes and scientific names used in the vegetation assessment analysis, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Original Code	Original Scientific Name	Code for Analysis	Scientific Name for Analysis
agrop	*Agropyron* sp.	elymu	*Elymus* sp.
andcha	*Androsace chamaejasme* ssp. *lehmannia*	andcha1	*Androsace chamaejasme*
aralyr	*Arabis lyrata* ssp. *kamchatica*	aralyr	*Arabis lyrata* ssp. *kamchatica*
arclat1	*Arctagrostis latifolia* ssp. *latifolia*	arclat	*Arctagrostis latifolia*
arcto1	*Arctostaphylos* sp.	arcto3	*Arctous* sp.
arcalp1	*Arctous alpina*	arcto3	*Arctous* sp.
arcrub1	*Arctous rubra*	arcto3	*Arctous* sp.
artarc1	*Artemisia arctica* ssp. *arctica*	artarc2	*Artemisia arctica*
asteuc	*Astragalus eucosmus* ssp. *eucosmus*	asteuc1	*Astragalus eucosmus*
astsea	*Astragalus eucosmus* ssp. *sealei*	asteuc1	*Astragalus eucosmus*
bropum5	*Bromus pumpellianus* ssp. *pumpellianus*	bropum3	*Bromus pumpellianus*
cackam	*Cacalia auriculata* ssp. *kamtschatica*	cackam	*Cacalia auriculata* ssp. *kamtschatica*
caline1	*Calamagrostis stricta* ssp. *inexpansa*	caline1	*Calamagrostis stricta* ssp. *inexpansa*
calgig	*Calliergon giganteum*	calric	*Calliergon richardsonii*
carpra1	*Cardamine pratensis* ssp. *angustifolia*	carpra3	*Cardamine pratensis*
caraqu	*Carex aquatilis* ssp. *aquatilis*	caraqu1	*Carex aquatilis*
carsax	*Carex saxatilis* ssp. *laxa*	carsax	*Carex saxatilis* ssp. *laxa*
cetisl2	*Cetraria islandica* ssp. *islandica*	cetisl	*Cetraria islandica*
decori	*Deschampsia cespitosa* ssp. *orientalis*	desces	*Deschampsia cespitosa*
equsci	*Equisetum scirpoides*	equis	*Equisetum* sp.
equvar	*Equisetum variegatum*	equis	*Equisetum* sp.
equvar1	*Equisetum variegatum* ssp. *variegatum*	equis	*Equisetum* sp.
eriang	*Eriophorum angustifolium* ssp. *subarcticum*	eriang1	*Eriophorum angustifolium*
erirus	*Eriophorum russeolum*	eriop	*Eriophorum* sp.
eriruf	*Eriophorum russeolum* ssp. *rufescens*	eriop	*Eriophorum* sp.
erisch	*Eriophorum scheuchzeri*	eriop	*Eriophorum* sp.

Table 3.7. Continued.

Original Code	Original Scientific Name	Code for Analysis	Scientific Name for Analysis
fesarc	*Festuca rubra* ssp. *arctica*	fesrub	*Festuca rubra*
fesrub3	*Festuca rubra* ssp. *pruinosa*	fesrub	*Festuca rubra*
genpro1	*Gentiana propinqua* ssp. *propinqua*	genpro	*Gentiana propinqua*
hedalp	*Hedysarum alpinum*	hedys	*Hedysarum* sp.
hedmac	*Hedysarum mackenzii*	hedys	*Hedysarum* sp.
leymol	*Leymus mollis* ssp. *mollis*	leymol1	*Leymus mollis*
luzarc1	*Luzula arctica*	luzul	*Luzula* sp.
luzarc2	*Luzula arcuata*	luzul	*Luzula* sp.
luzuna	*Luzula arcuata* ssp. *unalaschcensis*	luzul	*Luzula* sp.
luzcon	*Luzula confusa*	luzul	*Luzula* sp.
luzmul	*Luzula multiflora*	luzul	*Luzula* sp.
luzfri	*Luzula multiflora* ssp. *frigida*	luzul	*Luzula* sp.
luzkje	*Luzula multiflora* ssp. *multiflora var. kjellmaniana*	luzul	*Luzula* sp.
luzspi	*Luzula spicata*	luzul	*Luzula* sp.
luztun	*Luzula tundricola*	luzul	*Luzula* sp.
melarc	*Melandrium apetalum* ssp. *arcticum*	melarc	*Melandrium apetalum ssp. arcticum*
pedlan1	*Pedicularis langsdorffii* ssp. *arctica*	pedlan3	*Pedicularis langsdorffii*
pedlan2	*Pedicularis langsdorffii* ssp. *langsdorffii*	pedlan3	*Pedicularis langsdorffii*
pedalb	*Pedicularis sudetica* ssp. *albolabiata*	pedsud	*Pedicularis sudetica*
pedint	*Pedicularis sudetica* ssp. *interior*	pedsud	*Pedicularis sudetica*
phipum	*Philonotis fontana* var. *pumila*	phifon	*Philonotis fontana*
poaarc1	*Poa arctica* ssp. *arctica*	poaarc	*Poa arctica*
poalan1	*Poa arctica* ssp. *lanata*	poaarc	*Poa arctica*
poagla1	*Poa glauca* ssp. *glauca*	poagla	*Poa glauca*
poaalp3	*Poa pratensis* ssp. *alpigena*	poapra	*Poa pratensis*
polbis	*Polygonum bistorta* ssp. *plumosum*	polbis	*Polygonum bistorta ssp. plumosum*
poljen1	*Polytrichum commune* var. *jensenii*	polcom	*Polytrichum commune*
pyrsec2	*Pyrola secunda* ssp. *secunda*	pyrsec1	*Pyrola secunda*

Table 3.7. Continued.

Original Code	Original Scientific Name	Code for Analysis	Scientific Name for Analysis
rangme	*Ranunculus gmelini* ssp. *gmelini*	rangme1	*Ranunculus gmelini*
rubarc1	*Rubus arcticus*	rubus	*Rubus* sp.
saxpun	*Saxifraga punctata*	saxnel	*Saxifraga punctata* ssp. *nelsoniana*
saxnel	*Saxifraga punctata* ssp. *nelsoniana*	saxnel	*Saxifraga punctata* ssp. *nelsoniana*
sedros	*Sedum rosea* ssp. *integrifolium*	sedros	*Sedum rosea* ssp. *integrifolium*
stealp	*Stereocaulon alpinum*	stere	*Stereocaulon* sp.
utrint	*Utricularia intermedia*	utric	*Utricularia* sp.
utrmin	*Utricularia minor*	utric	*Utricularia* sp.
utrvul	*Utricularia vulgaris* ssp. *macrorhiza*	utric	*Utricularia* sp.

Finally, any plots that had less than 3 species, after the exclusion of the species described above, were withheld from the analysis. Additionally, all species that occurred in only one plot were withheld from the analysis. Plots that were withheld from the analysis were assessed by comparing the Viereck et al. (1992) Level IV vegetation class assigned to the plot in 2013 and 2016. Plots with the same vegetation class between years were considered to not have changed. Plots that differed in vegetation class were considered to have changed between 2013 and 2016. Lastly, the percent cover data were natural log transformed. The natural log transformation down-weights dominant species, which can skew the results of clustering and ordination analyses. The final floristic analysis dataset had both raw and natural log transformed cover values.

The combined 2013 and 2016 transformed Vegetation Plot datasets were then ingested in R statistical software. We partitioned the dataset into 4 sub-datasets:

1. 2013 plots classified as wet plot ecotypes (referred to herein as the "2013 wet plot ecotype sub-dataset"),
2. 2013 plots classified as moist plot ecotypes (referred to herein as the "2013 moist plot ecotype sub-dataset"),
3. 2013 and 2016 plots classified as wet plot ecotypes (referred to herein as the "2013/2016 wet plot ecotype sub-dataset"), and
4. 2013 and 2016 moist plot ecotypes (referred to herein as the "2013/2016 moist plot ecotype sub-dataset").

The partitioning based on wet and moist ecotypes follows from the vegetation classification and assessment methods used in the 2013 CD5 Habitat Monitoring Study (Wells et al. 2014); the 2013 data were partitioned into these two groups for analysis. The first group includes ecotypes characterized by wet sedge and wet sedge-willow tundra vegetation; the second group comprises all other ecotypes characterized as moist. See Wells et al. 2014 for detailed descriptions of the plot ecotypes.

Following the dataset partitioning, we used the natural log transformed cover data to calculate Bray/Curtis dissimilarity (Bray and Curtis 1957) matrices for the 2013/2016 wet plot ecotype and 2013/2016 moist plot ecotype sub-datasets. Based on exploratory analysis, a log transformation of the species-cover data was determined to be most suitable for the ordination analyses. The log transformation reduced the statistical weight of dominant species with high cover relative to species with lower cover and resulted in a more balanced representation of species composition within Vegetation Plots. We applied non-metric multidimensional scaling (NMDS) (Shepard 1962a&b, Kruskal 1964a&b) to the dissimilarity matrix to chart the plots in species space. For the analysis, we used the ordination plotting functions provided in the vegan (Oksanen et al. 2016) and rgl (Adler et al. 2016) R libraries to plot the NMDS ordinations for 2013/2016 wet plot ecotype (herein "2013/2016 wet NMDS") and 2013/2016 moist plot ecotype (herein "2013/2016 moist NMDS") sub-datasets as 3-dimensional, dynamic plots. The rgl function rotates the plots graphically and allows them to be viewed from multiple perspectives. The plot ecotypes were symbolized in the dynamic plots and the point dispersion of each plot ecotype grouping was reviewed visually for consistency within and between groups.

We used the natural log transformed cover data to calculate Bray/Curtis dissimilarity matrices for the 2013 moist plot ecotype and 2013 wet plot ecotype sub-datasets to place the two sub-datasets into clusters of plots with similar vegetation composition. We independently clustered the two sub-datasets using the fixed clustering algorithm Partitioning Around Medoids (PAM) (Kaufman and Rousseeuw 1990). Medoids are plots that are centrally located within a cluster and represent the "typical" plot for that cluster based in this case on plant species composition. This resulted in two clusterings, one for the 2013 moist plot ecotypes (herein "2013 moist clusters") and one for the 2013 wet plot ecotypes (herein "2013 wet clusters"). We applied NMDS to the dissimilarity matrices to chart the plots in 3-dimensional species space resulting in a NMDS diagram for the 2013 moist plot ecotypes (herein "2013 moist NMDS") and for the 2013 wet plot ecotypes (herein "2013 wet NMDS"). We then symbolized the respective PAM clustering and medoid in each NMDS diagram. Next, we used the xyz-coordinates of each plot in each NMDS to calculated the ordination distance of each plot from the medoid of each respective cluster. The plot-to-medoid distance was then averaged across all plots in each cluster (avg. cluster medoid distance) and the standard deviation (stdev cluster medoid distance), 2x standard deviation (2x stdev medoid distance), and 3x standard deviation (3x stdev medoid distance) were calculated. The results of this analysis served as the baseline data for comparing with the 2016 plots (see below).

We plotted the "2013/2016 moist NMDS" and "2013/2016 wet NMDS" and symbolized the 2013 moist clusters and 2013 wet clusters. Within each NMDS and cluster, for each plot we used the NMDS xyz-coordinates to calculate the distance between the 2013 (e.g., *plot_id* t1na-0200-veg sampled in 2013) and 2016 (e.g., *plot_id* t1na-0200-veg sampled in 2016) plots in the 2013/2016 moist NMDS and 2013/2016 wet NMDS, respectively. The ordination distance between the 2013 and 2016 plots was then compared to the 2x stdev medoid distances and 3x stdev medoid distances calculated above for each cluster. We grouped plots into 3 categories based on the stdev medoid distance between the 2013 and 2016 plot.

- Not changed: plots with a NMDS distance between the 2013 and 2016 plot of ≤2x stdev medoid distance for their respective 2013 cluster were considered to have not changed in species composition.
- Potentially changed: plots with a NMDS distance between the 2013 and 2016 plot of 2x stdev >3x stdev medoid distance for their respective 2013 cluster were considered to have shifted in species composition between 2013 and 2016 but the shift was minor and the shift may be related to natural variability between years and/or sampling error.
- Changed: plots with a NMDS distance between the 2013 and 2016 plot greater than the 3x stdev medoid distance for their respective 2013 cluster were flagged as having changed in species composition between 2013 and 2016.

Plots flagged as having changed were then plotted in the NMDS diagrams with arrows pointing from the 2013 plot to the 2016 plot to illustrate the direction and distance of change in ordination space. This approach follows the general methods underpinning the reference condition approach to monitoring ecological communities as per Reynoldson et al. (2001).

Non-metric Multidimensional Scaling (NMDS): Ecological Gradients and Vegetation Plot Assessment

The R function ordisurf() from the vegan package was used to fit a subset of environmental variables to the 2013/2016 moist and 2013/2016 wet NMDS axis scores using Generalized Additive Models (GAMs). This analysis is a type of indirect gradient analysis in which the ordination axis scores are treated as independent variables that are used to predict the dependent environmental variables. The end purpose of this analysis is to elucidate complex relationships between species composition and environmental gradients in the CD5 Habitat Monitoring Study Area. The results of ordisurf() is 1) a contour surface plotted over the ordination that represents the direction of the relationship between the species composition (as represented by the ordination axes) and the environment variable as predicted by the GAM; 2) a model fit value, deviance-squared (D^2), that indicates the strength of the relationship between the ordination axes and each environmental variable; and 3) a *p*-value that indicates the statistical significance of the model fit for each environmental variable. The higher the fit value, the better the model fits the actual distribution of the environment along the ordination axes, and (indirectly) the greater the importance of the variable in influencing the structure and composition of the vegetation. We ran ordisurf for all combinations of NMDS axes (i.e., [1,2],[1,3],[2,3]) and the following 9 environmental variables:

- Latitude (**monitoring_locations**.*lat_dd83*),

- Longitude (**monitoring_locations**.*long_dd83*),
- Elevation BPMSL (**monitoring_locations**.*elev_cm*),
- Distance from CD5 Road (**monitoring_locations**.*distance_to_edge_cd5_road_m*),
- Thaw depth (**monitoring_locations**.thaw_depth_cm),
- Soil surface organic thickness (**els**.*soil_surface_organic_thick_cm*),
- Water depth (**els**.*water_depth_cm*),
- Site pH (**els**.*site_ph_calc*),
- Site Electrical conductivity (**els.***site_ec_us_calc*)

The ordisurf() results were reviewed and the variables with the strongest fits were used to plot fitted surface contours overlaid on the NMDS diagrams. We used the ordtest() function from the labdsv package (Roberts 2016) to test for the degree of deviation from randomness of categorical variables along each set of ordination axes. Significant deviation from randomness suggested that the categories of the variable were more highly aggregated along the set of ordination axes than would be expected if the categories were randomly distributed across the ordination space. Categorical variables tested included the following:

- Sample year (**els**.*sample_year*)
- Area (**plot**.*area_id* aggregated to "Reference" and "Test")
- Plot ecotype code (**els**.*plot_ecotype_code*)

The ordtest() results were reviewed and the significant ($p < 0.05$) variables were symbolized on the NMDS diagrams.

Species Richness by Study Area, Plot Ecotype, and Sample Year

Species richness was calculated for each plot ecotype by Area and sample year by summing the total number of unique species occurrences in each class. For the species richness calculation the trace species were merged with the transformed vegetation dataset that was first applied to the NMDS analysis (see section Vegetation Plot Assessment, above). The trace species were transformed similarly, i.e., subspecies and varieties were aggregated to the species level and vascular species that were easily confused in the field were aggregated to genus level for the analysis. Unknown species codes, ground cover classes, and vascular taxa identified to genus level only (with the exception of those discussed above) were excluded from the species richness calculations. Plots where the *floristic_analysis_ynna_code* field in the **veg** table were equal to "no" (n), plots that had less than 3 species, after the exclusion of the species described above, and species that occurred in only 1 plot were included in the species richness calculation. The species richness data were summarized using stacked bar charts to compare vascular and non-vascular species richness for ecotype with a sample size of 2 or more by Area and sample year.

Detailed Ground Cover Class Assessment

We summarized percent cover of ground cover hits using the last hit at each point (bottom_cover). The percent cover of each ground cover class was calculated for each plot and then aggregated to average, min, and max cover values, and sample size for each ground cover class by grouping the plots in two ways: 1) by sample year and Area, and 2) by plot ecotype, sample year, and Area. The results of the aggregation were used to prepare ring charts of the proportion of average total ground cover by sample year and study Area, and ecotype, sample year, and Area. Proportion of average total ground cover was calculated as follows:

Proportion of average total ground cover = Average cover(%)/ sum(Average cover(%))

The transformation from percent cover to proportion of average total ground cover was performed to transform the average total cover by grouping, which in some cases summed to more than 100%, to a proportion that summed to 100% and which could be presented in a circular ring chart.

Environmental Data Assessment

We summarized 9 environmental variables by plot ecotype, Area, and year by calculating the average, standard deviation, min, max, and sample size of each. The environment variables summarized include Elevation BPMSL, Thaw depth, Soil surface organic thickness, Water depth, Site pH, and Site Electrical conductivity.

Vegetation Structure

The cover and height data for each vegetation structure class from the Vegetation Plots were summarized for each plot ecotype by Area and sample year. The mean cover value for each structure class in each plot ecotype by Area and sample year was calculated by averaging the cover values from all plots assigned to that plot ecotype. The mean height and frequency of woody and herbaceous vegetation for each plot ecotype were calculated in the same manner. The mean cover and height data were used to create stacked bar charts and summary tables for presentation. The mean cover data for each vegetation-structure class were combined with the mean top cover of the 3 non-vegetated classes (water, soil, litter) for each plot ecotype. The top cover, or first hit, identifies points where the non-vegetated class occurred without any overtopping vegetation. These are represented as water alone, soil alone, and litter alone in the stacked bar charts and summary tables.

3.3.3.C.ii Calibration Plot Analysis

Three of the Habitat Plots in the CD5 Study Area were sampled by six different field observers to assess the inter-observer variability in point-intercept data associated with the method itself. The point-intercept data from these plots were summarized using methods comparable to those used at Vegetation Plots (see Point-intercept Data Summaries under section 3.3.3.C.i., above), except that the data were summarized for each line at each plot.

The mean cover and 95% confidence intervals were calculated for each line and vegetation structure class (e.g., low shrub, dwarf shrub, sedge, moss). The confidence intervals were then scaled by the mean cover value, so that inter-observer variation was calculated as a percentage of the mean and averaged by vegetation structure class. These metrics were only calculated for vegetation structure classes with more than 5% cover in each line.

3.3.3.C.iii Habitat Analysis

The habitat analysis methods follow directly from the Monitoring Plan (ABR and Baker 2013) which specifies the following:

> For habitat sampling lines, mean and 95% confidence intervals for percent cover of vegetation structure classes (e.g., low shrub, dwarf shrub, graminoid, tussock) will be calculated for each habitat following year-1 data collection. Repeated measures analysis will be used to test for differences in vegetation structure within habitat types between Areas and sampling periods. Additionally, to aid in identification of trends in vegetation structure through time, the 95% and 75% confidence intervals for percent cover of vegetation structure classes will be calculated.

The Habitat Plot point-intercept data were summarized to cover metrics following methods similar to those used at Vegetation Plots (see Point-intercept Data Summaries under section 3.3.3.C.i., above). However, because the Habitat Plot locations were distributed systematically across the CD5 Study Area and the Habitat Plot Lines often covered multiple wildlife-habitat types, the Habitat Plot point-intercept data were summarized by wildlife-habitat class from the ITU mapping rather than by plot. The precise locations for each of the 25 Habitat Plot Points on each Habitat Plot Line were calculated in GIS from the survey-quality Habitat Plot Center Point and the Habitat Plot Line End Points.

The points were overlaid on the wildlife habitat map layer produced from the 2012 CD5 ITU Mapping, and each Habitat Line Point was assigned to the wildlife habitat class map polygon. The cover, top cover, and hit density of each vegetation structure class were then calculated for each wildlife habitat class with a sufficient sample size (75 points or more, equivalent to a full Habitat Plot).

The mean cover of each vegetation structure class and the mean height and frequency of woody and herbaceous vegetation were calculated for wildlife habitat classes with a sufficient sample size. The mean cover and height data were then used to create stacked bar charts and table summaries. Additionally, the mean cover data for each vegetation structure class were combined with the mean cover of the non-vegetated classes (water, soil, litter) for each wildlife habitat; the non-vegetated classes are represented as water alone, soil alone, and litter alone in stacked bar charts and summary tables.

Mean, 75%, and 95% confidence intervals for percent cover of these structure classes by wildlife habitat were calculated for each monitoring year (2013 and 2016) for both Test and Reference Areas, and a repeated measures analysis was performed using the Linear and Nonlinear Mixed Effects Models package, nlme (Pinheiro et al. 2016) in R to test for interaction effects of year and Area on cover percentage. For each wildlife habitat, we ran analyses attempting to predict the total live cover of vascular plants based on the interaction of year and Area, as well as additional models testing for an effect on each of the structure class variables with more than 10% cover in the habitat type.

3.3.3.C.iv. Landscape Change Analysis

To comply with the "Landscape Change Analysis" section of the Monitoring Plan developed for the CD5 Study Area (ABR and Baker 2013), we updated the baseline map to reflect natural and anthropogenic changes to ecosystem conditions that occurred since the baseline imagery was collected in summer 2012.

After completing map updates, we used geospatial tools to prepare areal summaries of the extent of geomorphic units, surface forms, vegetation classes, disturbance classes, map eco-types, and wildlife habitats as of July 2015. From these summaries, we calculated the percent change in area (+/-) of each class that occurred in the Test and Reference Areas; we excluded changes in area that pertained to map revisions (i.e., where 2016 field observations indicated that the original ITU assigned in the baseline map was inaccurate) or the footprint of the CD5 road. Within each of the six map themes, we flagged classes for which the areal extent changed across the full CD5 Study Area by a magnitude of ≥5%. For these classes, we assessed whether the percent change in the Test area exceeded the percent change in the Reference area by ≥5% and then flagged that class for further evaluation as to the likelihood that CD5 infrastructure played a role in the landscape change.

3.3.3.C.v. Ground Surface Elevation and Thaw Depth

The ground surface elevation and thaw depth data were analyzed by spatially connecting Vegetation Plot Start Points and Thaw Depth/ Elevation Points (creating transects). For each location along the transect, distance (west to east), thaw depth and ground surface elevation were generated. The full transect lines were then spatially joined to the 2016 ITU Map polygons and the transitions between zones for geomorphology, surface form, and vegetation type were reported along with the distance along the transects. A total of 39 segments comprised 13 transects in the Reference Area (North = 7 segments; South = 9 segments. Within the Test Area, a total of 39 segments comprised 9 transects (North = 12 segments; South = 11 segments). The Thaw Depth/ Elevation Point data were summarized in a topo-sequence diagram and thaw depth and elevation cross section diagrams. For the toposequence diagram, a portion of one monitoring transect from each subarea was selected to prepare toposequence diagrams, which display a two-dimensional cross-sectional view of the landscape. The diagram was annotated using the ITU mapping data from the spatial join and the Integrated Habitat Monitoring Plot data along the transect sections (e.g., Figure 3.22, from Wells et al. 2014). Thaw depth and elevation point data from the Vegetation Plot Start Points, Thaw Depth/Elevation Points, Grade Breaks, Cut Banks, and Water Edge Points for each monitoring transect were co-plotted to create two-dimensional cross sectional views. Ground surface elevation points were connected by a line to approximate the ground surface in 2013 and 2016, with visible differences representing physical change (e.g., erosion, deposition). Thaw depth in 2013 and 2016 also was plotted at each location to allow for a visual comparison of the active layer between years across each transect.

3.3.3.C.vi. Broad-scale Monitoring of Geomorphology

To assess sedimentation and erosion rates along Monitoring Transect we calculated the average and 95% confidence intervals (CI) for surface organic thickness in the Test and Reference Areas by year for the most common surface terrain units and used this to compare changes in surface organic thickness through time as per the Monitoring Plan (ABR and Baker 2013). We used surface organic thickness instead of sediment thickness because the nails placed in 2013 at marker horizons were not readily found in 2016. Surface organic thickness can be readily and consistently measured and serves as a proxy for sedimentation; effectively a thinning of surface organics through time indicates more frequent sedimentation, while a thickening of the surface organics indicates less frequent or an absence of sedimentation. The results this analysis were prepared in tabular form and plotted as bar charts with 95% CI overlaid.

3.4 RESULTS AND DISCUSSION

3.4.1 SPRING BREAKUP

The 2016 spring breakup flood progression for the Colville River was reported by Baker (2016). ABR field staff observed water levels rising at MON1 on 15 May 2016. The observation of the leading edge for floodwaters at the MON1 gage station was 7 days earlier than the 2002–2016 average leading edge at MON1C (Baker 2016). ABR field staff observed water levels around Alpine rising on 16 May 2016. ABR observed a large ice jam approximately 22 miles upriver of MON1 growing in size by about 13 river miles on 17 May 2016. Cooling air temperatures in the Brooks Range foothills slowed breakup activities between 18–20 May 2016, until rising air temperatures returned on 21 May (Baker, 2016). ABR field staff were not present for peak discharge on 22 May due to the unpredictable nature of breakup on the Colville River.

3.4.2 HABITAT MONITORING

3.4.2.A. Vegetation Plot Analysis

3.4.2.A.i. Vegetation Assessment

The PAM clustering of the 2013 moist plot ecotype and 2013 wet plot ecotype sub-datasets resulted in 8 and 3 clusters for the moist and wet plots, respectively (Figures 3.8 and 3.9). The average cluster medoid distances are presented in Table 3.8. For the 2013 moist plot ecotype sub-dataset, cluster 2 has the lowest average distance from the medoid (0.14 ordination distance) and the third lowest standard deviation (0.07), indicating that plots in this cluster are very similar and uniform in species composition. Cluster 5 has the highest average distance from the medoid (0.39 ordination distance) and the highest standard deviation (0.37), indicating that plots in this cluster are relatively diverse in species composition when compared to the other 7 clusters. For the 2013 wet plot ecotypes sub-dataset, the average distance from the medoid and standard deviation was very similar among all 3 clusters, with the average ranging between an ordination distance of 0.22 and 0.25 and standard deviation ranging between 0.10 and 0.12. This indicates that the 2013 wet plot ecotypes are similarly variable in species composition.

Of the total 179 vegetation plots, 162 plots were included in the vegetation analysis and 17 plots were withheld, based on the criteria described in section 3.3.3.C.i Vegetation Plot Analysis, above. The 17 plots withheld from the analysis were all classified as the same Viereck et al. (1992) Level IV vegetation class in 2013 and 2016 and hence, did not change between years. Of the 162 vegetation plots included in the vegetation analysis, 132 plots plots did not change in species composition between 2013 and 2016, based on the vegetation assessment analysis. In combination, a total of 149 vegetation plots (132+17) or 83% did not change in species composition between 2013 and 2016. The NMDS ordination distances between the 2013 and 2016 plots greater than 2 times the standard deviation of the 2013 cluster medoid distance are presented in Table 3.9. A total of 6 plots from the 2013/2016 moist plot ecotype sub-dataset and 16 plots from the 2013/2016 wet plot ecotype sub-dataset had an ordination distances between the 2013 and 2016 plots of 2x stdev > 3x stdev the medoid distance of the 2013 clusters. These 22 plots represent 12% of the total 179 Vegetation Plots and have been flagged in the database as having potentially changed in species composition between 2013 and 2016. Of these 22 plots, 16 occurred in the Test Areas (plot_id starting with "t"), and 6 in Reference Areas (plot_id starting with "r"). Of those in the Test Areas, 10 plots were located on the first transect north or south of the road (plot_id starting with "t1"), and 3 plots were located on the second

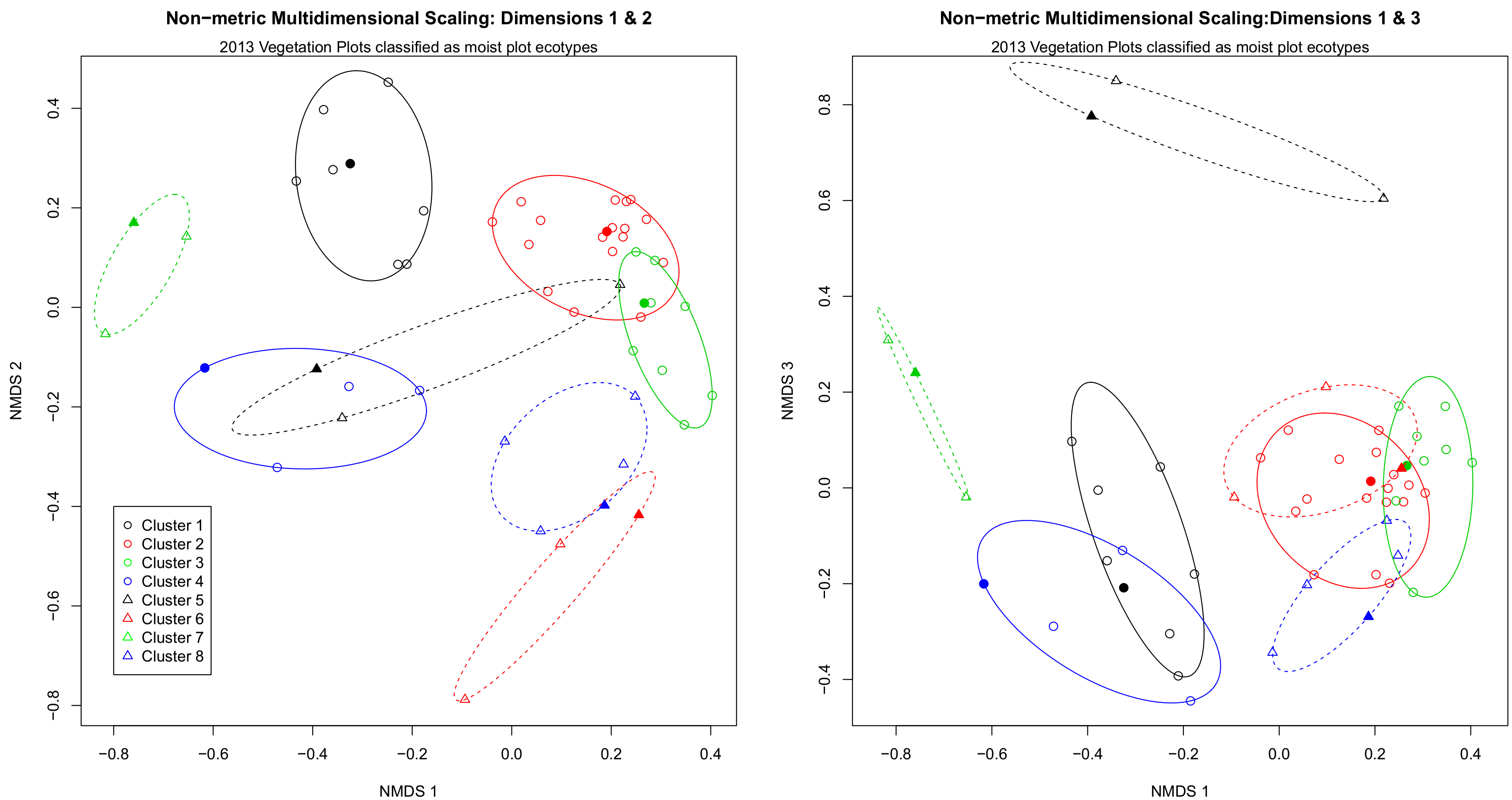


Figure 3.8. Non-metric Multidimensional Scaling (NMDS) diagram of 2013 Vegetation Plots classified as moist plot ecotypes with Partitioning Around Medoids (PAM) 8-cluster solution symbolized.Medoids for each cluster symbolized with solid fill, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

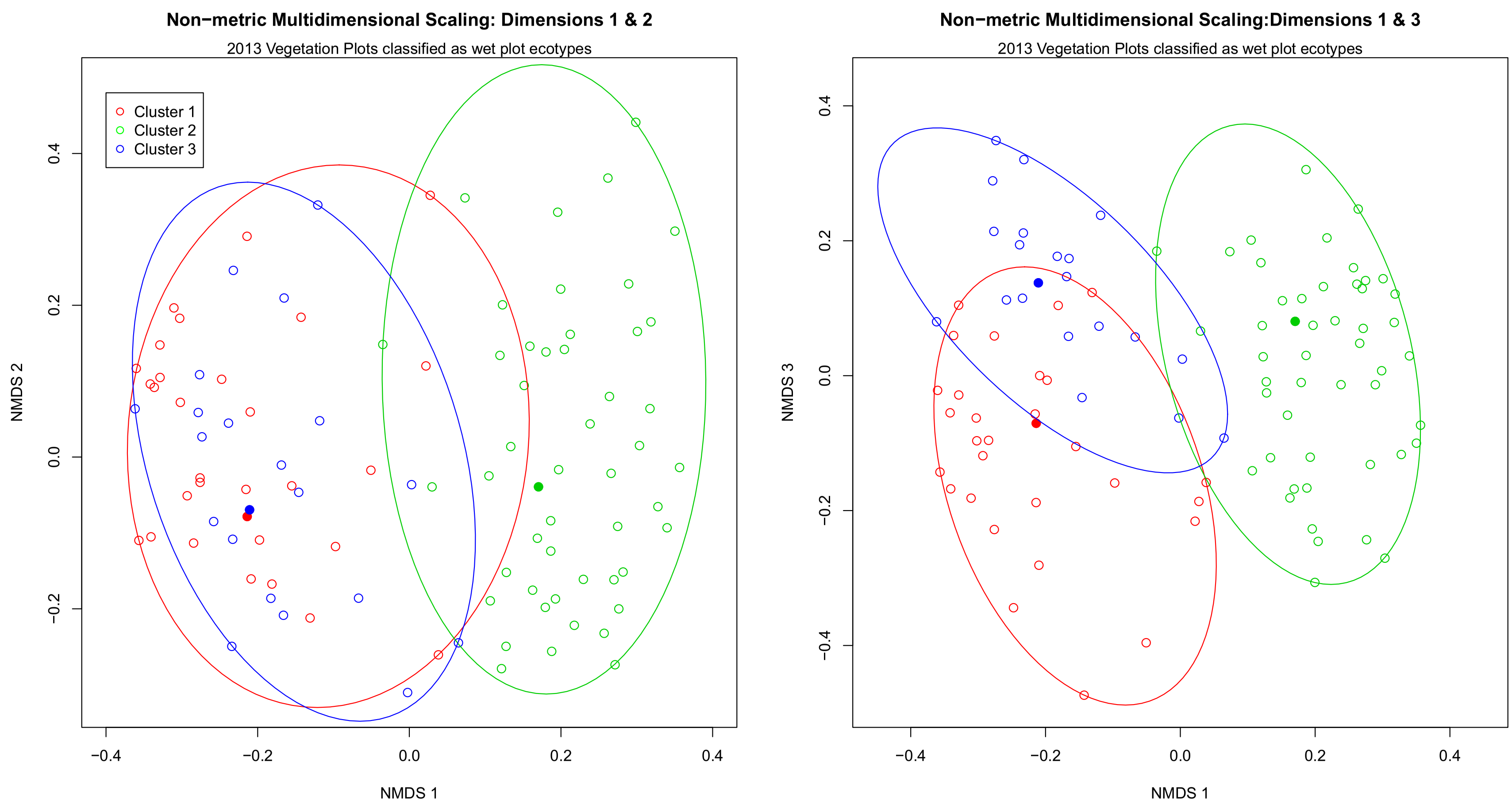


Figure 3.9. Non-metric Multidimensional Scaling (NMDS) diagram of 2013 Vegetation Plots classified as wet plot ecotypes with Partitioning Around Medoids (PAM) 3-cluster solution symbolized. Medoids for each cluster symbolized with solid fill, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Table 3.8. Average NMDS distance from medoid, standard deviation, two-times standard deviation, and three-times standard deviation for 2013 moist and wet ecotype clusters, CD5 Habitat Monitoring Study Area, northern Alaska.

Ecotype Group	Cluster	Average NMDS Distance from Medoid	St.Dev.	2x St.Dev.	3x St.Dev.
Moist Ecotypes	1	0.24	0.09	0.18	0.27
Moist Ecotypes	2	0.14	0.07	0.14	0.22
Moist Ecotypes	3	0.18	0.08	0.15	0.23
Moist Ecotypes	4	0.35	0.13	0.25	0.38
Moist Ecotypes	5	0.39	0.37	0.74	1.11
Moist Ecotypes	6	0.38	0.19	0.39	0.58
Moist Ecotypes	7	0.26	0.03	0.06	0.09
Moist Ecotypes	8	0.22	0.05	0.1	0.14
Wet Ecotypes	1	0.23	0.12	0.24	0.36
Wet Ecotypes	2	0.25	0.1	0.21	0.31
Wet Ecotypes	3	0.22	0.11	0.21	0.32

transect north or south of the road (plot_id starting with “t2”). The effects on vegetation on nearby gravel roads in arctic Alaska are well known (Walker et al. 1987, Myers-Smith et al. 2006). Thus, the close proximity of the first transects north and south (approximately 100 m) of the CD5 road may in part explain the potential changes identified for those 10 plots nearest the road. However, of plots located on the first and second transects north and south of the road, approximately two-thirds of these showed no potential change in species composition based on the methods employed here. Additionally, not all plots flagged for potential change were in the Test Areas (6 were in the Reference Areas) indicating that some of the potential change identified in this analysis may be related to natural changes. These 22 plots will be reassessed in 2019 to determine if they have become less similar to the 2013 plot (i.e., move further away from the 2013 plot), or if they become more similar in species composition (i.e., move back toward the 2013 plot).

A total of 2 plots from the 2013/2016 moist plot ecotype sub-dataset and 6 plots from the 2013/2016 moist plot ecotype sub-dataset had an ordination distance between the 2013 and 2016 plots of > 3x stdev of the medoid distance of the 2013 clusters. These 8 plots represent 4% of the total 179 Vegetation Plots and are considered to have changed in species composition between 2013 and 2016. These plots have been flagged in the database and will be reassessed in 2019 to determine if they have continued to change, i.e., moving further away from the 2013 plot, or if they become more similar in species composition, i.e., moving back toward the 2013 plot.

Plots with an ordination distance of >3x stdev medoid distance are considered to have changed in species composition between 2013 and 2016 (Figures 3.10 and 3.11). The 2 moist plots that changed between years, r5sb-0211-veg and r6sb-0250-veg, are both from Reference Area South. These 2 plots are both located in highly dynamic environments on river bars where changes in vegetation composition due to natural fluvial processes are common. The results of the indirect gradient analysis for the 2013/2016 moist NMDS ordination found the strongest fits for the continuous variables Soil Thaw Depth, Soil Surface Organic Thickness, and Site pH (Figures 3.12 and 3.13; Table 3.10). Plot Ecotype was the only significant ($p < 0.001$) categorical variable in the 2013/2016 moist NMDS ordination. Comparing the direction of movement of the two plots

Table 3.9. Ordination distances between 2013 and 2016 plots for plots with distances between years greater than two-times the standard deviation of mean of the 2013 clusters, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

dist_class	Plot ID	Ecotype Group	Cluster	2x St.Dev.	3x St.Dev.	2013/2016 NMDS Distan
Greater than 2x St.Dev.	r1na-1400-veg	Moist Ecotypes	2	0.14	0.22	0.15
	r2na-2400-veg	Moist Ecotypes	3	0.15	0.23	0.17
	t1na-1800-veg	Moist Ecotypes	8	0.1	0.14	0.12
	t1nb-0149-veg	Moist Ecotypes	2	0.14	0.22	0.16
	t1sa-2400-veg	Moist Ecotypes	8	0.1	0.14	0.12
	t2sc-0000-veg	Moist Ecotypes	7	0.06	0.09	0.09
	r1sa-1426-veg	Wet Ecotypes	3	0.21	0.32	0.28
	r4sa-0396-veg	Wet Ecotypes	3	0.21	0.32	0.22
	r5sa-0832-veg	Wet Ecotypes	2	0.21	0.31	0.25
	r6sb-0600-veg	Wet Ecotypes	3	0.21	0.32	0.22
	t1na-1219-veg	Wet Ecotypes	3	0.21	0.32	0.24
	t1nb-0621-veg	Wet Ecotypes	3	0.21	0.32	0.26
	t1nc-0400-veg	Wet Ecotypes	2	0.21	0.31	0.25
	t1sa-0410-veg	Wet Ecotypes	1	0.24	0.36	0.29
	t1sa-1824-veg	Wet Ecotypes	2	0.21	0.31	0.28
	t1sa-2200-veg	Wet Ecotypes	2	0.21	0.31	0.27
	t1sb-0200-veg	Wet Ecotypes	3	0.21	0.32	0.25
	t2na-0633-veg	Wet Ecotypes	3	0.21	0.32	0.26
	t2sa-1800-veg	Wet Ecotypes	3	0.21	0.32	0.29
	t3na-0000-veg	Wet Ecotypes	2	0.21	0.31	0.25
	t3sb-0950-veg	Wet Ecotypes	2	0.21	0.31	0.28
	t4sa-1200-veg	Wet Ecotypes	2	0.21	0.31	0.21
Greater than 3x St.Dev.	r5sb-0211-veg	Moist Ecotypes	7	0.06	0.09	0.17
	r6sb-0250-veg	Moist Ecotypes	7	0.06	0.09	0.22
	r4sa-0809-veg	Wet Ecotypes	2	0.21	0.31	0.42
	t1na-0200-veg	Wet Ecotypes	1	0.24	0.36	0.41
	t1na-2000-veg	Wet Ecotypes	1	0.24	0.36	0.43
	t1sb-0600-veg	Wet Ecotypes	2	0.21	0.31	0.32
	t1sc-0695-veg	Wet Ecotypes	1	0.24	0.36	0.42
	t2sb-0800-veg	Wet Ecotypes	2	0.21	0.31	0.32

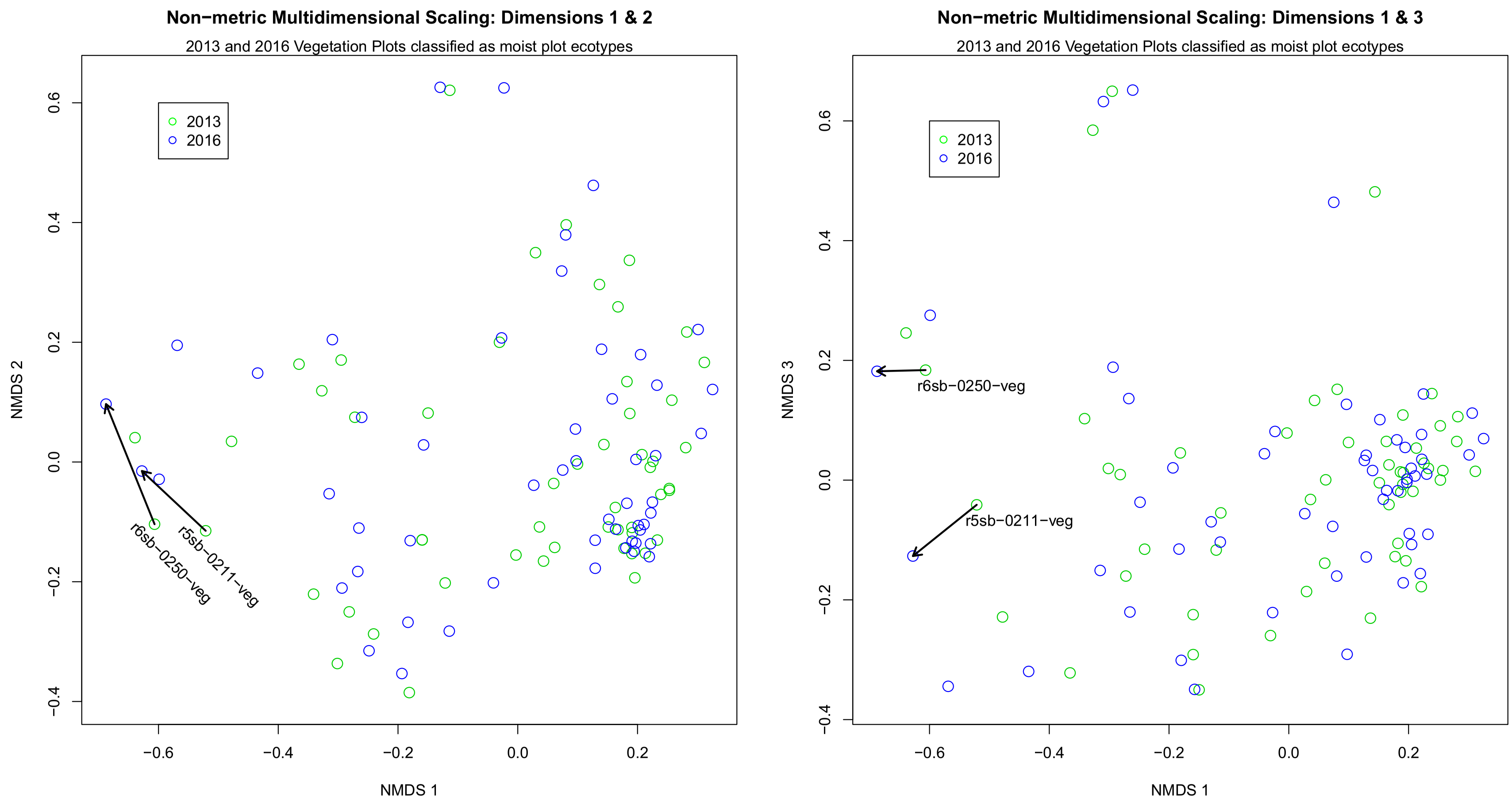


Figure 3.10. Non-metric Multidimensional Scaling diagram (NMDS) of the combined 2013/2016 Vegetation Plots classified as moist plot ecotypes with study year symbolized. Plots that changed in vegetation composition between years leading to a change in ordination distance between the 2013 and 2016 plot of greater than 3 standard deviations around the medoid of the 2013 cluster are illustrated using arrows. The arrows show the direction along ordination axes of the same plot sampled in 2013 and 2016, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

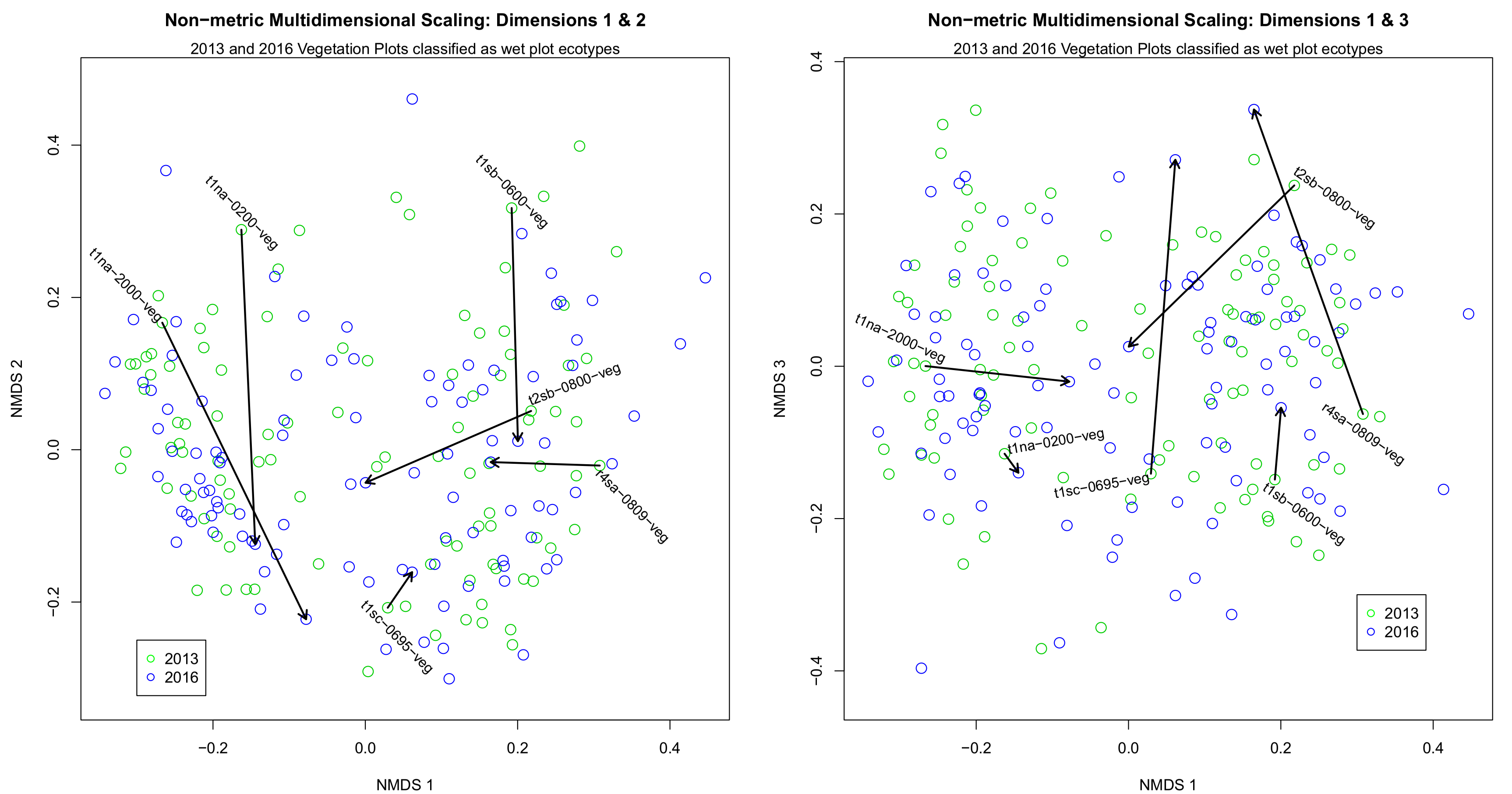


Figure 3.11. Non-metric Multidimensional Scaling (NMDS) diagram of the combined 2013/2016 Vegetation Plots classified as wet plot ecotypes with study year symbolized. Plots that changed in vegetation composition between years leading to a change in ordination distance between the 2013 and 2016 plot of greater than 3 standard deviations around the medoid of the 2013 cluster are illustrated using arrows.The arrows show the direction along ordination axes of the same plot sampled in 2013 and 2016, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

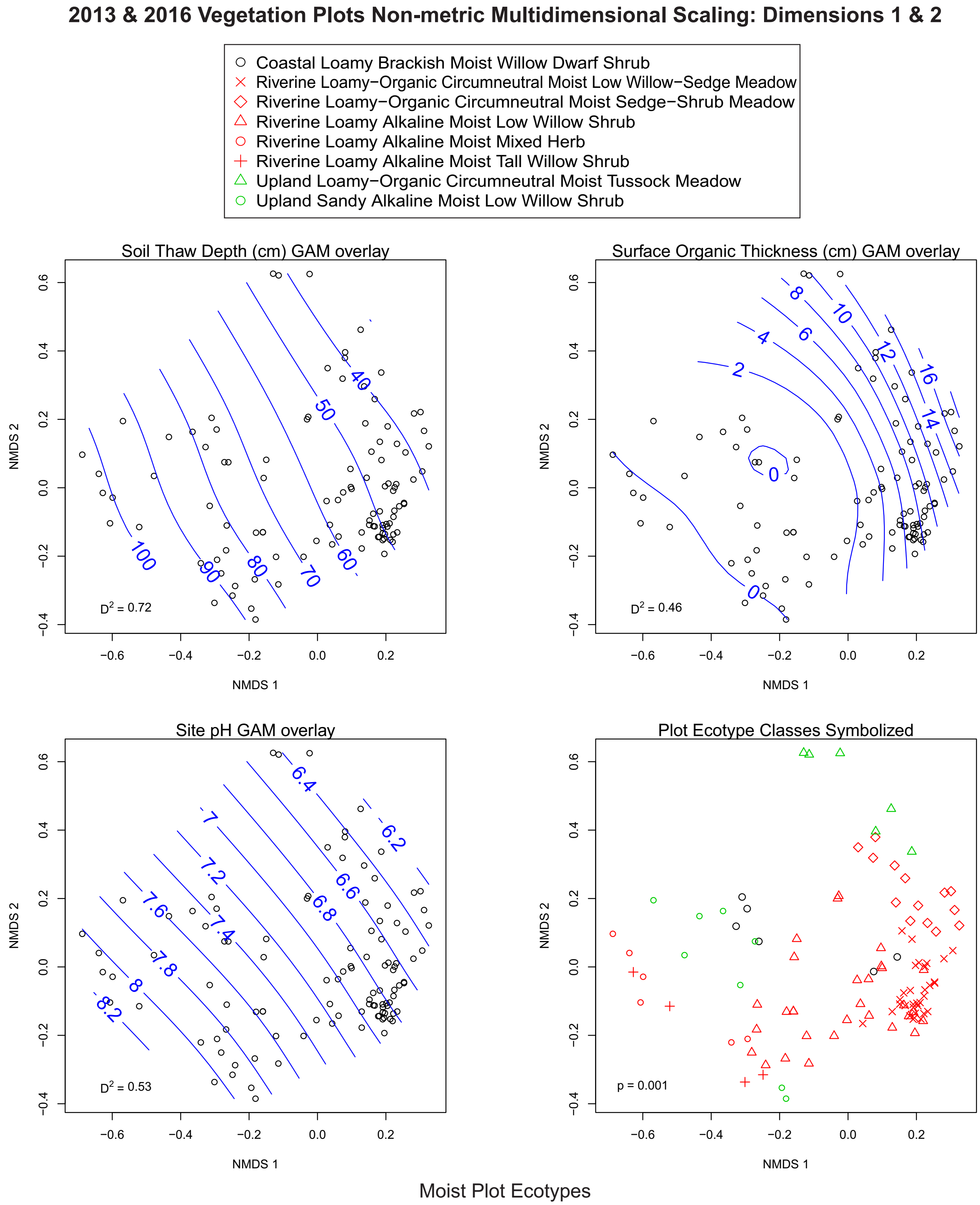


Figure 3.12. Plots of dimensions 1 and 2 for the Non-metric Multidimensional Scaling (NMDS) of the combined 2013/2016 Vegetation Plots classified as moist plot ecotypes with (from top to bottom, left to right) Soil Thaw Depth (cm), Soil Surface Organic Thickness (cm), and Site pH Generalized Additive Model (GAM) contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

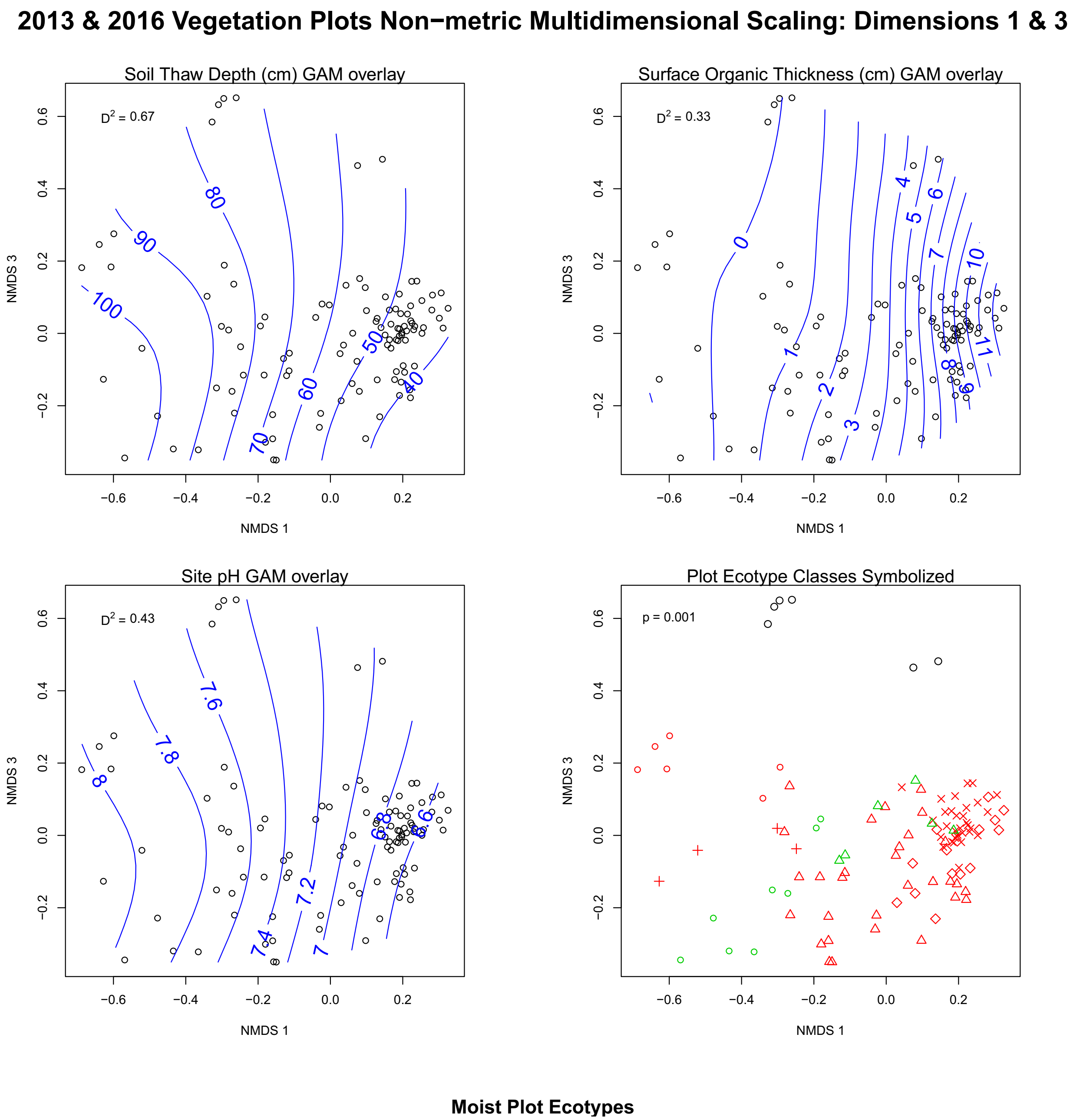


Figure 3.13. Plots of dimensions 1 and 3 for the Non-metric Multidimensional Scaling (NMDS) of the combined 2013/2016 Vegetation Plots classified as moist plot ecotypes with (from top to bottom, left to right) Soil Thaw Depth (cm), Soil Surface Organic Thickness (cm), and Site pH Generalized Additive Model (GAM) contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Table 3.10. Results of the NMDS indirect gradient analysis for environment variables with a *p*-value <0.05 and a deviance-squared fit value of >0.10, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Ecotype Group	Environment Variable	NMDS X-dimension	NMDS Y-dimension	P-Value	Deviance-squared
Moist Ecotypes	lat_dd83	1	2	<0.001	0.17
	long_dd83	1	2	<0.001	0.25
	distance_cd5_rd_m	1	2	0.009	0.12
	thaw_depth_cm	1	2	<0.001	0.72
	soil_surforg_cm	1	2	<0.001	0.46
	water_depth_cm	1	2	<0.001	0.38
	site_ph_calc	1	2	<0.001	0.53
	lat_dd83	1	3	<0.001	0.2
	long_dd83	1	3	<0.001	0.26
	elev_cm	1	3	<0.001	0.25
	thaw_depth_cm	1	3	<0.001	0.67
	soil_surforg_cm	1	3	<0.001	0.33
	water_depth_cm	1	3	<0.001	0.35
	site_ph_calc	1	3	<0.001	0.43
	site_ec_us_calc	1	3	<0.001	0.26
	elev_cm	2	3	<0.001	0.22
	thaw_depth_cm	2	3	<0.001	0.39
	soil_surforg_cm	2	3	<0.001	0.3
	water_depth_cm	2	3	0.019	0.17
	site_ph_calc	2	3	<0.001	0.29
	site_ec_us_calc	2	3	<0.001	0.28
	plot_ecotype_code	123	123	0.001	-999
Wet Ecotypes	lat_dd83	1	2	<0.001	0.1
	long_dd83	1	2	<0.001	0.18
	elev_cm	1	2	<0.001	0.24
	soil_surforg_cm	1	2	<0.001	0.18
	water_depth_cm	1	2	<0.001	0.11
	site_ph_calc	1	2	<0.001	0.11
	long_dd83	1	3	<0.001	0.18
	elev_cm	1	3	<0.001	0.13
	distance_cd5_rd_m	1	3	<0.001	0.14
	soil_surforg_cm	1	3	<0.001	0.25
	water_depth_cm	1	3	<0.001	0.15
	lat_dd83	2	3	<0.001	0.13
	long_dd83	2	3	<0.001	0.24
	elev_cm	2	3	<0.001	0.2
	study_area	123	123	0.013	-999
	plot_ecotype_code	123	123	0.001	-999

(Figure 3.10) with the fitted contour surfaces from the GAMs (Figures 3.12 and 3.13) shows that movement of the 2 plots down on axis 1 corresponds to deeper thaw depths, higher pH, and thinner soil surface organics. These factors are all related to riverine processes of flooding (i.e., flushing away of organic matter and adding river waters high in cations); sedimentation (burying organic surface horizon); and deeper thaw depths related to the latent heat of river water that creates thaw bulbs around rivers in permafrost environments. In essence, the vegetation at these two plots is expressing a higher degree of riverine activity in 2016 than 2013.

Five of the 6 wet plots that changed between years were from Test Areas: t1na-0200-veg, t1na-2000-veg, t1sb-0600-veg, t1sc-0695-veg, and t2sb-0800-veg. Of the 5 Test Area plots, 4 are located on the first transects north or south of the road, while the 5th is located on the second transect south of the road. Three of the six plots, t1na-2000-veg, t1na-0200-veg, and t1sb-0600-veg, were classified as Wet Sedge Meadow Tundra, while the other 3, r4sa-0809-veg, t1sc-0695- veg, and t2sb-0800-veg, were classified as Wet Sedge-Willow Tundra. The primary difference between these 2 vegetation classes being the presence of willows at 5–18% cover in Wet Sedge-Willow Tundra, whereas willows are either absent or present at <5% cover in Wet Sedge Meadow Tundra. The strongest fits for continuous variables were for Elevation, Longitude, Soil Surface Organic Thickness, Water Depth, and Distance from CD5 Road (Figures 3.14 and 3.15). Plot Ecotype ($p < 0.001$) and Study Area ($p < 0.013$) were the significant categorical variables. Comparing the direction of movement of the 3 Wet Sedge Meadow Tundra plots (Figure 3.11) with the fitted contour surfaces from the GAMs (Figures 3.14 and 3.15) shows that these 3 plots all moved down on NMDS axis 2. The GAM for axis 2 represents an elevation gradient, with higher elevations predicted at the top of axis 2 and lower elevations predicted at the bottom. Thus, the vegetation at these three plots in 2016 is more representative of lower elevation sites. In deltaic environments, lower elevation sites are flooded more frequently than higher elevation sites. This was reflected in all three plots having a decreased surface organic thickness in 2016, indicating sedimentation at these plots since 2013. The primary vegetative change at all three plots between 2013 and 2016 was an increase in cover of *Carex aquatilis* and *Eriophorum angustifolium*, an indication that these sites were more productive in 2016 than 2013.

Comparing the downward movement on NMDS axis 1 (Figure 3.11) with the fitted contour surfaces from the GAMs (Figures 3.14 and 3.15) predicted that Wet Sedge-Willow Tundra plots t2sb-0800-veg and r4sa-0809-veg have shallower water tables (i.e., wetter soil conditions) than the third plot (t1sc-0695-veg). The third plot moved very little in dimensions 1 and 2. In dimensions 1 and 3, however, this plot (t1sc-0695-veg) and plot r4sa-0809-veg moved up along axis 3, which corresponds with plots having shallower water tables (i.e., wetter soil conditions). Plot t2sb-0800-veg moved down on both axis 1 and 3, which reflects plots in the Lowland Organic-rich Circumneutral Wet Sedge Meadow and Riverine Organic-rich Circumneutral Wet Sedge Meadow. The results of the analysis show that vegetation composition of the 3 Wet Sedge-Willow Tundra plots in 2016 is more representative of wetter plots. In addition, plot t2sb-0800-veg in 2016 was more similar in vegetation composition to plots with lower willow cover (i.e., the Wet Sedge Meadow Tundra Plots); willow cover in this plot went from 7.9% in 2013 to 1.3% in 2016. In addition, the number of species in Plot t2sb-0800-veg was higher in 2016 (9) than 2013 (7), and the cover of sedges increased slightly between 2013 and 2016 (21.1% vs. 22.4%, respectively). Plot r4sa-0809-veg had a lower number of species in 2016 (5) compared to 2013 (9); a lower sedge cover in 2016 (7.9%) compared to 2013 (11.8%); and a slight increase in low willow cover in 2016 (9.2%) compared to 2013 (6.6%). Plots t2sb-0800-veg and r4sa-0809-veg had an ice road over them in one or more winters between 2013 and 2016. Both of these plots were classified as Wet Sedge-Willow Tundra in 2013 and 2016. A total of 13 plots had ice roads or pads over them in one or more winters between 2013 and 2016 (Table 3.11), and 2 of the plots (t2sb-0800-veg and r4sa-0809-veg) were determined to have changed in species composition.

2013 & 2016 Vegetation Plots Non-metric Multidimensional Scaling: Dimensions 1 & 2

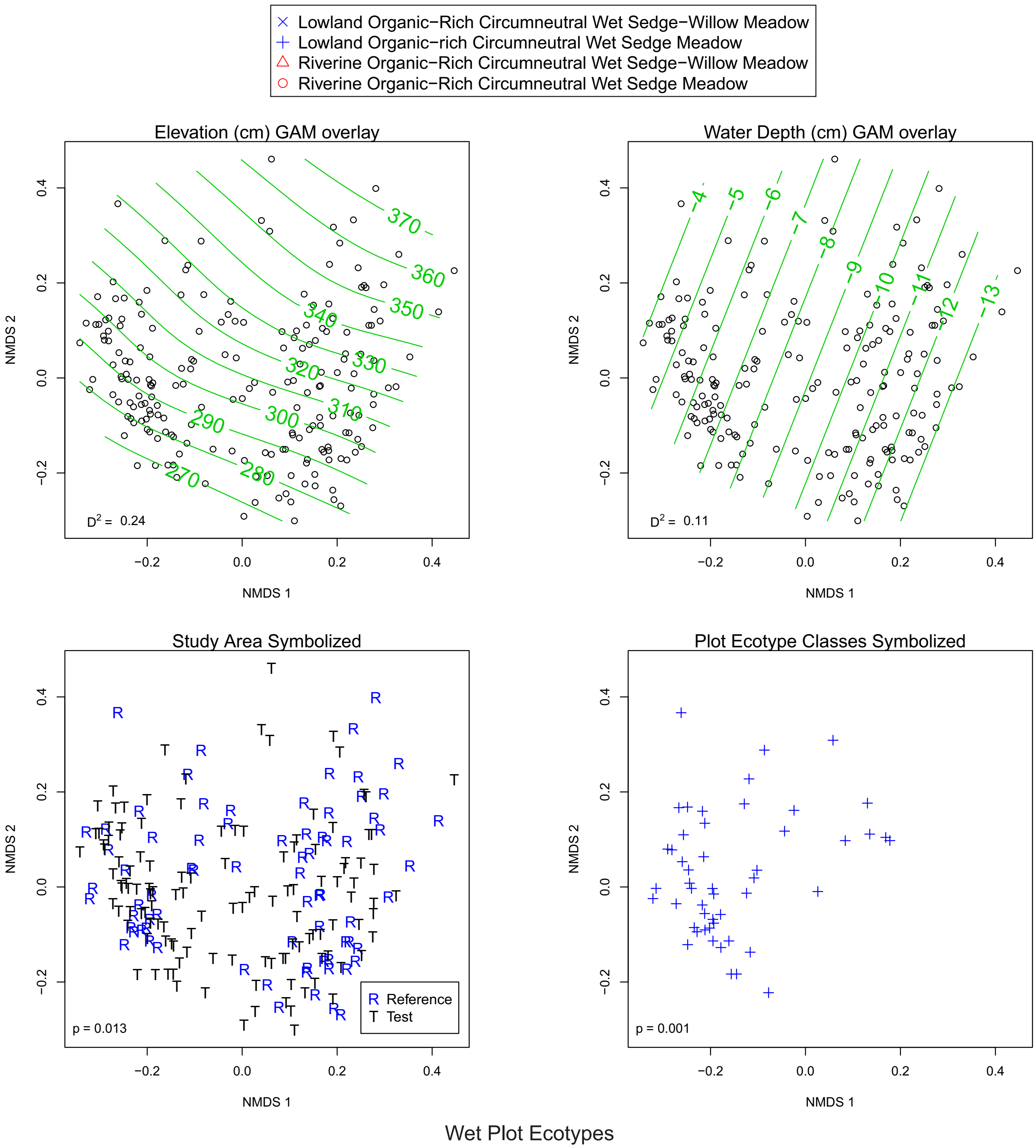


Figure 3.14. Plots of dimensions 1 and 2 for the Non-metric Multidimensional Scaling (NMDS) of the combined 2013/2016 Vegetation Plots classified as wet plot ecotypes with (from top to bottom, left to right) Elevation (cm) and Soil Surface Organic Thickness (cm) Generalized Additive Model (GAM) contour surfaces overlaid; and Study Area and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

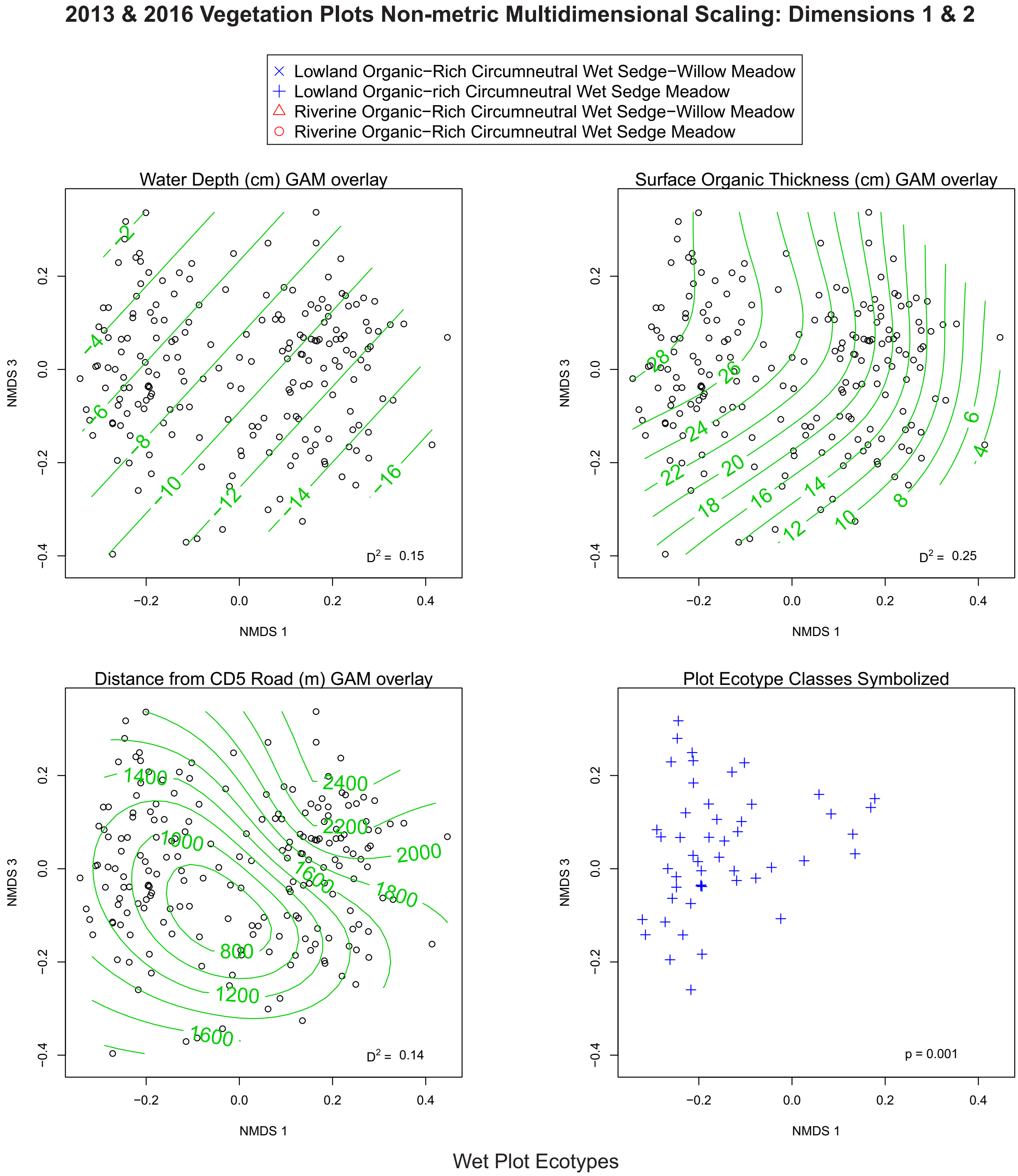


Figure 3.15. Plots of dimensions 1 and 3 for the Non-metric Multidimensional Scaling (NMDS) of the combined 2013/2016 Vegetation Plots classified as wet plot ecotypes with (from top to bottom, left to right) Water Depth (cm), Soil Surface Organic Thickness (cm); and Distance from CD5 Road (m) Generalized Additive Model (GAM) contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Table 3.11. Vegetation Plots with ice roads or pads over them for one or more winters between monitoring years, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Plot ID	Winter 2013–2014	Winter 2014–2015	Winter 2015–2016
r4sa-0809-veg	None	Ice Pad	Ice Road
r4sa-1153-veg	None	Ice Road	Ice Pad
r4sb-0800-veg	None	Ice Road	Ice Road
r5sa-0395-veg	Ice Road	None	None
t1na-1424-veg	None	Ice Road	None
t1na-1600-veg	None	Ice Road	None
t1na-1800-veg	None	Ice Road	None
t1sa-0200-veg	Ice Pad	None	None
t1sa-0410-veg	Ice Pad	None	None
t1sb-0420-veg	Ice Pad	None	None
t1sc-0875-veg	Ice Pad	None	None
t2sb-0800-veg	Ice Road	None	None
t4sb-1000-veg	Ice Road	None	None

3.4.2.A.ii. Species Richness Assessment

Species richness by Area and year is summarized in Figure 3.16 for 14 ecotypes with a sample size of 2 or more. Across all ecotypes and Areas, changes in species richness between years were relatively small and within the range of variability, based on the standard deviation (Appendix B). The most notable change in vascular species richness between years was in the ecotype Coastal Loamy Brackish Moist Willow Dwarf Shrub, which had a reduction in vascular species richness from 16 in 2013 to 10 in 2016. This ecotype is in the Test Areas and occurs in a naturally dynamic environment on river bars subject to regular natural disturbances, including sedimentation, erosion, ice gouging, and salt-water intrusion. These processes can bury or physically remove plants or raise soil salinity levels above the tolerance of many plants. However, the single sample point for this ecotype in this Test Areas makes it difficult to generalize this pattern too broadly across all the Test Areas.

The ecotypes Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow and Upland Loamy-Organic Circumneutral Moist Tussock Meadow had the highest overall species richness in both Reference and Test Areas in 2013 and 2016 (Figure 3.16, Appendix B). Vascular and non-vascular species richness in the Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow ecotype did not change between years in the Test Area, but non-vascular richness went down in 2016 (15 vs.11) in the Reference Area. Vascular species richness showed little change in the Reference Areas (24 vs. 25). The drop in non-vascular species richness in this ecotype represents the second largest change in non-vascular species richness between years in the Reference Area (Figure 3.16, Appendix B). In the ecotype Upland Loamy-Organic Circumneutral Moist Tussock Meadow, non-vascular species richness in the Test Area dropped from 10 (± 1) to 5 (± 6), while vascular richness was virtually unchanged. The drop in non-vascular species richness in this ecotype represents the second largest change in non-vascular species richness between years in the Test Area (Figure 3.16, Appendix B). In Reference Areas, non-vascular richness increased dramatically for this ecotype, while vascular richness increased slightly. We suspect the substantial increase in non-vascular species richness in this ecotype in the Reference Area, which represents the largest increase in species richness between years, is related to a more

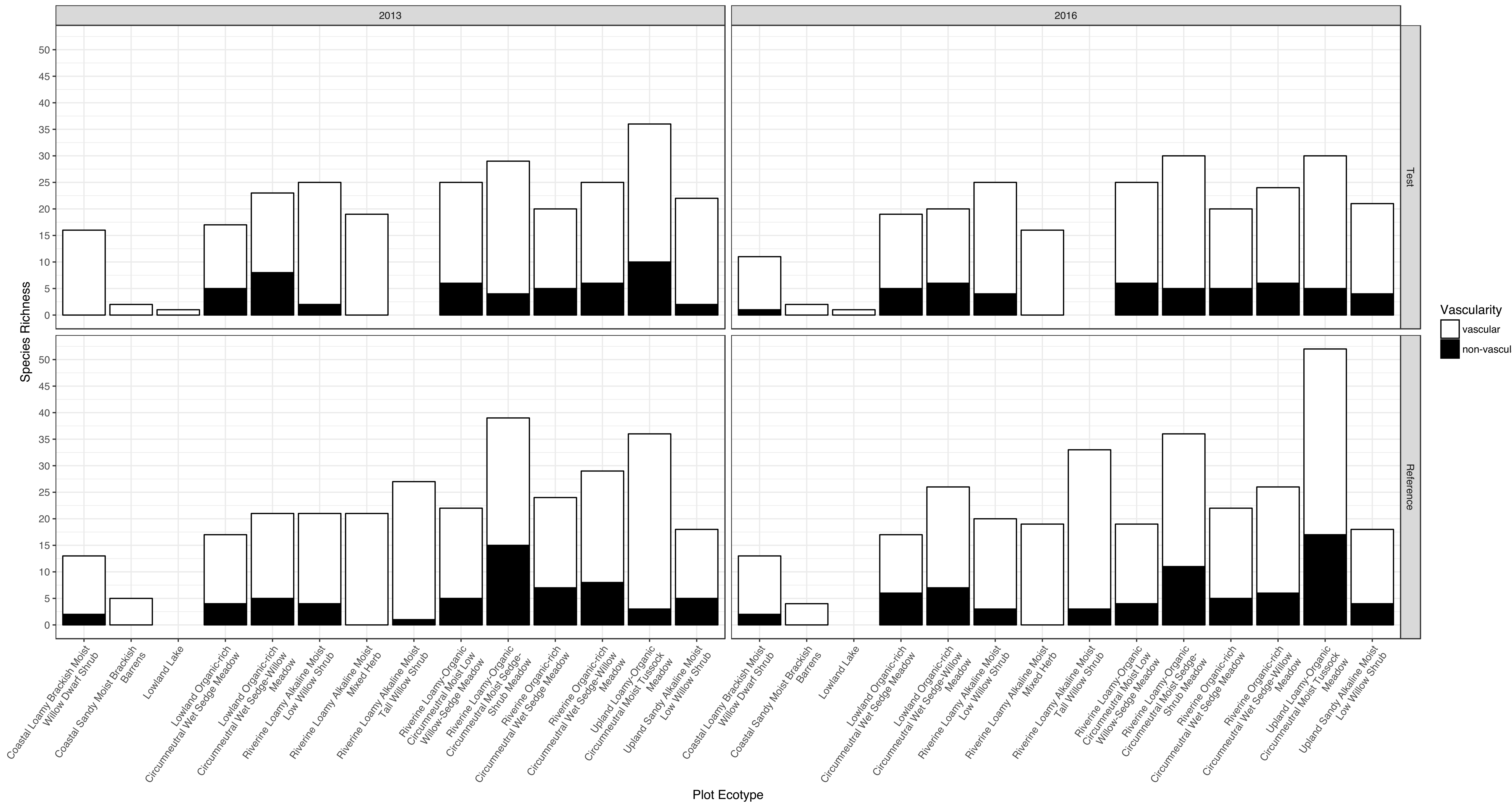


Figure 3.16. Mean vascular and non-vascular species richness for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2013 and 2016.

thorough trace species search in 2016 compared to 2013. In future monitoring years, trace searches will be timed, thus allowing us to determine the degree to which species richness is a function of time spent searching. The largest increase in vascular species richness between years (from 26 to 30) occurred in the ecotype Riverine Loamy Alkaline Moist Tall Willow Shrub (Figure 3.16, Appendix B). This ecotype occurs in the highly dynamic river bar environment, which floods regularly. As discussed above, riverine flooding can be destructive, but floodwaters also carry plant propagules that can add to the species richness at a site. Ecotypes with the lowest species richness in both Reference and Test Areas and between sample years included Coastal Loamy Brackish Moist Willow Dwarf Shrub, Coastal Sandy Moist Brackish Barrens, and Lowland Lake. The low species richness in these three ecotypes is typical of extreme environments likes lakes and tidally-influenced areas. This is because the suite of plant species that can tolerate aquatic or saline conditions is more limited than in non-tidal, terrestrial environments.

<u>3.4.2.A.iii. Detailed Ground Cover Class and Environment Assessment</u>

Coastal Loamy Brackish Moist Willow Dwarf Shrub had mineral soil as the predominant ground cover in all Areas and years (Appendix C-1). Both Reference and Test Areas had higher average cover percentages of mineral soil in 2013 (78 and 93%, respectively, Appendix D) than in 2016 (70 and 64%, respectively). Mosses were also present as a ground cover in all Areas and years, but had higher average covers in the Reference Area (22% in 2013 and 8% in 2016) than the Test Area (3% in 2013 and 5% in 2016). Cover of water was observed only in the Reference Area in 2016, with an average cover of 3%.

As a result of frequently flooded, active and inactive channel deposits of the Colville River Delta, a surface organic horizon for Coastal Loamy Brackish Willow Dwarf Shrub was absent in both Reference and Test Areas in both years (Appendix E). Surface organic thickness is the thickness of continuous organic soil material from the soil surface to the first mineral-textured layer that is ≥0.5 cm. Average EC was slightly higher in 2016 than 2013 in the Reference (+400 µS/cm) and Test (+10 µS/cm) Areas. The Reference Area EC remained higher than the Test Area EC in both years. This is likely due to a greater inter-tidal influence in Reference Area North, which occurs in the northern portion of the CD5 Study Area. Average thaw and water table depths in the Reference and Test Areas did not change substantially between 2013 and 2016 (Appendix E), but note that the water table is highly dynamic in this environment, which could influence future measurements.

Coastal Sandy Moist Brackish Barrens ground covers were generally consistent between 2013 and 2016, but varied between Reference and Test Areas (Appendix C-2). Mineral soil was the predominant ground cover in all Areas and years, but average cover was consistently higher in the Test Area (99% each year, Appendix D) than in the Reference Area (87% in 2013 and 88% in 2016). Water was present in the Reference Area in both years (average cover 28–30%), but absent from the Test Area. The Coastal Sandy Moist Brackish Barrens plot ecotype is restricted to frequently flooded, active channel deposits of the Colville River Delta. Consequently, a surface organic horizon was absent in both Reference and Test Areas in both years (Appendix E). The average thaw depth decreased in both Test (103 cm in 2013 and 92 cm in 2016) and Reference (102 cm in 2013 and 85 cm in 2016) Areas between 2013 to 2016. The average water table depth in the Reference Area (-12 cm) was shallower than in the Test Area (-37 cm) in 2016, while in 2013 the opposite was true; water table depth in the Reference Area (-46 cm) was deeper than the Test Area (-30 cm). Variability in water table depth is to be expected, due to the fluctuating water level of the Colville River.

Lowland Lake was only located in the Test Area. Water was the only ground cover in both 2013 and 2016 (Appendices C-3 and D). Average EC and pH rose in the Test Area from 2013 to 2016 (+0.5 pH and +185 µS/cm, respectively), which was likely the result of freshwater inputs from overland flooding by the Colville River during the 2015 breakup (Appendix E)(Baker 2015).

Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow was only located in the Test

Area. Herbaceous litter and moss accounted for the most cover in both 2013 and 2016 (Appendix C-4), with lower values in 2013 (43% and 36%, respectively; Appendix D) than in 2016 (61% and 32%, respectively). The drop in water table depth from -16 cm in 2013 to -35 cm in 2016 parallels the observed changes in standing water cover (Appendix E).

Lowland Organic-rich Circumneutral Sedge Marsh was only located in the Test Area. Water was the predominant ground cover in both 2013 and 2016 (Appendix C-5), with a higher cover in 2013 (93%, Appendix D) than in 2016 (88%). Algae and vascular base were the only other ground covers observed in 2013, while algae, herbaceous litter, mosses, and organic soil were observed in 2016. Between 2013 to 2016, EC increased (+250 µS/cm), water depth decreased from 15 cm to 8 cm above the soil surface, and thaw depth decreased from 15 cm in 2013 to 8 cm in 2016 (Appendix E).

Lowland Organic-rich Circumneutral Wet Sedge Meadow ground covers varied by both Area and year (Appendix C-6). Water was observed in both Reference and Test Areas, with higher average cover values in 2013 (57% and 45%, respectively; Appendix D) than in 2016 (12% and 24%, respectively). Mineral soil was observed in both Reference and Test Areas, but only in 2016. Mosses were observed in both Reference and Test Areas, with higher average cover values in the Reference Area than in the Test Area, and higher average cover values in 2016 than in 2013. From 2013 to 2016, the average EC rose in both the Reference (+122 µS/cm) and Test (+201 µS/cm) Areas (Appendix E). Average EC varied between the Areas and years. The average EC in the Reference Area in 2013 (442 µS/cm) was higher than the average EC in the Test Area in 2013 (357 µS/cm). This pattern reversed in 2016, with average EC slightly lower in the Reference Area (544 µS/cm) than the Test Area (558 µS/cm). Average water table depth decreased from 2013 to 2016 for both Reference (-9 cm) and Test Areas (-8 cm) paralleling the observed changes in standing water cover. The average thaw depth for both the Reference and Test Areas was 46 cm in 2013 and 38 cm in 2016.

Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow had moss as the predominant ground cover class for all Areas and years (Appendix C-7). Average moss cover was higher in the Reference Areas (68% in 2013 and 83% in 2016, Appendix D) than Test Areas (64% in 2013 and 71% in 2016). Average moss cover was higher in all Areas, however, in 2016 versus 2013. Water was observed in both Reference and Test Areas in 2013 (average covers of 21% and 15%, respectively). In 2016, water was only observed in the Test Area (average 7% cover), with an average mineral soil cover of 1% in the Reference Area. The average pH in the Test Area (6.5 in 2013 and 6.3 in 2016) remained lower than the pH in the Reference Area (6.9 in 2013 and 6.5 in 2016)(Appendix E). The water table depth was shallower in the Reference Area than the Test Area in both 2013 and 2016, but both Reference and Test Areas experienced a deepening of the water table between 2013 and 2016 (-6 cm and -9 cm, respectively). Thaw depth was shallower in both the Reference and Test Areas in 2016 (37 cm and 40 cm, respectively) compared to 2013 (41 cm and 45 cm, respectively).

Riverine Loamy Alkaline Moist Mixed Herb had mineral soil as the predominant ground cover class in both Areas and years (Appendix C-8). Herbaceous litter cover was observed in the Test Area in both years (14%–16%) and in the Reference Area in 2016 (29%). Moss cover was present in the Test, but not Reference Area in both years (Appendix D). The Riverine Loamy Alkaline Moist Mixed Herb plot ecotype is limited to frequently flooded, inactive channel deposits of the Colville River Delta. A soil surface organic horizon was absent in both the Reference and Test Areas in 2013 and 2016 (Appendix E). Average EC was higher in the Reference Area in 2016 than 2013 (730 µS/cm and 580 µS/cm, respectively), but was lower in the Test Area in 2016 compared to 2013 (380 µS/cm versus 490 µS/cm, respectively). A water table was absent within 40 cm of the soil surface in all Areas and years. Fluctuations in both the water table and soil chemistry are not unusual on these lower floodplain geomorphic positions. The thaw depth in the Reference Area in both 2013 and 2016 (105 cm and 92 cm, respectively) was consistently deeper than in the Test Area (86 cm and 84 cm, respectively). Additionally, both Reference and Test Areas had a shallower active layer in 2016 than 2013 in this ecotype.

Riverine Loamy Alkaline Moist Low Willow Shrub ground cover was generally similar between Areas and years, with the exceptions of water cover in the Reference Area in 2013 and liverwort in the Reference Area in both years (Appendix C-9). Moss (average 39–44%, Appendix D) and herbaceous litter (average 24–43%) were the predominant ground cover classes in both Areas and years. Mineral soil was also a common ground cover (average 17–29%). The Riverine Loamy Alkaline Moist Low Willow Shrub plot ecotype is common on active and inactive overbank deposits of the Colville River Delta. The soil surface organic thickness in this ecotype is variable due to the dynamic hydrology in the floodplain zone (e.g., ice jam flooding and scour). In general, the surface organic thickness in the Test Area was slightly thicker than in the Reference Area in both 2013 and 2016 (Appendix E). However, the average surface organic thickness decreased slightly from 2013 to 2016 in both the Reference (2.1 cm in 2013, and 1.9 cm in 2016) and Test Areas (3.8 cm in 2013 and 2.9 cm in 2016), a likely result of sedimentation during the 2015 breakup flooding (Baker 2015). Average water table depth, EC, and pH are variable in this plot ecotype due to fluctuating river levels that are influenced by both non-saline surface water run-off and occasional, brackish tidal intrusions.

Riverine Loamy Alkaline Moist Tall Willow Shrub was only located in the Test Area. Cover of mineral soil comprised the vast majority of ground cover observed in 2013 (average 83%, Appendix C-10, Appendix D), but in 2016 was notably lower (average 26%) than both herbaceous litter (average 37%) and moss (average 34%). The Riverine Loamy Alkaline Moist Tall Willow Shrub plot ecotype is limited to frequently flooded, inactive channel deposits of the Colville River Delta. The average thaw depth decreased from 2013 (118 cm) to 2016 (93 cm) (Appendix E). A surface organic horizon was absent and the water table was not encountered in the upper 40 cm in both 2013 and 2016.

Riverine Organic-rich Circumneutral Wet Sedge Meadow ground cover was dominated by herbaceous litter, moss, and water (Appendix C-11). Average cover of herbaceous litter was lower in 2013 than 2016 for both the Reference (11 and 32%, respectively, Appendix D) and Test (19 and 29%, respectively) Areas. The average moss cover was also lower in 2013 than 2016 for both the Reference (52 and 56%, respectively) and Test (44 and 53%, respectively) Areas. Conversely, the average cover of water was higher in 2013 than in 2016 for both the Reference (52 and 24%, respectively) and Test (39 and 21%, respectively) Areas. In both years, the average cover of water was higher in the Reference than Test Area. The Riverine Organic-rich Circumneutral Wet Sedge Meadow plot ecotype is common on inactive overbank deposits of the Colville River Delta. The average soil surface organic thickness was lower in both the Reference and the Test Areas in 2016 compared to 2013 (Appendix E). The average surface organic thickness in the Reference Area decreased from 14.9 cm in 2013 to 12.8 cm in 2016. The average surface organic thickness in the Test Area decreased from 21.8 cm in 2013 to 21.2 cm in 2016. The average surface organic thickness was thicker in the Test Area than in the Reference Area in both years. The average thaw depth was shallower in 2016 compared to 2013 in both the Reference (37 cm and 45 cm, respectively) and Test Areas (40 cm and 48 cm, respectively). The water table was shallower in 2013 than in 2016 for both the Reference (-5 cm and -15 cm, respectively) and the Test Area (-3 cm and -13 cm, respectively).

Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow ground cover was generally similar between Areas and years (Appendix C-12). Mosses were the predominant ground cover (average 63–70%) (Appendix D), followed by herbaceous litter (average 19–25%). Average cover of water was higher in 2013 than 2016 in both the Reference (10% and 7%, respectively) and Test (11% and 5%, respectively) Areas. The Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow plot ecotype is common on inactive overbank deposits of the Colville River Delta. The average thaw depth was shallower in 2016 compared to 2013 in both the Reference (38 cm and 47 cm, respectively) and Test Areas (37 cm and 47 cm, respectively), (Appendix E). The water table was shallower in 2013 than in 2016 for both the Reference (-6 cm and -18 cm, respectively) and (-7 cm and -20 cm, respectively) Areas.

Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow ground cover was generally similar between Areas and years (Appendix C-13) with the exception of water, which was present in both the Reference and Test Areas in 2013 (average covers of 6 and 7%, respectively, Appendix D) but absent in 2016. Mosses (average 50–65%) and herbaceous litter (average 30–42%) cover were the predominant ground cover classes in both Areas and years. This plot ecotype occurs predominantly on inactive overbank deposits. The water table was shallower in 2013 than in 2016 for both Reference (-12 cm and -28 cm, respectively) and Test Areas (-10 cm and -24 cm, respectively)(Appendix E).

Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow ground cover was predominantly mosses and herbaceous litter (Appendix C-14). Average moss cover was higher in the Reference Area (68% in 2013, 67% in 2016) than in the Test Area (57% in 2013, 53% in 2016)(Appendix D). Conversely, average herbaceous litter cover was lower in the Reference Area (25% in 2013, 31% in 2016) than in the Test Area (35% in 2013, 38% in 2016). Water was only observed in the Test Area in 2013. The plot ecotype occurs on inactive overbank deposits of the Colville River Delta. The average EC dropped in the Reference Area from 2013 to 2016 (600 µS/cm to 380 µS/cm, respectively, Appendix E). The water table was shallower in 2013 than in 2016 for both the Reference (-29 cm and -35 cm, respectively) and the Test Area (-27 cm and -36 cm, respectively).

Upland Loamy-Organic Circumneutral Moist Tussock Meadow ground cover was predominantly herbaceous litter and mosses (Appendix C-15). Average cover of herbaceous litter was higher in the Reference Area (67% in 2013, 61% in 2016, than the Test Area (40% in 2013, 49% in 2016) (Appendix D). Conversely, average cover of moss was lower in the Reference Area (13% in 2013, 20% in 2016) than in the Test Area (46% in 2013, 39% in 2016). Average cover of lichen was lower in 2013 than in 2016 for both the Reference Area (9 and 12%, respectively) and Test Area (9 and 13 9%, respectively). This plot ecotype has limited spatial extent in both Areas, occurring on abandoned overbank and terrace deposits of the Colville River Delta. The increase in surface organic thickness from 2013 (15 cm) to 2016 (22 cm) at a single plot in the Reference Area appears to be the result of the high microtopographic variability in this plot ecotype (Appendix E). The EC in the Reference Area remained higher in both 2013 and 2016 (590 µS/cm and 510 µS/cm, respectively) than in the Test Area in both years (170 µS/cm and 140 µS/cm, respectively). The water table was shallower in 2013 than in 2016 for both the Reference (-11 cm and -36 cm, respectively) and the Test Areas. The average water table depth in the Test Area was -26 cm in 2013 and was absent within 40 cm (recorded as -999) in 2016.

Upland Sandy Alkaline Dry Barrens was sampled in the Test Area only. Mineral soil was the predominant ground cover in both 2013 and 2016 (Appendix C-16) and the average percent cover of mineral soil was higher in 2013 (96%) than in 2016 (74%) Appendix D). Herbaceous litter had the second greatest average percent cover in both years, yet was substantially lower in 2013 (3%) than in 2016 (24%). This plot ecotype had little to no cover of Mosses in both years. This plot ecotype is uncommon, occurring on active sand dune deposits. Sand dunes are dynamic geomorphic landforms, that are regularly re-shaped by wind events. Active, sandy, dune deposits can be difficult for vegetation to establish, resulting in the absence of a surface organic horizon in both years (Appendix E).

Upland Sandy Alkaline Moist Low Willow Shrub ground cover in the Reference and Test Areas in both 2013 and 2016 was predominantly herbaceous litter (Appendix C-17). However, the average cover of herbaceous litter in the Test Area (46–50%) was substantially lower than that found in the Reference Area (83–97%)(Appendix D). Other common ground cover classes in the Test Area included mineral soil (average 31–35%) and mosses (average 17–18%). Mineral soil was observed only in the Reference Area in 2016 (average 8% cover). Moss cover (average 1–9%) in the Reference Area in both years was substantially lower than that found in the Test Area. This plot ecotype is uncommon and although it occurs on active and inactive sand dune deposits, it is less vulnerable to wind disturbance then the Upland Sandy Alkaline Dry Barrens due to recruitment and establishment of vegetation. Average surface organic thickness was low in both the Reference and Test Areas in both 2013 and 2013 (0.5 cm and 0 cm in Reference, and 0.3 cm and 0.3 cm in Test, respectively)(Appendix E). The one plot in this ecotype experienced both a decrease in EC (450 µS/cm to 100 µS/cm) and pH (8.2 to 7.1) from 2013 to 2016. The thaw depth was shallower in 2016 compared to 2013 in both the Reference (120 cm and 101 cm, respectively) and Test Areas (105 cm and 92 cm, respectively).

The detailed assessment of ground cover and environment characteristics by plot ecotype revealed several common patterns of change in ground cover and environment characteristics between 2013 and 2016 across plot ecotypes and Areas. The cover of standing water decreased and depth to water table increased in 2016 in both Test and Reference Areas. Warmer temperatures, a shallower snowpack, earlier snow melt, higher evapotranspiration, and lower July precipitation occurred in 2016 compared to 2013 (see Climate Monitoring, above). This explains the lower cover of water and deeper water table depths across the entire CD5 Study Area. In addition to these climatic conditions, break-up flooding in 2013 was extensive, inundating a large portion of the CD5 Study Area. In contrast, break-up in 2016 was more subdued with much of the CD5 Study Area not flooding (Baker 2016). In general, mineral and organic soil and mosses and liverworts cover increased in 2016 in both Reference and Test Areas. This can be explained by the reduction in standing water, caused by the 2016 climatic conditions listed above, resulting in soil surfaces being exposed in 2016. Sedimentation caused by 2015 breakup flooding (Baker 2015), which covered most of the CD5 Study Area with flood water, is also a likely cause of increase mineral soil cover in 2016 in both Reference and Test Areas. The drier soil conditions and exposed soil surfaces provided a greater surface area for non-vasculars to establish and expand, resulting in a higher cover of mosses and liverworts. Thaw depth decreased (i.e., thinner active layer) in 2016 across both Reference and Test Areas. This is related to the timing of the RTK Surveys in 2013 as compared to 2016. In 2013 the RTK surveys were conducted in the first and second weeks of August, while in 2016 the RTK surveys were conducted approximately 3 weeks earlier, during the second and third weeks of July. Additionally, the record low snowpack from the winter of 2015/2016 compared to the long-term record (i.e., diminished insulating properties) may also be a contributing factor in the shallower active layer depths observed in 2016 (see Climate Monitoring, above).

3.4.2.A.iv. Vegetation Structure Class Qualitative Assessment

The Vegetation Plot cover and height data summaries for each vegetation structure class by plot ecotype, Area, and sample year are presented in Figures 3.17 and 3.18. In general, total live cover stayed approximately the same or increased between 2013 and 2016 in both Reference and Test Areas and across ecotypes. Increases in total live cover were most commonly related to increases in mosses and sedge cover. In 2013, total live cover was greatest in Riverine Loamy Alkaline Moist Low Willow Shrub and Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow in Test and Reference Areas, respectively. In 2016, Riverine Loamy Alkaline Moist Low Willow Shrub again had the highest total live cover in the Test Area; we attribute the higher value to an increase in forbs and low and tall shrubs. In the Reference Area, Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow was tied for highest total live cover in 2016 with Lowland Organic-Rich Circumneutral Wet Sedge-Willow Meadow, which saw an increase between years in mosses, forb, and sedge cover. Total live cover decreased appreciably in Coastal Loamy Brackish Moist Willow Dwarf Shrub in Reference Areas, despite a slight increase in dwarf shrub cover. The decrease in total live cover in this ecotype was attributed primarily to a drop in moss and grass cover. The drop in moss cover is likely related to the increase in soil alone cover in 2016, indicating mosses were buried by sediment. In the Test Area, total live cover decreased appreciably in Upland Sandy Alkaline Moist Low Willow Shrub in 2016, a result predominantly associated with a drop in forb cover.

The top cover of the non-vegetated classes water alone, soil alone, litter alone, as well as moss are included in Figure 3.17 and mirror the results of the detailed ground cover class assessment (Appendices C and D). The results were generally consistent between Areas and years (section 3.4.2.A.iii, above). For instance, for the wet plot ecotypes Lowland Organic-rich Circumneutral Wet Sedge Meadow, Lowland Organic-Rich Circumneutral Wet Sedge-Willow Meadow, Riverine Organic-Rich Circumneutral Wet Sedge Meadow, and Riverine Organic-Rich Circumneutral Wet Sedge-Willow Meadow, the general trend was a reduction in water cover, deeper water tables, and an increase in soil, litter, and non-vascular cover between 2013 and 2016. This trend is related to the overall warmer conditions in 2016 vs. 2013; higher evapo-transpiration and earlier melt-off of snow in 2016; and the predominance of summer precipitation falling in July 2013 vs. August and September of 2016. In addition, the higher water cover in 2013 is also likely related in part to the more extensive break-up flooding in 2013 when most of the CD5 Study Area was flooded for up to several days (Baker 2016). In contrast, spring break-up was more subdued in 2016 and the CD5 Study Area was flooded less extensively (Baker 2016). Lower cover of standing water in 2016 resulted in a higher amount of exposed litter and mineral soil, which is expressed in the higher percentages of these ground cover classes in 2016. The increased cover of non-vasculars, which are highly sensitive to soil moisture gradients (Turetsky et al. 2012), may in part be related to the non-vascular lifeforms mosses and liverworts capitalizing on the slightly drier conditions in 2016. The ecotypes Coastal Loamy Brackish Moist Willow Dwarf Shrub, Coastal Sandy Moist Brackish Barrens, Riverine Loamy Alkaline Moist Mixed Herb, Riverine Loamy Alkaline Moist Low Willow Shrub, and Riverine Loamy Alkaline Moist Tall Willow Shrub are characterized by highly dynamic environments (e.g., river bars and lower floodplain surfaces). The variability in non-vegetated classes and mosses between Areas and years is due in large part to the dynamic nature of the environments characteristic of these ecotypes. For example, the lower mineral soil cover and higher litter cover in 2016 in several of these ecotypes is likely attributable to a combination of the more subdued breakup flooding in 2016 as compared to 2013, and the point-intercept methods for recording last hit (as explained in Section 3.2.2.B.i. Vegetation Plots—Point-intercept Sampling). Less intense flooding would result in less scour, thus, leaving litter overlying mineral soil in place as opposed to flushing it away. The point-intercept sampling methods call for no hits of abiotic ground cover classes below litter; hence mineral soil below litter is not counted.

The Vegetation Plot height data summaries for herbaceous ("herb") and woody species by plot ecotype, Area, and sample year are presented in Figure 3.18. In general, herb and woody heights stayed approximately the same between 2013 and 2016 in both Reference and Test Areas and across ecotypes with few exceptions. Herbs were shorter in 2016 in the Coastal Loamy Brackish Moist Willow Dwarf Shrub, while woody height remained approximately the same. In the ecotype Coastal Sandy Moist Brackish Barrens, herbs were taller and woody species were shorter in Reference Areas in 2016, while in Test Areas herbs were appreciably shorter and similar to 2013; woody species were absent. The ecotype Riverine Loamy Alkaline Moist Mixed Herb in the Test Area (not sampled in the Reference Area) saw an increase in both herb and woody heights in 2016 compared to 2013, and an increase from 44% to 50% in the frequency of points where woody heights were measured in 2016. Lastly, in the Test Area (not sampled in the Reference Area), herb height increased slightly in the ecotype Upland Loamy-Organic Circumneutral Moist Tussock Meadow between 2013 and 2016, while woody height and the frequency of points where woody heights were measured decreased from 100% in 2013 to 81% in 2016.

3.4.2.B Habitat Assessment

Calibration Plot Analysis

The calibration plot analysis, in which 6 botanists took turns sampling the same Habitat Plot Lines at 3 Habitat Plots was designed to provide an estimate of the inter-observer error associated with the point-intercept sampling method. The calibration plots also provided an opportunity for field teams to work together and discuss the point-intercept sampling methods to ensure that the methods were being applied consistently between botanists. The plot sampling occured on three different days, one plot ten days into field work and one on each of the last two days, The results of the calibration plot analysis, including 95% confidence intervals of cover

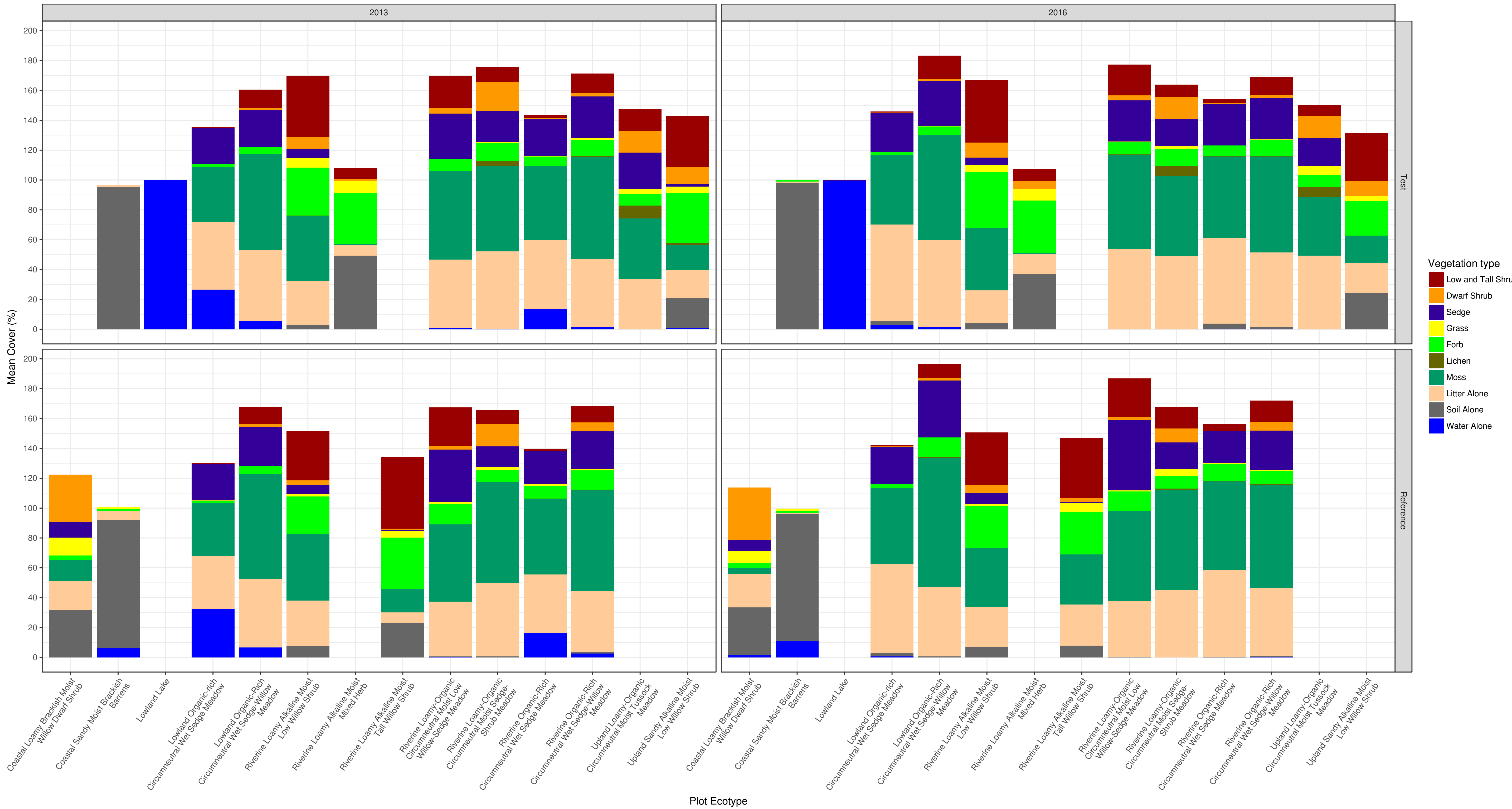


Figure 3.17. Mean cover by vegetation structure class for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2013 and 2016.

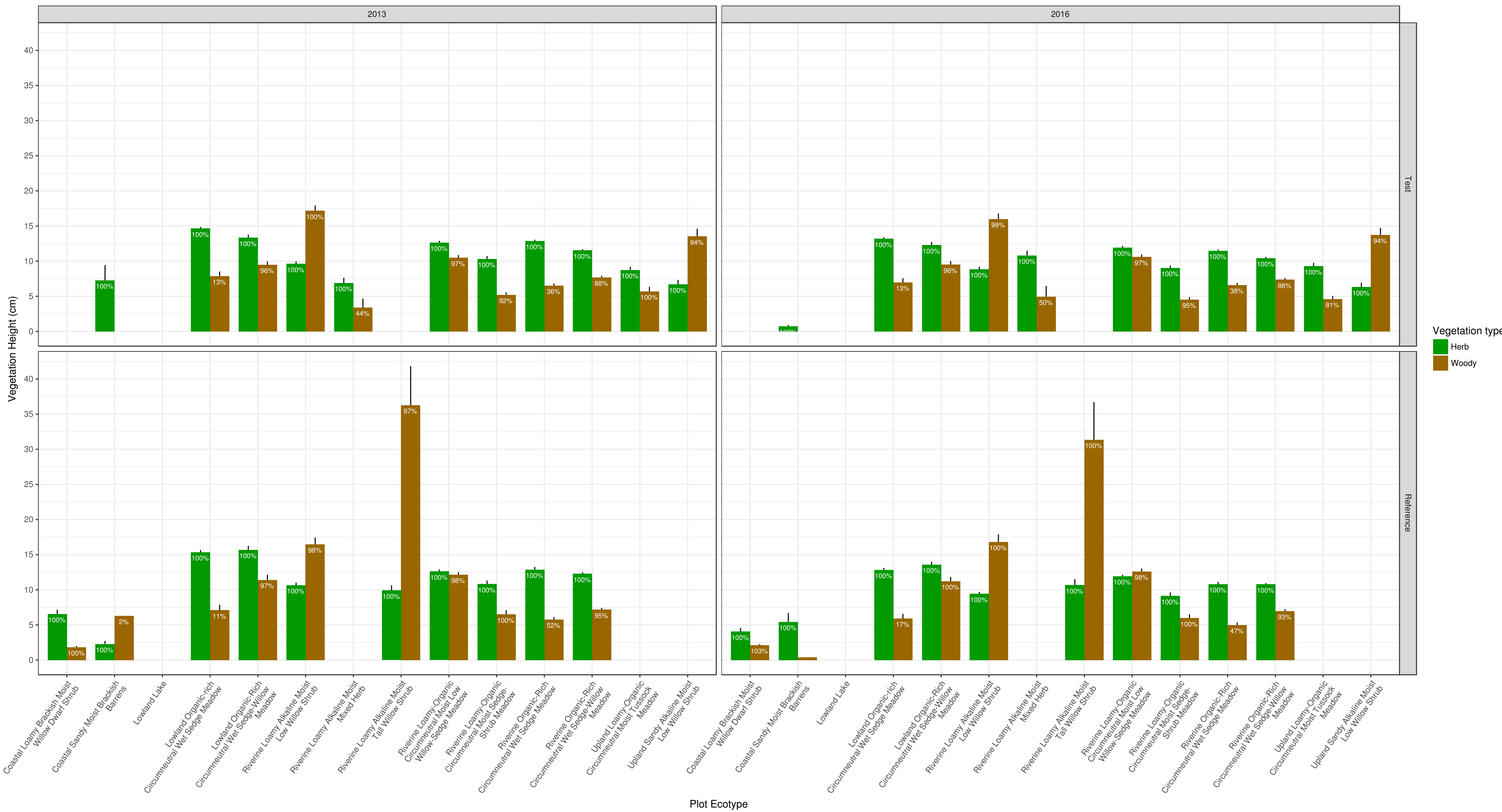


Figure 3.18. Herbaceous and woody plant height for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2013 and 2016.

estimates by vegetation structure class, are summarized in Table 3.12. Five of the vegetation structure classes were not present in high enough amounts for analysis, hence these 5 classes were not evaluated. Of those with higher than 5% cover, Mosses and Liverworts had the greatest methodological variation; the 95% confidence interval is 20.3% of the mean cover for this class. The non-vegetated classes Bare Ground and Litter had the lowest variation, 5.1% and 2.9% respectively. The high methodological variation in the Mosses and Liverworts category may in part be attributed to the complexity of the point-intercept rules associated with sampling this structure class category. For instance, live hits of mosses and liverworts are recorded below litter, whereas all other live hits below litter are not counted. In addition, it was noted after the completion of the first calibration plot that 1) some botanists were only recording moss and liverwort hits if the majority of the laser beam covered the moss or liverwort, while others were recording moss and liverwort hits if any portion of the laser beam covered the moss or liverwort, and 2) some botanists were recording live cover of mosses and liverworts below litter while others were not. The methodological variation seen for this class at the calibration plots is largely due to the differences in application of the above rules for mosses and liverworts. Once these differences in methods were realized the botanists discussed ways to improve consistency and clarified the rules for future point-intercept sampling for mosses and liverworts. The calibration plots served to improve consistency in point-intercept sampling between botanists in addition to providing an estimate of the inter-observer error inherent to the point-intercept method itself.

Table 3.12. Ninety-five percent confidence interval range as a percentage of mean cover for calibration plots by structure class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Structure Class	Confidence Interval Range (% of mean)
Mosses and Liverworts	20.3
Forbs	14.9
Dwarf Shrubs	13.6
Low Shrubs	10.8
Total Live Vascular	9.3
Salix	9.1
Sedges and Rushes	7.0
Bare Ground	5.1
Litter	2.9

Qualitative Assessment

Summaries of vegetation structure cover, non-vegetated cover, and herb and woody vegetation heights by wildlife habitat class are provided below. These summaries provide 1) quantitative cover and height values of general vegetation structural classes and ground cover types for wildlife habitat map classes for use in describing the mapping classes; and 2) quantitative baseline data for long-term habitat monitoring.

Habitat Plot data were summarized by wildlife habitat class for all wildlife habitats with at least 75 points. Of the 24 wildlife habitats in the CD5 Habitat Monitoring Study Area, 12 had sufficient data. The sampling design avoided placing Habitat Plot Center Points in waterbodies and as a result, waterbody habitats were not frequently sampled. Thus, of the 7 waterbody habitats in the Study Area, only the "River or Stream" class met the 75 point criteria. The 6 terrestrial wildlife habitat classes with insufficient data from the Habitat Plots were all rare. The 11 terrestrial wildlife habitat classes with sufficient data cover 97.7% of the non-water portion of the CD5 Study Area (see 3.4.2.C ITU Mapping, below).

Summaries of mean vegetation structure class cover, non-vegetated cover, and herbaceous and woody height by wildlife habitat class and grouped by year and Area are presented in Figure 3.19, Appendix F. Wildlife habitats with the highest cover of water alone include River or Stream and Deep Polygon Complex. Soil alone had the highest cover in Barrens, Dry Halophytic Meadow, and Moist Herb Meadow. Moist Low Shrub and Moist Halophytic Dwarf Shrub also had appreciable soil alone cover. Litter alone was highest in Patterned Wet Meadow, Nonpatterned Wet Meadow, Moist Sedge-Shrub Meadow, and Dry Dwarf Shrub. Cover of mosses was highest in Moist Sedge-Shrub

Meadow, Patterned Wet Meadow, and Nonpatterned Wet Meadow. Lichen cover was generally absent to low across all wildlife habitats, but was highest in Dwarf Low Shrub and Moist Tussock Tundra. Forbs were most abundant in Moist Herb Meadow and Moist Low Shrub, while grasses had the highest cover in Moist Herb Meadow and Dry Halophytic Meadow. Wildlife habitats with the highest cover of sedges included Moist Tussock Tundra, Patterned Wet Meadow, and Nonpatterned Wet Meadow. Dwarf shrubs were most common in Moist Halophytic Dwarf Shrub, Dry Dwarf Shrub, and Moist Sedge-Shrub Meadow. Lastly, low and tall shrub cover was highest in Moist Low Shrub, Tussock Tundra, and Dry Dwarf Shrub. These broad patterns are consistent in both years of the study (2013 and 2016) and over both the Test and Reference Areas, although some habitat types are not present in both Areas.

Summaries of herbaceous and woody vegetation heights by wildlife habitat class at Habitat Plot Points and grouped by year and Area are presented in Figure 3.20 and Appendix F. Woody vegetation frequency was highest in Moist Sedge-Shrub Meadow, Moist Halophytic Dwarf Shrub, Dry Dwarf Shrub, and Moist Low Shrub. Moist Low Shrub and Moist Herb Meadow were associated with some of the highest woody vegetation heights. Barrens also had high average woody vegetation heights, although frequency of woody vegetation was low. Note that Tall Shrub habitat classes were relatively rare and were excluded from these results due to insufficient sample points. Herb frequency was greater than 93% in all but 2 habitats, Barrens and River or Stream. Herb heights were highest in Moist Tussock Tundra, Nonpatterned Wet Meadow, Patterned Wet Meadow, and Deep Polygon Complex. Similar to the cover percentages, the broad patterns apply to both years and Areas, with the exception of those habitat types not present in both Areas. The significantly taller shrub vegetation in the Test Area between 2013 and 2016 for the Dry Halophytic Meadow habitat type represents a real increase in shrub height for this habitat in 2016 (see section 3.4.2.G Repeat Photo Monitoring). However, this change was observed at only one habitat line (*plot_id* t5na-0798-hab, line_id 1), and given the small sample size of woody height measurements within that habitat type, the significance of this change is more an artifact of the small sample size.

Quantitative Assessment

For the quantitative assessment of habitat changes between years and Areas, we relied on the repeated measures analysis, but have included mean and 75% and 95% confidence intervals for percent cover of vegetation structure classes by wildlife habitat for 2013 and 2016, and Test and Reference Areas (Figure 3.21 and Appendix G) as required by the CD5 Monitoring Plan (ABR and Baker 2013).

The first set of results compared total live vascular cover between Areas and years using habitat lines as the repeated measures subject, and reported significance (*p*-value) for a between Area effect, a between year effect, and an interaction effect of Area and year (Table 3.13). For the purposes of evaluating the potential effects of the CD5 project, the interaction effect is the important parameter because it signifies a change between 2013 and 2016 that was different in the Test Area than the Reference Area. For total live vascular cover, there were no significant ($p < 0.05$) interaction effects and only one significant year effect in the Moist Herb Meadow wildlife habitat. This suggests that total live vascular cover was different between 2013 and 2016 in this wildlife habitat, but that the changes occurred in both the Test and Reference Areas.

The second set of results compared each of the structure classes with more than 10% cover within a habitat between Areas and years, again using habitat lines as the repeated measures subject (Table 3.14). Several significant Area effects, including a difference in Sedges and Rushes in Moist Low Shrub and Litter in Moist Sedge-Shrub Meadow were found between Test and Reference Areas (Figure 3.21).

Litter is significantly different between years in several wildlife habitats, including Deep Polygon Complex (along with water and mosses and liverworts), Moist Herb Meadow (along with bare ground and mineral soil), Moist Low Shrub, and Patterned Wet Meadow (in addition to *Salix* cover). Mosses and liverworts show a significant year effect in Nonpatterned Wet Meadow.

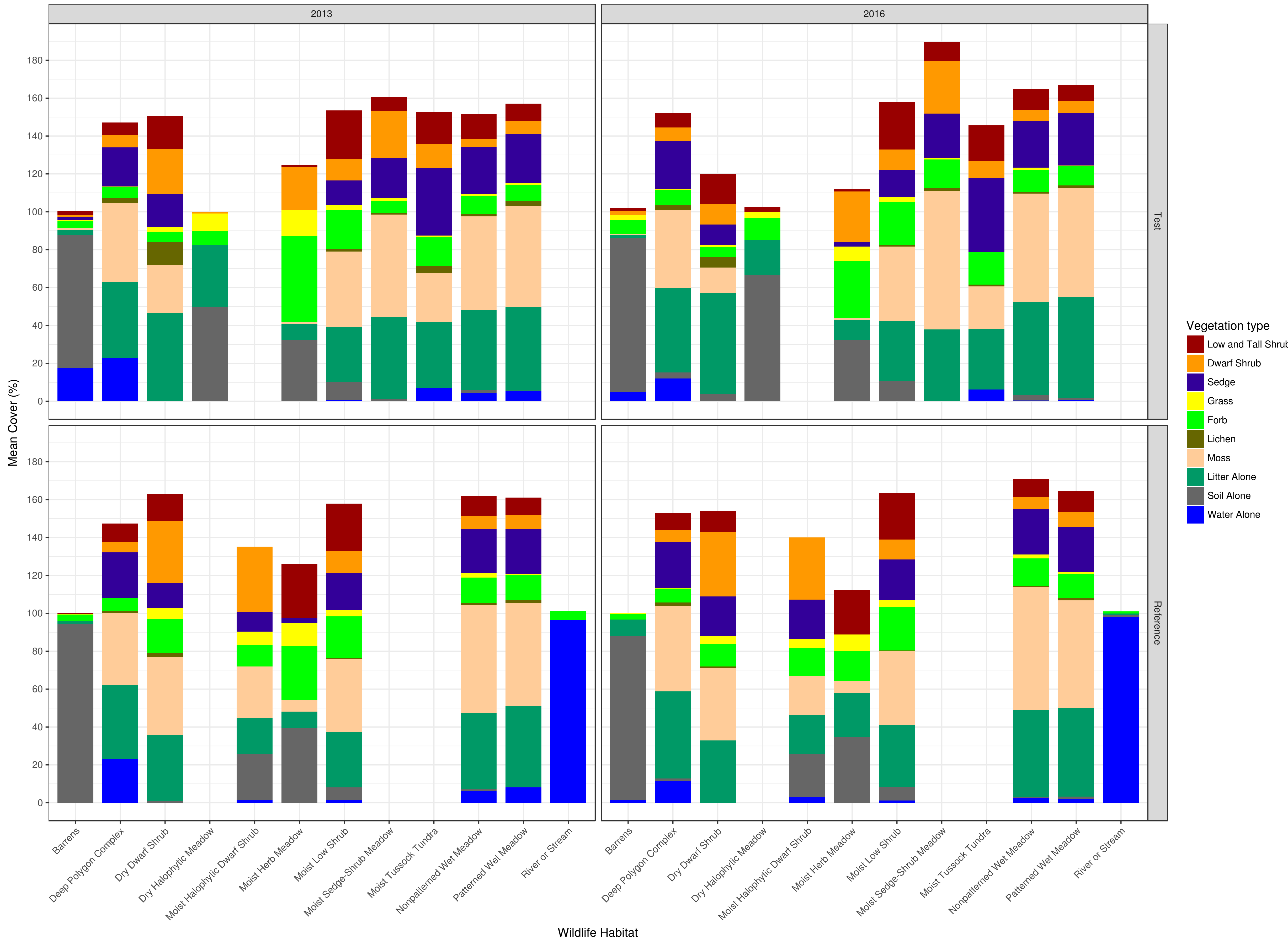


Figure 3.19. Mean cover by vegetation structure class for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

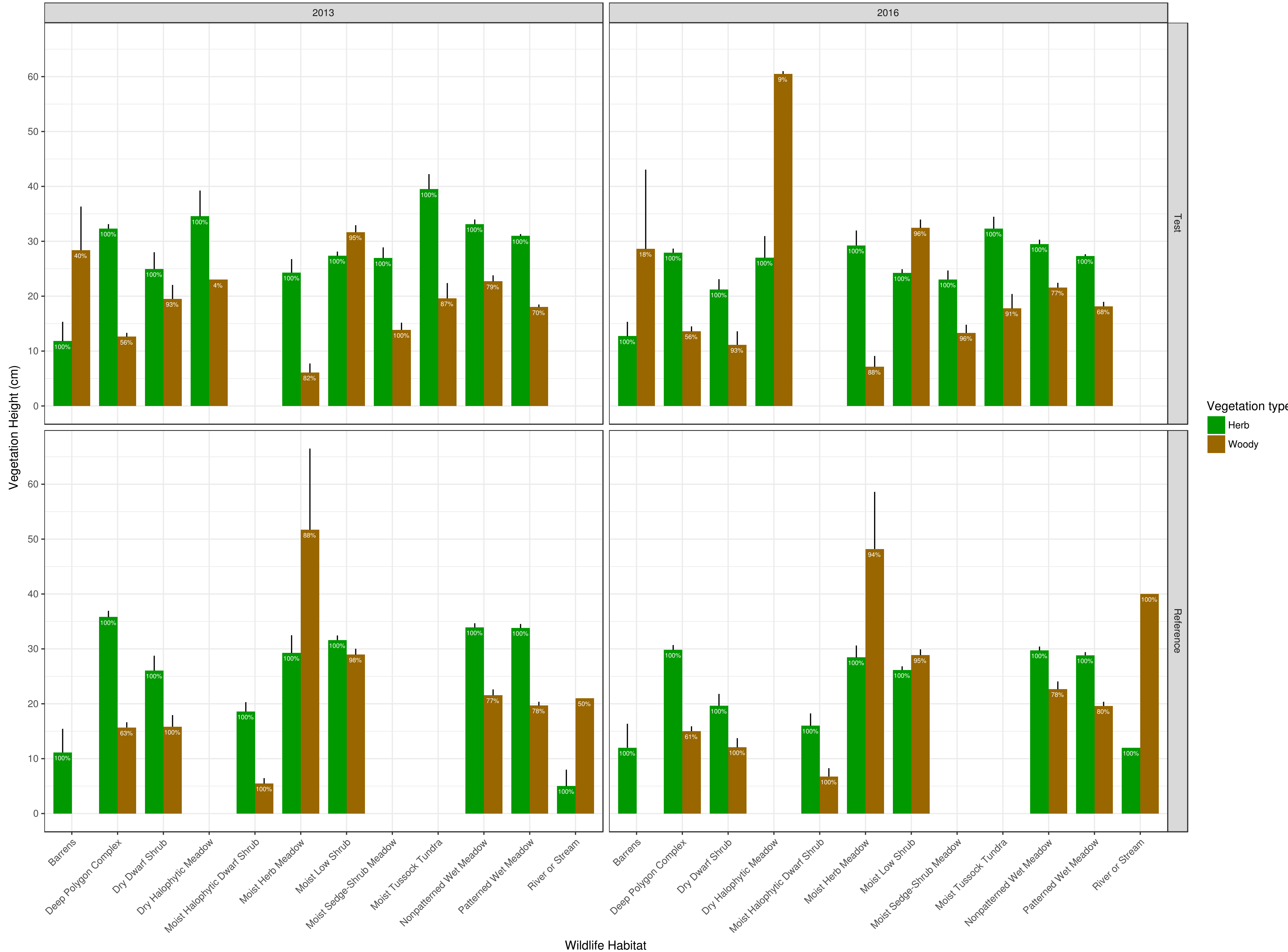


Figure 3.20. Herbaceous and woody plant height for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

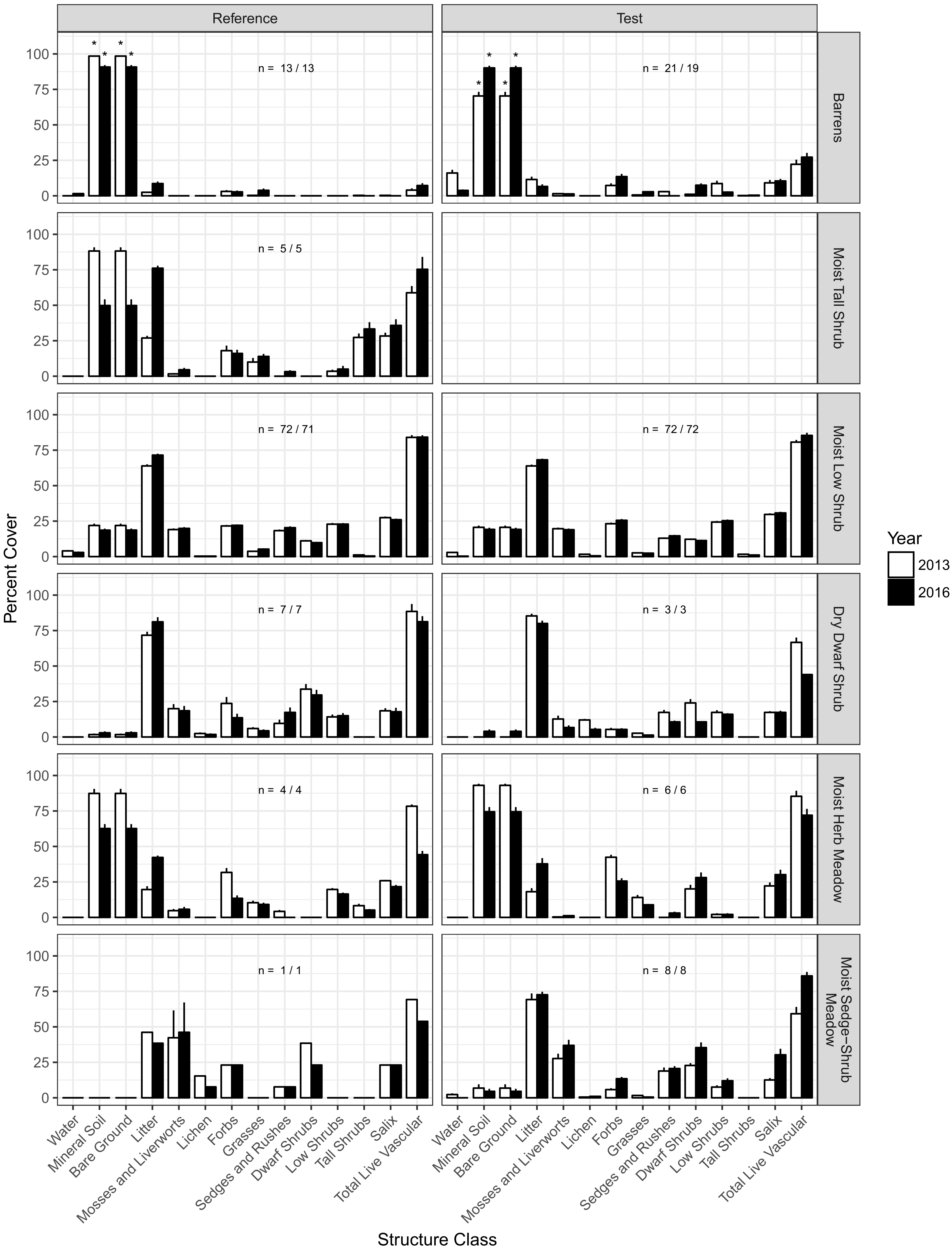


Figure 3.21. Mean cover and 95% confidence intervals by vegetation structure class, grouped by common wildlife habitat classes and Area classification.

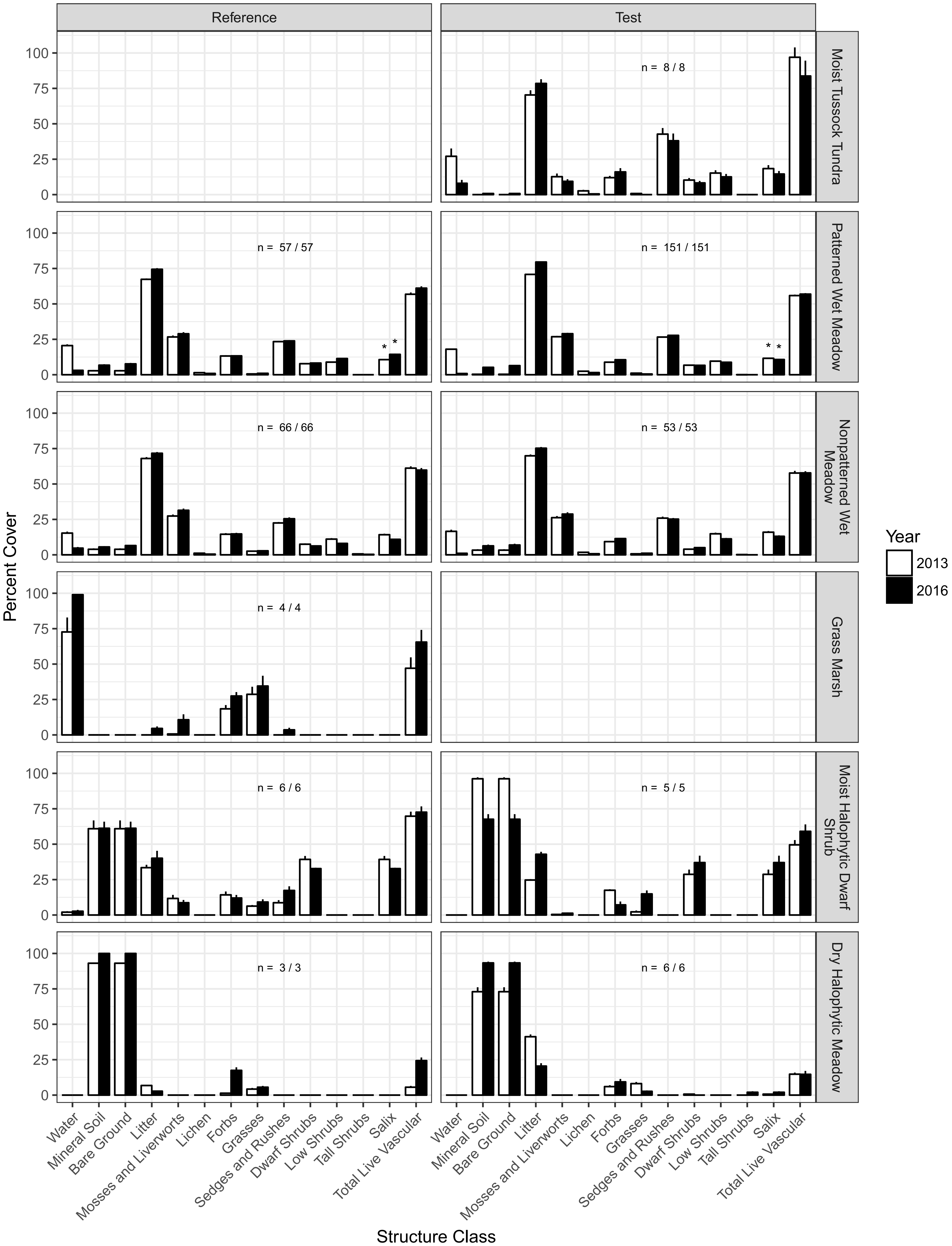


Figure 3.21. Continued.

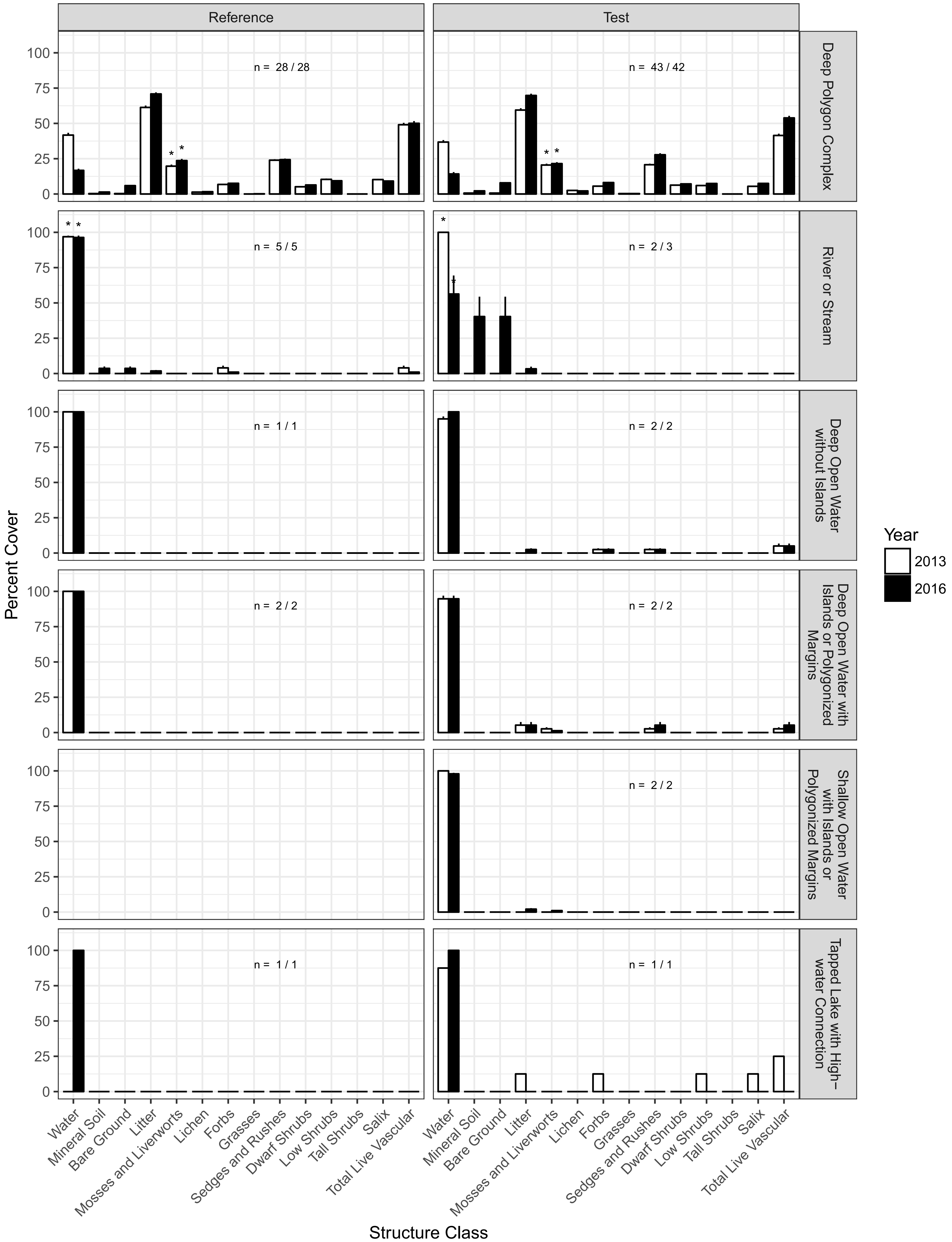


Figure 3.21. Continued.

Table 3.13. Significance (*p*-value) of Area, Year, and Area × Year interaction on total live vascular cover by wildlife habitat from repeated measures analysis, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Wildlife Habitat	Area	Area x Year	Year
Barrens	0.6270	0.2669	0.8381
Deep Open Water with Islands or Polygonized Margins	0.7773	0.6667	1.0000
Deep Polygon Complex	0.3877	0.1311	0.7969
Dry Dwarf Shrub	0.2997	0.1081	0.9155
Dry Halophytic Meadow	0.1701	0.1375	0.0749
Moist Halophytic Dwarf Shrub	0.8108	0.9238	0.2163
Moist Herb Meadow	0.4359	0.6708	0.0113
Moist Low Shrub	0.0536	0.3409	0.8133
Moist Sedge-Shrub Meadow	0.9540	0.1253	0.3896
Nonpatterned Wet Meadow	0.2816	0.6188	0.7394
Patterned Wet Meadow	0.6804	0.6541	0.4241
River or Stream	0.4974	0.6221	0.3244

Five significant interaction effects were found. Both bare ground and mineral soil in Barrens changed significantly for the interaction of Area and year, with percent cover dropping between 2013 and 2016 in the Reference Area, but rising in the Test Area. One explanation for this pattern is that water covered almost 16% of the habitat in the Test Area in 2013 but was absent in the Reference Area. A lot less water was present in the Test Area in 2016 (3.8%), resulting in an increase in percent cover of bare ground and mineral soil. A similar effect was seen for water in the River or Stream wildlife habitat; percent of water cover was unchanged between years in the Reference Area, but dropped in the Test Area (replaced by mineral soil and bare ground). The Barrens habitat class occurs in highly dynamic environments, on active river bars, where daily fluctuations in water level related to changes in river stage and tidal influences are common.

Cover of mosses and liverworts in Deep Polygon Complex wildlife habitats also had a significant interaction effect, with percent cover increasing in the Reference Area between 2013 and 2016 (19.7% to 23.6%), but increasing only slightly in the Test Area (from 20.5% to 21.5%) between years. It is worth noting that the calibration results (see Section 3.4.2.B, Calibration Plot Analysis, above) indicated that this vegetation structure class is the most sensitive of all the classes to sampling error. Extrapolating a methodological confidence interval onto the mean cover percentages in the Reference Area for this class results in clearly overlapping ranges.

The final significant interaction effect is seen for the *Salix* structure class in Patterned Wet Meadow habitats. *Salix* cover increased in the Reference Areas (10.7% to 14.4%) but declined slightly in the Test Areas (11.6% to 10.7%) between 2013 and 2016. The cause of the increase in *Salix* cover in the Reference Areas, and slight decrease in *Salix* cover in Test Areas, is unknown. The slight decrease of <1% could be sampling error (i.e., this difference is within the range of variation between observers). We will assess the *Salix* cover in all Areas as part of the 2019 CD5 Monitoring effort to determine whether the patterns of observed change remains.

3.4.2.C ITU Mapping

The original ITU map developed from 2012 imagery provided a quantifiable baseline for assessing landscape change over time for the CD5 Habitat Monitoring Study Area. We updated the ITU mapping using newer imagery acquired in July 2015. Although shifts in map unit boundaries and ITU parameters were locally common along the Niġliq Channel and along the CD5 road, most map units remained unchanged. We did not observe any new ITU classes that were not present

Table 3.14. Significance (p-value) of Area (asig), Year (ysig), and Area × Year (isig) interaction on common vegetation structure classes by wildlife habitat from repeated measures analysis, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Wildlife Habitat	Structure Class	Area	asig	Year	ysig	Area × Year	isig
Barrens	Bare Ground	0.0037	**	0.2275		0.0111	*
	Mineral Soil	0.0037	**	0.2275		0.0111	*
Deep Polygon Complex	Litter	0.7961		0.0016	**	0.9268	
	Mosses and Liverworts	0.4981		0.0212	*	0.0356	*
	Sedges and Rushes	0.3440		0.8929		0.1568	
	Water	0.2693		0.0000	*	0.4220	
Dry Dwarf Shrub	Dwarf Shrub	0.7484		0.7881		0.2409	
	Litter	0.1724		0.3801		0.3460	
	Mosses and Liverworts	0.3756		0.6038		0.5811	
	Salix	0.8605		0.4141		0.5853	
	Sedges and Rushes	0.9669		0.2612		0.2322	
Dry Halophytic Meadow	Bare Ground	0.1245		0.4154		0.4807	
	Mineral Soil	0.1245		0.4154		0.4807	
Moist Halophytic Dwarf Shrub	Bare Ground	0.1792		0.6111		0.1833	
	Dwarf Shrub	0.4737		0.8627		0.5678	
	Forbs	0.4980		0.4443		0.2729	
	Litter	0.6255		0.1641		0.6244	
Moist Halophytic Dwarf Shrub	Salix	0.4737		0.8627		0.5678	
	Mineral Soil	0.1792		0.6111		0.1833	
Moist Herb Meadow	Bare Ground	0.8028		0.0362	*	0.3220	
	Forbs	0.0686		0.3286		0.6437	
	Litter	0.5690		0.0021	**	0.0858	
	Salix	0.7897		0.5535		0.3490	
	Mineral Soil	0.8028		0.0362	*	0.3220	

Table 3.14. Continued.

Wildlife Habitat	Structure Class	Area	asig	Year	ysig	Area x Year	isig
Moist Low Shrub	Bare Ground	0.6216		0.8907		0.7928	
	Dwarf Shrub	0.8507		0.3546		0.8459	
	Forbs	0.3698		0.9900		0.4305	
	Litter	0.1713		0.0016	**	0.4124	
	Low Shrub	0.9649		0.9953		0.9549	
	Mosses and Liverworts	0.8620		0.9363		0.9608	
	Salix	0.6521		0.7333		0.9831	
	Sedges and Rushes	0.0278	*	0.2442		0.9730	
	Mineral Soil	0.6217		0.8691		0.8079	
Moist Sedge-Shrub Meadow	Dwarf Shrub	0.1238		0.1451		0.1663	
	Litter	0.0492	*	0.6799		0.8906	
	Mosses and Liverworts	0.1473		0.5885		0.4052	
	Salix	0.4738		1.0000		0.6521	
Nonpatterned Wet Meadow	Forbs	0.1693		0.4309		0.8877	
	Litter	0.4797		0.1219		0.8509	
	Mosses and Liverworts	0.1322		0.0143	*	0.7101	
	Salix	0.3852		0.3042		0.8045	
	Sedges and Rushes	0.9791		0.4058		0.5311	
Patterned Wet Meadow	Litter	0.1287		0.0011	**	0.5006	
	Mosses and Liverworts	0.7051		0.5259		0.5237	
	Salix	0.6362		0.0197	*	0.0075	**
	Sedges and Rushes	0.1396		0.9601		0.5407	
River or Stream	Water	0.2023		0.2996		0.0256	*

* = $p < 0.05$
** = $p < 0.01$

in the baseline map, with the exception of disturbance classes and human-modified ecotypes related to CD5 infrastructure.

Geomorphic Units

Eighteen terrestrial geomorphic units are represented in the updated map and account for 79% of the CD5 Habitat Monitoring Study Area (Figure 3.22, Table 3.15). Delta Inactive Overbank Deposit remains the dominant geomorphic unit, covering over 44% of the CD5 Study Area. Delta Active Channel Deposit, Delta Active Overbank Deposit, and Delta Abandoned Overbank Deposit are also common, with areal cover values ranging from 7.4 to 9.9%. All other terrestrial geomorphic units cover <3% of the CD5 Study Area.

Seven aquatic geomorphic units collectively account for the remaining 21.0% of the CD5 Study Area (Figure 3.23, Table 3.16). As in the 2012 baseline map, Tidal River is the most extensive aquatic geomorphic unit (9.9% areal cover). In addition, Deep Isolated Riverine Lakes make up a substantial portion of the landscape (6.6%). The remaining aquatic geomorphic units account for ≤ 2.1%.

Surface Forms

Seventeen surface forms occur in the updated mapping (Figure 3.24, Table 3.17). As in the 2012 map, the dominant surface forms were Disjunct Polygon Rims; Low-centered, Low-relief, Low-density Polygons; and Nonpatterned, each of which cover approximately 20% of the CD5 Study Area. Surface forms related to low-centered polygons are very common; these features are associated with ice-rich permafrost and collectively cover nearly one-third of the CD5 Study Area. Water accounts for 13.6% of the total area, and Lakes with Islands 7.4%. All other surface forms are relatively rare, with an areal cover <2% each. Examples of common ice-wedge polygon surface forms are provided in Figure 3.25.

Vegetation

Twenty vegetation classes (Level IV, AVC) are represented in the updated mapping (Figure 3.26, Table 3.18). Wet Sedge Meadow Tundra, Wet Sedge-Willow Tundra, and Brackish Water remain the dominant vegetation classes, with areal cover values of 22.6%, 17.6%, and 11.1%, respectively. Other common vegetation classes include Fresh Water (9.5%), Open Low Willow (7.9%), Deep Polygon Complex (6.4%), Barrens (6.1%), and Open Low Willow-Sedge Shrub Tundra (5.7%). All other vegetation classes account for less than 4% of the CD5 Study Area.

Disturbance

The updated mapping identified 11 disturbance classes within the CD5 Study Area (Figure 3.27); the disturbance classification includes one new anthropogenic category—Bridge—that was not present in the original CBCP disturbance classification (Table 3.19). The vast majority of the CD5 Study Area has not undergone natural or anthropogenic disturbance since 2012; the areal extent of undisturbed ground is 98.5% (Table 3.20). The anthropogenic disturbance class Snow/Ice Pads and Roads is the most extensive disturbance class (0.5% areal cover). Thermokarst, which refers to the subsidence of ice-rich ground after thawing, is the most common natural disturbance type (0.4%). In addition, Fluvial Deposition and Fluvial Erosion/Channel Migration are locally common disturbance classes adjacent to the Niġliq Channel.

Map Ecotypes

Map ecotypes are mapping classes that represent local-scale ecosystems classified by aggregating ITU map units with similar ecological components, including geomorphology, surface form, vegetation, and disturbance. Thirty-eight ecotypes are represented in the updated mapping for the CD5 Study Area; this total includes three disturbed classes—Human-modified Marsh, Human-modified Moist Meadow, and Human-modified Waterbody—that occur adjacent to CD5 infrastructure and were not present in the baseline map (Figure 3.28). Riverine Wet Sedge Meadow and Riverine Wet Sedge-Willow Meadow remain the dominant ecotypes, with 19.4% and 17.2% areal cover, respectively (Table 3.21). Other common map ecotypes include Tidal River (9.9% areal cover), Coastal Barrens (9.1%), Riverine Moist Low Willow Shrub (7.9%), Riverine Lake (7.3%), and Riverine Moist Low Willow-Sedge Meadow (5.7%). All other map ecotypes account for less than 5% of the CD5 Study Area.

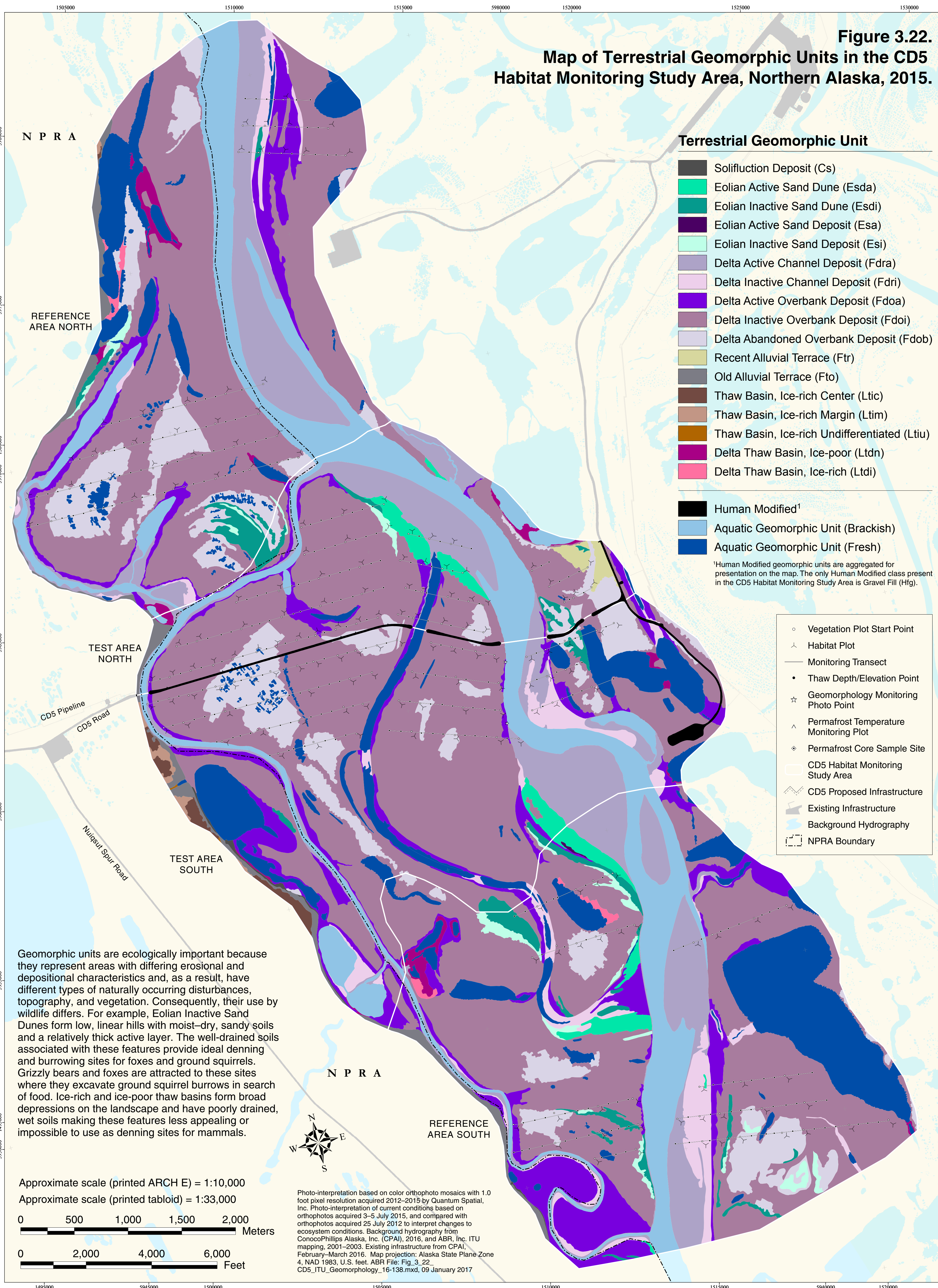


Figure 3.22.
Map of Terrestrial Geomorphic Units in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.
Terrestrial Geomorphic Unit
Solifluction Deposit (Cs)
Eolian Active Sand Dune (Esda)
Eolian Inactive Sand Dune (Esdi)
Eolian Active Sand Deposit (Esa)
Eolian Inactive Sand Deposit (Esi)
Delta Active Channel Deposit (Fdra)
Delta Inactive Channel Deposit (Fdri)
Delta Active Overbank Deposit (Fdoa)
Delta Inactive Overbank Deposit (Fdoi)
Delta Abandoned Overbank Deposit (Fdob)
Recent Alluvial Terrace (Ftr)
Old Alluvial Terrace (Fto)
Thaw Basin, Ice-rich Center (Ltic)
Thaw Basin, Ice-rich Margin (Ltim)
Thaw Basin, Ice-rich Undifferentiated (Ltiu)
Delta Thaw Basin, Ice-poor (Ltdn)
Delta Thaw Basin, Ice-rich (Ltdi)
Human Modified[1]
Aquatic Geomorphic Unit (Brackish)
Aquatic Geomorphic Unit (Fresh)
[1]Human Modified geomorphic units are aggregated for presentation on the map. The only Human Modified class present in the CD5 Habitat Monitoring Study Area is Gravel Fill (Hfg).
Vegetation Plot Start Point
Habitat Plot
Monitoring Transect
Thaw Depth/Elevation Point
Geomorphology Monitoring Photo Point
Permafrost Temperature Monitoring Plot
Permafrost Core Sample Site
CD5 Habitat Monitoring Study Area
CD5 Proposed Infrastructure
Existing Infrastructure
Background Hydrography
NPRA Boundary
N P R A
REFERENCE AREA NORTH
TEST AREA NORTH
CD5 Pipeline
CD5 Road
Nuiqsut Spur Road
TEST AREA SOUTH
N P R A
REFERENCE AREA SOUTH
N
E
S
W
Geomorphic units are ecologically important because they represent areas with differing erosional and depositional characteristics and, as a result, have different types of naturally occurring disturbances, topography, and vegetation. Consequently, their use by wildlife differs. For example, Eolian Inactive Sand Dunes form low, linear hills with moist–dry, sandy soils and a relatively thick active layer. The well-drained soils associated with these features provide ideal denning and burrowing sites for foxes and ground squirrels. Grizzly bears and foxes are attracted to these sites where they excavate ground squirrel burrows in search of food. Ice-rich and ice-poor thaw basins form broad depressions on the landscape and have poorly drained, wet soils making these features less appealing or impossible to use as denning sites for mammals.
Approximate scale (printed ARCH E) = 1:10,000
Approximate scale (printed tabloid) = 1:33,000
0 500 1,000 1,500 2,000 Meters
0 2,000 4,000 6,000 Feet
Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc. Photo-interpretation of current conditions based on orthophotos acquired 3–5 July 2015, and compared with orthophotos acquired 25 July 2012 to interpret changes to ecosystem conditions. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, February–March 2016. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR File: Fig_3_22_CD5_ITU_Geomorphology_16-138.mxd, 09 January 2017

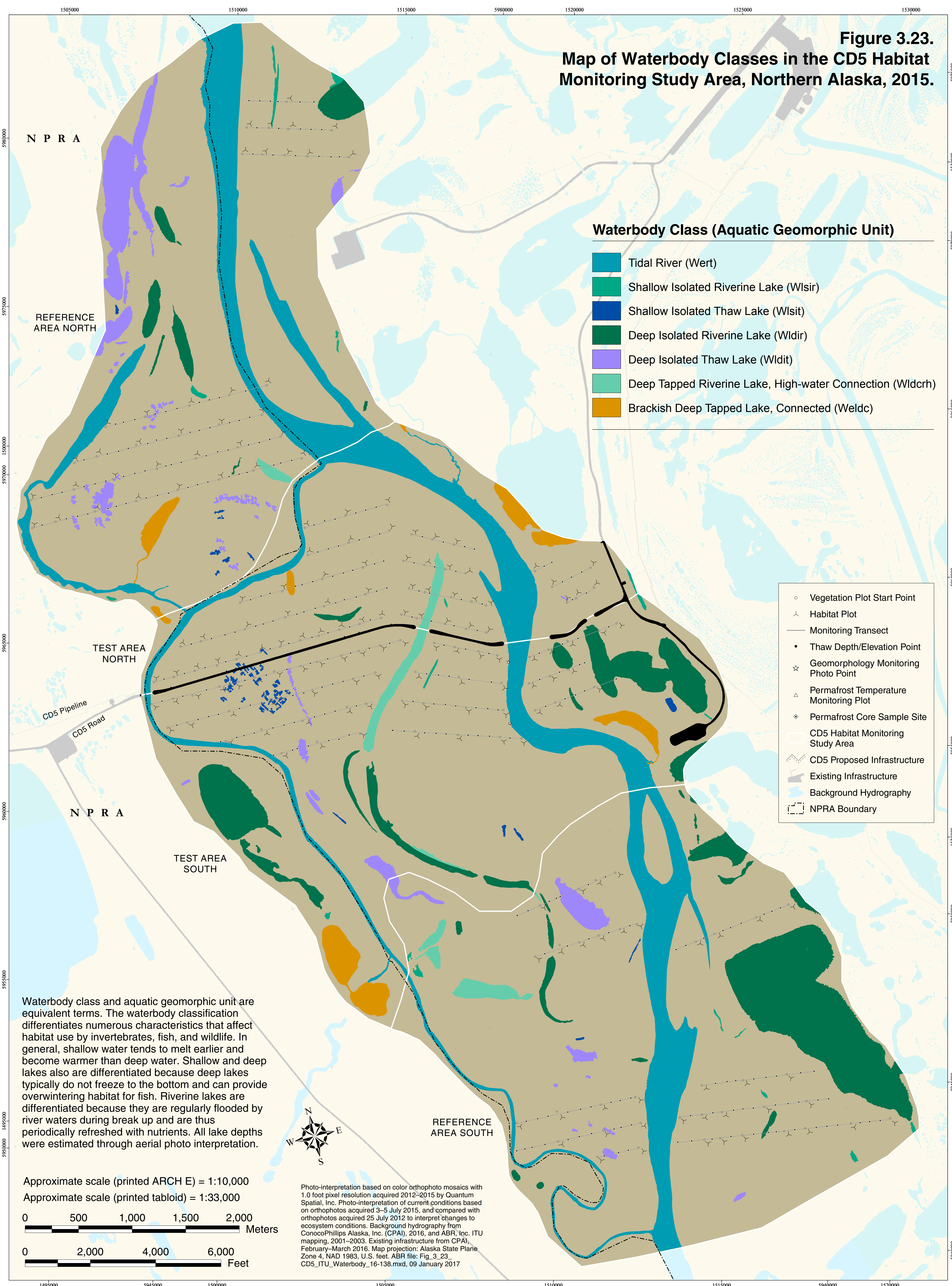


Figure 3.23. Map of Waterbody Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.

Table 3.15. Areal extent (ha) of terrestrial geomorphic units and the percent change in the total area of each unit between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference			Test*			Total*		
Gemorphic Unit	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Delta Abandoned Overbank Deposit	202.0	201.8	(0.1)	144.7	144.7	0.0	346.6	346.5	0.0
Delta Active Channel Deposit	257.1	257.9	0.3	166.1	163.9	(1.3)	423.2	421.8	(0.3)
Delta Active Overbank Deposit	208.7	208.5	(0.1)	108.0	107.9	(0.1)	316.7	316.4	(0.1)
Delta Inactive Channel Deposit	80.5	80.5	0.0	32.0	31.0	(3.1)	112.5	111.5	(0.9)
Delta Inactive Overbank Deposit	1108.6	1106.9	(0.2)	795.1	794.1	(0.1)	1903.8	1901.1	(0.1)
Delta Thaw Basin, Ice-poor	18.9	18.9	0.0	6.4	6.4	0.0	25.3	25.3	0.0
Delta Thaw Basin, Ice-rich	7.5	7.5	0.0	-	-	-	7.5	7.5	0.0
Eolian Active Sand Deposit	0.5	0.5	0.0	-	-	-	0.5	0.5	0.0
Eolian Active Sand Dune	23.3	23.3	0.0	26.6	26.3	(1.1)	49.9	49.6	(0.6)
Eolian Inactive Sand Deposit	26.8	26.8	0.0	3.9	3.9	0.0	30.7	30.7	0.0
Eolian Inactive Sand Dune	44.8	44.8	0.0	18.7	18.7	0.0	63.5	63.5	0.0
Gravel Fill	-	-	-	7.9	8.0	1.8	7.9	8.0	1.8
Old Alluvial Terrace	31.4	31.2	(0.5)	19.2	19.2	0.0	50.6	50.4	(0.3)
Recent Alluvial Terrace	-	-	-	10.3	10.3	0.0	10.3	10.3	0.0
Solifluction Deposit	0.5	0.5	0.0	2.8	2.8	0.0	3.3	3.3	0.0
Thaw Basin, Ice-rich Center	0.3	0.3	0.0	11.8	11.8	0.0	12.1	12.1	0.0
Thaw Basin, Ice-rich Margin	0.5	0.5	0.0	5.1	5.1	0.0	5.6	5.6	0.0
Thaw Basin, Ice-rich Undifferentiated	-	-	-	0.2	0.2	0.0	0.2	0.2	0.0
Grand Total	2011.4	2010.0	(0.1)	1358.8	1354.3	(0.3)	3370.2	3364.3	(0.2)

* The footprint of the CD5 road is not included

Table 3.16. Areal extent (ha) of aquatic geomorphic units and the percent change in the total area of each unit between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference			Test			Total		
Geomorphic Unit	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Brackish Deep Tapped Lake, Connected	8.5	8.5	0.0	42.2	42.5	0.6	50.6	50.9	0.5
Deep Isolated Riverine Lake	178.1	178.8	0.4	103.7	103.7	0.0	281.8	282.5	0.2
Deep Isolated Thaw Lake	80.9	81.1	0.2	7.9	7.9	0.0	88.8	89.0	0.2
Deep Tapped Riverine Lake, High-water Connection	16.4	16.4	0.0	17.7	17.7	0.0	34.0	34.0	0.0
Shallow Isolated Riverine Lake	6.2	6.2	0.0	2.1	2.1	0.0	8.3	8.3	0.0
Shallow Isolated Thaw Lake	1.7	1.7	0.0	6.3	6.3	(0.1)	8.0	8.0	0.0
Tidal River	279.1	279.6	0.2	137.4	141.6	3.1	416.4	421.2	1.1
Grand Total	570.8	572.2	0.2	317.2	321.7	1.4	888.0	893.9	0.7

Figure 3.24. Map of Surface Forms in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.

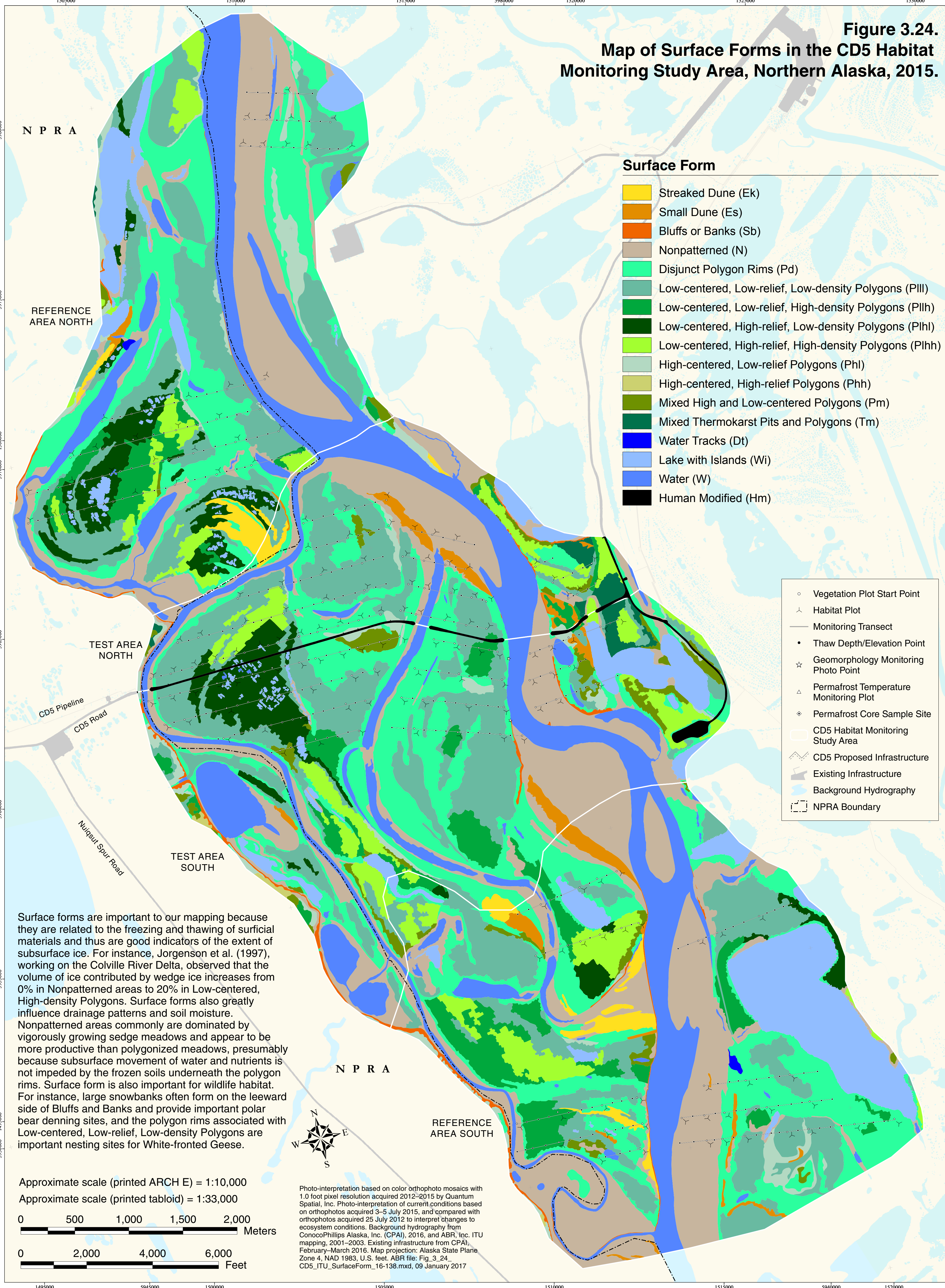
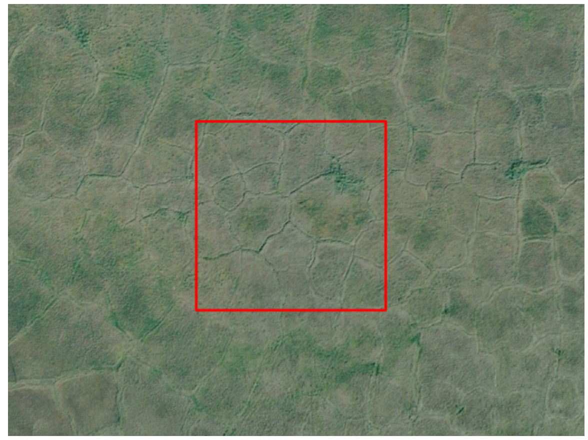


Table 3.17. Areal extent (ha) of surface forms and the percent change in the total area of each class between 2012 and 2015 by Reference and Test area, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference			Test*			Total*		
Surface Form	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Bluffs or Banks	13.0	13.8	5.9	14.6	13.6	(6.9)	27.7	27.4	(0.8)
Disjunct Polygon Rims	522.9	522.1	(0.2)	310.8	310.7	0.0	833.7	832.7	(0.1)
High-centered, High-relief Polygons	0.4	0.4	0.0	3.0	3.0	0.0	3.4	3.4	0.0
High-centered, Low-relief Polygons	55.1	54.8	(0.7)	33.0	33.0	(0.3)	88.2	87.7	(0.5)
Human Modified	-	-	-	7.9	7.9	(0.6)	7.9	7.9	(0.6)
Lake with Islands	240.9	241.7	0.3	75.1	75.1	0.0	315.9	316.8	0.3
Low-centered, High-relief, High-density Polygons	106.0	105.9	(0.1)	84.1	84.0	(0.1)	190.1	189.8	(0.1)
Low-centered, High-relief, Low-density Polygons	92.5	92.5	0.0	68.4	68.5	0.0	161.0	160.9	0.0
Low-centered, Low-relief, High-density Polygons	131.3	131.2	(0.1)	60.8	60.8	0.0	192.1	192.0	(0.1)
Low-centered, Low-relief, Low-density Polygons	458.0	457.6	(0.1)	366.4	366.4	0.0	824.4	824.0	(0.1)
Mixed High and Low-centered Polygons	19.6	19.5	(0.2)	45.6	45.1	(1.2)	65.2	64.6	(0.9)
Mixed Thermokarst Pits and Polygons	0.6	0.6	0.0	22.3	22.3	0.0	22.9	22.9	0.0
Nonpatterned	545.5	545.3	0.0	306.7	304.5	(0.7)	852.2	849.8	(0.3)
Small Dune	24.7	24.7	0.0	25.9	25.9	0.0	50.7	50.7	0.0
Streaked Dune	39.6	39.6	0.0	9.2	8.9	(3.6)	48.8	48.5	(0.7)
Water	329.9	330.5	0.2	242.1	246.6	1.9	572.1	577.1	0.9
Water Tracks	2.0	2.0	0.0	-	-	-	2.0	2.0	0.0
Grand Total	2582.2	2582.2	0.0	1676.0	1676.0	0.0	4258.2	4258.2	0.0

*The footprint of the CD5 road is not included

Disjunct Polygon Rims (Pd)

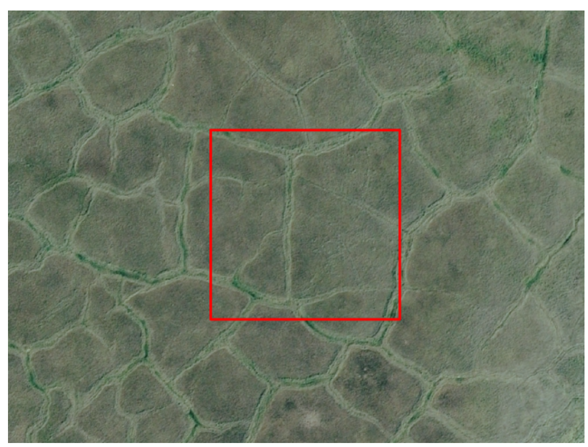


High-centered, Low-relief Polygons (Phl)

Low-centered, High-relief, High-density Polygons (Plhh)

Low-centered, High-relief, Low-density Polygons (Plhl)

Low-centered, Low-relief, High-density Polygons (Pllh)



Low-centered, Low-relief, Low-density Polygons (Plll)

Figure 3.25. Examples of common ice-wedge polygon surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. Red bounding box highlights each respective type and provides scale; bounding box represents approximate 328×328 ft (100×100 m) on the ground. Background imagery is a color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution.

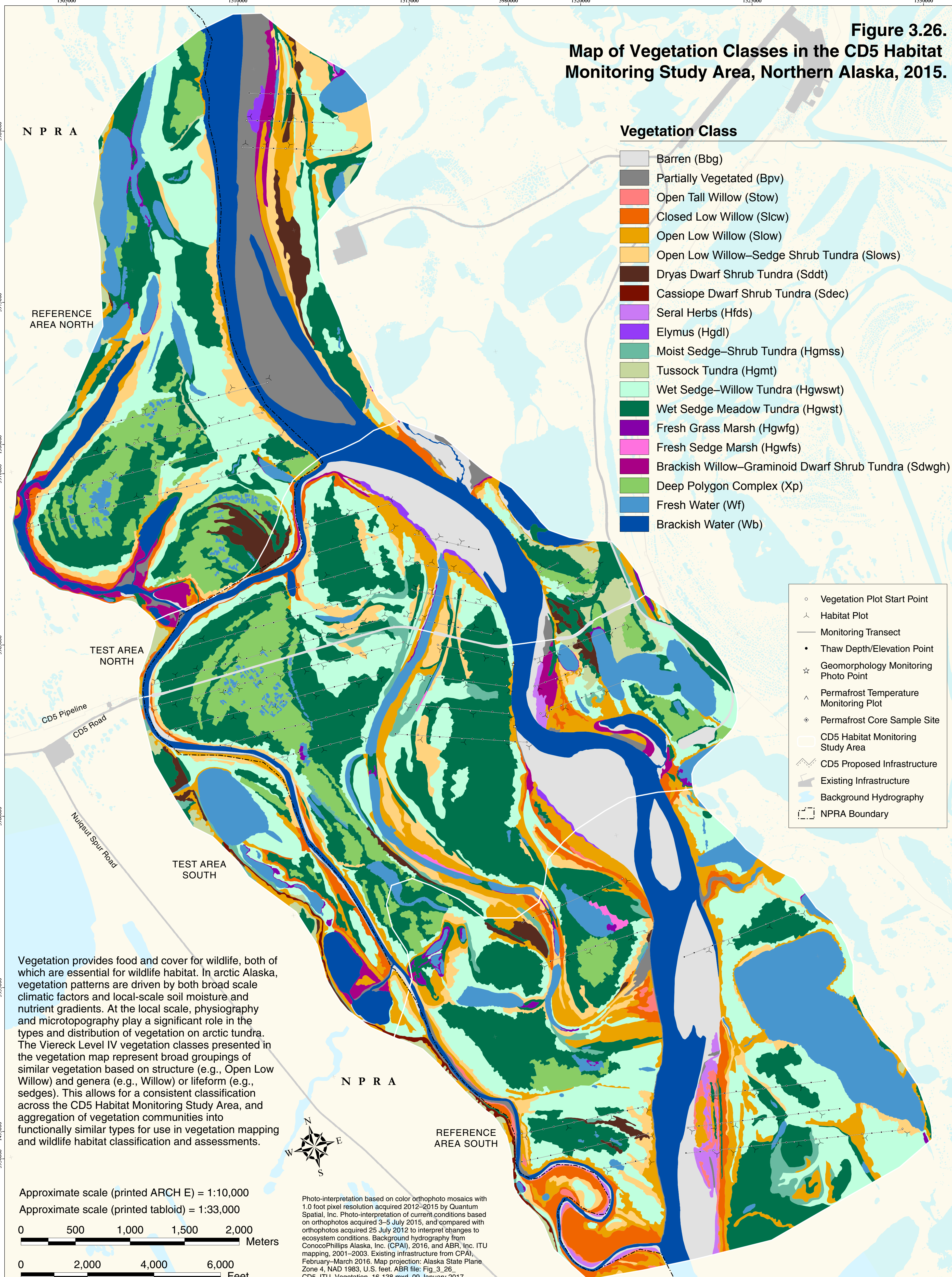


Figure 3.26. Map of Vegetation Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.

Vegetation provides food and cover for wildlife, both of which are essential for wildlife habitat. In arctic Alaska, vegetation patterns are driven by both broad scale climatic factors and local-scale soil moisture and nutrient gradients. At the local scale, physiography and microtopography play a significant role in the types and distribution of vegetation on arctic tundra. The Viereck Level IV vegetation classes presented in the vegetation map represent broad groupings of similar vegetation based on structure (e.g., Open Low Willow) and genera (e.g., Willow) or lifeform (e.g., sedges). This allows for a consistent classification across the CD5 Habitat Monitoring Study Area, and aggregation of vegetation communities into functionally similar types for use in vegetation mapping and wildlife habitat classification and assessments.

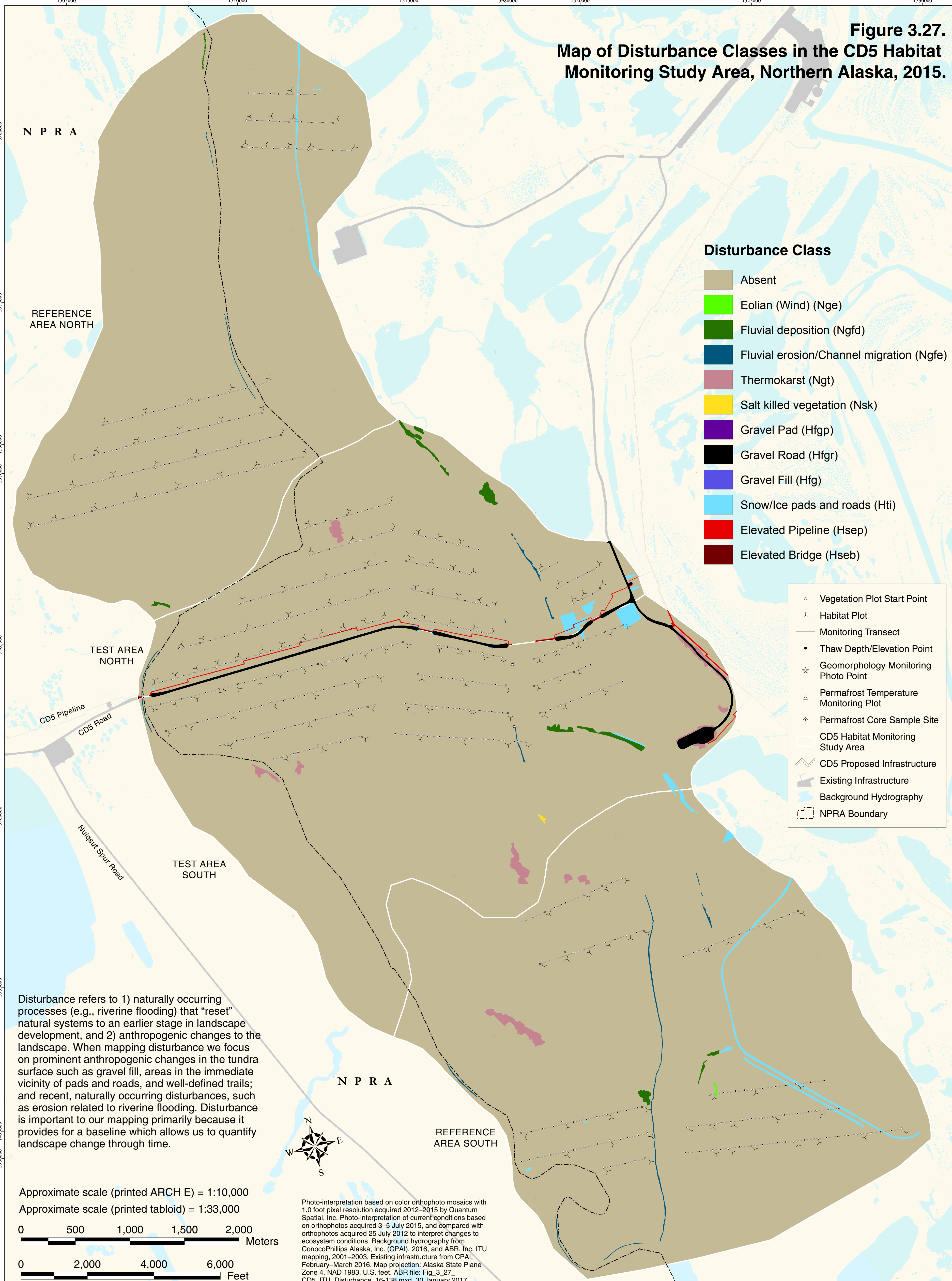


Figure 3.27. Map of Disturbance Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.

Table 3.18. Areal extent (ha) of vegetation classes and the percent change in the total area of each unit between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

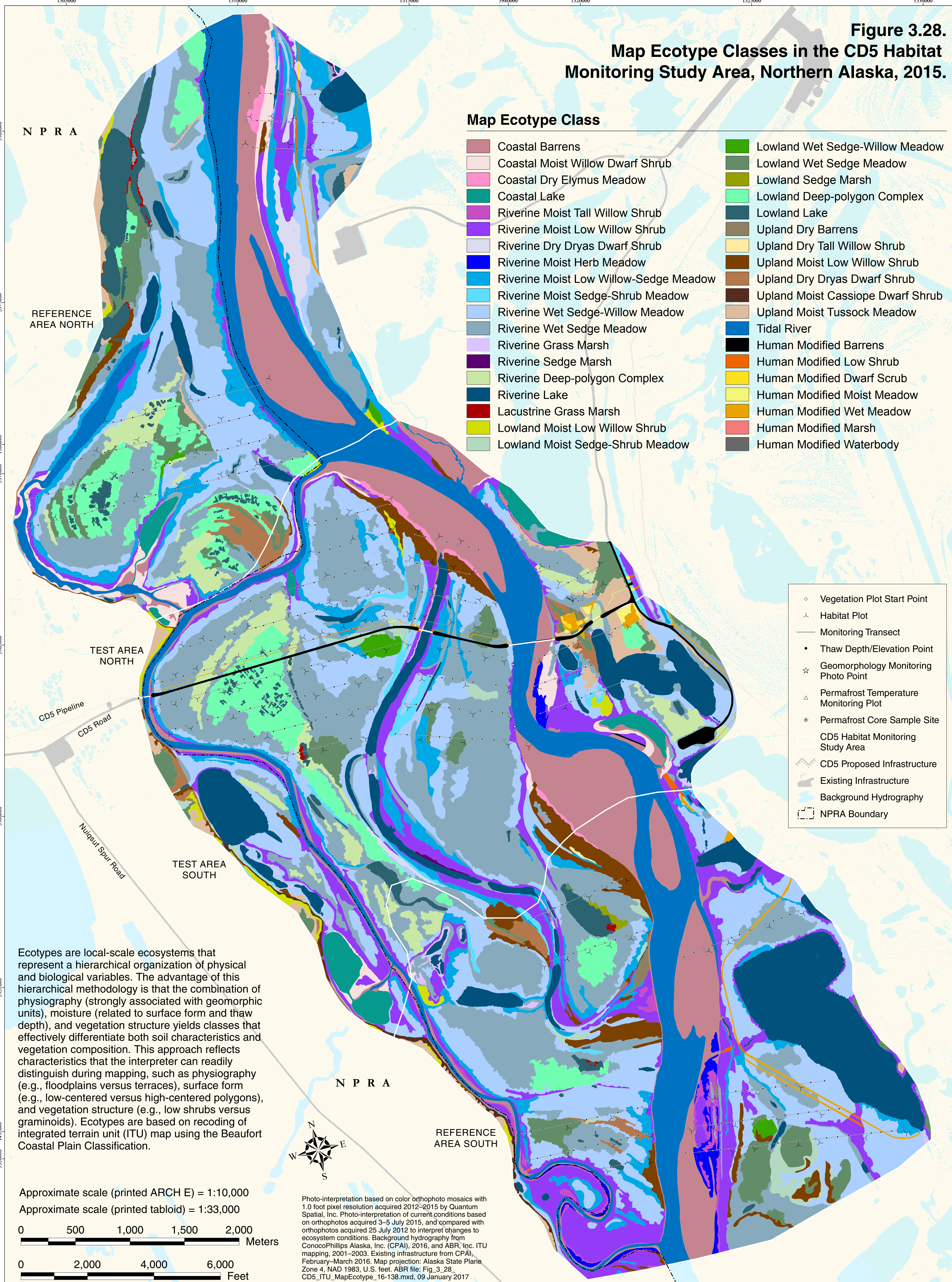
	Reference			Test*			Total*		
Vegetation Class	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Barren	113.0	113.0	0.0	146.8	147.7	0.6	259.8	260.7	0.3
Brackish Water	287.5	288.1	0.2	179.5	184.0	2.5	467.1	472.1	1.1
Cassiope Dwarf Shrub Tundra	5.6	5.6	0.0	3.3	3.3	0.0	8.9	8.9	0.0
Closed Low Willow	83.5	83.5	0.0	38.4	38.1	(0.9)	121.9	121.6	(0.3)
Deep Polygon Complex	144.5	144.4	(0.1)	125.9	125.9	0.0	270.4	270.3	0.0
Dryas Dwarf Shrub Tundra	45.0	45.0	0.0	19.0	19.0	0.0	64.0	64.0	0.0
Elymus	3.0	3.8	29.8	6.5	6.5	0.0	9.4	10.3	9.4
Fresh Grass Marsh	10.0	10.0	0.0	5.2	5.2	0.0	15.1	15.1	0.0
Fresh Sedge Marsh	2.6	2.6	0.0	1.4	1.4	0.0	4.0	4.0	0.0
Fresh Water	273.3	274.1	0.3	131.4	131.4	0.0	404.7	405.5	0.2
Halophytic Willow-Graminoid Dwarf Shrub Tundra	30.2	30.3	0.5	22.0	19.5	(11.1)	52.2	49.9	(4.4)
Moist Sedge-Shrub Tundra	23.4	23.4	0.0	30.1	30.0	(0.3)	53.5	53.5	(0.2)
Open Low Willow	197.6	196.9	(0.3)	141.5	138.0	(2.5)	339.1	334.9	(1.2)
Open Low Willow-Sedge Shrub Tundra	171.3	170.6	(0.4)	72.9	72.9	0.0	244.2	243.5	(0.3)
Open Tall Willow	15.5	15.5	0.0	-	-	-	15.5	15.5	0.0
Partially Vegetated	127.5	127.8	0.3	10.7	11.7	9.7	138.2	139.5	1.0
Seral Herbs	17.4	16.8	(3.3)	3.9	3.9	(1.5)	21.3	20.7	(3.0)
Tussock Tundra	17.4	17.3	(0.7)	37.6	37.6	0.0	55.1	55.0	(0.2)
Wet Sedge Meadow Tundra	520.5	520.5	0.0	441.8	441.9	0.0	962.3	962.5	0.0
Wet Sedge-Willow Tundra	493.4	492.8	(0.1)	258.1	258.0	0.0	751.5	750.8	(0.1)
Grand Total	2582.2	2582.2	0.0	1676.0	1676.0	0.0	4258.2	4258.2	0.0

*The footprint of the CD5 road is not included

Table 3.19. Classification and description of disturbance regime categories in the CD5 Habitat Monitoring Study Area, northern Alaska, 2016. Class descriptions modified from Jorgenson et al. (1997, 2003) and Roth et al. (2007). Disturbance regime classes that were identified in the field but not mapped are identified with an asterisk.

Disturbance regime	Description
Absent (A)	No disturbance within approximately a 5-year period.
Bridge (Hseb)	Bridges over distributaries of the Colville River Delta associated with the CD5 Road.
Elevated Pipeline (Hsep)	Pipelines which are all elevated to a minimum height of 5 ft (1.5 m) above ground level and supported by Vertical Support Members (VSMs).
Eolian Wind (Nge)*	Common along the western, downwind side of the Colville River, this category refers to the evolution of active dunes, or the remobilization of vegetated dunes due to eolian processes.
Fluvial (Ngf)*	Undifferentiated fluvial disturbance processes along active river channels and overbanks. Disturbances can be annual (e.g., flooding of active channels during peak flow in spring), but episodic events (e.g., large floods with low return periods) can affect much larger areas.
Fluvial Deposition (Ngfd)*	Fluvial disturbance associated with sediment deposition during and after flood events.
Fluvial Erosion/Channel Migration (Ngfe)	Fluvial disturbance associated with the evolution of distributary channels on the Colville River delta, such as cutbank erosion.
Gravel Pad (Hfgp)	Gravel and sandy gravel that has been placed as fill for pads. The gravel is obtained from deep riverbed deposits or gravelly coastal plain deposits.
Gravel Road (Hfgr)	Similar to above but the gravel here is placed as fill for roads.
Salt Killed Vegetation (Nsk)	Coastal areas where saltwater intrusions from storm surges have killed much of the original terrestrial vegetation and where salt-tolerant plants are actively colonizing.
Snow/Ice pads and Roads (Hti)	Disturbed vegetation due to previous placement of snow (from plowed gravel pads) or ice roads and pads on tundra.
Thermokarst (Ngt)	The processes associated with the thawing permafrost that leads to local or widespread collapse, subsidence, erosion and instability of the ground surface.

Figure 3.28. Map Ecotype Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.



Ecotypes are local-scale ecosystems that represent a hierarchical organization of physical and biological variables. The advantage of this hierarchical methodology is that the combination of physiography (strongly associated with geomorphic units), moisture (related to surface form and thaw depth), and vegetation structure yields classes that effectively differentiate both soil characteristics and vegetation composition. This approach reflects characteristics that the interpreter can readily distinguish during mapping, such as physiography (e.g., floodplains versus terraces), surface form (e.g., low-centered versus high-centered polygons), and vegetation structure (e.g., low shrubs versus graminoids). Ecotypes are based on recoding of integrated terrain unit (ITU) map using the Beaufort Coastal Plain Classification.

Approximate scale (printed ARCH E) = 1:10,000
Approximate scale (printed tabloid) = 1:33,000

0 500 1,000 1,500 2,000 Meters

0 2,000 4,000 6,000 Feet

Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc. Photo-interpretation of current conditions based on orthophotos acquired 3–5 July 2015, and compared with orthophotos acquired 25 July 2012 to interpret changes to ecosystem conditions. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, February–March 2016. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_28_CD5_ITU_MapEcotype_16-138.mxd, 09 January 2017

Table 3.20. Areal extent (ha) of disturbance classes and the percent change in the total area of each class between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

Disturbance Class	Reference			Test*			Total*		
	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Absent	2564.1	2557.2	(0.3)	1653.4	1637.3	(1.0)	4217.5	4194.5	(0.5)
Elevated Pipeline	-	-	-	1.2	4.1	236.4	1.2	4.1	236.4
Eolian (Wind)	0.2	0.2	0.0	-	-	-	0.2	0.2	0.0
Fluvial deposition	0.0	2.3	n/a	0.0	6.7	n/a	0.0	9.0	n/a
Fluvial erosion/Channel migration	3.4	4.2	22.8	2.6	1.6	(40.6)	6.0	5.7	(5.0)
Gravel Fill	-	-	-	0.0	<0.1	n/a	0.0	<0.1	n/a
Gravel Pad	-	-	-	3.9	4.1	4.6	3.9	4.1	4.6
Gravel Road	-	-	-	4.0	3.9	(1.1)	4.0	3.9	(1.1)
Salt killed vegetation	-	-	-	0.5	0.2	(53.1)	0.5	0.2	(53.1)
Snow/Ice pads and roads	9.2	13.0	41.5	0.6	8.5	1278.2	9.8	21.5	119.2
Thermokarst	5.2	5.2	0.0	9.8	9.7	(1.4)	15.1	14.9	(0.9)
Grand Total	2582.2	2582.2	0.0	1676.0	1676.0	0.0	4258.2	4258.2	0.0

*The footprint of the CD5 road is not included

Table 3.21. Areal extent (ha) of map ecotypes and the percent change in the total area of each ecotype between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference			Test*			Total*		
Map Ecotype	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Coastal Barrens	237.2	237.5	0.1	149.6	150.9	0.8	386.8	388.4	0.4
Coastal Dry Elymus Meadow	3.0	3.8	29.8	6.5	6.5	0.0	9.4	10.3	9.4
Coastal Lake	8.5	8.5	0.0	42.2	42.5	0.6	50.6	50.9	0.5
Coastal Moist Willow Dwarf Shrub	30.2	30.3	0.5	22.0	19.5	(11.1)	52.2	49.9	(4.4)
Human Modified Barrens	-	-	-	7.9	8.5	8.2	7.9	8.5	8.2
Human Modified Dwarf Scrub	0.2	0.3	18.4	-	0.7	n/a	0.2	0.9	328.6
Human Modified Low Shrub	1.8	2.6	46.0	0.6	1.6	167.2	2.4	4.2	77.1
Human Modified Marsh	-	-	-	-	0.0	n/a	0.0	<0.1	n/a
Human Modified Moist Meadow	-	-	-	-	2.5	n/a	0.0	2.5	n/a
Human Modified Waterbody	-	-	-	-	0.1	n/a	0.0	0.1	n/a
Human Modified Wet Meadow	7.2	10.1	41.1	1.2	7.1	488.8	8.4	17.2	105.5
Lacustrine Grass Marsh	2.9	2.9	0.0	0.5	0.5	0.0	3.4	3.4	0.0
Lowland Deep-polygon Complex	105.7	105.6	(0.1)	66.4	65.2	(1.8)	172.1	170.8	(0.8)
Lowland Lake	79.7	79.9	0.2	13.7	13.7	(0.3)	93.4	93.5	0.1
Lowland Moist Low Willow Shrub	6.1	6.0	(0.6)	11.8	11.8	(0.1)	17.9	17.9	(0.3)
Lowland Moist Sedge-Shrub Meadow	19.3	19.3	0.0	11.6	11.6	(0.5)	30.9	30.8	(0.2)
Lowland Sedge Marsh	2.2	2.2	0.0	-	-	-	2.2	2.2	0.0
Lowland Wet Sedge Meadow	83.4	83.4	0.0	49.0	46.2	(5.8)	132.4	129.6	(2.1)
Lowland Wet Sedge-Willow Meadow	5.7	5.7	0.0	6.5	6.5	0.0	12.2	12.2	0.0
Riverine Deep-polygon Complex	38.8	38.8	0.0	59.4	59.1	(0.4)	98.2	98.0	(0.2)
Riverine Dry Dryas Dwarf Shrub	18.8	18.8	0.0	2.8	2.8	0.0	21.6	21.6	0.0
Riverine Grass Marsh	7.1	7.1	0.0	4.7	4.7	(0.3)	11.8	11.8	(0.1)
Riverine Lake	193.6	194.2	0.4	117.7	117.7	0.0	311.2	311.9	0.2
Riverine Moist Herb Meadow	17.4	16.8	(3.3)	3.9	3.9	(1.5)	21.3	20.7	(3.0)
Riverine Moist Low Willow Shrub	212.8	211.5	(0.6)	131.2	126.9	(3.3)	344.0	338.4	(1.6)
Riverine Moist Low Willow-Sedge Meadow	169.9	169.1	(0.5)	72.9	72.6	(0.4)	242.8	241.7	(0.4)

Table 3.21. Continued.

Map Ecotype	Reference			Test*			Total*		
	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Riverine Moist Sedge-Shrub Meadow	4.2	4.2	0.0	18.5	18.2	(1.7)	22.7	22.3	(1.4)
Riverine Moist Tall Willow Shrub	14.9	14.9	0.0	-	-	-	14.9	14.9	0.0
Riverine Sedge Marsh	0.3	0.3	0.0	1.4	1.4	0.0	1.8	1.8	0.0
Riverine Wet Sedge Meadow	434.9	433.9	(0.2)	391.7	390.7	(0.3)	826.7	824.6	(0.3)
Riverine Wet Sedge-Willow Meadow	482.7	480.2	(0.5)	251.4	251.0	(0.2)	734.1	731.2	(0.4)
Tidal River	279.1	279.6	0.2	137.4	141.6	3.1	416.4	421.2	1.1
Upland Dry Barrens	3.4	3.4	0.0	-	-	-	3.4	3.4	0.0
Upland Dry Dryas Dwarf Shrub	26.0	25.9	(0.2)	16.2	15.5	(4.2)	42.2	41.4	(1.7)
Upland Dry Tall Willow Shrub	0.5	0.5	0.0	-	-	-	0.5	0.5	0.0
Upland Moist Cassiope Dwarf Shrub	5.6	5.6	0.0	3.3	3.3	0.0	8.9	8.9	0.0
Upland Moist Low Willow Shrub	61.9	61.8	0.0	36.3	36.0	(0.8)	98.1	97.8	(0.3)
Upland Moist Tussock Meadow	17.4	17.3	(0.7)	37.6	35.4	(6.0)	55.1	52.7	(4.3)
Grand Total	2582.2	2582.2	0.0	1676.0	1676.0	0.0	4258.2	4258.2	0.0

*The footprint of the CD5 road is not included

Wildlife Habitat

Twenty-four wildlife-habitat classes are represented in the updated mapping for the CD5 Study Area (Figure 3.29, Table 3.22); for detailed descriptions of the wildlife habitats, see Wells et al. (2014). As in the baseline mapping, the most extensive habitat type is Patterned Wet Meadow, with an areal cover of 25.9%. Other widespread terrestrial habitat classes remain unchanged from 2012, including Moist Low Shrub (16.3% areal cover), Nonpatterned Wet Meadow (13.9%), Barrens (9.2%), and Deep Polygon Complex (6.3%). The aquatic habitat classes River or Stream (9.9% areal cover) and Deep Open Water with Islands or Polygonized Margins (6.8%) are also common. All other wildlife habitat classes had less than 2% areal cover.

3.4.2.D Landscape Change Assessment

We evaluated natural and anthropogenic landscape change across the CD5 Study Area between 2012 and 2015 by updating the baseline ITU mapping using imagery acquired in July 2015. The map update effort revealed little change across most of the CD5 Study Area; however, landscape disturbances were locally common along the banks of the Niġliq Channel and in association with newly constructed CD5 infrastructure (Figure 3.30). Overall, only 0.8% (35.6 ha) of the CD5 Study Area was affected by landscape-change processes that required updates to map unit boundaries, or to ITU codes assigned to map units (Table 3.23).

Natural fluvial erosion and fluvial sedimentation along the Niġliq Channel accounted for most of the observed changes (Figure 3.31). Erosion was most apparent along sections of the Niġliq Channel, where cutbank erosion claimed several meters of riverbank between 2012 and 2015. Sedimentation and resulting mortality of vegetation were locally common on river overbanks near the Niġliq Channel, and in the basin of Nanuk Lake. We also observed recent thermokarst along the shorelines of thaw lakes in the southwest and outermost northeast portions of the CD5 Study Area. One landscape change mechanism—succession—was evident in areas where vegetation had colonized recent Delta Active Channel Deposits.

Human activities, including construction of CD5 infrastructure and winter ice roads, created linear changes primarily in the central Test Area. Changes were most pronounced within the footprint of the CD5 road, which is now gravel fill. Vegetation changes outside the road footprint (based on aerial photo signatures) included partial mortality and/or delayed green-up associated with corridors regularly used for ice road construction in Test Area South and Reference Area South. Construction of elevated structures (i.e., CD5 pipeline and bridges) generally left underlying vegetation and waterbodies intact.

Geomorphic Units

Changes to terrestrial and aquatic geomorphic units were rare in the CD5 Study Area between 2012 and 2015, and no class changed in extent by more than 5% within the Test and Reference Areas. On a percent basis, the largest change in terrestrial geomorphic units across the CD5 Study Area was a 1.8% increase in the extent of Gravel Fill (from 7.9 to 8.0 ha) (Table 3.24). All of this change occurred within the Test Area and is associated with the CD5 road; Gravel Fill associated with the CD5 road is being assessed separately for monitoring purposes (see below). Within the Test Area, the most substantial change to terrestrial geomorphic units on a percent basis was a 3.1% decline in the extent of Delta Inactive Channel Deposits (from 32.0 to 31.0 ha). All of this change occurred along the Niġliq Channel in the South Test Area, where cutbank erosion affected an approximately 1 km long section of the shoreline west of CD4. No terrestrial geomorphic units changed in area by more than 1% within the Reference Area. Among aquatic geomorphic units, the most extensive change observed across the CD5 Study Area was a 1.1% increase in the extent of Tidal River (Table 3.16). Most of this increase occurred due to cutbank erosion along sections of the Niġliq Channel in the central and northern parts of the CD5 Study Area.

Surface Form

Similar to geomorphic unit, changes to surface forms were rare between 2012 and 2015 and no class changed in extent by more than 5% across the CD5 Study Area (Table 3.17). However, compensatory increases and decreases in the extent

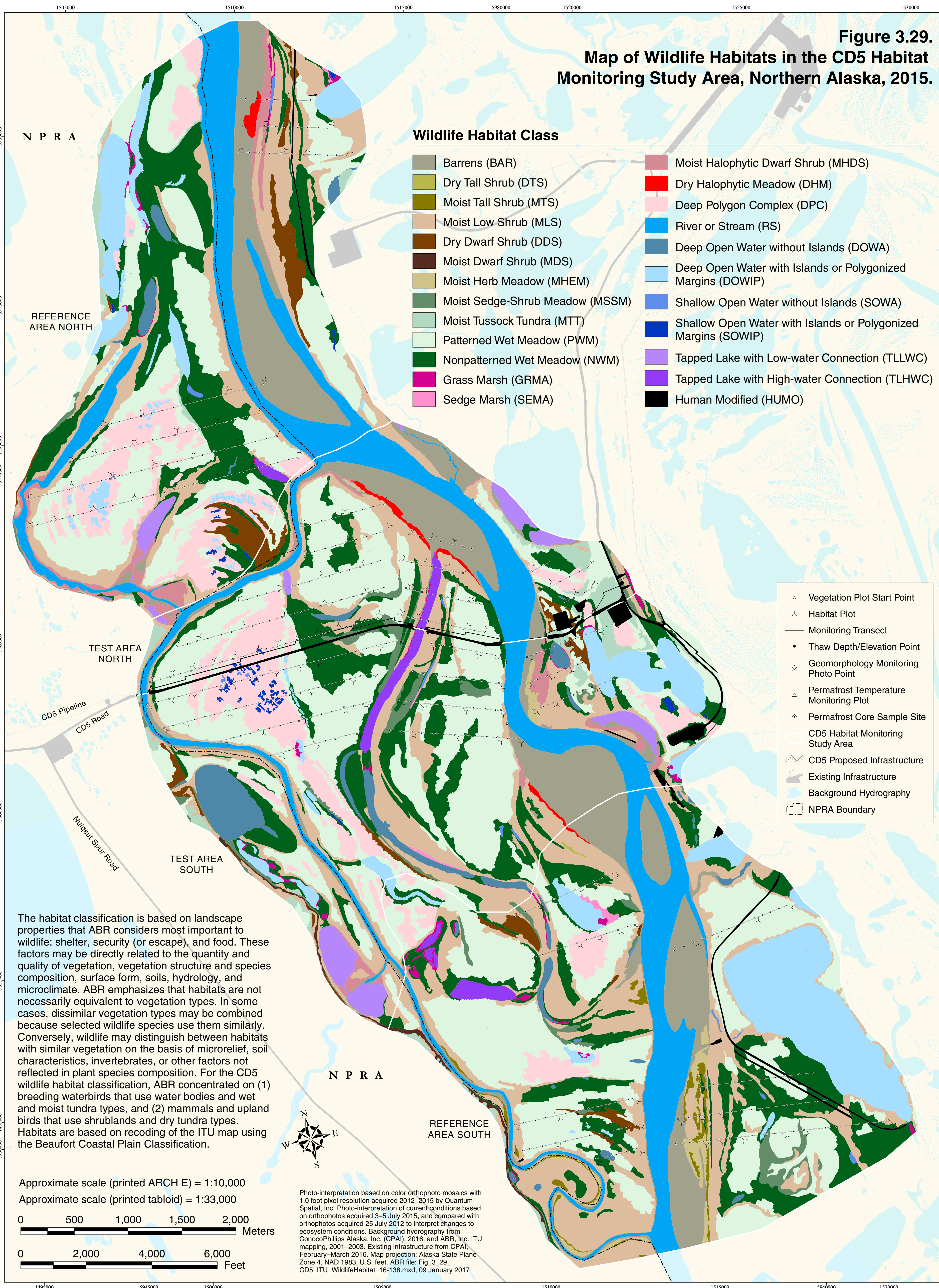
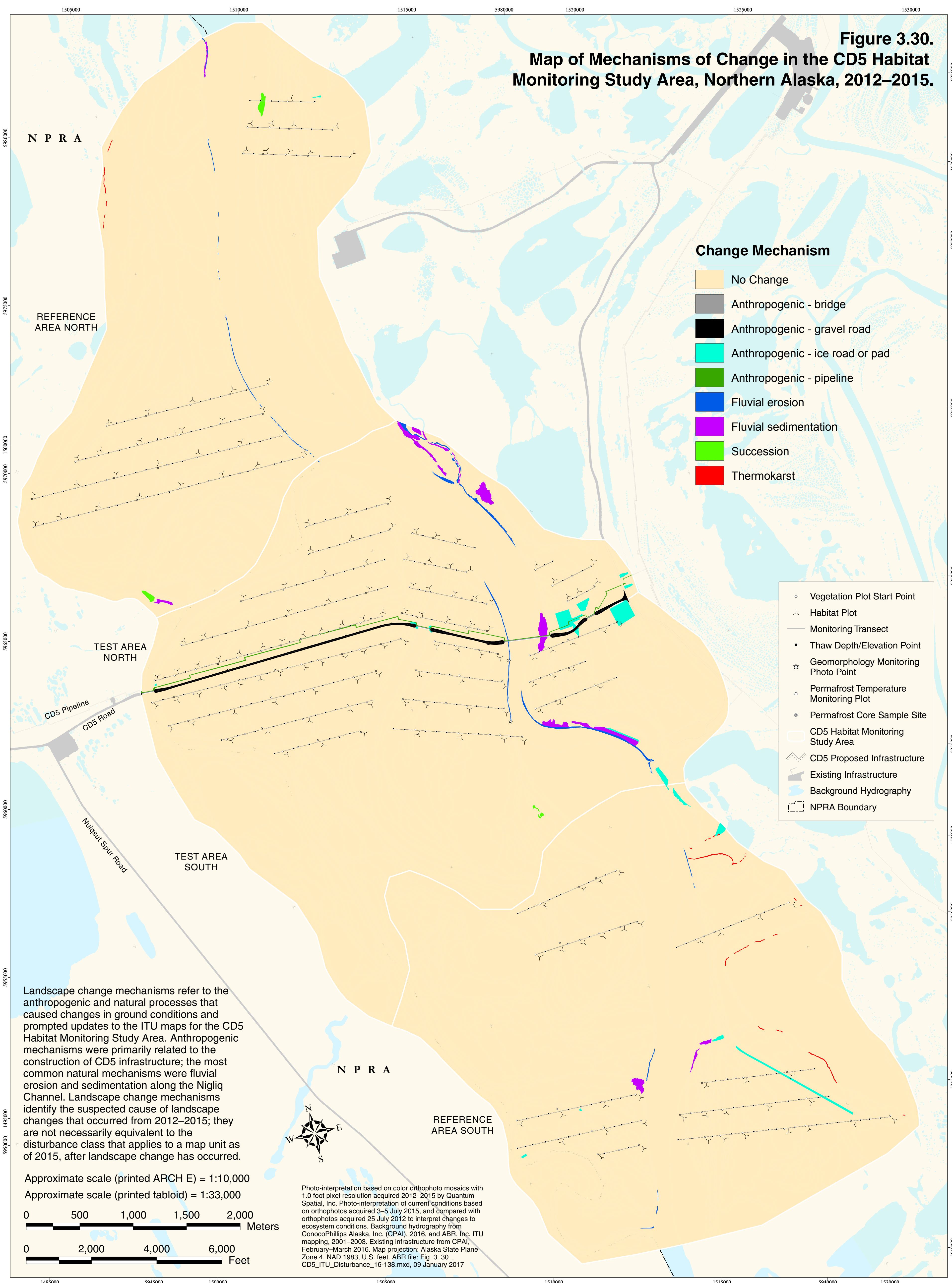


Figure 3.29.
Map of Wildlife Habitats in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015.
Wildlife Habitat Class
Barrens (BAR)
Dry Tall Shrub (DTS)
Moist Tall Shrub (MTS)
Moist Low Shrub (MLS)
Dry Dwarf Shrub (DDS)
Moist Dwarf Shrub (MDS)
Moist Herb Meadow (MHEM)
Moist Sedge-Shrub Meadow (MSSM)
Moist Tussock Tundra (MTT)
Patterned Wet Meadow (PWM)
Nonpatterned Wet Meadow (NWM)
Grass Marsh (GRMA)
Sedge Marsh (SEMA)
Moist Halophytic Dwarf Shrub (MHDS)
Dry Halophytic Meadow (DHM)
Deep Polygon Complex (DPC)
River or Stream (RS)
Deep Open Water without Islands (DOWA)
Deep Open Water with Islands or Polygonized Margins (DOWIP)
Shallow Open Water without Islands (SOWA)
Shallow Open Water with Islands or Polygonized Margins (SOWIP)
Tapped Lake with Low-water Connection (TLLWC)
Tapped Lake with High-water Connection (TLHWC)
Human Modified (HUMO)
N P R A
REFERENCE AREA NORTH
TEST AREA NORTH
TEST AREA SOUTH
REFERENCE AREA SOUTH
CD5 Pipeline
CD5 Road
Nuiqsut Spur Road
Vegetation Plot Start Point
Habitat Plot
Monitoring Transect
Thaw Depth/Elevation Point
Geomorphology Monitoring Photo Point
Permafrost Temperature Monitoring Plot
Permafrost Core Sample Site
CD5 Habitat Monitoring Study Area
CD5 Proposed Infrastructure
Existing Infrastructure
Background Hydrography
NPRA Boundary
The habitat classification is based on landscape properties that ABR considers most important to wildlife: shelter, security (or escape), and food. These factors may be directly related to the quantity and quality of vegetation, vegetation structure and species composition, surface form, soils, hydrology, and microclimate. ABR emphasizes that habitats are not necessarily equivalent to vegetation types. In some cases, dissimilar vegetation types may be combined because selected wildlife species use them similarly. Conversely, wildlife may distinguish between habitats with similar vegetation on the basis of microrelief, soil characteristics, invertebrates, or other factors not reflected in plant species composition. For the CD5 wildlife habitat classification, ABR concentrated on (1) breeding waterbirds that use water bodies and wet and moist tundra types, and (2) mammals and upland birds that use shrublands and dry tundra types. Habitats are based on recoding of the ITU map using the Beaufort Coastal Plain Classification.
Approximate scale (printed ARCH E) = 1:10,000
Approximate scale (printed tabloid) = 1:33,000
0 500 1,000 1,500 2,000 Meters
0 2,000 4,000 6,000 Feet
N E S W
Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc. Photo-interpretation of current conditions based on orthophotos acquired 3–5 July 2015, and compared with orthophotos acquired 25 July 2012 to interpret changes to ecosystem conditions. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, February–March 2016. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_29_CD5_ITU_WildlifeHabitat_16-138.mxd, 09 January 2017

Figure 3.30. Map of Mechanisms of Change in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2012–2015.



Landscape change mechanisms refer to the anthropogenic and natural processes that caused changes in ground conditions and prompted updates to the ITU maps for the CD5 Habitat Monitoring Study Area. Anthropogenic mechanisms were primarily related to the construction of CD5 infrastructure; the most common natural mechanisms were fluvial erosion and sedimentation along the Nigliq Channel. Landscape change mechanisms identify the suspected cause of landscape changes that occurred from 2012–2015; they are not necessarily equivalent to the disturbance class that applies to a map unit as of 2015, after landscape change has occurred.

Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc. Photo-interpretation of current conditions based on orthophotos acquired 3–5 July 2015, and compared with orthophotos acquired 25 July 2012 to interpret changes to ecosystem conditions. Background hydrography from ConocoPhillips Alaska, Inc. (CPAI), 2016, and ABR, Inc. ITU mapping, 2001–2003. Existing infrastructure from CPAI, February–March 2016. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_30_CD5_ITU_Disturbance_16-138.mxd, 09 January 2017

Table 3.22. Areal extent (ha) of wildlife habitats and the percent change in the total area of each habitat between 2012 and 2015 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference			Test*			Total*		
Habitat	2012	2015	Δ(%)	2012	2015	Δ(%)	2012	2015	Δ(%)
Barrens	240.5	240.8	0.1	149.6	150.9	0.8	390.1	391.7	0.4
Deep Open Water with Islands or Polygonized Margins	232.9	233.7	0.4	56.4	56.4	0.0	289.3	290.1	0.3
Deep Open Water without Islands	21.8	21.8	0.0	52.1	52.1	0.0	73.9	73.9	0.0
Deep Polygon Complex	144.5	144.4	(0.1)	125.8	124.3	(1.2)	270.3	268.7	(0.6)
Dry Dwarf Shrub	44.8	44.7	(0.1)	19.0	18.3	(3.6)	63.8	63.1	(1.1)
Dry Halophytic Meadow	3.0	3.8	29.8	6.5	6.5	0.0	9.4	10.3	9.4
Dry Tall Shrub	0.5	0.5	0.0	-	-	-	0.5	0.5	0.0
Grass Marsh	10.0	10.0	0.0	5.2	5.2	(0.3)	15.1	15.1	(0.1)
Human Modified	9.2	13.0	41.5	9.7	20.6	111.8	18.9	33.6	77.7
Moist Dwarf Shrub	5.6	5.6	0.0	3.3	3.3	0.0	8.9	8.9	0.0
Moist Halophytic Dwarf Shrub	30.2	30.3	0.5	22.0	19.5	(11.1)	52.2	49.9	(4.4)
Moist Herb Meadow	17.4	16.8	(3.3)	3.9	3.9	(1.5)	21.3	20.7	(3.0)
Moist Low Shrub	450.6	448.4	(0.5)	252.2	247.3	(1.9)	702.8	695.8	(1.0)
Moist Sedge-Shrub Meadow	23.4	23.4	0.0	30.1	29.7	(1.2)	53.5	53.2	(0.7)
Moist Tall Shrub	14.9	14.9	0.0	-	-	-	14.9	14.9	0.0
Moist Tussock Tundra	17.4	17.3	(0.7)	37.6	35.4	(6.0)	55.1	52.7	(4.3)
Nonpatterned Wet Meadow	375.9	374.2	(0.5)	219.8	219.1	(0.3)	595.7	593.3	(0.4)
Patterned Wet Meadow	630.9	629.0	(0.3)	478.9	475.2	(0.8)	1109.8	1104.2	(0.5)
River or Stream	279.1	279.6	0.2	137.4	141.6	3.1	416.4	421.2	1.1
Sedge Marsh	2.6	2.6	0.0	1.4	1.4	0.0	4.0	4.0	0.0
Shallow Open Water with Islands or Polygonized Margins	1.9	1.9	0.0	5.4	5.3	(0.7)	7.2	7.2	(0.6)
Shallow Open Water without Islands	3.2	3.2	0.0	1.7	1.7	0.0	4.9	4.9	0.0
Tapped Lake with High-water Connection	13.5	13.5	0.0	15.8	15.8	(0.2)	29.3	29.3	(0.1)
Tapped Lake with Low-water Connection	8.5	8.5	0.0	42.2	42.5	0.6	50.6	50.9	0.5
Grand Total	2582.2	2582.2	0.0	1676.0	1676.0	0.0	4258.2	4258.2	0.0

*The footprint of the CD5 road is not included

Table 3.23. Areal extent (ha) of landscape change mechanisms that affected Reference and Test Areas between 2012 and 2015, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference		Test*		Total*	
Mechanism	Area (ha)	% of total	Area (ha)	% of total	Area (ha)	% of total
Absent	2572.4	99.6	1650.2	98.5	4222.6	99.2
Anthropogenic - gravel road	-	-	<0.1	<0.1	<0.1	<0.1
Anthropogenic - ice road or pad	3.8	0.1	8.3	0.5	12.1	0.3
Anthropogenic - pipeline	-	-	3.0	0.2	3.0	0.1
Fluvial erosion	1.4	0.1	5.0	0.3	6.5	0.2
Fluvial sedimentation	2.3	0.1	9.3	0.6	11.6	0.3
Succession	1.4	0.1	0.2	<0.1	1.7	<0.1
Thermokarst	0.8	<0.1	-	-	0.8	<0.1
Grand Total	2582.2	100.0	1676.0	100.0	4258.2	100.0

*The footprint of the CD5 road is not included

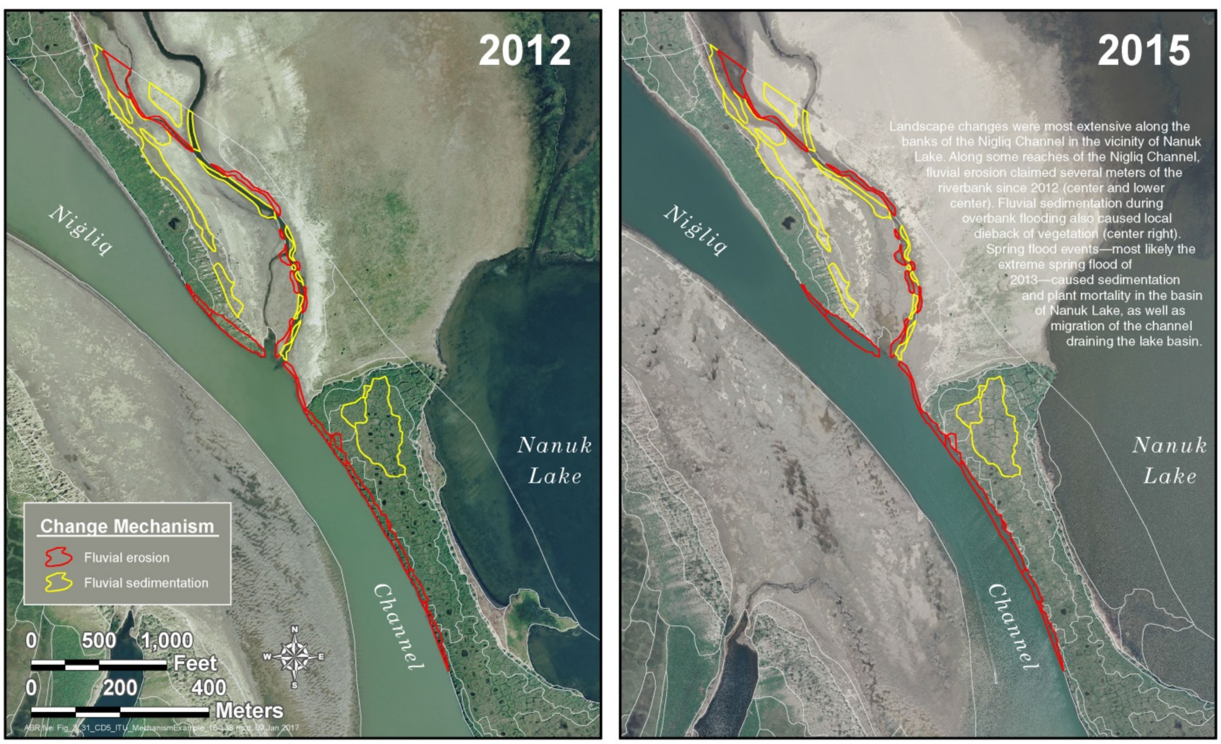


Figure 3.31. Example of landscape change resulting from fluvial processes along Niġliq Channel near Nanuk Lake, CD5 Habitat Monitoring Study Area, northern Alaska, 2012 and 2015.

Table 3.24. Areal extent (ha) of anthropogenic disturbance classes in 2012 and 2015 including the CD5 road for Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska.

	Reference		Test		Total	
Disturbance class	2012	2015	2012	2015	2012	2015
Elevated Pipeline	-	-	1.2	4.1	1.2	4.1
Gravel Fill	-	-		<0.1	0.0	<0.1
Gravel Pad	-	-	3.9	4.1	3.9	4.1
Gravel Road	-	-	4.0	13.0	4.0	13.0
Snow/Ice pads and roads	9.2	13.0	0.6	8.5	9.8	21.5
Grand Total	9.2	13.0	9.7	20.6	18.9	33.6

of one surface form—Bluffs or Banks—occurred within the Reference and Test Areas, respectively. The extent of Bluffs or Banks decreased by 6.9% in the Test Area (from 14.6 to 13.6 ha), but increased 5.9% in the Reference Area (from 13.0 to 13.8 ha). All of these changes were associated with cutbank erosion along the Niġliq Channel. Along some sections, river erosion has created very steep banks that lack a mappable fringe of Bluffs and Banks, while in others, bank collapse has widened the fringe of Bluffs and Banks. These contrasting effects of river channel migration and erosion within the Test and Reference Areas do not appear to be related to infrastructure and are consistent with riverine processes seen along stream reaches elsewhere on the CRD. The only other changes resulting in a >1% magnitude change in surface form was a 3.6% decrease in the extent of Streaked Dune in the Test Area, again due to cutbank erosion; and a 1.9% increase in Water in the Test Area, resulting from river channel migration and thermokarst along lakeshores.

Vegetation

Changes in vegetation class were more prevalent than changes in geomorphic unit and surface form in the CD5 Study Area (Table 3.18). Across the CD5 Study Area, we observed changes in excess of +/-5% for one vegetation class—*Elymus* (+9.4%). This vegetation class is among the least extensive classes on the CRD, where it occurs on early successional sites such as young fluvial and eolian deposits. All of the observed change occurred in one landscape patch in the Reference Area, where the density of vegetation has increased since 2012; *Elymus* map units remained unchanged in the Test Area. Within the Test Area, we observed changes in excess of 5% for two vegetation classes: Halophytic Willow-Graminoid Dwarf Shrub Tundra (-11.1%, from 22.0 to 19.5 ha) and Partially Vegetated (+9.7%, from 10.7 to 11.7 ha). Halophytic Willow-Graminoid Dwarf Shrub Tundra is a rare vegetation class in the CD5 Study Area (1.1% areal cover) and the changes documented pertain to a single landscape patch near the Niġliq Channel bridge that underwent heavy sedimentation. This area is now mapped as Partially Vegetated, and thus accounts for most of the increase in Partially Vegetated observed in the Test Area.

Disturbance

Only about 1.5% of the CD5 Study Area was assigned to a disturbance class in the updated mapping, indicating that most of the CD5 Study Area has not experienced recent natural or anthropogenic disturbance. Disturbance is defined as any natural or anthropogenic process or activity that results in a change in site characteristics and/or vegetation composition. Although the extent of several disturbance classes increased markedly on a percent basis, these increases involved small magnitude changes to classes with low areal extents. Across the CD5 Study Area, the area of Elevated Pipeline increased 236% (from 1.2 to 4.1 ha) and Snow/Ice Pads and Roads increased 119% (from 9.8 to 21.5 ha) (Table 3.20). The increase in Elevated Pipeline was entirely within the Test Area due to the construction of the CD5 pipeline. Increases in the extent of the Snow/Ice Pads and Roads disturbance class were most pronounced in the Test Areas, adjacent to CD5 infrastructure (+1,278%; from 0.6 to 8.5 ha); however, there were also some increases in ice road disturbance in the Reference Areas (+41.5%; from 9.2 to 13.0 ha). Both of the anthropogenic disturbance classes summarized above generally resulted in partial mortality and/or delayed green-up of vegetation, rather than transitions from one vegetation class to another. Changes in the extent of natural disturbance classes included a 53.1% decrease in the rare class, Salt-killed Vegetation (from 0.5 to 0.2 ha); this occurred entirely in a single landscape patch in the Test Area, where there has been notable recovery of vegetation. Fluvial erosion/Channel migration is the most extensive natural disturbance class overall (5.7 ha in the updated map); its overall extent declined 5% across the CD5 Study Area. Most of the decline occurred in the Test Area (-40.6%; from 2.6 to 1.6 ha) but this was partially offset by an increase in extent in the Reference Area (+22.8%; from 3.4 to 4.2 ha).

Map Ecotype

Of the 38 ecotypes mapped across the CD5 Study Area, 5 underwent changes in extent that exceeded +/-5%: Coastal Dry Elymus Meadow (+9.4%), Human Modified Barrens (+8.2%), Human Modified Dwarf Scrub (+329%), Human Modified Low Shrub (+77.1%), and Human Modified Wet Meadow (+106%) (Table 3.21). An additional 3 human-modified classes occur in the updated map that were not present in the 2012 baseline map, as described in Section 3.4.2.C. Increases in Coastal Dry Elymus Meadow occurred entirely due to successional processes in the Reference Area, as described for the *Elymus* vegetation class, above. The increase in Human Modified Barrens occurred entirely in the Test Area and was related to road improvements along the CD4 road (from 7.9 ha in 2012 to 8.5 ha in 2015). Human Modified Dwarf Scrub, Human Modified Low Shrub, and Human Modified Wet Meadow are rare classes (2015 areas = 0.9 ha, 4.2 ha, and 17.2 ha respectively) and the large percent increases in the areal extent of these ecotypes pertain to localized changes associated with bridge and pipeline construction in previously undisturbed ecotypes.

Wildlife Habitat

Of the 24 wildlife habitats mapped in the CD5 Study Area, only 2 experienced changes in extent that exceeded +/-5%. Dry Halophytic Meadow increased 9.4% (9.4 to 10.3 ha) and Human Modified increased 77.7% (18.9 to 33.6 ha) (Table 3.22). All of the increase in Dry Halophytic Meadow was observed in the Reference Area, where it was associated with successional processes on young fluvial deposits. Most of the increase in Human Modified was observed in the Test Area (112% increase in areal cover) and was associated with ice roads and pads and linear sections of tundra that lie beneath the CD5 pipeline and bridges. Human Modified also increased however, by 41.5% in the Reference Area. Within the Test Area, Moist Halophytic Dwarf Scrub decreased in extent by 11.1% (22.0 to 19.5 ha) due to fluvial sedimentation in one landscape patch near the Niġliq Channel bridge (see Vegetation section, above). Moist Tussock Tundra also decreased in extent by 6.0% in the Test Area (37.6 to 35.4 ha) due to construction of CD5 infrastructure; vegetation remains intact in most of these areas, but is now mapped as Human Modified.

CD5 Infrastructure

The CD5 infrastructure was not present when the ITU mapping was completed for the 2013 CD5 Habitat Monitoring Report (Wells et al. 2014). Hence we report on it here to acknowledge that this permitted development occurred and is now part of the ITU mapping. For purposes of long-term monitoring, the direct footprint of the CD5 road (9.1 ha) was excluded from calculations of the percent change in area of ITU, map ecotype, and wildlife habitat classes within the Reference and Test Areas. Human activities were mainly evident in the Test Area, but disturbances were also evident in the Reference Area in association with ice roads and ice pads. The total extent of anthropogenic disturbance classes, including the CD5 road, is presented in Table 3.24.

Assessment of CD5 Infrastructure Indirect Effects

This report summarizes results from the first monitoring effort following baseline studies conducted in 2013 to support the CD5 Habitat Monitoring Study and the construction of CD5 infrastructure. While many ecosystems of the CRD are unlikely to undergo significant natural changes since 2012, some landscape positions are highly dynamic (e.g., active dunes) and other areas have been altered by the construction of CD5 infrastructure. Objective criteria have been established by which to identify potential impacts of the infrastructure by tracking the areal extent of ITU classes, map ecotypes, and wildlife habitats within Test and Reference Areas. During each 3-year monitoring interval, any map class that changes in area by more than +/- 5% is flagged for review of differential changes between the Test and Reference Areas. Any such class for which the percent change in area between Areas differs by a magnitude of more than 5% is then subject to review to determine whether the difference might be due to direct or indirect effects of CD5 infrastructure. These criteria are conservative, in that a 5% change in the extent of rare map classes can involve relatively small magnitude changes that could be expected due to natural processes and spatial variability, particularly in deltaic landscapes which are subject to a wide range of processes affecting landscape evolution.

Comparison of the baseline and updated ecosystem map products indicate that changes to geomorphic units and surface forms were limited, and no changes in the extent of these map classes exceeded the 5% threshold across the CD5 Study Area. This is not surprising, because geomorphic units and surface forms are mainly related to subsurface properties (e.g., fluvial sediments and ground-ice) that generally require intense physical disturbance to initiate a change from one class to another. Such physical disturbance is frequent in certain landscape positions, particularly along riverbanks; the exceptional spring floods of 2013 and 2015 likely promoted more riverbank erosion than would be expected in a typical 3-year monitoring period. The level of disturbance required to affect vegetation is generally lower, and we observed areal changes in excess of 5% for one vegetation class, *Elymus*. This class is linked to highly dynamic, poorly stabilized landforms such as young fluvial deposits and active dunes. All of the observed changes occurred in one landscape patch in the Reference Area that transitioned from Partially Vegetated to *Elymus*; the lack of change in the Test Area is probably the result of natural variation and is not readily explained by the presence of CD5 infrastructure.

Several disturbance classes changed in extent by >5% across the CD5 Study Area, most of which were related to anthropogenic changes along the CD5 road. Two natural disturbance classes changed in extent by >5%: Salt-killed Vegetation and Fluvial Erosion/Channel Migration. Salt-killed Vegetation is limited to one landscape patch in the Reference Area North, where we observed substantial recovery of vegetation. There was no Salt-killed Vegetation mapped in the Test Area in 2012 or 2015 and the observed changes appear to represent natural successional processes rather than infrastructure effects. Fluvial Erosion/Channel Migration changed in extent by 5%, and there were large differences in the magnitude of change between Test and Reference Areas. However, such variation is to be expected in dynamic fluvial environments as described above and the changes observed in proximity to CD5 infrastructure (e.g., cutbank erosion of several meters of riverbank) are comparable to changes seen elsewhere. There were also changes to five map ecotypes and two wildlife habitats; however, all of these changes were linked to the same landscape patches and dynamic processes described above for human-modified vegetation classes and the *Elymus* vegetation class.

In summary, the first ecosystem map update effort revealed localized landscape changes across the CD5 Study Area, but the observed changes are consistent with natural changes that are known to occur in deltaic environments elsewhere on the CRD are not readily explained by the presence of CD5 infrastructure.

3.4.2.E Elevation and Thaw Depth

Summary statistics of ground surface elevation and thaw depth in 2013 and 2016 are presented in Appendix H-1 and Appendix H-2, respectively. Cross sections of ground surface elevation and thaw depth along the monitoring transects in the Test and Reference Areas are presented in Appendix I and J, respectively. Differences between years within the Reference Area reflect natural variation but can be used to better understand changes that occur in the Test Area.

Ground surface elevation was measured in the Reference Area in 2013 and 2016 at 266 and 332 locations, respectively, and at 298 and 378 locations in the Test Area, respectively. In 2016, the minimum ground surface elevation in the Reference Area (-0.18 m) and Test Area (0.03 m) occurred at the edge of a waterbody in Riverine Moist Low Willow Shrub and Coastal Barrens, respectively. Maximum ground surface elevation for both Areas (5.01–5.25 m) occurred in Upland Moist Low Willow Shrub.

Thaw depth was measured in the Reference Area in 2013 and 2016 at 240 and 228 locations respectively, and at 261 and 256 locations within the Test Area, respectively. In 2016, the minimum thaw depth was 22 cm in both the Reference and Test Areas, occurring in Lowland Moist Sedge-Shrub Meadow and Riverine Moist Sedge-Shrub Meadow, respectively. In 2016, the maximum thaw depth measured in the Reference Area (114 cm) occurred in Coastal Dry Elymus Meadow. The maximum thaw depth measured in the Test Area in 2016 (118 cm) occurred in Upland Moist Low Willow Shrub.

Thaw Depth/Elevation Point Data were summarized by map ecotype class for each of the map ecotype with at least 2 Thaw Depth/Elevation Points, which included 18 terrestrial ecotype map classes for ground surface elevation (Table 3.25) and 17 classes for thaw depth (Table 3.26). Map ecotypes were generally organized along an elevation gradient from coastal ecotypes at the lowest elevations, riverine ecotypes at moderate elevations, and lowland and upland ecotypes at the highest elevations. In both 2013 and 2016, the ecotype in the Test Area with the highest average elevation above sea level was Upland Moist Low Willow Shrub (Figure 3.32). In the Reference Area, the average elevation of Upland Moist Willow Shrub was exceeded only by Upland Dry Dryas Dwarf Shrub (Figure 3.33). These ecotypes are typical of active and inactive sand dunes and feature some the highest elevations in the CD5 Habitat Monitoring Study Area. Map ecotypes with the lowest average elevation included Coastal Barrens and Coastal Moist Willow Dwarf Shrub. These ecotypes occur on active channel deposits along river channels and are regularly subjected to coastal and fluvial processes, including saltwater intrusion, channelized flooding, sedimentation, and erosion.

Map ecotypes in the Test Area with shallow thaw depths in 2016 included Upland Moist Tussock Meadow, Lowland Deep-polygon Complex, and Human Modified Wet Meadow (Figure 3.34). Map ecotypes in the Reference Area with shallow thaw depths included Riverine and Lowland Wet Sedge Meadow (Figure 3.35).

The deepest thaw depths occurred in ecotypes with sandy, well-drained soils, or in ecotypes located near river channels where seasonal melt is amplified due to the close proximity of flowing water during the summer months. In the Test Area in 2016, ecotypes with the deepest thaw depths included Upland Moist Low Willow Shrub and Coastal Barrens. In the Reference Area in 2016, ecotypes with the deepest thaw depths included Riverine Moist Herb Meadow and Coastal Barrens.

The summary of Thaw Depth/Elevation Point data by map ecotype class provides a quantitative assessment of elevation and thaw depth, as per the Monitoring Plan (ABR and Baker 2013). In general, elevations remained approximately the same between 2013 and 2016 across all ecotypes in both Reference and Test Areas. Thaw depth generally decreased (i.e., thinner active layer) in 2016 across all ecotypes in both Reference and Test Areas. This is related to the timing of the RTK Surveys in 2013 as compared to 2016. In 2013, the RTK surveys were conducted in the first and second weeks of August, while in 2016 the RTK surveys were conducted approximately 3 weeks earlier, during the second and third weeks of July. Additionally, the overall thinner snowpack in 2016 compared to 2013 (i.e., diminished insulating properties) may also be a contributing factor in the shallower active layer depths observed in 2016 (see Climate Monitoring, above).

3.4.2.F Broad-scale Monitoring of Geomorphology

Surface organic thickness is the thickness of continuous organic soil material from the soil surface to the first mineral-textured layer that is ≥0.5 cm. In deltaic environments, surface organics tend to be thicker on floodplain surfaces that are less frequently flooded, and thinner on more fluvially active surfaces because sedimentation related to overbank flooding bury existing surface organics. Surface organic thickness provides a metric by which to assess changes in sedimentation

Table 3.25. Mean, standard error (SE), and sample size (n) for measurements of ground surface elevation (m) above British Petroleum Mean Sea Level (BPMSL) summarized by map ecotype class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

	Reference						Test					
	Mean		SE		n		Mean		SE		n	
Map Ecotype Class	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Coastal Barrens	1.0	1.0	0.1	0.1	12	11	1.0	1.1	0.2	0.2	12	10
Coastal Dry Elymus Meadow		1.6		0.2		2						
Coastal Moist Willow Dwarf Shrub	1.4	1.4	0.4	0.3	3	3	1.8	1.8	0.1	0.1	3	3
Human Modified Wet Meadow	3.7	3.7	0.1	0.2	2	2		2.8		0.4		2
Lowland Deep-polygon Complex	2.7	2.7	0.1	0.1	22	22	3.0	3.0	0.0	0.0	19	18
Lowland Wet Sedge Meadow	3.5	3.5	0.2	0.2	18	18	3.1	3.1	0.1	0.1	11	11
Lowland Wet Sedge-Willow Meadow							3.4	3.3	0.1	0.1	3	3
Riverine Deep-polygon Complex	2.3	2.3	0.0	0.0	9	9	3.0	2.9	0.0	0.1	12	12
Riverine Grass Marsh							1.4		0.0		3	
Riverine Moist Herb Meadow	2.7	2.6	0.1	0.1	3	3	2.1	2.1	0.4	0.4	2	2
Riverine Moist Low Willow Shrub	3.0	2.8	0.2	0.2	19	20	2.3	2.6	0.2	0.2	18	9
Riverine Moist Low Willow-Sedge Meadow	2.6	2.5	0.2	0.2	21	21	2.7	2.8	0.2	0.1	20	18
Riverine Moist Sedge-Shrub Meadow							3.1	3.0	0.2	0.2	5	5
Riverine Wet Sedge Meadow	3.2	3.1	0.1	0.1	42	43	3.0	3.0	0.0	0.0	107	106
Riverine Wet Sedge-Willow Meadow	3.2	3.2	0.1	0.1	65	66	2.9	3.0	0.1	0.1	49	44
Upland Dry Dryas Dwarf Shrub	4.8	4.7	0.2	0.2	2	2						
Upland Moist Low Willow Shrub	4.2	4.1	0.7	0.7	4	4	3.8	3.8	0.3	0.3	7	7
Upland Moist Tussock Meadow							3.0	3.0	0.2	0.2	6	6

Table 3.26. Mean, standard error (SE), and sample size (n) for measurements of thaw depth (cm) summarized by map ecotype class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

	Reference						Test					
	Mean		SE		n		Mean		SE		n	
Map Ecotype Class	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Coastal Barrens	-102.6	-83.4	2.0	2.9	20	11	-99.5	-91.7	2.8	4.1	12	10
Coastal Moist Willow Dwarf Shrub	-65.0	-64.0	3.5	4.6	4	3	-90.0	-74.3	7.1	1.7	3	3
Human Modified Wet Meadow	-51.0	-40.0	1.0	1.0	2	2		-34.0		1.0		2
Lowland Deep-polygon Complex	-46.5	-37.2	1.3	1.4	24	22	-44.3	-33.4	1.2	0.9	19	22
Lowland Moist Low Willow Shrub	-45.0				2							
Lowland Wet Sedge Meadow	-48.2	-37.4	1.2	1.4	18	18	-43.5	-38.3	1.1	1.8	11	11
Lowland Wet Sedge-Willow Meadow							-42.7	-41.0	2.2	2.3	3	3
Riverine Deep-polygon Complex	-42.8	-38.0	2.3	2.2	9	9	-46.3	-34.8	1.2	1.6	12	12
Riverine Moist Herb Meadow	-103.3	-91.0	0.9	1.0	3	3	-85.5	-84.0	5.5	8.0	2	2
Riverine Moist Low Willow Shrub	-68.7	-54.7	4.1	4.0	26	20	-70.3	-61.2	4.3	5.5	18	10
Riverine Moist Low Willow-Sedge Meadow	-54.2	-47.2	3.0	2.2	26	21	-53.0	-45.2	2.9	3.1	20	20
Riverine Moist Sedge-Shrub Meadow							-42.8	-37.8	3.5	6.3	5	5
Riverine Wet Sedge Meadow	-49.5	-36.5	1.8	1.1	42	42	-47.4	-37.1	0.6	0.5	107	106
Riverine Wet Sedge-Willow Meadow	-46.1	-37.3	1.0	0.9	69	66	-50.6	-40.5	1.4	1.0	49	44
Upland Dry Dryas Dwarf Shrub	-93.7	-59.0	20.1	18.0	4	2						
Upland Moist Low Willow Shrub	-73.8	-54.5	18.3	17.4	5	4	-98.9	-97.0	7.4	7.8	7	7
Upland Moist Tussock Meadow							-43.0	-31.3	3.2	2.0	6	6

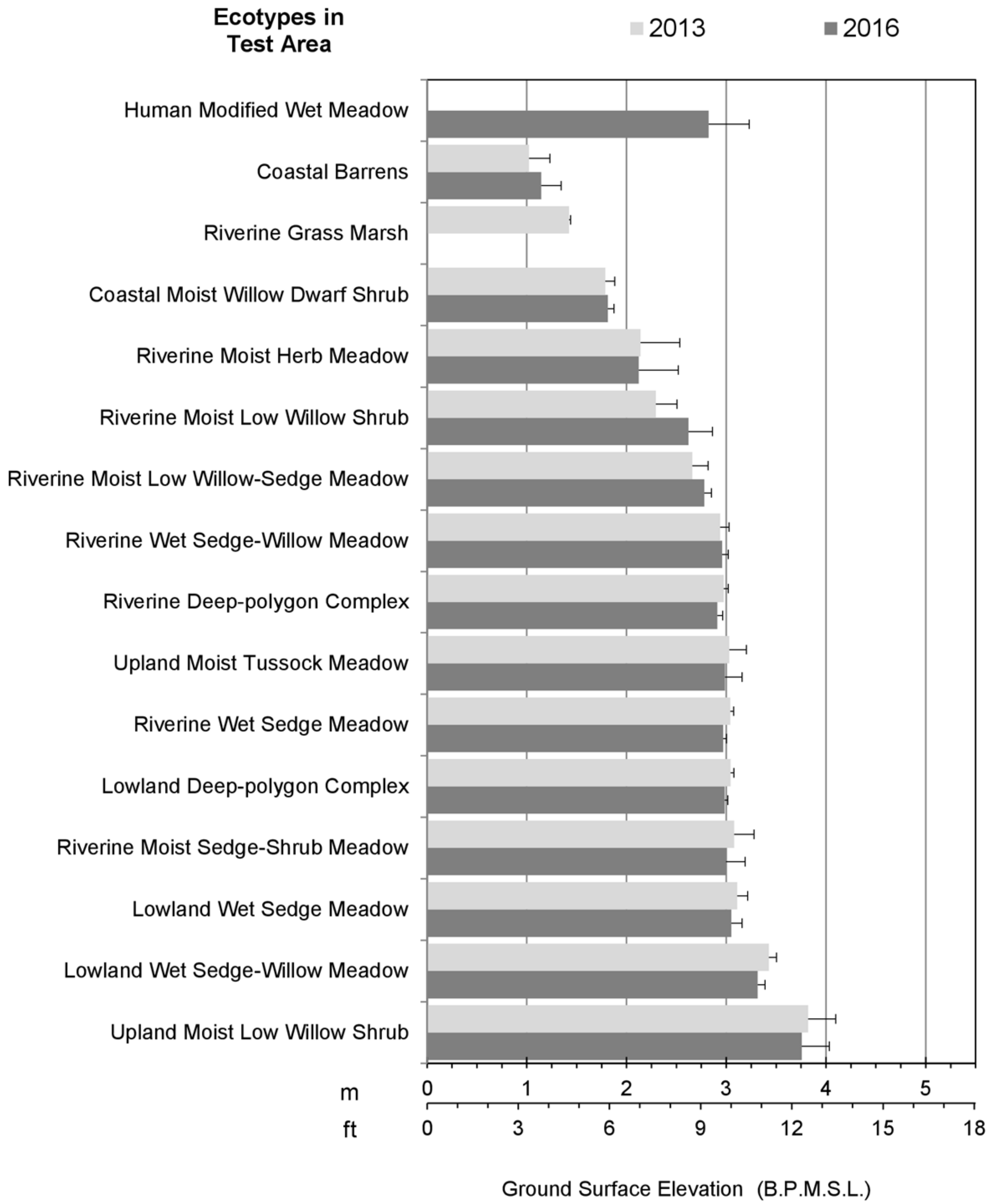


Figure 3.32. Barchart illustrating average elevation above British Petroleum mean sea level, and standard error, sorted from smallest to largest in 2013 compared to 2016 for map ecotype classes in the CD5 Habitat Monitoring Test Area, northern Alaska.

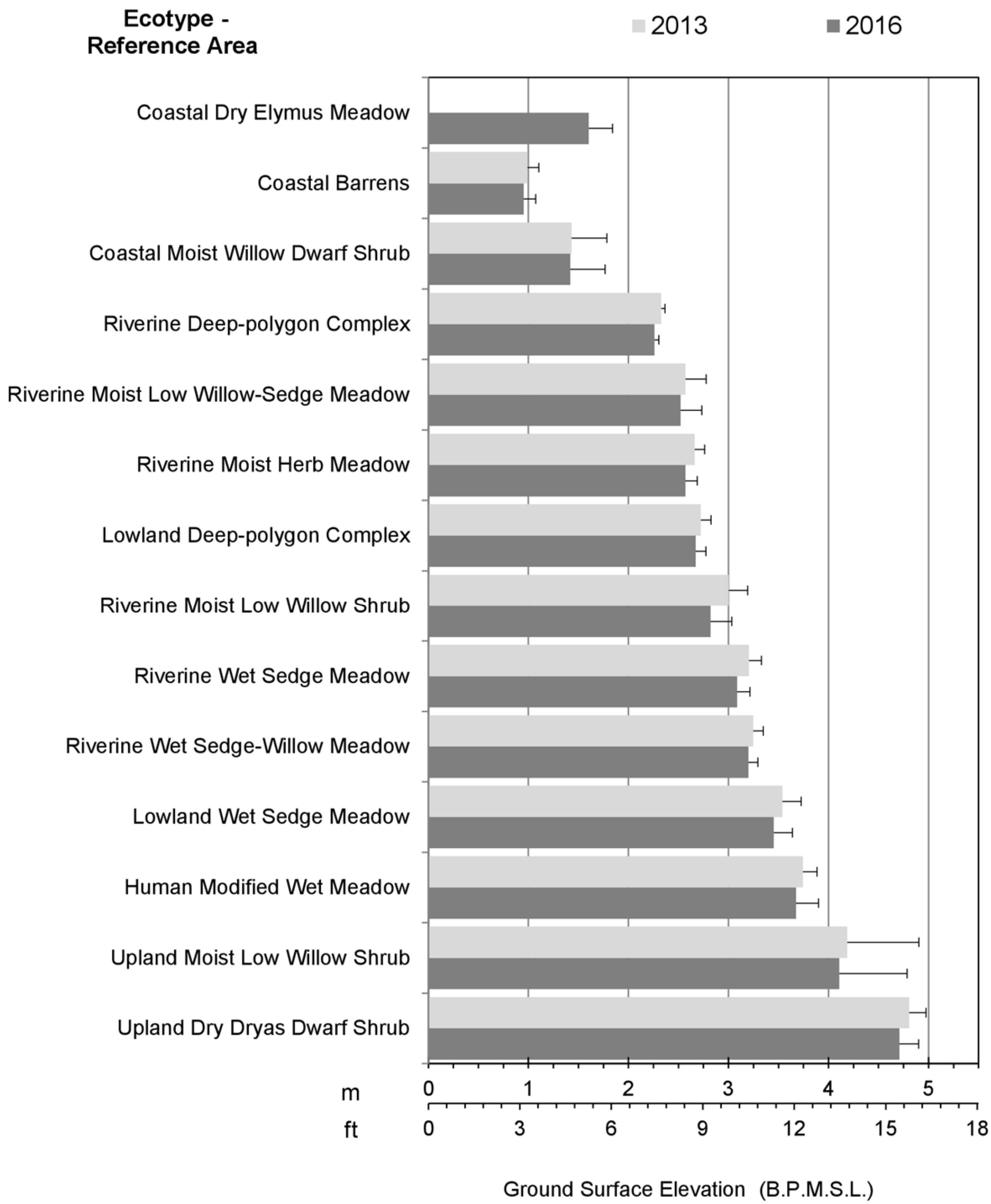


Figure 3.33. Barchart illustrating average elevation above British Petroleum mean sea level, and standard error, sorted from smallest to largest in 2013 compared to 2016 for map ecotype classes in the CD5 Habitat Monitoring Reference Area, northern Alaska.

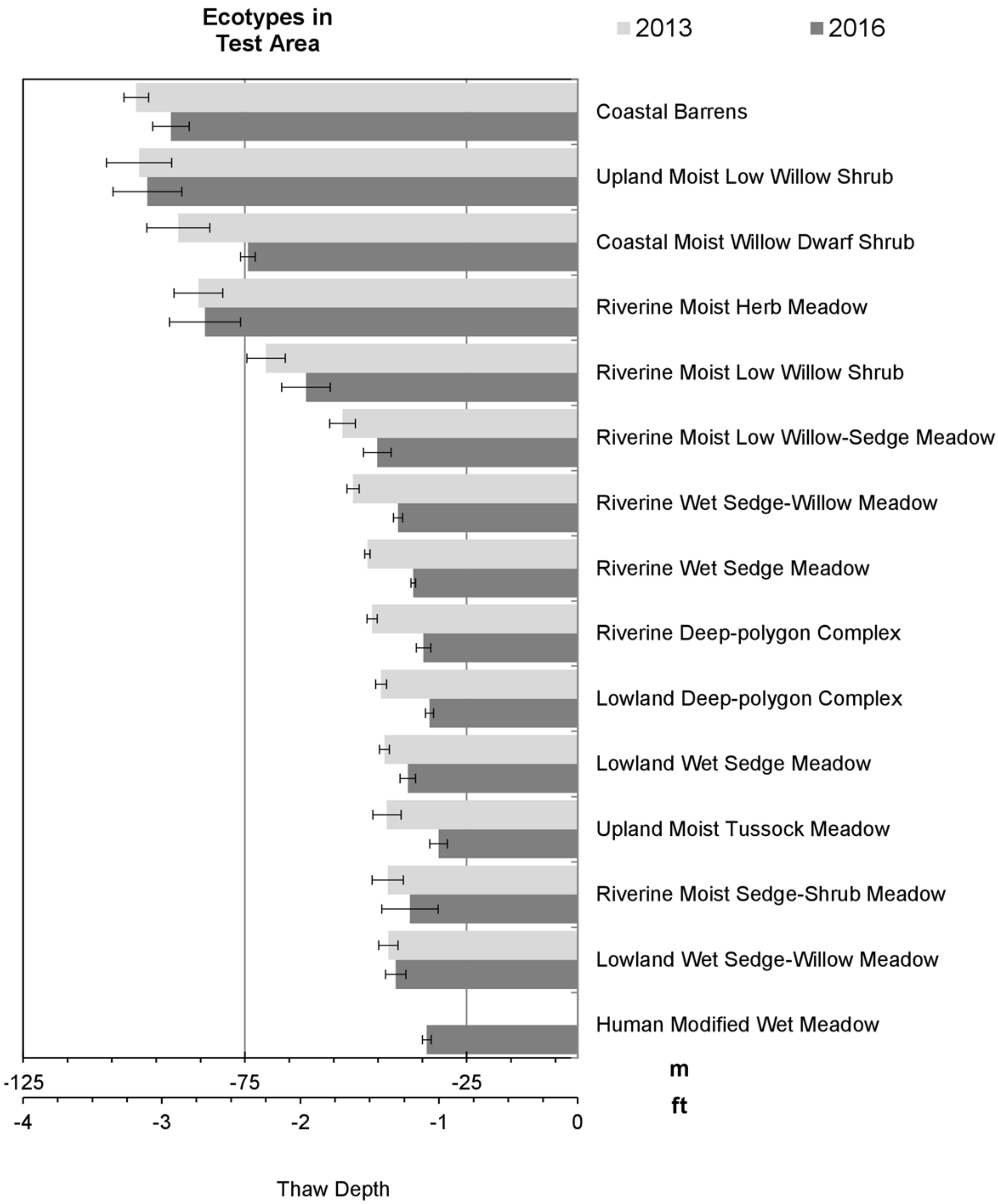


Figure 3.34. Barchart illustrating average thaw depth and standard error for map ecotype, sorted from deep to shallow in 2013 and 2016 in the CD5 Habitat Monitoring Test Area, northern Alaska.

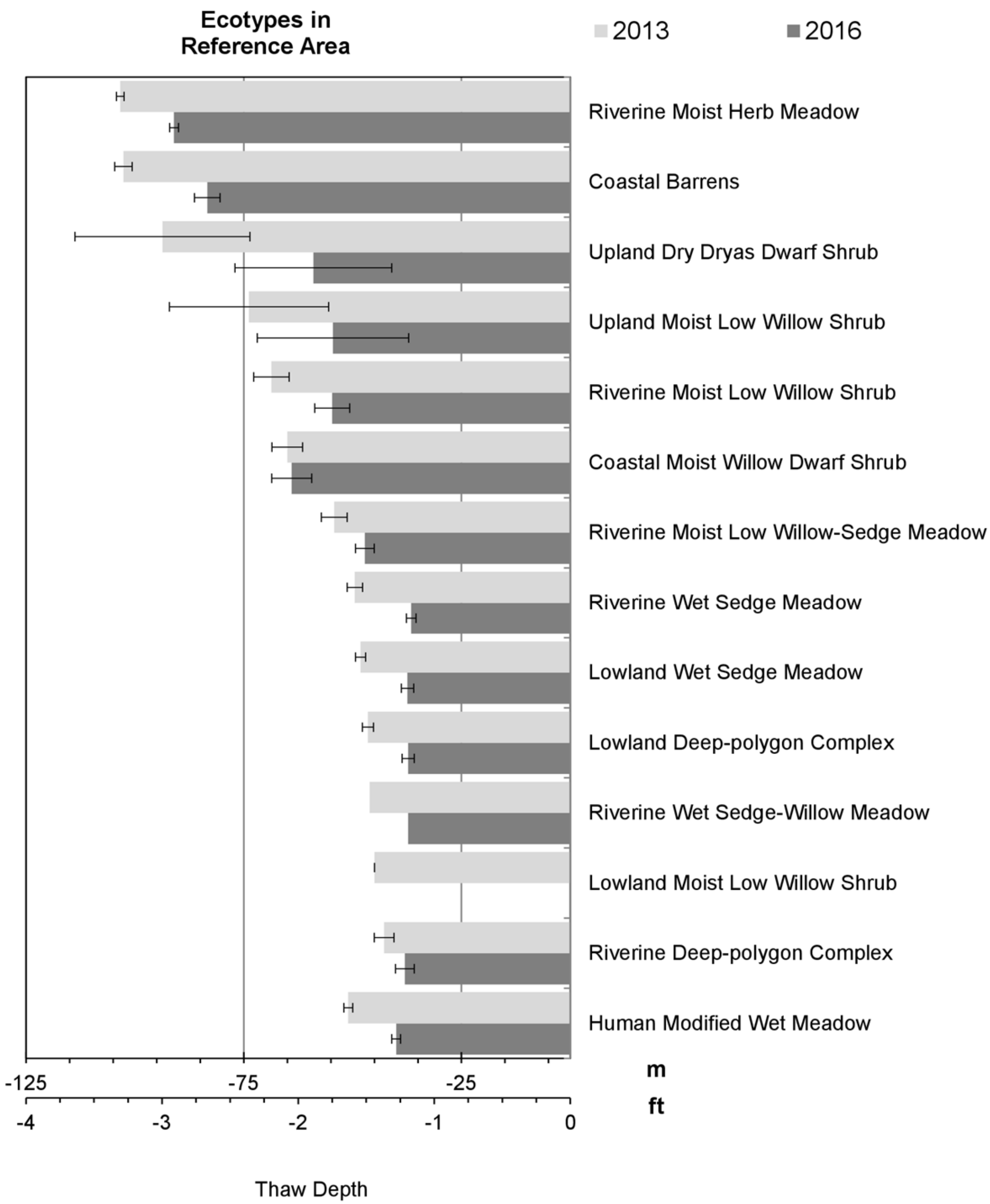


Figure 3.35. Barchart illustrating average thaw depth and standard error for map ecotype, sorted from deep to shallow in 2013 and 2016 in the CD5 Habitat Monitoring Reference Area, northern Alaska.

across the CD5 Study Area. Average and 95% confidence intervals (CI) of surface organic thickness by geomorphic unit, Area, and year are presented in Figure 3.36 and Table 3.27. Average surface organic thickness was greatest in Delta Abandoned Overbank Deposits, moderately thick in Delta Inactive Overbank Deposits, and thinnest in Delta Active Overbank Deposits. This pattern held true for Reference and Test Areas in both years. For surface terrain units Delta Abandoned Overbank Deposit and Delta Active Overbank Deposit in the Test Area, average surface organic thickness overlapped the 95% confidence intervals of the corresponding surface terrain unit in the Reference Area in both years. This indicates that the observed differences in surface organic thickness for these surface geomorphic units are not significant between years and areas. Average surface organic thickness in Delta Inactive Overbank Deposits in the Test Area were greater than the upper 95% confidence interval of surface organics in the same surface terrain unit in the Reference Area in both years. This indicates that average surface organic thickness is significantly greater in the Test Area. This pattern was the same for both 2013 and 2016 and the lower 95% CI of the Test Area overlaps with the upper 95% CI in the Reference Area. Thus, the observed differences are related to natural differences in the surface organic thickness on Delta Inactive Overbank Deposits in the Reference and Test Areas, rather than a difference related to changes in sedimentation related to the CD5 Road.

An assessment of ground cover classes in Reference and Test Areas by year (Figure 3.37) showed that mosses and mineral soil were the predominant ground cover classes in all years and Areas. While the average mineral soil cover was slightly higher in 2013 (36% in the Reference Area and 44% in the Test Area, Appendix K) than in 2016 (25% in the Reference Area and 32% in the Test Area), the number of plots where mineral soil hits were recorded increased in 2016 (n = 48 and 49 in the Reference and Test Areas, respectively) relative to 2013 (n = 34 and 26 in the Reference and Test Areas, respectively). The slight drop in average mineral soil cover in 2016 reflects a higher number of plots with low mineral soil cover in 2016. Mineral soils were less widespread in 2013 but at Vegetation Plots where mineral soils were present, its cover was on average higher. In contrast, mineral soils in 2016 were more widespread but at Vegetation Plots where mineral soils were present, its cover was on average lower. This can be explained by the reduction in standing water caused by the drier climatic conditions, resulting in soil surfaces being exposed that in 2013 were covered in standing water. Sedimentation caused by 2015 break up flooding (Baker 2015), which covered most of the CD5 Study Area with flood water, is also a likely cause of increased frequency of mineral soil hits in 2016 in both Reference and Test Areas.

Water was observed in all Areas and years, with consistently higher average cover in 2013 when compared to 2016 in both Test Areas and Reference Areas (Figure 3.37). The average water cover was greater in the Reference Area in 2013 (29%) when compared to 2016 (13%), and was also more widespread in 2013 (n = 41 and 66 in the Reference and Test Areas, respectively) than in 2016 (n = 12 and 13 in the Reference and Test Areas, respectively). Conditions in 2016 included an early snowmelt, lower than normal precipitation through July, and extreme high temperatures in mid-July, which contributed to the lower surface water observations in 2016 when compared to 2013.

The 2013 and 2016 Geomorphology Monitoring Photo Points photos for Photo Points 1 and 2 are presented Figure 3.6. Photo Point 1 at 110° (Panels 1a and 1b in Figure 3.6) shows the differences in water levels between years, thus illustrating the diurnal fluctuations related to tidal influence that occur in the Niġliq Channel at this location. Photo Point 1 at 190° (Panels 2a and 2b in Figure 3.6) shows the bank erosion that occurred at this site between 2013 and 2016. The erosion observed here provides an on the ground example of fluvial erosion mapped in the ITU mapping component of the 2016 Habitat Monitoring (Figure 3.30). Photo Point 2 (Panels 3a and 3b in Figure 3.6) shows slight bank erosion, increased scour on the top of the bank, deposition of driftwood at the edge of the bank, and sedimentation on the river bar. Figure 3.7 displays the photographs from Photo Point 3, the new Geomorphology Monitoring Photo Point established in 2016. The location of this Photo Point on the Niġliq Channel Bridge provides a stable location to use for repeat

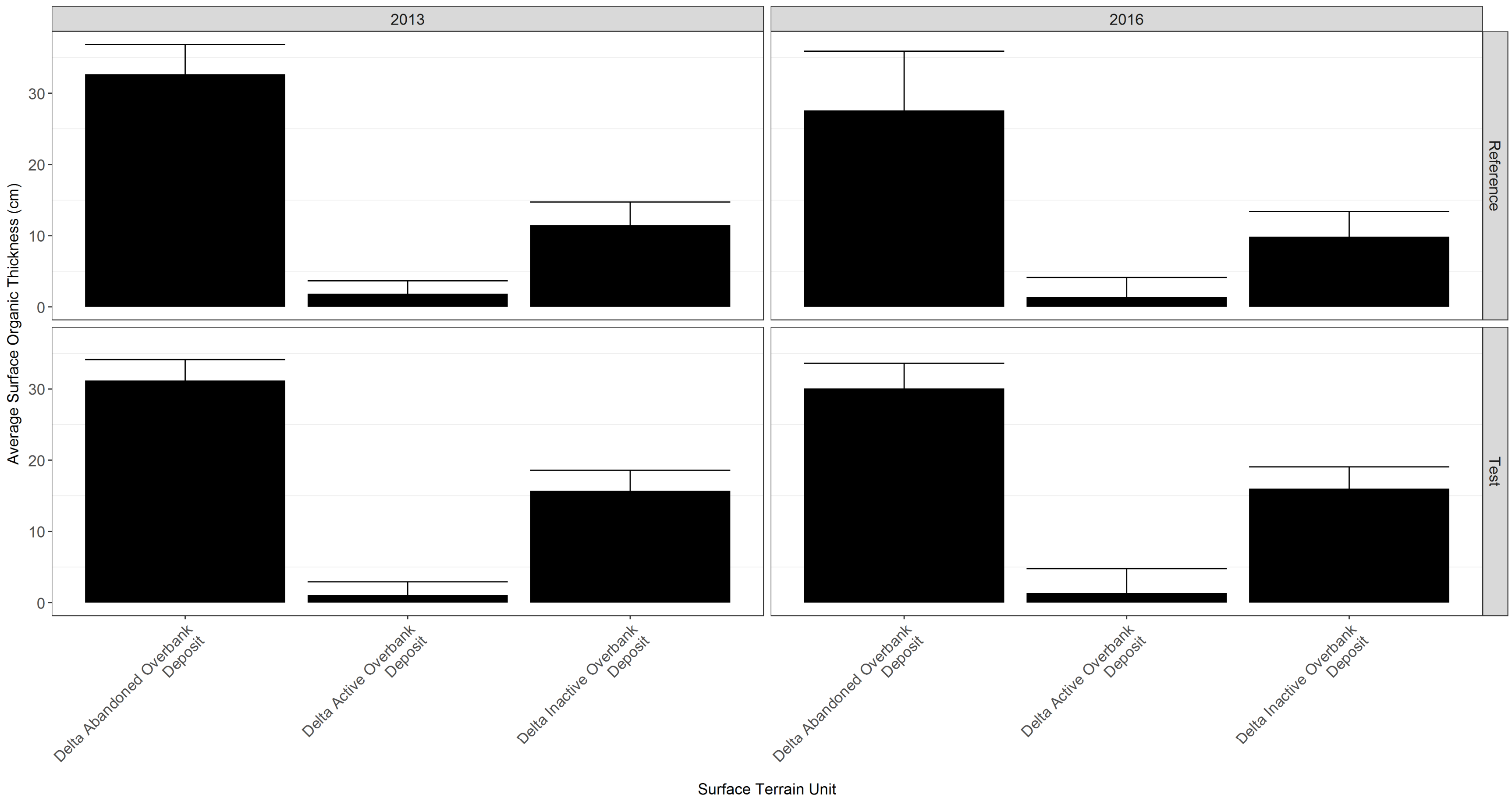


Figure 3.36. Surface organic thickness bar charts with 95% confidence intervals by surface terrain unit, area, and year for common surface terrain unit classes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Table 3.27. Average and 95% confidence intervals of surface organic thickness by geomorphic unit, study area, and year, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Surface Terrain Unit	Study Area	Sample Year	Average Surface Organic Thickness (cm)	Standard Deviation	N	Standard Error	95% CI
Delta Abandoned Overbank Deposit	Reference	2013	32.6	7.7	15	1.988131	4.237602
	Reference	2016	27.5	15.3	15	3.950443	8.42017
	Test	2013	31.1	6.3	19	1.445319	3.025088
	Test	2016	30	7.5	19	1.720618	3.601295
Delta Active Overbank Deposit	Reference	2013	1.8	2.3	8	0.813173	1.87518
	Reference	2016	1.3	3.5	8	1.237437	2.853535
	Test	2013	1	1.4	4	0.7	1.943512
	Test	2016	1.3	2.5	4	1.25	3.470556
Delta Inactive Overbank Deposit	Reference	2013	11.4	10.1	38	1.638436	3.316841
	Reference	2016	9.8	10.9	38	1.768213	3.579561
	Test	2013	15.6	12.1	66	1.489407	2.973697
	Test	2016	15.9	12.8	66	1.575571	3.145729

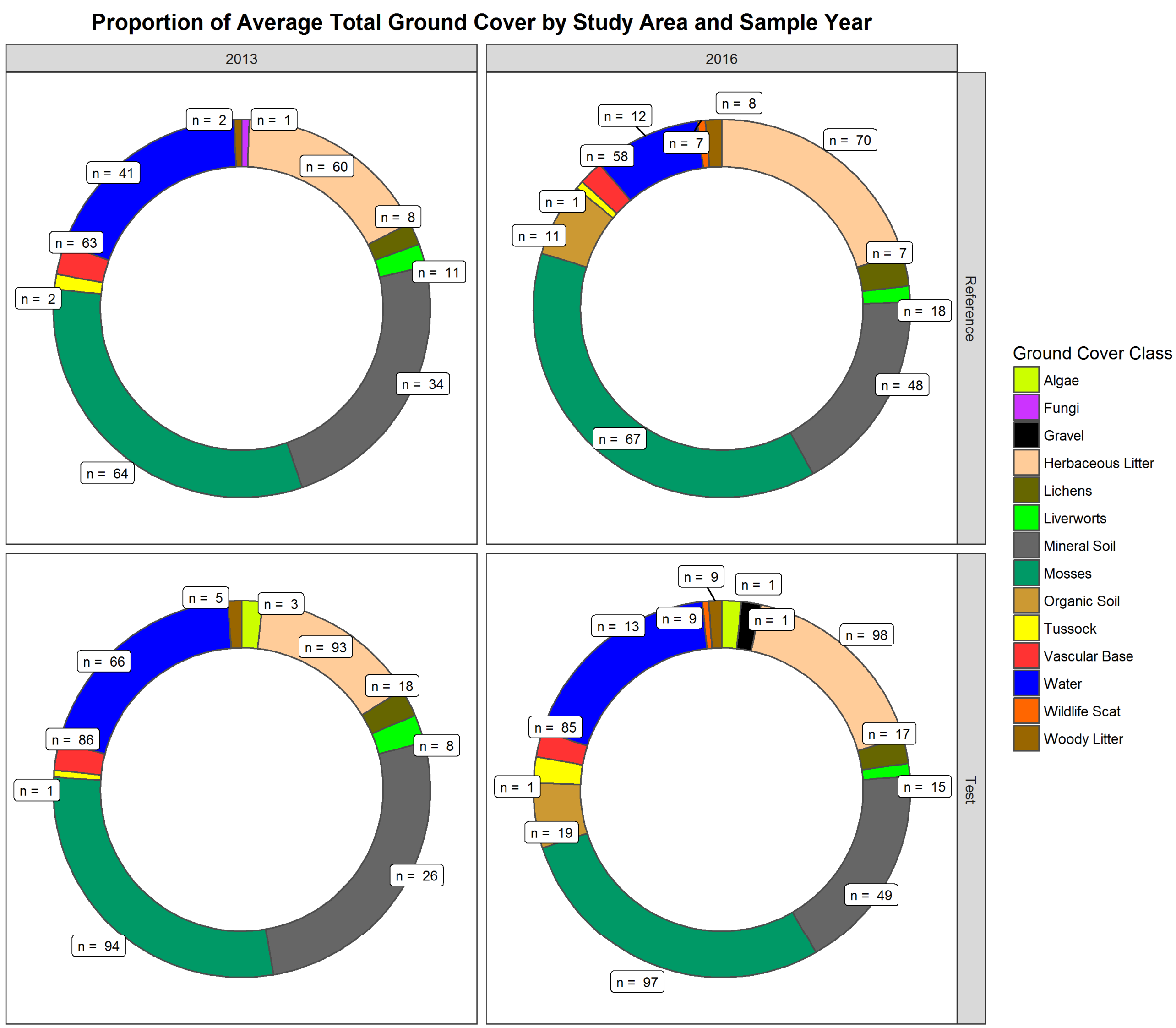


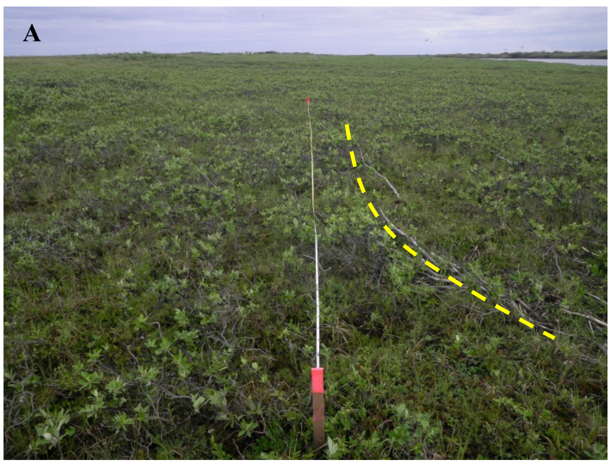
Figure 3.37. Ring chart displaying the proportion of average total ground cover for all ecotypes by sample year and study area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

photography in the future for use in monitoring landscape change on the north- and south-side of the Niġliq Channel Bridge.

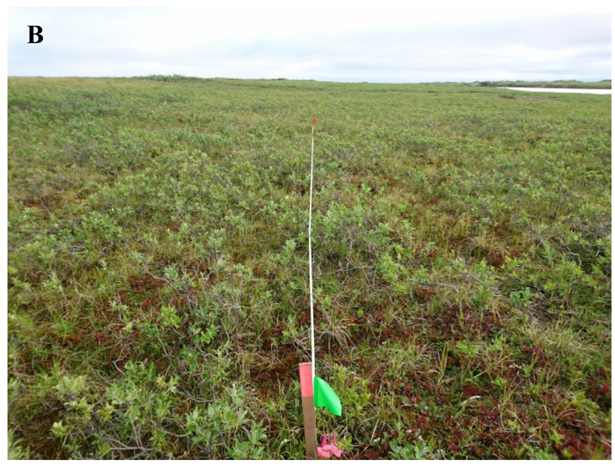
As detailed in the Monitoring Plan, observations of drift lines were recorded opportunistically while traversing monitoring transects. Observations included field notes and photographs (Figure 3.38). Drift lines and driftwood were observed across the CD5 Study Area in 2016. In some cases drift lines that were observed in 2013 were no longer present in 2016 (Panels A and B in Figure 3.38) indicating that flood waters had moved the drift materials. In other cases, drift lines and driftwood were found in 2016 at sites where drift lines were absent in 2013 (Panel C in Figure 3.38), while in other cases drift lines were found in both years at the same location (Panel D in Figure 3.38).

3.4.2.G Repeat Photo Monitoring

The photographs taken at the Vegetation Plot Start Point, Vegetation Plot Soil Pit, and Habitat Line Start and End Points are taken each monitoring year from the same location and in the same orientation. These repeat photographs represent a vast dataset (over 4,500 photos taken to



Plot t2nb-0150-veg as observed in 2013. Note the drift line located to the right of the tape measure.



Plot t2nb-0150-veg as observed in 2016. Note that the drift line observed in 2013 is no longer present.

Plot t1na-2000-hab with woody debris on line 1, observed in 2016.

Plot t1sc-0184-veg and woody debris observed in 2016. Note the drift line located to the left of the tape measure.

Figure 3.38. Examples of drift lines observed in 2013 but not 2016, drift lines observed in 2016 only, and drift lines observed in both years, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

date) unto themselves that can be used for monitoring landscape change through time. Examples of using the repeat photographs for monitoring are provided in Figure 3.39. Panels 1a and 1b in Figure 3.39 show the soil plug at plot t2sb-0800-veg in 2013 and 2016, respectively. The 2016 photos shows the addition of several centimeters of sediment deposited at this plot since 2013. Panels 2a and 2b illustrate the difference in standing water cover between 2013 and 2016 at plot t1na-1219-veg; a pattern that was common across both Test and Reference Areas as discussed throughout this report. The 2013 photos shows abundant standing water, while the 2016 photo shows little to no standing water and an abundance of exposed reddish-brown organic soil material. Panels 3a and 3b are the Habitat Plot Line 3 End Point Photos in 2013 and 2016, respectively, showing the removal of driftwood, addition of sediment, and the robust growth of willows at this site since 2013. The photos presented here illustrate just a few examples of the power of the repeat photo dataset for visualizing landscape changes through time and providing additional information to support the results of the habitat monitoring data analysis.

3.4.3 SYNTHESIS OF 2016 HABITAT MONITORING

The 2016 Habitat Monitoring effort was focused on collecting the first year of post-construction data, and comparing these data with the baseline data collected in 2013 to assess potential ecosystem changes associated with the CD5 Project. However, as specified in the Monitoring Plan, management of the direct effects of the CD5 Project are most likely to be focused on landscape changes detected as a result of the annual hydrological monitoring being conducted for the Project (see HYDROLOGY MONITORING in ABR and Baker 2013). The habitat monitoring program is designed to provide supplemental information and confirm whether any potential hydrologic changes have effects on soils, permafrost, vegetation, and wildlife habitat. Incorporating operational changes or modifications specifically for the habitat monitoring task was not proposed in the Monitoring Plan because effects are secondary and indirect from any potential changes in hydrology, sedimentation, and erosion.

Several common patterns were identified in the analysis of 2016 habitat monitoring data that have bearing on the Hydrology Monitoring task. The habitat assessment showed a decrease in percent cover of standing water and an increase in cover of mineral soil and mosses in 2016 when compared to 2013 in both the Reference and Test Areas. The results of the assessment of detailed ground cover classes at Vegetation Plots by plot ecotype, Area, and year agreed with the results of the habitat analysis; surface water cover decreased and mineral soil increased in 2016 when compared to 2013 in both the Reference and Test Areas. Results of the assessment of depth to water table by plot ecotype corroborated the finding of a reduction in standing water cover across the CD5 Study Areas; water tables were consistently deeper in 2016 when compared to 2013 across ecotypes and Reference and Test Areas. These results indicate that the observed differences in standing water and water table depth between 2013 and 2016 are not related to the CD5 Road. Instead these differences are related to warmer temperatures, a shallower snowpack, earlier snow melt, higher evapotranspiration, and lower July precipitation in 2016 when compared to 2013 (see Climate Monitoring, above). The observed increases in mineral soil in 2016 in both Reference and Test Areas can be explained by the reduction in standing water caused by the 2016 climatic conditions listed above, resulting in soil surfaces being exposed in 2016 that were otherwise covered in standing water in 2013. Sedimentation caused by 2015 breakup flooding (Baker 2015), which covered most of the CD5 Study Area with flood water, is also likely a contributing factor. The increase in mineral soil cover in 2016 in both Reference and Test Areas suggests that this increase is not related to the CD5 Road.

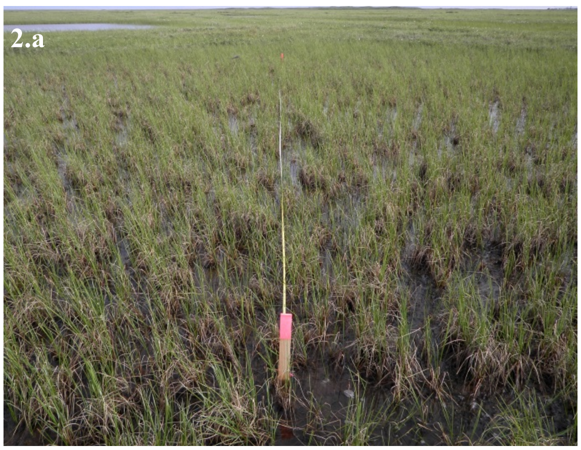
Comparing the average and 95% confidence intervals (CI) of surface organic thickness by geomorphic unit, Area, and year showed that there were no significant differences in surface organic thickness between Reference and Test between years. A difference in thickness of surface organics in Inactive Overbank Deposits between Reference and Test Areas was observed in both 2013 and

2013

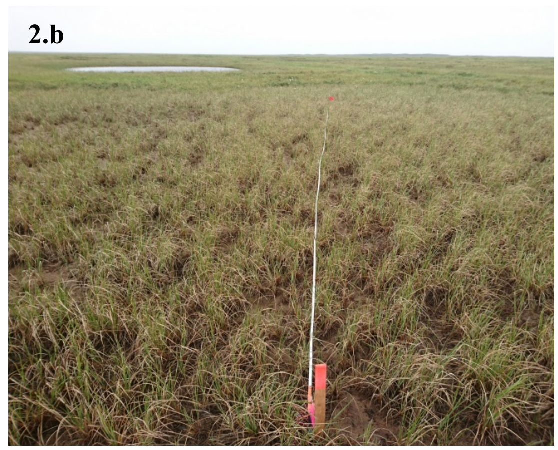
Vegetation Plot Soil Pit t2sb-0800-veg

2016

Vegetation Plot Soil Pit t2sb-0800-veg



Vegetation Plot Start Point t1na-1219-veg



Vegetation Plot Start Point t1na-1219-veg

Habitat Plot Line 1 End

Habitat Plot Line 1 End

Figure 3.39. Examples of change over time using repeat photography at a Vegetation Plot Soil Pit, Vegetation Plot Start Point, and Habitat Plot Line, in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

2016, indicating the difference was related to the natural variability of the surface organic thickness in the Reference and Test Areas rather than CD5 Road-related sedimentation changes. Drift line observations from across the CD5 Study Area in 2016 corroborate the results of the analysis of surface organic thickness and indicate that the Reference and Test area were similarly affected by sedimentation related to break-up flooding in the years between Habitat Monitoring periods.

The vegetation assessment found that 96% of Vegetation Plots (171 plots) had not changed in species composition between 2013 and 2016, with the remaining 4% of the Vegetation Plots (8 plots total) showing a change between years. Of the 8 plots that showed changes in species composition, the change at the plots (2) located in the Reference Areas was attributed to natural changes in species composition. The changes at 3 plots in the Test Area were attributable to increases in the cover of sedges in 2016, an indicator of increased productivity. The changes at the remaining 3 plots were related to either a increases or decreases in willow *(Salix* sp.) and sedge (*Carex* sp. and *Eriophorum* sp.) and increases and decreases in the number species detected at the plots. In summary, the total number of Vegetation Plots identified as having changed in species composition between 2013 and 2016 is very small (<5% of the total plots), the plots were located in both the Test and Reference Areas, and the plots were not specific to any single plot ecotype.

Changes in species richness between ecotypes, years, and Areas were relatively small and within the range of variability, based on the standard deviation. Changes in vegetation structure classes were also generally consistent between ecotypes, Areas, and years. In general, total live cover increased between 2013 and 2016, a change driven largely by an increase in cover of mosses and sedges in several ecotypes.

The landscape change analysis showed that, apart from the expected landscape changes related to the direct placement of the CD5 development infrastructure, the first ecosystem map update effort revealed localized landscape changes across the CD5 Study Area. The observed changes are consistent, however, with natural changes that are known to occur in deltaic environments elsewhere on the CRD and are not readily explained by the presence of CD5 infrastructure.

The Thaw Depth/Elevation surveys showed that in general, elevations remained approximately the same between 2013 and 2016 across all ecotypes in both Reference and Test Areas. Thaw depth generally decreased (i.e., thinner active layer) in 2016 across all ecotypes in both Reference and Test Areas. The differences in thaw depth between years is predominantly related to the timing of the RTK Surveys in 2013 (early August) as compared to 2016 (mid-July).

In summary, the results of the 2016 Habitat Monitoring showed very little ecosystem change between 2013 and 2016. Broad-scale changes that were significant between years, including the decrease of standing water cover and increase in mineral soil cover, were observed in both Reference and Test Areas and hence not attributable to the CD5 Road. Rather, differences in broad-scale climatic factors and break-up flooding between 2013 and 2016 are the primary causal factors lending to the differences observed. The CD5 Habitat Monitoring Study effort is scheduled to be conducted again in 2019.

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Appendix A. Cross-reference table of aggregated Integrated Terrain Unit (ITU) code combinations with map ecotype and wildlife habitat class from the Central Beaufort Coastal Plain ITU classification, CD5 Habitat Monitoring Study, northern Alaska, 2016.

Map ecotype	Wildlife Habitat	ITU Code*	
Coastal Barrens	Barrens	Fdoa/N/Bpv/Nsk	Fdra/Sb/Bpv
		Fdoi/N/Bpv/Nsk	Fdra/Sb/Bpv/Ngfd*
		Fdra/N/Bbg	Fdra/Sb/Bpv/Ngfe
		Fdra/N/Bbg/Ngfd*	Fdri/N/Bpv/Ngfd*
		Fdra/N/Bpv	Ltdn/N/Bbg
		Fdra/N/Bpv/Ngfd*	Ltdn/N/Bpv
		Fdra/N/Bpv/Ngfe*	
Coastal Dry Elymus Meadow	Dry Halophytic Meadow	Esda/Es/Hgdl	Fdra/N/Hgdl
Coastal Lake	Tapped Lake with Low-water Connection	Weldc/W/Wb	Weldc/Wi/Wb
Coastal Moist Willow Dwarf Shrub	Moist Halophytic Dwarf Shrub	Fdra/N/Sdwgh	Ltdn/N/Sdwgh
		Fdri/N/Sdwgh	
Human Modified Barrens	Human Modified	Fdra/N/Bbg/Hseb*	Fdra/Sb/Bpv/Hsep*
		Fdra/N/Bbg/Hsep*	Fdri/N/Bpv/Hti*
		Fdra/N/Bpv/Hseb*	Hfg/Hm/Bbg/Hfgp
		Fdra/N/Bpv/Hsep*	Hfg/Hm/Bbg/Hfgr
		Fdra/Sb/Bpv/Hseb*	
Human Modified Dwarf Scrub	Human Modified	Esdi/Ek/Sddt/Hti*	Esdi/Es/Sddt/Hti*
		Esdi/Es/Sddt/Hsep*	Fdoi/Phl/Sddt/Hti
Human Modified Low Shrub	Human Modified	Fdoa/N/Slcw/Hseb*	Fdoa/Pd/Slows/Hti
		Fdoa/N/Slcw/Hsep*	Fdoi/Pd/Slow/Hseb*
		Fdoa/N/Slcw/Hti*	Fdoi/Pd/Slow/Hsep*
		Fdoa/N/Slow/Hseb*	Fdoi/Pd/Slow/Hti
		Fdoa/N/Slow/Hsep*	Fdoi/Pd/Slows/Hsep*
		Fdoa/N/Slow/Hti	Fdoi/Pd/Slows/Hti
		Fdoa/N/Slows/Hsep*	Fdri/N/Slcw/Hti
		Fdoa/N/Slows/Hti	Fdri/N/Slow/Hti
Human Modified Marsh*	Human Modified	Wldcrh/W/Hgwfg/Hseb*	Wlsir/W/Hgwfg/Hsep*
		Wldcrh/W/Hgwfg/Hsep*	
Human Modified Moist Meadow*	Human Modified	Fdob/Phl/Hgmss/Hsep*	Fdob/Tm/Hgmt/Hti*
		Fdob/Phl/Hgmt/Hsep*	Fdoi/Pd/Hgmss/Hsep*
		Fdob/Phl/Hgmt/Hti*	Fdoi/Pd/Hgmss/Hti*
		Fdob/Tm/Hgmt/Hsep*	Fto/Phl/Hgmt/Hsep*
Human Modified Waterbody*	Human Modified	Wert/W/Wb/Hseb*	Wldcrh/W/Wf/Hsep*
		Wert/W/Wb/Hsep*	Wlsit/Wi/Wf/Hsep*
		Wldcrh/W/Wf/Hseb*	
Human Modified Wet Meadow	Human Modified	Fdoa/Pd/Hgwswt/Hti	Fdoi/Pd/Hgwswt/Hti
		Fdoa/N/Hgwst/Hseb*	Fdoi/Pd/Hgwst/Hti*
		Fdoa/N/Hgwst/Hsep*	Fdoi/Pd/Hgwswt/Hsep*

Appendix A. Continued.

Map ecotype	Wildlife Habitat	ITU Code*	
Human Modified Wet Meadow (continued)	Human Modified	Fdoa/N/Hgwswt/Hti*	Fdoi/Plhh/Xp/Hsep
		Fdob/Plhh/Hgwst/Hsep	Fdoi/Plhh/Xp/Hseb*
		Fdob/Plhh/Xp/Hti*	Fdoi/Plhl/Xp/Hsep*
		Fdob/Plhl/Xp/Hsep*	Fdoi/Pllh/Hgwst/Hsep*
		Fdob/Pllh/Hgwst/Hsep*	Fdoi/Plll/Hgwst/Hsep
		Fdob/Pllh/Hgwst/Hti*	Fdoi/Plll/Hgwst/Hti
		Fdob/Plll/Hgwst/Hsep*	Fdoi/Plll/Hgwswt/Hsep*
		Fdob/Plll/Hgwst/Hti*	Fdoi/Plll/Hgwswt/Hti
		Fdoi/N/Hgwst/Hsep*	Fdri/N/Hgwst/Hsep*
		Fdoi/N/Hgwst/Hti*	Fdri/N/Hgwst/Hti
		Fdoi/Pd/Hgwst/Hsep	Ftr/Plhh/Hgwst/Hsep*
		Fdoi/Pd/Hgwswt/Hseb*	
Lacustrine Grass Marsh	Grass Marsh	Wldit/W/Hgwfg	Wldit/Wi/Hgwfg
Lowland Deep-polygon Complex	Deep Polygon Complex	Fdob/Plhh/Xp	Fdob/Plhl/Xp
		Fdob/Plhh/Xp/Ngfd*	
Lowland Lake	Deep Open Water with Islands or Polygonized Margins	Wldit/Wi/Wf	
	Deep Open Water without Islands	Wldit/W/Wf	
	Shallow Open Water with Islands or Polygonized Margins	Wlsit/Wi/Wf	
	Shallow Open Water without Islands	Wlsit/W/Wf	
Lowland Moist Low Willow Shrub	Moist Low Shrub	Esi/Phl/Slow	Ltdi/Plll/Slow
		Fdob/Phl/Slow	Ltic/Pd/Slow
		Fto/N/Slcw	Ltic/Phh/Slow
		Fto/N/Slow	Ltic/Pllh/Slow
		Fto/Pd/Slow	Ltic/Pm/Slow
		Fto/Phl/Slow	
Lowland Moist Sedge-Shrub Meadow	Moist Sedge-Shrub Meadow	Cs/N/Hgmss	Ltim/Pd/Hgmss
		Esi/Pd/Hgmss	Ltim/Phl/Hgmss
		Fdob/Phl/Hgmss	Ltim/Pm/Hgmss
		Fto/N/Hgmss	Ltiu/Pd/Hgmss
		Fto/Phl/Hgmss	
Lowland Sedge Marsh	Sedge Marsh	Ltdi/Pd/Hgwfs	
Lowland Wet Sedge Meadow	Nonpatterned Wet Meadow	Esi/Pd/Hgwst	Ltdi/Pd/Hgwst
		Fto/Pd/Hgwst	Ltiu/Pd/Hgwst
		Ltdi/N/Hgwst	
	Patterned Wet Meadow	Fdob/Plhh/Hgwst	Fto/Plll/Hgwst
		Fdob/Pllh/Hgwst	Ftr/Plhh/Hgwst
		Fdob/Plll/Hgwst	Ltdi/Plhh/Hgwst
		Fdob/Plll/Hgwst/Ngt	Ltic/Pllh/Hgwst

Appendix A. Continued.

Map ecotype	Wildlife Habitat	ITU Code*	
Lowland Wet Sedge Meadow (continued)		Fdob/Pm/Hgwst	Ltim/Plll/Hgwst
		Fto/Plhh/Hgwst	
Lowland Wet Sedge-Willow Meadow	Patterned Wet Meadow	Fdob/Pllh/Hgwswt	Fdob/Pm/Hgwswt
		Fdob/Plll/Hgwswt	
Riverine Deep-polygon Complex	Deep Polygon Complex	Fdoi/Plhh/Xp	Fdoi/Plhl/Xp
Riverine Dry Dryas Dwarf Shrub	Dry Dwarf Shrub	Fdoi/Phl/Sddt	
Riverine Grass Marsh	Grass Marsh	Wldcrh/W/Hgwfg	Wldir/Wi/Hgwfg
		Wldcrh/Wi/Hgwfg	Wlsir/W/Hgwfg
		Wldir/W/Hgwfg	Wlsir/Wi/Hgwfg
Riverine Lake	Deep Open Water with Islands or Polygonized Margins	Wldir/Wi/Wf	
	Deep Open Water without Islands	Wldir/W/Wf	
	Shallow Open Water with Islands or Polygonized Margins	Wlsir/Wi/Wf	
	Shallow Open Water without Islands	Wlsir/W/Wf	
	Tapped Lake with High-water Connection	Wldcrh/W/Wf	
		Wldcrh/Wi/Wf	
Riverine Moist Herb Meadow	Moist Herb Meadow	Fdri/N/Hfds	
Riverine Moist Low Willow Shrub	Moist Low Shrub	Fdoa/N/Slcw	Fdoi/Pm/Slow
		Fdoa/N/Slow	Fdoi/Sb/Slcw
		Fdoa/Pd/Slow	Fdoi/Sb/Slow
		Fdoa/Sb/Slow	Fdoi/Sb/Slow/Ngfe
		Fdoi/N/Slcw	Fdra/N/Slow
		Fdoi/N/Slow	Fdri/N/Slcw
		Fdoi/Pd/Slcw	Fdri/N/Slow
		Fdoi/Pd/Slow	Fdri/N/Slow/Ngfd*
		Fdoi/Phl/Slcw	Fdri/N/Slow/Ngfe
		Fdoi/Phl/Slow	Fdri/Sb/Slow/Ngfe
		Fdoi/Pm/Slow/Ngfd*	Ltdn/N/Slow
Riverine Moist Low Willow-Sedge Meadow	Moist Low Shrub	Fdoa/Dt/Slows	Fdoi/Phl/Slows
		Fdoa/N/Slows	Fdoi/Pllh/Slows
		Fdoa/Pd/Slows	Fdoi/Pllh/Slows/Ngfd*
		Fdoi/N/Slows	Fdoi/Plll/Slows
		Fdoi/Pd/Slows	Fdoi/Pm/Slows
		Fdoi/Pd/Slows/Ngfd*	Fdri/N/Slows
Riverine Moist Sedge-Shrub Meadow	Moist Sedge-Shrub Meadow	Fdoi/Pd/Hgmss	Fdoi/Pm/Hgmss
		Fdoi/Phl/Hgmss	Ltdn/N/Hgmss
Riverine Moist Tall Willow Shrub	Moist Tall Shrub	Fdoa/N/Stow	Fdri/N/Stow
Riverine Sedge Marsh	Sedge Marsh	Fdoi/N/Hgwfs	Wldcrh/W/Hgwfs

Appendix A. Continued.

Map ecotype	Wildlife Habitat	ITU Code*	
Riverine Wet Sedge Meadow	Nonpatterned Wet Meadow	Fdoa/N/Hgwst	Fdoi/Pd/Hgwst/Ngt
		Fdoa/Pd/Hgwst	Fdra/N/Hgwst
		Fdoi/N/Hgwst	Fdri/N/Hgwst
		Fdoi/N/Hgwst/Ngt	Ltdn/N/Hgwst
		Fdoi/Pd/Hgwst	
	Patterned Wet Meadow	Fdoi/Plhh/Hgwst	Fdoi/Plll/Hgwst/Ngt
		Fdoi/Plhl/Hgwst	Fdoi/Pm/Hgwst
		Fdoi/Pllh/Hgwst	Fdoi/Pm/Hgwst/Ngt
		Fdoi/Plll/Hgwst	
Riverine Wet Sedge-Willow Meadow	Nonpatterned Wet Meadow	Fdoa/N/Hgwswt	Fdoi/Pd/Hgwswt
		Fdoa/Pd/Hgwswt	Fdoi/Pd/Hgwswt/Ngt
		Fdoa/Pd/Hgwswt/Ngt	Fdri/N/Hgwswt
		Fdoi/N/Hgwswt	Ltdn/N/Hgwswt
	Patterned Wet Meadow	Fdoi/Dt/Hgwswt	Fdoi/Pllh/Hgwswt
		Fdoi/Plhh/Hgwswt	Fdoi/Plll/Hgwswt
		Fdoi/Plhh/Hgwswt/Ngfd*	Fdoi/Pm/Hgwswt
		Fdoi/Plhl/Hgwswt	
Tidal River	River or Stream	Wert/W/Wb	
Upland Dry Barrens	Barrens	Esda/Ek/Bpv	Esda/En/Bpv/Nge*
Upland Dry Dryas Dwarf Shrub	Dry Dwarf Shrub	Cs/Sb/Sddt	Esi/Phl/Sddt
		Esdi/Ek/Sddt	Fto/Phl/Sddt
		Esdi/Es/Sddt	Fto/Sb/Sddt
		Esi/Pd/Sddt	
Upland Dry Tall Willow Shrub	Dry Tall Shrub	Esa/N/Stow	
Upland Moist Cassiope Dwarf Shrub	Moist Dwarf Shrub	Fto/Sb/Sdec	
Upland Moist Low Willow Shrub	Moist Low Shrub	Cs/N/Slow	Esdi/N/Slow
		Esda/Ek/Slow	Esi/Es/Slow
		Esda/Es/Slow	Esi/N/Slcw
		Esda/N/Slcw	Esi/N/Slow
		Esda/N/Slow	Esi/Pd/Slow
		Esdi/Ek/Slow	Esi/Pm/Slow
		Esdi/Es/Slcw	Fto/Sb/Slcw
		Esdi/Es/Slow	Fto/Sb/Slow
		Esdi/N/Slcw	Ltim/Sb/Slcw
Upland Moist Tussock Meadow	Moist Tussock Tundra	Fdob/Phl/Hgmt	Fto/Pm/Hgmt
		Fdob/Phl/Hgmt/Ngt	Fto/Tm/Hgmt
		Fdob/Pm/Hgmt	Ftr/Tm/Hgmt
		Fdob/Tm/Hgmt	Ltic/Phh/Hgmt
		Fto/Phh/Hgmt	Ltic/Phl/Hgmt
		Fto/Phl/Hgmt	Ltic/Pm/Hgmt

*Asterisk indicates Map Ecotype or ITU Code that was not present in baseline map (Wells et al. 2014)

Appendix B. Difference in vascular and non-vascular species richness between years by plot ecotype and study area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

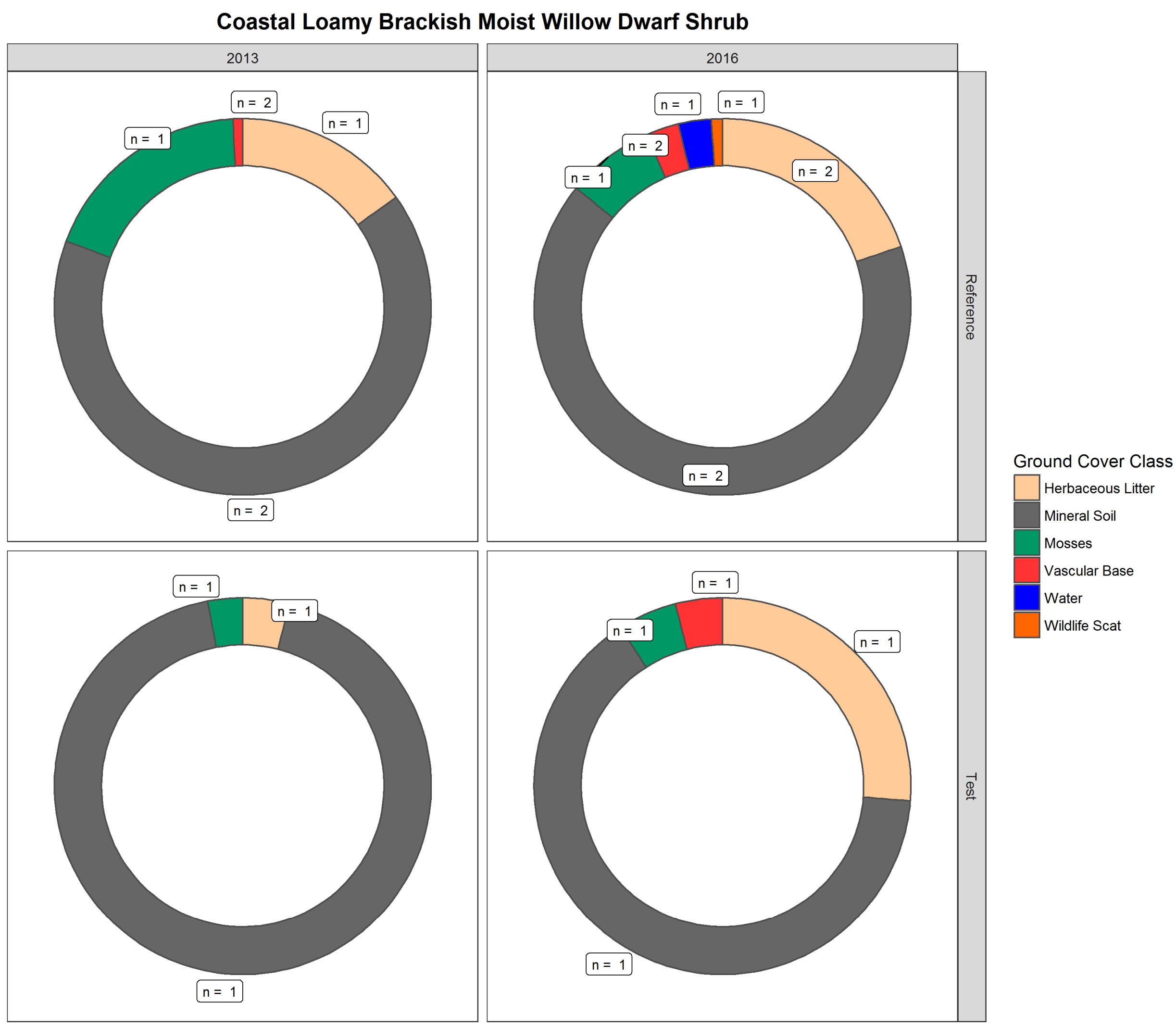
Plot Ecotype	Study Area	Vascularity	2013 Species Richness	2013 St. Dev.	2013 Sample Size	2016 Species Richness	2016 St. Dev.	2016 Sample Size	Species Richness Diff.
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	Non-Vascular	2		1	2		1	0
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	Vascular	11	4	2	11	7	2	0
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Test	Vascular	16		1	10		1	-6
Coastal Sandy Moist Brackish Barrens	Reference	Vascular	5	5	5	4	4	3	-1
Coastal Sandy Moist Brackish Barrens	Test	Vascular	2	1	3	2	1	4	0
Lowland Lake	Test	Vascular	1		1	1	0	2	0
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	Non-Vascular	4	3	12	6	2	12	2
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	Vascular	13	3	13	11	4	13	-2
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Test	Non-Vascular	5	2	13	5	3	13	0
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Test	Vascular	12	3	13	14	3	13	2
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Non-Vascular	5		1	7		1	2
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Vascular	16		1	19		1	3
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	Non-Vascular	8	3	3	6	2	3	-2
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	Vascular	15	2	3	14	2	3	-1
Riverine Loamy Alkaline Moist Low Willow Shrub	Reference	Non-Vascular	4	2	8	3	2	8	-1
Riverine Loamy Alkaline Moist Low Willow Shrub	Reference	Vascular	17	2	8	17	2	8	0
Riverine Loamy Alkaline Moist Low Willow Shrub	Test	Non-Vascular	2	1	7	4	3	7	2

Appendix B. Continued.

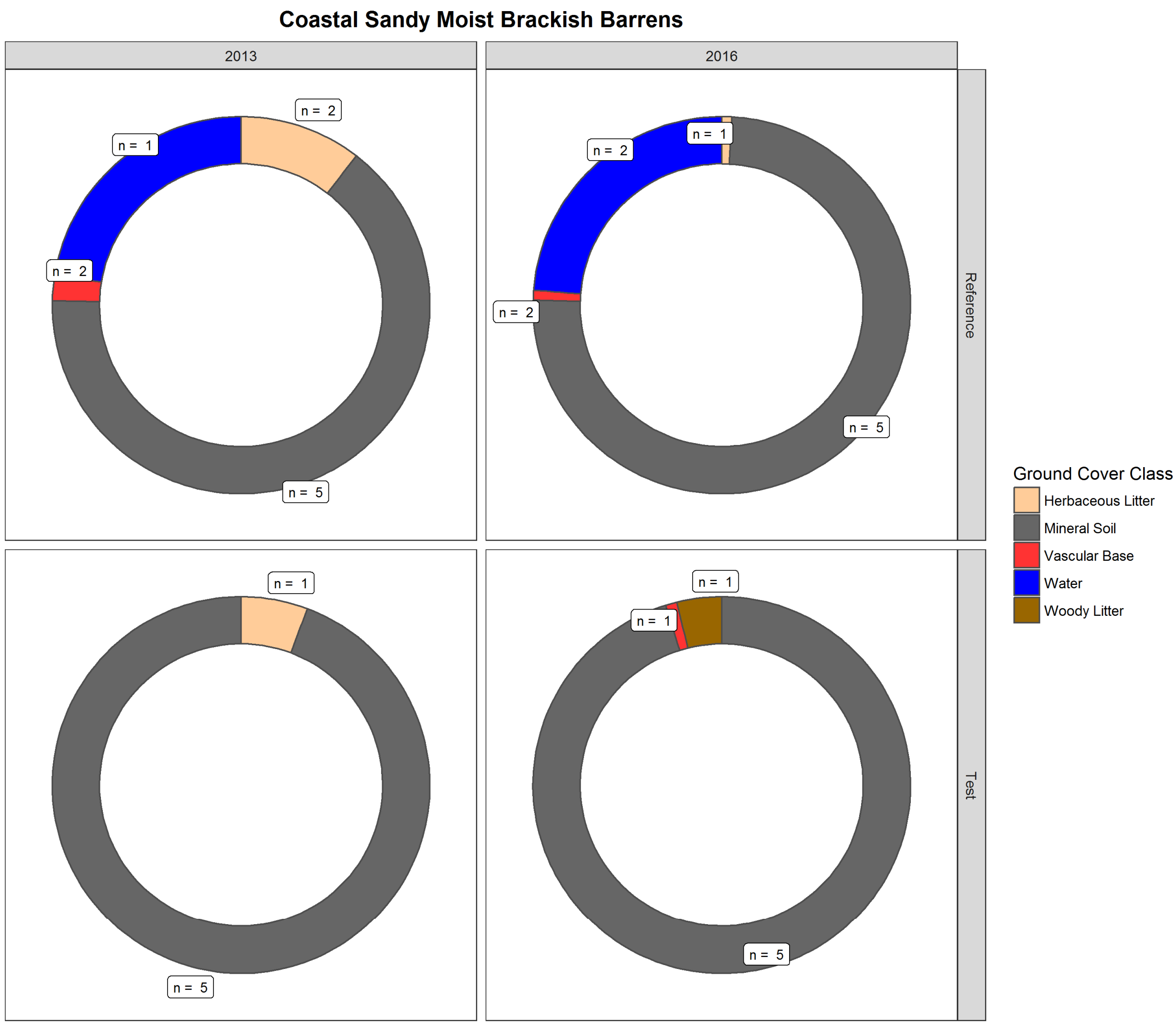
Plot Ecotype	Study Area	Vascularity	2013 Species Richness	2013 St. Dev.	2013 Sample Size	2016 Species Richness	2016 St. Dev.	2016 Sample Size	Species Richness Diff.
Riverine Loamy Alkaline Moist Low Willow Shrub	Test	Vascular	23	5	7	21	6	7	-2
Riverine Loamy Alkaline Moist Mixed Herb	Reference	Vascular	21		1	19		1	-2
Riverine Loamy Alkaline Moist Mixed Herb	Test	Vascular	19	2	2	16	1	2	-3
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	Non-Vascular	1	0	2	3	1	2	2
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	Vascular	26	1	2	30	4	2	4
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	Non-Vascular	5	2	7	4	2	7	-1
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	Vascular	17	4	8	15	5	8	-2
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Test	Non-Vascular	6	4	8	6	2	8	0
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Test	Vascular	19	6	8	19	5	8	0
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	Non-Vascular	15	8	2	11	2	2	-4
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	Vascular	24	5	2	25	6	2	1
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Test	Non-Vascular	4	3	5	5	3	5	1
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Test	Vascular	25	4	5	25	5	5	0
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Reference	Non-Vascular	7	2	8	5	2	8	-2
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Reference	Vascular	17	5	8	17	2	8	0

Appendix B. Continued.

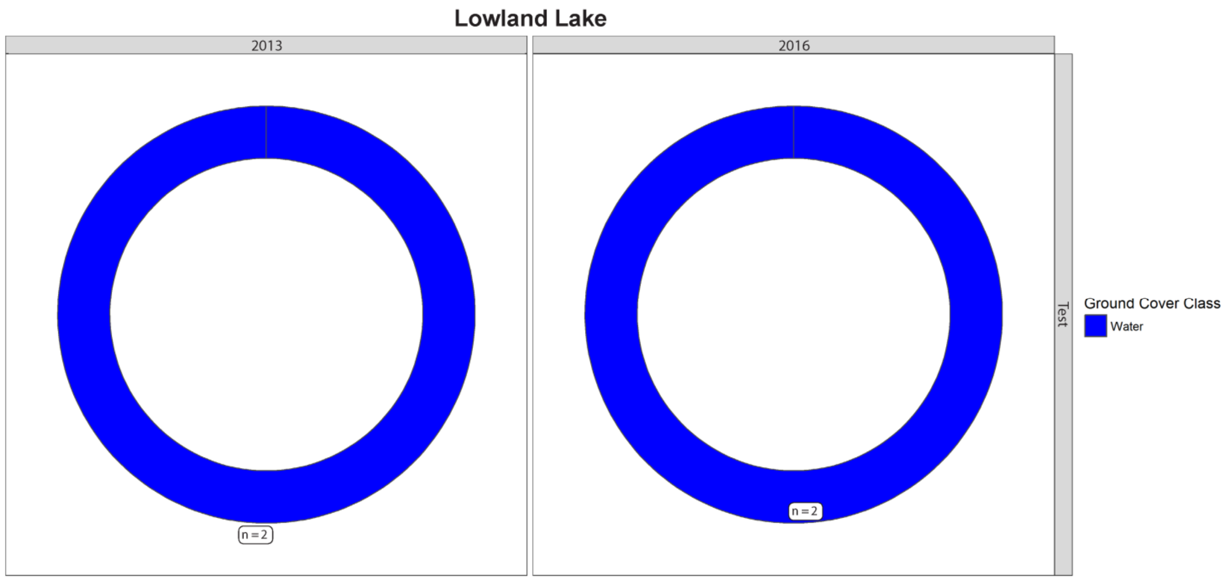
Plot Ecotype	Study Area	Vascularity	2013 Species Richness	2013 St. Dev.	2013 Sample Size	2016 Species Richness	2016 St. Dev.	2016 Sample Size	Species Richness Diff.
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Test	Non-Vascular	5	3	27	5	2	29	0
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Test	Vascular	15	4	29	15	5	29	0
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Non-Vascular	8	3	16	6	3	16	-2
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Vascular	21	4	16	20	5	16	-1
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	Non-Vascular	6	3	18	6	4	19	0
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	Vascular	19	3	19	18	6	19	-1
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	Non-Vascular	3		1	17		1	14
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	Vascular	33		1	35		1	2
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Test	Non-Vascular	10	1	2	5	6	2	-5
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Test	Vascular	26	5	2	25	1	2	-1
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	Non-Vascular	5		1	4		1	-1
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	Vascular	13		1	14		1	1
Upland Sandy Alkaline Moist Low Willow Shrub	Test	Non-Vascular	2	1	2	4		1	2
Upland Sandy Alkaline Moist Low Willow Shrub	Test	Vascular	20	6	3	17	6	3	-3



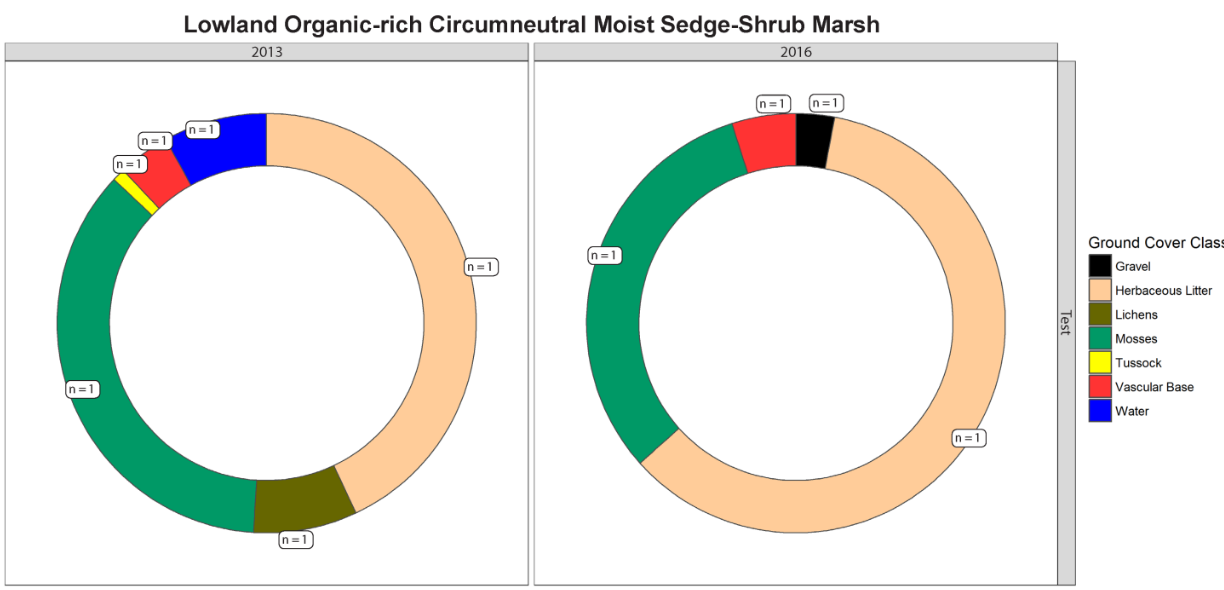
Appendix C1. Ring charts displaying the proportion of average total ground cover for the plot ecotype Coastal Loamy Brackish Moist Willow Dwarf Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



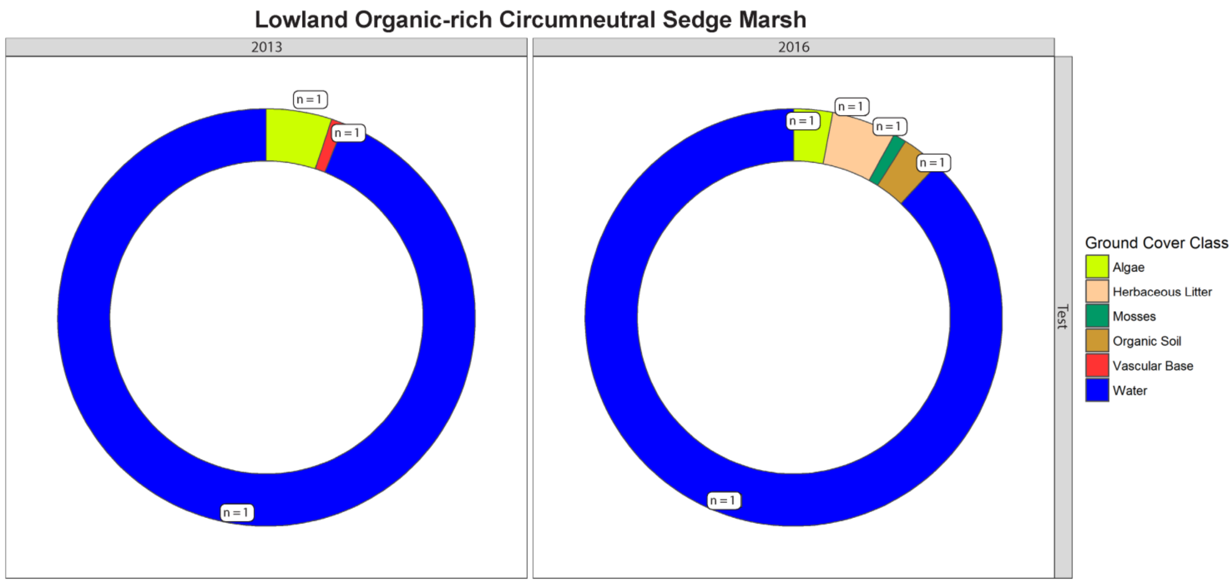
Appendix C2. Ring charts displaying the proportion of average total ground cover for the plot ecotype Coastal Sandy Moist Brackish Barrens by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



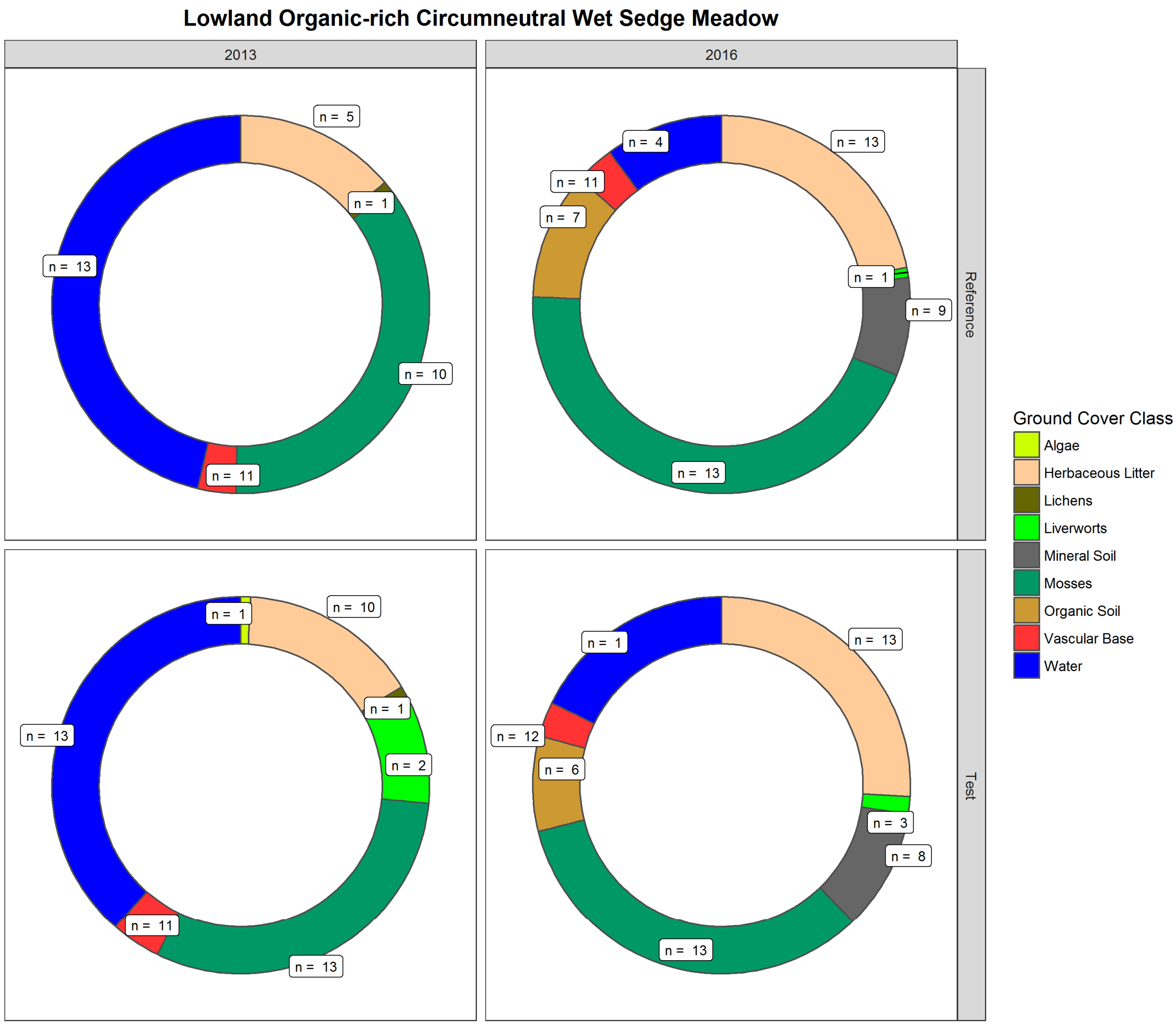
Appendix C3. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Lake by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



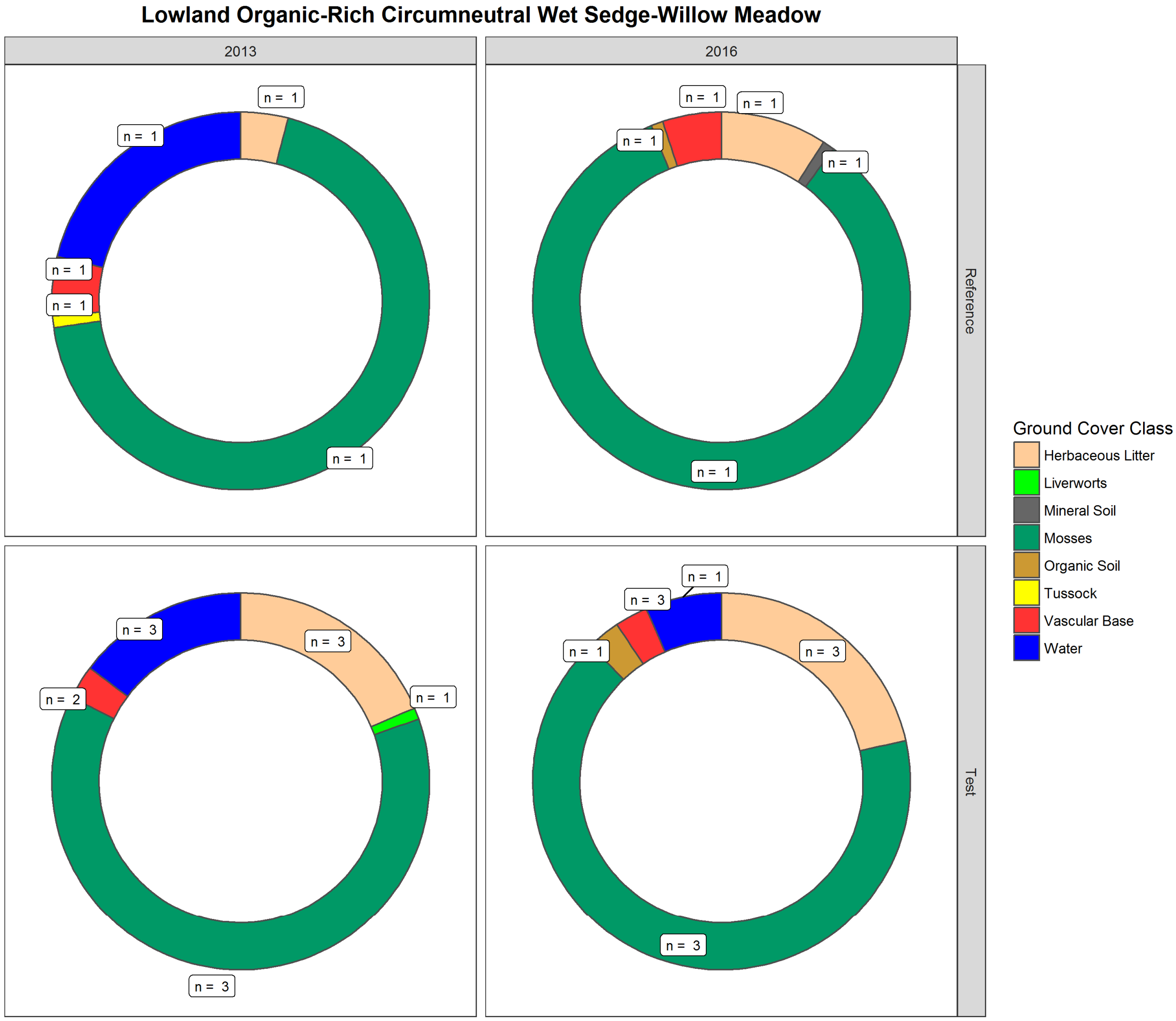
Appendix C4. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix C5. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-rich Circumneutral Sedge Marsh by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



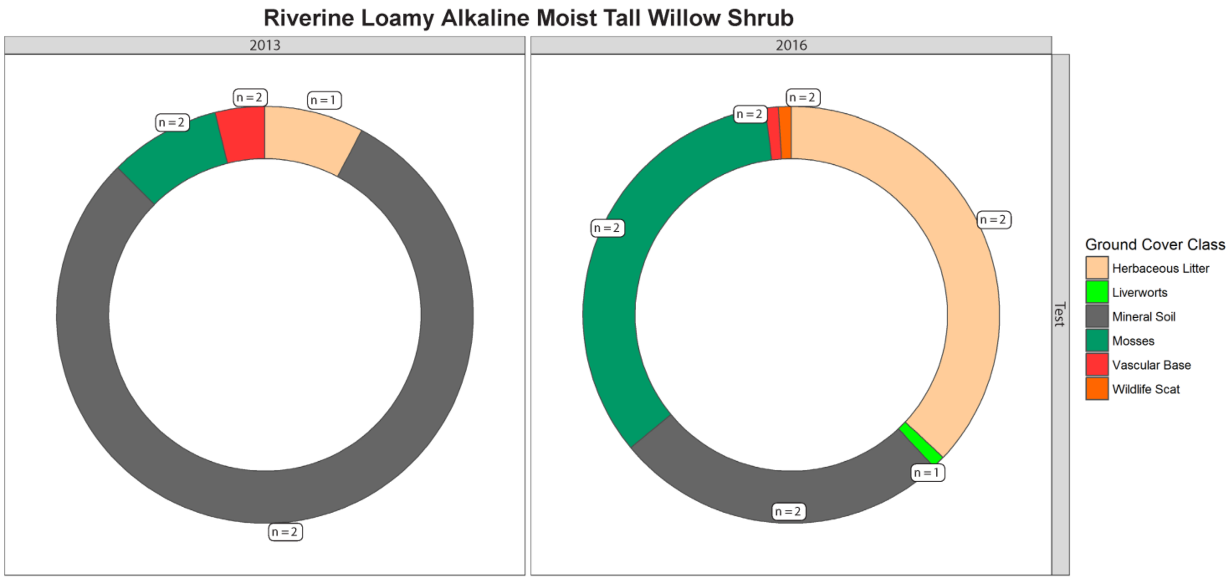
Appendix C6. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-rich Circumneutral Wet Sedge Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



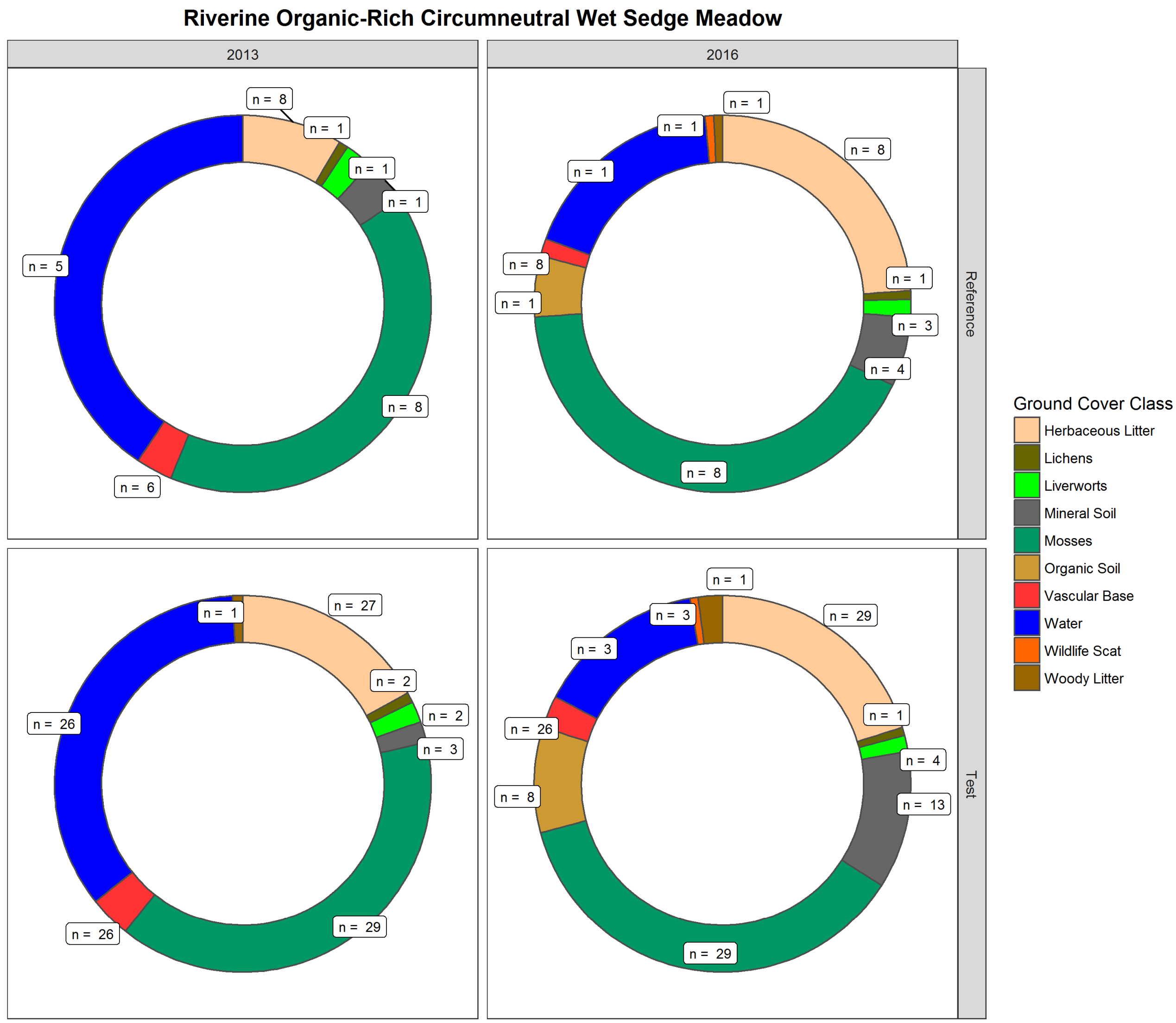
Appendix C7. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-Rich Circumneutral Wet Sedge-Willow Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Appendix C8. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Mixed Herb by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

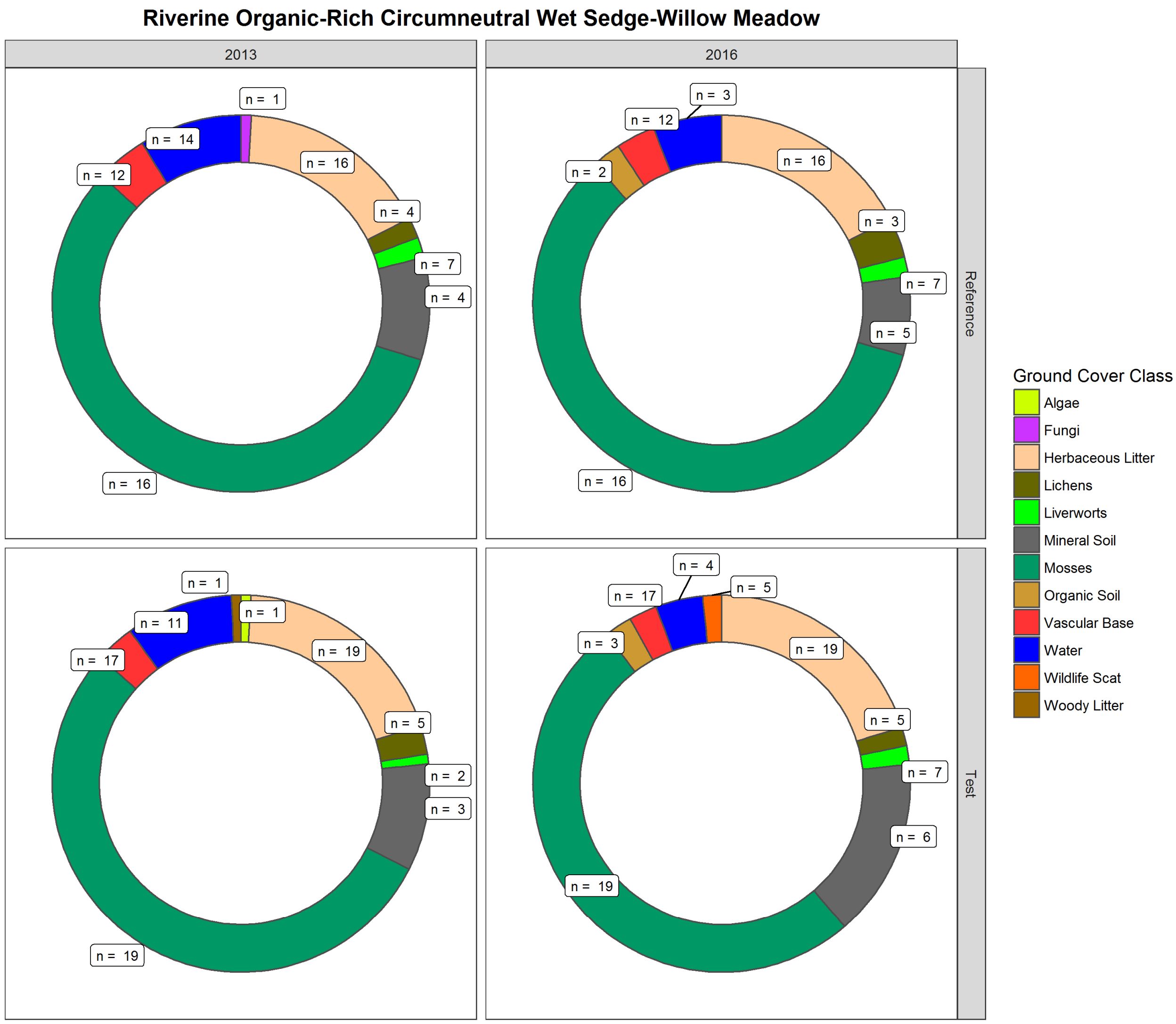
Appendix C9. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Low Willow Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



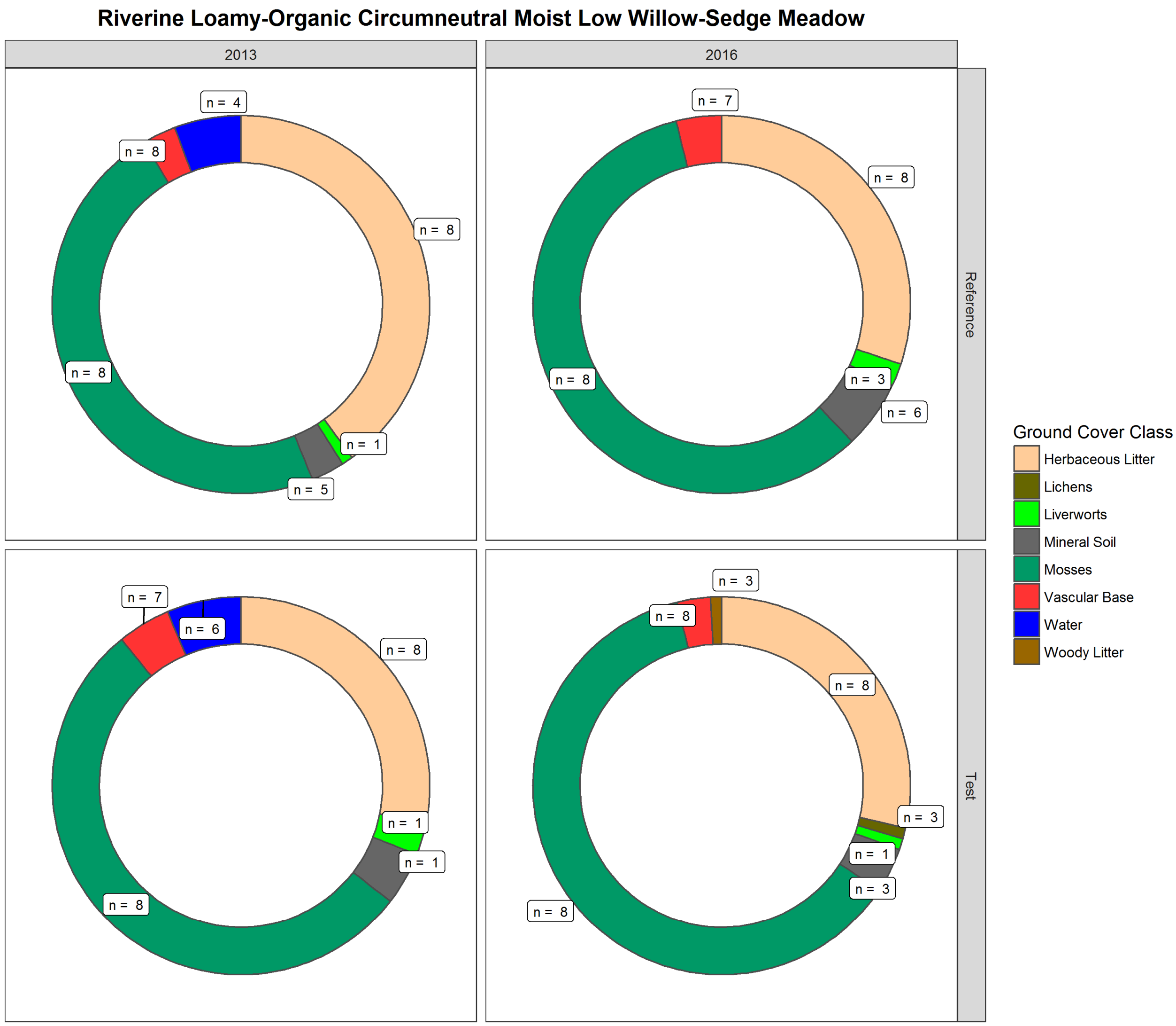
Appendix C10. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Tall Willow Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



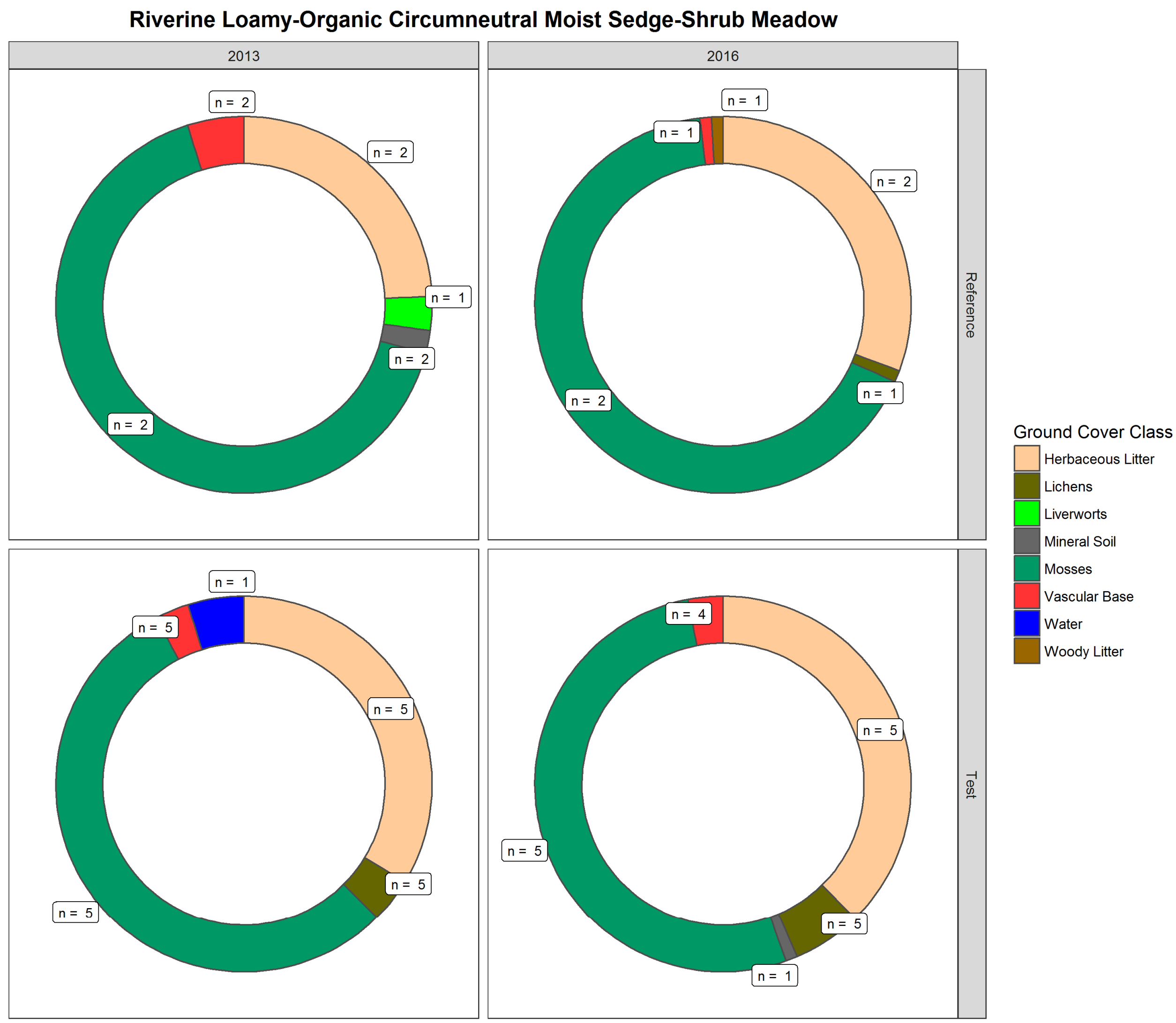
Appendix C11. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Organic-Rich Circumneutral Wet Sedge Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



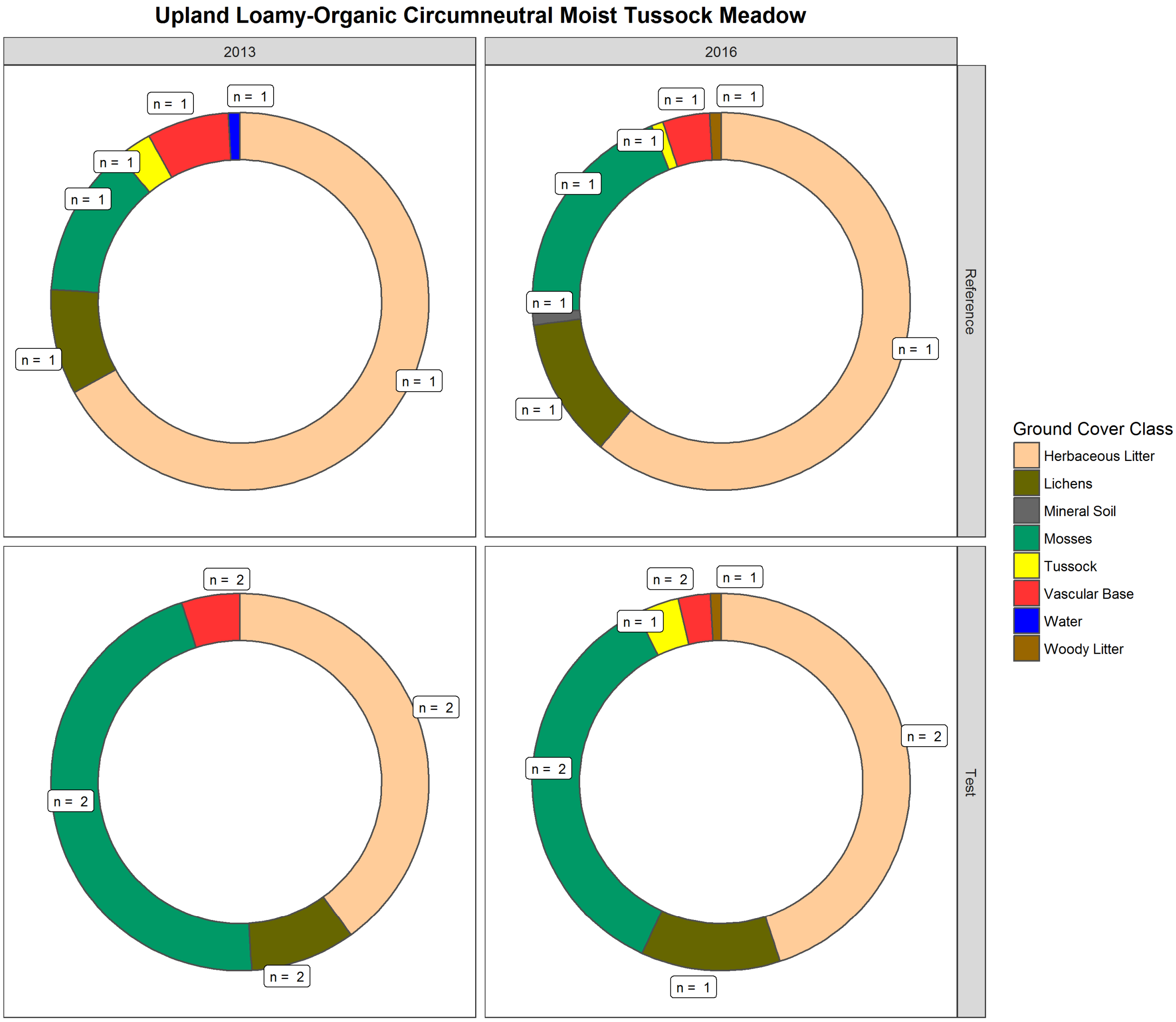
Appendix C12. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Organic-Rich Circumneutral Wet Sedge-Willow Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



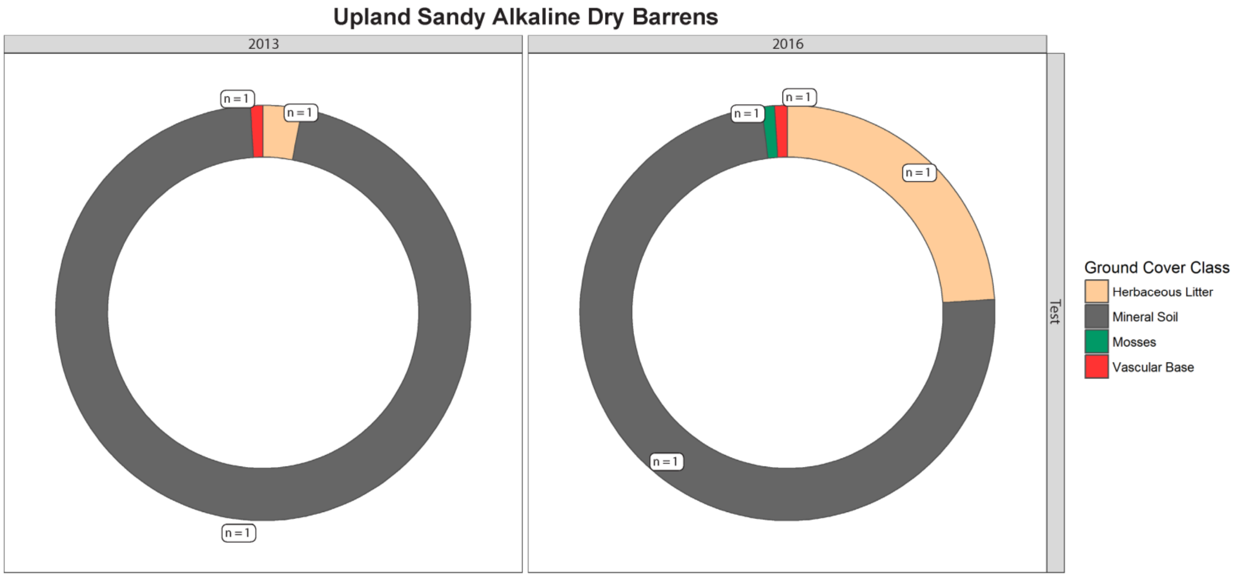
Appendix C13. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix C14. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix C15. Ring charts displaying the proportion of average total ground cover for the plot ecotype Upland Loamy-Organic Circumneutral Moist Tussock Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix C16. Ring charts displaying the proportion of average total ground cover for the plot ecotype Upland Sandy Alkaline Dry Barrens by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Appendix C17. Ring charts displaying the proportion of average total ground cover for the plot ecotype Upland Sandy Alkaline Moist Low Willow Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Appendix D. Detailed ground cover summary statistics by plot ecotype, sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	2013	Herbaceous Litter	18.4	18.4	18	1
		2013	Mineral Soil	57.9	98.7	78	2
		2013	Mosses	22.4	22.4	22	1
		2013	Vascular Base	1.3	1.3	1	2
		2016	Herbaceous Litter	10.5	31.6	21	2
		2016	Mineral Soil	54	85.5	70	2
		2016	Mosses	7.9	7.9	8	1
		2016	Vascular Base	1.3	5.3	3	2
		2016	Water	2.6	2.6	3	1
		2016	Wildlife Scat	1.3	1.3	1	1
	Test	2013	Herbaceous Litter	4	4	4	1
		2013	Mineral Soil	93.4	93.4	93	1
		2013	Mosses	2.6	2.6	3	1
		2016	Herbaceous Litter	26.3	26.3	26	1
		2016	Mineral Soil	64.5	64.5	64	1
		2016	Mosses	5.3	5.3	5	1
		2016	Vascular Base	4	4	4	1
Coastal Sandy Moist Brackish Barrens	Reference	2013	Herbaceous Litter	6.6	21.3	14	2
		2013	Mineral Soil	68.4	100	87	5
		2013	Vascular Base	1.3	5.3	3	2
		2013	Water	30.3	30.3	30	1
		2016	Herbaceous Litter	1.3	1.3	1	1
		2016	Mineral Soil	60	100	88	5
		2016	Vascular Base	1.3	1.3	1	2
		2016	Water	17.1	38.7	28	2

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Coastal Sandy Moist Brackish Barrens (continued)	Test	2013	Herbaceous Litter	6.3	6.3	6	1
		2013	Mineral Soil	93.8	100	99	5
		2016	Mineral Soil	96.1	100	99	5
		2016	Vascular Base	1.3	1.3	1	1
		2016	Woody Litter	4	4	4	1
Lowland Lake	Test	2013	Water	100	100	100	2
	Test	2016	Water	100	100	100	2
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	Test	2013	Herbaceous Litter	43.4	43.4	43	1
		2013	Lichens	7.9	7.9	8	1
		2013	Mosses	35.5	35.5	36	1
		2013	Tussock	1.3	1.3	1	1
		2013	Vascular Base	4	4	4	1
		2013	Water	7.9	7.9	8	1
		2016	Gravel	2.6	2.6	3	1
		2016	Herbaceous Litter	60.5	60.5	61	1
		2016	Mosses	31.6	31.6	32	1
		2016	Vascular Base	5.3	5.3	5	1
Lowland Organic-rich Circumneutral Sedge Marsh	Test	2013	Algae	5.3	5.3	5	1
		2013	Vascular Base	1.3	1.3	1	1
		2013	Water	93.3	93.3	93	1
		2016	Algae	2.6	2.6	3	1
		2016	Herbaceous Litter	5.3	5.3	5	1
		2016	Mosses	1.3	1.3	1	1

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Lowland Organic-rich Circumneutral Sedge Marsh (continued)	Test	2016	Organic Soil	2.6	2.6	3	1
		2016	Water	88.2	88.2	88	1
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	2013	Herbaceous Litter	13.3	23.7	17	5
		2013	Lichens	1.3	1.3	1	1
		2013	Mosses	1.3	71.1	44	10
		2013	Vascular Base	1.3	9.2	4	11
		2013	Water	13.2	100	57	13
		2016	Herbaceous Litter	9.2	63.2	26	13
		2016	Liverworts	1.3	1.3	1	1
		2016	Mineral Soil	1.3	42.1	10	9
		2016	Mosses	6.6	88.2	53	13
		2016	Organic Soil	1.3	27.6	13	7
		2016	Vascular Base	1.3	7.9	4	11
		2016	Water	1.3	30.3	12	4
	Test	2013	Algae	1.3	1.3	1	1
		2013	Herbaceous Litter	2.6	40.8	18	10
		2013	Lichens	1.3	1.3	1	1
		2013	Liverworts	1.3	21.1	11	2
		2013	Mosses	10.5	67.1	36	13
		2013	Vascular Base	1.3	13.3	5	11
		2013	Water	2.6	71.1	45	13
		2016	Herbaceous Litter	9.2	77.6	35	13
		2016	Liverworts	1.3	2.6	2	3
		2016	Mineral Soil	1.3	30.3	14	8
		2016	Mosses	19.7	88.2	45	13
		2016	Organic Soil	2.6	21.1	11	6

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Lowland Organic-rich Circumneutral Wet Sedge Meadow (continued)	Test	2016	Vascular Base	1.3	6.6	4	12
		2016	Water	23.7	23.7	24	1
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Herbaceous Litter	4	4	4	1
		2013	Mosses	68.4	68.4	68	1
		2013	Tussock	1.3	1.3	1	1
		2013	Vascular Base	5.3	5.3	5	1
		2013	Water	21.1	21.1	21	1
		2016	Herbaceous Litter	9.2	9.2	9	1
		2016	Mineral Soil	1.3	1.3	1	1
		2016	Mosses	82.9	82.9	83	1
		2016	Organic Soil	1.3	1.3	1	1
		2016	Vascular Base	5.3	5.3	5	1
	Test	2013	Herbaceous Litter	6.6	30.3	19	3
		2013	Liverworts	1.3	1.3	1	1
		2013	Mosses	54	72.4	64	3
		2013	Vascular Base	1.3	4	3	2
		2013	Water	11.8	19.7	15	3
		2016	Herbaceous Litter	9.2	34.2	23	3
		2016	Mosses	63.2	84.2	71	3
		2016	Organic Soil	2.6	2.6	3	1
		2016	Vascular Base	2.6	4	3	3
		2016	Water	6.6	6.6	7	1
Outlier	Reference	2013	Herbaceous Litter	7.9	84.2	47	6
		2013	Lichens	2.6	2.6	3	1
		2013	Mineral Soil	1.3	77.6	21	4

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Outlier (continued)	Reference	2013	Mosses	6.6	75	34	6
		2013	Vascular Base	1.3	6.6	4	6
		2013	Water	2.6	2.6	3	1
		2013	Woody Litter	1.3	1.3	1	1
		2016	Herbaceous Litter	6.6	75	38	6
		2016	Lichens	1.3	1.3	1	1
		2016	Mineral Soil	1.3	72.4	35	3
		2016	Mosses	5.3	90.8	40	6
		2016	Vascular Base	2.6	5.3	4	4
		2016	Water	1.3	1.3	1	1
		2016	Wildlife Scat	1.3	1.3	1	2
		2016	Woody Litter	1.3	1.3	1	2
	Test	2013	Herbaceous Litter	12	29	18	3
		2013	Lichens	7.9	7.9	8	1
		2013	Mineral Soil	22.7	71.1	47	2
		2013	Mosses	4	77.6	41	2
		2013	Vascular Base	4	4	4	1
		2013	Water	57.3	57.3	57	1
		2016	Herbaceous Litter	15.8	26.3	20	3
		2016	Lichens	4	4	4	1
		2016	Mineral Soil	40.8	40.8	41	2
		2016	Mosses	13.2	73.7	39	3
		2016	Vascular Base	2.6	6.6	5	2
		2016	Water	29	29	29	1
Riverine Loamy Alkaline Moist Low Willow Shrub	Reference	2013	Herbaceous Litter	6.6	36.8	24	8
		2013	Liverworts	6.6	6.6	7	1

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Loamy Alkaline Moist Low Willow Shrub (continued)	Reference	2013	Mineral Soil	1.3	84.2	29	8
		2013	Mosses	5.3	77.6	44	8
		2013	Vascular Base	1.3	5.3	2	8
		2013	Water	1.3	1.3	1	1
		2013	Woody Litter	1.3	1.3	1	1
		2016	Herbaceous Litter	18.4	64.5	34	8
		2016	Liverworts	1.3	6.6	4	3
		2016	Mineral Soil	2.6	50	22	8
		2016	Mosses	6.6	68.4	39	8
		2016	Vascular Base	1.3	4	3	7
		2016	Wildlife Scat	1.3	1.3	1	1
		2016	Woody Litter	1.3	4	3	3
	Test	2013	Herbaceous Litter	9.2	80.3	43	7
		2013	Lichens	2.6	2.6	3	1
		2013	Mineral Soil	1.3	71.1	17	5
		2013	Mosses	13.2	75	41	7
		2013	Vascular Base	1.3	5.3	3	7
		2013	Woody Litter	2.6	5.3	4	2
		2016	Herbaceous Litter	11.8	69.7	40	7
		2016	Lichens	1.3	1.3	1	1
		2016	Mineral Soil	1.3	64.5	28	4
		2016	Mosses	11.8	72.4	42	7
		2016	Vascular Base	1.3	4	2	5
		2016	Woody Litter	1.3	1.3	1	2
Riverine Loamy Alkaline Moist Mixed Herb	Reference	2013	Mineral Soil	93.4	93.4	93	1
			Vascular Base	6.6	6.6	7	1

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Loamy Alkaline Moist Mixed Herb	Reference	2016	Herbaceous Litter	29	29	29	1
		2016	Mineral Soil	71.1	71.1	71	1
	Test	2013	Herbaceous Litter	6.6	22.4	14	2
		2013	Mineral Soil	71.1	89.5	80	2
		2013	Mosses	1.3	1.3	1	1
		2013	Vascular Base	4	4	4	2
		2013	Woody Litter	1.3	1.3	1	1
		2016	Herbaceous Litter	10.5	22.4	16	2
		2016	Mineral Soil	75	88.2	82	2
		2016	Mosses	1.3	1.3	1	1
		2016	Vascular Base	2.6	2.6	3	1
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	2013	Herbaceous Litter	7.9	7.9	8	1
		2013	Mineral Soil	72.4	93.3	83	2
		2013	Mosses	5.3	13.2	9	2
		2013	Vascular Base	1.3	6.6	4	2
		2016	Herbaceous Litter	36.8	36.8	37	2
		2016	Liverworts	1.3	1.3	1	1
		2016	Mineral Soil	25	27.6	26	2
		2016	Mosses	31.6	35.5	34	2
		2016	Vascular Base	1.3	1.3	1	2
		2016	Wildlife Scat	1.3	1.3	1	2
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	2013	Herbaceous Litter	13.2	84.2	42	8
		2013	Liverworts	1.3	1.3	1	1
		2013	Mineral Soil	1	5.3	3	5
		2013	Mosses	10.5	75	50	8

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	2013	Vascular Base	1.3	5.3	3	8
(continued)		2013	Water	1.3	18.4	6	4
		2016	Herbaceous Litter	5.3	82.9	31	8
		2016	Liverworts	1.3	2.6	2	3
		2016	Mineral Soil	1.3	11.8	6	6
		2016	Mosses	5.3	88.2	60	8
		2016	Vascular Base	1.3	6.6	4	7
	Test	2013	Herbaceous Litter	9.2	65.8	31	8
		2013	Liverworts	2.6	2.6	3	1
		2013	Mineral Soil	5.3	5.3	5	1
		2013	Mosses	25	74.7	59	8
		2013	Vascular Base	1.3	8	5	7
		2013	Water	1.3	22.4	7	6
		2016	Herbaceous Litter	9.2	57.9	30	8
		2016	Lichens	1.3	1.3	1	3
		2016	Liverworts	1.3	1.3	1	1
		2016	Mineral Soil	1.3	7.9	4	3
		2016	Mosses	34.2	82.9	65	8
		2016	Vascular Base	1.3	6.6	3	8
		2016	Woody Litter	1.3	1.3	1	3
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	2013	Herbaceous Litter	22.4	26.7	25	2
		2013	Liverworts	2.6	2.6	3	1
		2013	Mineral Soil	1.3	2.7	2	2
		2013	Mosses	65.3	69.7	68	2
		2013	Vascular Base	4	5.3	5	2
		2016	Herbaceous Litter	23.7	38.2	31	2

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	2016	Lichens	1.3	1.3	1	1
(continued)		2016	Mosses	57.9	76.3	67	2
		2016	Vascular Base	1.3	1.3	1	1
		2016	Woody Litter	1.3	1.3	1	1
	Test	2013	Herbaceous Litter	23	50	35	5
		2013	Lichens	1.3	8.1	4	5
		2013	Mosses	42.1	67.6	57	5
		2013	Vascular Base	1.3	6.6	3	5
		2013	Water	5.3	5.3	5	1
		2016	Herbaceous Litter	14.5	57.9	38	5
		2016	Lichens	1.3	10.5	6	5
		2016	Mineral Soil	1.3	1.3	1	1
		2016	Mosses	32.9	71.1	53	5
		2016	Vascular Base	1.3	6.6	3	4
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Reference	2013	Herbaceous Litter	2.6	34.3	11	8
		2013	Lichens	1.3	1.3	1	1
		2013	Liverworts	2.7	2.7	3	1
		2013	Mineral Soil	5.3	5.3	5	1
		2013	Mosses	5.3	93.4	52	8
		2013	Vascular Base	1.3	10.5	4	6
		2013	Water	1.4	89.3	52	5
		2016	Herbaceous Litter	2.6	65.8	32	8
		2016	Lichens	1.3	1.3	1	1
		2016	Liverworts	1.3	2.6	2	3
		2016	Mineral Soil	2.6	13.2	8	4
		2016	Mosses	7.9	92.1	56	8

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Organic-rich Circumneutral Wet Sedge Meadow (continued)	Reference	2016	Organic Soil	6.6	6.6	7	1
		2016	Vascular Base	1.3	4	2	8
		2016	Water	23.7	23.7	24	1
		2016	Wildlife Scat	1.3	1.3	1	1
		2016	Woody Litter	1.3	1.3	1	1
	Test	2013	Herbaceous Litter	1.3	46.1	19	27
		2013	Lichens	1.3	1.3	1	2
		2013	Liverworts	1.3	2.6	2	2
		2013	Mineral Soil	1.3	2.6	2	3
		2013	Mosses	1.3	89.3	44	29
		2013	Vascular Base	1.3	14.5	4	26
		2013	Water	1.3	80	39	26
		2013	Woody Litter	1.3	1.3	1	1
		2016	Herbaceous Litter	1.3	72.4	29	29
		2016	Lichens	1.3	1.3	1	1
		2016	Liverworts	1.3	2.6	2	4
		2016	Mineral Soil	1.3	80.3	17	13
		2016	Mosses	10.5	89.5	53	29
		2016	Organic Soil	1.3	54	13	8
		2016	Vascular Base	1.3	9.2	4	26
		2016	Water	2.6	54	21	3
		2016	Wildlife Scat	1.3	1.3	1	3
		2016	Woody Litter	2.6	2.6	3	1
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Fungi	1.3	1.3	1	1
		2013	Herbaceous Litter	5.3	52	19	16
		2013	Lichens	1.3	4	2	4

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Liverworts	1.3	4	2	7
(continued)		2013	Mineral Soil	1.3	27.6	10	4
		2013	Mosses	30.3	82.9	65	16
		2013	Vascular Base	1.3	14.5	5	12
		2013	Water	1.3	36.8	10	14
		2016	Herbaceous Litter	2.6	50	21	16
		2016	Lichens	1.3	9.2	4	3
		2016	Liverworts	1.3	5.3	2	7
		2016	Mineral Soil	2.6	29	8	5
		2016	Mosses	38.2	97.4	70	16
		2016	Organic Soil	1.3	4	3	2
		2016	Vascular Base	1.3	7.9	4	12
		2016	Water	1.3	19.7	7	3
	Test	2013	Algae	1.3	1.3	1	1
		2013	Herbaceous Litter	4	43.4	23	19
		2013	Lichens	1.3	5.3	3	5
		2013	Liverworts	1.3	1.3	1	2
		2013	Mineral Soil	1.3	27.6	11	3
		2013	Mosses	36.8	92.1	65	19
		2013	Vascular Base	1.3	5.3	4	17
		2013	Water	1.3	18.4	11	11
		2013	Woody Litter	1.3	1.3	1	1
		2016	Herbaceous Litter	4	43.4	25	19
		2016	Lichens	1.3	4	2	5
		2016	Liverworts	1.3	4	2	7
		2016	Mineral Soil	1.3	75	19	6
		2016	Mosses	17.1	85.5	63	19

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	2016	Organic Soil	1.3	4	3	3
(continued)		2016	Vascular Base	1.3	9.2	3	17
		2016	Water	1.3	13.2	5	4
		2016	Wildlife Scat	1.3	2.6	2	5
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	2013	Herbaceous Litter	67.1	67.1	67	1
		2013	Lichens	9.2	9.2	9	1
		2013	Mosses	13.2	13.2	13	1
		2013	Tussock	2.6	2.6	3	1
		2013	Vascular Base	6.6	6.6	7	1
		2013	Water	1.3	1.3	1	1
		2016	Herbaceous Litter	60.5	60.5	61	1
		2016	Lichens	11.8	11.8	12	1
		2016	Mineral Soil	1.3	1.3	1	1
		2016	Mosses	19.7	19.7	20	1
		2016	Tussock	1.3	1.3	1	1
		2016	Vascular Base	4	4	4	1
		2016	Woody Litter	1.3	1.3	1	1
	Test	2013	Herbaceous Litter	38.2	42.1	40	2
		2013	Lichens	4	14.5	9	2
		2013	Mosses	44.7	47.4	46	2
		2013	Vascular Base	2.6	6.6	5	2
		2016	Herbaceous Litter	40.8	56.6	49	2
		2016	Lichens	13.2	13.2	13	1
		2016	Mosses	35.5	43.4	39	2
		2016	Tussock	4	4	4	1
		2016	Vascular Base	2.6	2.6	3	2

Appendix D. Continued.

Plot Ecotype	Study Area	Sample Year	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	n
Upland Loamy-Organic Circumneutral Moist Tussock Meadow (continued)	Test	2016	Woody Litter	1.3	1.3	1	1
Upland Sandy Alkaline Dry Barrens	Test	2013	Herbaceous Litter	2.6	2.6	3	1
		2013	Mineral Soil	96.1	96.1	96	1
		2013	Vascular Base	1.3	1.3	1	1
		2016	Herbaceous Litter	23.7	23.7	24	1
		2016	Mineral Soil	73.7	73.7	74	1
		2016	Mosses	1.3	1.3	1	1
		2016	Vascular Base	1.3	1.3	1	1
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	2013	Herbaceous Litter	97.4	97.4	97	1
		2013	Mosses	1.3	1.3	1	1
		2013	Vascular Base	1.3	1.3	1	1
		2016	Herbaceous Litter	82.9	82.9	83	1
		2016	Mineral Soil	7.9	7.9	8	1
		2016	Mosses	9.2	9.2	9	1
	Test	2013	Herbaceous Litter	17.3	68.4	50	3
		2013	Mineral Soil	1.3	76	31	3
		2013	Mosses	5.3	27.6	17	3
		2013	Vascular Base	1.3	1.3	1	3
		2013	Water	1.3	1.3	1	1
		2016	Herbaceous Litter	15.8	64.5	46	3
		2016	Mineral Soil	5.3	77.6	35	3
		2016	Mosses	6.6	34.2	18	3
		2016	Vascular Base	1.3	1.3	1	1
		2016	Wildlife Scat	1.3	1.3	1	1
		2016	Woody Litter	1.3	1.3	1	1

Appendix E. Mean (± standard deviation) elevation (above British Petroleum Mean Level Sea Level, BPMSL), thaw depth (depth below ground), water table depth, surface organic thickness (cm), pH, and electrical conductivity (µS) for all plot ecotypes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016. Values of -999 indicate no data for a given attribute.

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	2013	Elevation (cm)	190	165	73	306	2
		2016		121	67	73	168	2
	Test	2013		187		187	187	1
		2016		188		188	188	1
	Reference	2013	Thaw Depth (cm)	64	9	57	70	2
		2016		66	11	58	73	2
	Test	2013		81		81	81	1
		2016		76		76	76	1
	Reference	2013	Surface Organic Thickness (cm)	0	0	0	0	2
		2016		0	0	0	0	2
	Test	2013		0		0	0	1
		2016		0		0	0	1
	Reference	2013	Water Table Depth (cm)	-34	14	-44	-24	2
		2016		-37	1	-38	-36	2
	Test	2013		-68		-68	-68	1
		2016		-999		-999	-999	1
	Reference	2013	Electrical Conductivity (um)	1770	184	1640	1900	2
		2016		2170	608	1740	2600	2
	Test	2013		500		500	500	1
		2016		510		510	510	1
	Reference	2013	pH	7.6	0.7	7.1	8.1	2
		2016		7	0.1	6.9	7.1	2
	Test	2013		7.3		7.3	7.3	1
		2016		7.8		7.8	7.8	1
Coastal Sandy Moist Brackish Barrens	Reference	2013	Elevation (cm)	102	44	56	151	5
		2016		90	57	39	156	5
	Test	2013		107	55	46	193	5
		2016		103	59	42	192	5
	Reference	2013	Thaw Depth (cm)	102	4	96	107	5
		2016		85	9	76	97	5
	Test	2013		103	9	93	114	5
		2016		92	17	77	112	5
	Reference	2013	Surface Organic Thickness (cm)	0	0	0	0	5
		2016		0	0	0	0	5
	Test	2013		0	0	0	0	5
		2016		0	0	0	0	5

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Coastal Sandy Moist Brackish Barrens (continued)	Reference	2013	Water Table Depth (cm)	-46	41	-90	-9	3
		2016		-12	7	-19	-6	3
	Test	2013		-30	22	-60	-8	4
		2016		-37	5	-40	-33	2
	Reference	2013	Electrical Conductivity (um)	2196	2677	500	6900	5
		2016		3004	4946	100	11800	5
	Test	2013		4644	7814	450	18600	5
		2016		498	245	230	790	4
	Reference	2013	pH	7.9	0.3	7.6	8.4	5
		2016		7.2	0.7	6.3	8	5
	Test	2013		7.3	0.4	6.6	7.6	5
		2016		7.4	0.5	6.7	8	5
Lowland Lake	Test	2013	Elevation (cm)	299	2	297	300	2
		2016		295	3	293	297	2
		2013	Thaw Depth (cm)	42	6	38	46	2
		2016		33	4	30	35	2
		2013	Surface Organic Thickness (cm)	0	0	0	0	2
		2016		0	0	0	0	2
		2013	Water Table Depth (cm)	23	3	21	25	2
		2016		15	7	10	20	2
		2013	Electrical Conductivity (um)	275	7	270	280	2
		2016		460	14	450	470	2
		2013	pH	7.9	0.2	7.7	8	2
		2016		8.4	0.1	8.3	8.4	2
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	Test	2013	Elevation (cm)	347		347	347	1
		2016		323		323	323	1
		2013	Thaw Depth (cm)	40		40	40	1
		2016		35		35	35	1
	Test	2013	Surface Organic Thickness (cm)	26		26	26	1
		2016		30		30	30	1
		2013	Water Table Depth (cm)	-16		-16	-16	1
		2016		-35		-35	-35	1
	Test	2013	Electrical Conductivity (um)	410		410	410	1
		2016		380		380	380	1
		2013	pH	6.2		6.2	6.2	1
		2016		5.9		5.9	5.9	1

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Lowland Organic-rich Circumneutral Sedge Marsh	Test	2013	Elevation (cm)	297		297	297	1
		2016		290		290	290	1
		2013	Thaw Depth (cm)	47		47	47	1
		2016		35		35	35	1
	Test	2013	Surface Organic Thickness (cm)	40		40	40	1
		2016		40		40	40	1
		2013	Water Table Depth (cm)	15		15	15	1
		2016		8		8	8	1
	Test	2013	Electrical Conductivity (um)	310		310	310	1
		2016		560		560	560	1
		2013	pH	7		7	7	1
		2016		6.6		6.6	6.6	1
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	2013	Elevation (cm)	327	81	216	430	13
		2016		319	76	218	414	13
	Test	2013		292	25	252	340	13
		2016		285	25	243	330	13
	Reference	2013	Thaw Depth (cm)	46	3	40	51	13
		2016		38	4	27	44	13
	Test	2013		46	5	35	52	13
		2016		38	3	33	44	13
	Reference	2013	Surface Organic Thickness (cm)	34	6.4	22	40	13
		2016		27.9	16.4	0	40	13
	Test	2013		31.8	4.4	27	40	13
		2016		31.1	5.6	25	40	13
	Reference	2013	Water Table Depth (cm)	1	4	-4	11	13
		2016		-8	5	-15	-1	13
	Test	2013		-1	4	-9	5	13
		2016		-9	4	-13	-2	13
	Reference	2013	Electrical Conductivity (um)	442	121	210	680	13
		2016		544	187	200	870	12
	Test	2013		357	82	250	530	13
		2016		558	172	310	850	13
	Reference	2013	pH	6.8	0.4	6.1	7.4	13
		2016		6.4	0.2	6	6.7	12
	Test	2013		6.5	0.3	6	7.1	13
		2016		6.3	0.2	6.1	6.8	13

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Lowland Organic-Rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Elevation (cm)	357		357	357	1
		2016		350		350	350	1
	Test	2013		270	15	258	287	3
		2016		260	20	243	282	3
	Reference	2013	Thaw Depth (cm)	41		41	41	1
		2016		37		37	37	1
	Test	2013		45	2	44	47	3
		2016		40	1	39	41	3
	Reference	2013	Surface Organic Thickness (cm)	32		32	32	1
		2016		28		28	28	1
	Test	2013		31	10.1	20	40	3
		2016		28.7	7.5	20	33	3
	Reference	2013	Water Table Depth (cm)	0		0	0	1
		2016		-6		-6	-6	1
	Test	2013		-4	4	-8	-1	3
		2016		-13	9	-20	-3	3
	Reference	2013	Electrical Conductivity (um)	400		400	400	1
		2016		360		360	360	1
	Test	2013		293	98	180	350	3
		2016		507	23	480	520	3
	Reference	2013	pH	6.9		6.9	6.9	1
		2016		6.5		6.5	6.5	1
	Test	2013		6.5	0.3	6.3	6.8	3
		2016		6.3	0.1	6.3	6.4	3
Riverine Loamy Alkaline Moist Low Willow Shrub	Reference	2013	Elevation (cm)	289	91	121	415	8
		2016		284	92	111	409	8
	Test	2013		260	43	204	347	7
		2016		256	44	205	347	7
	Reference	2013	Thaw Depth (cm)	59	18	40	92	8
		2016		56	15	36	77	8
	Test	2013		61	17	34	78	7
		2016		56	15	35	72	7
	Reference	2013	Surface Organic Thickness (cm)	2.1	4.8	0	14	8
		2016		1.9	5.3	0	15	8
	Test	2013		3.8	3.8	0	10	7
		2016		2.9	3.9	0	10	7

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Riverine Loamy Alkaline Moist Low Willow Shrub (continued)	Reference	2013	Water Table Depth (cm)	-29	18	-65	-13	6
		2016		-35	11	-42	-22	3
	Test	2013		-36	17	-60	-22	4
		2016		-40		-40	-40	1
	Reference	2013	Electrical Conductivity (um)	544	322	260	1250	8
		2016		447	150	190	670	7
	Test	2013		439	244	220	860	7
		2016		327	145	160	530	7
Riverine Loamy Alkaline Moist Low Willow Shrub (continued)	Reference	2013	pH	7.2	0.7	6	8	8
		2016		7.1	0.8	6	7.9	7
	Test	2013		7.3	1	5.6	8.1	7
		2016		7.3	0.8	5.5	8	7
Riverine Loamy Alkaline Moist Mixed Herb	Reference	2013	Elevation (cm)	258		258	258	1
		2016		247		247	247	1
	Test	2013		214	55	175	253	2
		2016		213	56	173	252	2
	Reference	2013	Thaw Depth (cm)	105		105	105	1
		2016		92		92	92	1
	Test	2013		86	8	80	91	2
		2016		84	11	76	92	2
	Reference	2013	Surface Organic Thickness (cm)	0		0	0	1
		2016		0		0	0	1
	Test	2013		0	0	0	0	2
		2016		0	0	0	0	2
	Reference	2013	Water Table Depth (cm)	-85		-85	-85	1
		2016		-999		-999	-999	1
	Test	2013		-999	0	-999	-999	2
		2016		-999	0	-999	-999	2
	Reference	2013	Electrical Conductivity (um)	580		580	580	1
		2016		730		730	730	1
	Test	2013		490	0	490	490	2
		2016		380	42	350	410	2
	Reference	2013	pH	8.1		8.1	8.1	1
		2016		7.9		7.9	7.9	1
	Test	2013		8.1	0.1	8	8.1	2
		2016		7.6	0.3	7.4	7.8	2

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	2013	Elevation (cm)	252	49	217	286	2
		2016		244	52	207	280	2
		2013	Thaw Depth (cm)	118	21	103	133	2
		2016		93	6	89	97	2
		2013	Surface Organic Thickness (cm)	0	0	0	0	2
		2016		0	0	0	0	2
		2013	Water Table Depth (cm)	-999	0	-999	-999	2
		2016		-999	0	-999	-999	2
		2013	Electrical Conductivity (um)	430	226	270	590	2
		2016		550	170	430	670	2
	Reference	2013	pH	8.2	0	8.2	8.2	2
		2016	pH	7.9	0.1	7.8	7.9	2
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	2013	Elevation (cm)	229	79	113	385	8
		2016		222	77	107	374	8
	Test	2013		296	46	239	381	8
		2016		292	46	238	378	8
	Reference	2013	Thaw Depth (cm)	50	19	5	67	8
		2016		50	10	32	67	8
	Test	2013		52	9	44	70	8
		2016		46	9	33	63	8
	Reference	2013	Surface Organic Thickness (cm)	6.5	7.1	0	19	8
		2016		4.3	5.3	0	16	8
	Test	2013		10.1	7.3	0	21	8
		2016		13.4	13.9	0	40	8
	Reference	2013	Water Table Depth (cm)	-12	14	-38	-2	8
		2016		-28	14	-43	-6	6
	Test	2013		-10	7	-20	-3	8
		2016		-24	9	-36	-16	4
	Reference	2013	Electrical Conductivity (um)	916	497	390	1840	8
		2016		684	377	260	1390	8
	Test	2013		519	597	180	1980	8
		2016		498	741	40	2300	8
	Reference	2013	pH	7	0.5	6.4	7.8	8
		2016		6.5	0.4	5.7	7.2	8
	Test	2013		6.6	0.5	5.9	7.3	8
		2016		6.4	0.8	5	7.5	8

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	2013	Elevation (cm)	263	48	229	297	2
		2016		258	52	221	295	2
	Test	2013		305	44	277	383	5
		2016		298	43	266	372	5
	Reference	2013	Thaw Depth (cm)	48	15	37	58	2
		2016		45	14	35	55	2
	Test	2013		46	8	37	56	5
		2016		39	13	26	58	5
	Reference	2013	Surface Organic Thickness (cm)	13	15.6	2	24	2
		2016		12.5	13.4	3	22	2
	Test	2013		11.4	5.9	4	18	5
		2016		10.2	5.4	3	16	5
	Reference	2013	Water Table Depth (cm)	-29	0	-29	-29	2
		2016		-35		-35	-35	1
	Test	2013		-27	7	-33	-16	5
		2016		-36	4	-39	-31	3
	Reference	2013	Electrical Conductivity (um)	600	71	550	650	2
		2016		380	71	330	430	2
	Test	2013		360	172	179	610	5
		2016		408	154	260	620	5
	Reference	2013	pH	7	0.4	6.7	7.3	2
		2016		6.5	0	6.5	6.5	2
	Test	2013		6.6	0.6	5.7	7.2	5
		2016		6.5	0.2	6.4	6.9	5
Riverine Organic-Rich Circumneutral Wet Sedge Meadow	Reference	2013	Elevation (cm)	338	75	206	395	8
		2016		330	76	200	390	8
	Test	2013		305	33	238	383	29
		2016		297	34	221	378	29
	Reference	2013	Thaw Depth (cm)	45	6	38	53	8
		2016		37	5	29	45	8
	Test	2013		48	4	38	56	29
		2016		40	5	33	52	29
	Reference	2013	Surface Organic Thickness (cm)	14.9	12.7	0	40	8
		2016		12.8	12.6	0	37	8
	Test	2013		21.8	12.7	4	40	29
		2016		21.2	12.8	0	40	29

Appendix E. Continued.

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Riverine Organic-Rich Circumneutral Wet Sedge Meadow (continued)	Reference	2013	Water Table Depth (cm)	-5	9	-24	5	8
		2016		-15	5	-20	-7	7
	Test	2013		-3	4	-10	5	29
		2016		-13	7	-26	0	28
	Reference	2013	Electrical Conductivity (um)	453	233	170	770	8
		2016		545	275	300	1050	8
	Test	2013		474	172	230	830	29
		2016		559	167	310	1030	29
	Reference	2013	pH	6.7	0.3	6.2	7.2	8
		2016		6.7	0.7	6	8	8
	Test	2013		6.5	0.2	6.1	7.2	29
		2016		6.4	0.2	6.1	6.8	29
Riverine Organic-Rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Elevation (cm)	331	70	231	425	16
		2016		307	82	178	420	16
	Test	2013		295	25	246	338	19
		2016		287	26	237	330	19
	Reference	2013	Thaw Depth (cm)	47	7	37	62	16
		2016		38	6	28	48	16
	Test	2013		47	5	31	55	19
		2016		37	6	24	49	19
	Reference	2013	Surface Organic Thickness (cm)	13.8	9.2	0	37	16
		2016		12.8	11.7	0	40	16
	Test	2013		12.4	11.1	0.3	36	19
		2016		13.6	12.2	0	40	19
	Reference	2013	Water Table Depth (cm)	-6	4	-11	2	16
		2016		-18	9	-39	-2	16
	Test	2013		-7	6	-25	8	19
		2016		-20	10	-39	-5	17
	Reference	2013	Electrical Conductivity (um)	517	280	190	1250	16
		2016		663	317	160	1350	16
	Test	2013		455	280	200	1470	19
		2016		594	238	160	930	18
	Reference	2013	pH	6.8	0.3	6.3	7.4	16
		2016		6.4	0.3	6	6.9	16
	Test	2013		6.5	0.3	6	7.3	19
		2016		6.5	0.3	5.7	6.9	18

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	2013	Elevation (cm)	273		273	273	1
		2016		265		265	265	1
	Test	2013		341	23	325	357	2
		2016		336	23	320	352	2
	Reference	2013	Thaw Depth (cm)	40		40	40	1
		2016		32		32	32	1
	Test	2013		39	13	29	48	2
		2016		28	4	25	31	2
	Reference	2013	Surface Organic Thickness (cm)	15		15	15	1
		2016		22		22	22	1
	Test	2013		12.5	7.8	7	18	2
		2016		10	0	10	10	2
	Reference	2013	Water Table Depth (cm)	-11		-11	-11	1
		2016		-36		-36	-36	1
	Test	2013		-26	8	-32	-20	2
		2016		-999	0	-999	-999	2
	Reference	2013	Electrical Conductivity (um)	590		590	590	1
		2016		510		510	510	1
	Test	2013		170	71	120	220	2
		2016		140	0	140	140	2
	Reference	2013	pH	6.8		6.8	6.8	1
		2016		6.4		6.4	6.4	1
	Test	2013		6.2	0	6.2	6.2	2
		2016		6.3	0.3	6.1	6.5	2
Upland Sandy Alkaline Dry Barrens	Test	2013	Elevation (cm)	364		364	364	1
		2016		363		363	363	1
		2013	Thaw Depth (cm)	82		82	82	1
		2016		117		117	117	1
		2013	Surface Organic Thickness (cm)	0		0	0	1
		2016		0		0	0	1
		2013	Water Table Depth (cm)	-999		-999	-999	1
		2016		-999		-999	-999	1
		2013	Electrical Conductivity (um)	30		30	30	1
		2016		80		80	80	1
		2013	pH	8.6		8.6	8.6	1
		2016		7.8		7.8	7.8	1

ecotype_title	study_area	sample_year	data_attribute	Average	Standard Deviation	Min	Max	n
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	2013	Elevation (cm)	538		538	538	1
		2016		525		525	525	1
	Test	2013		419	86	340	510	3
		2016		412	85	333	501	3
	Reference	2013	Thaw Depth (cm)	120		120	120	1
		2016		101		101	101	1
	Test	2013		105	13	90	114	3
		2016		92	11	79	100	3
	Reference	2013	Surface Organic Thickness (cm)	0.5		0.5	0.5	1
		2016		0		0	0	1
	Test	2013		0.3	0.6	0	1	3
		2016		0.3	0.6	0	1	3
	Reference	2013	Water Table Depth (cm)	-999		-999	-999	1
		2016		-999		-999	-999	1
	Test	2013		-999	0	-999	-999	3
		2016		-999	0	-999	-999	3
	Reference	2013	Electrical Conductivity (um)	450		450	450	1
		2016		100		100	100	1
	Test	2013		167	168	60	360	3
		2016		117	90	60	220	3
	Reference	2013	pH	8.2		8.2	8.2	1
		2016		7.1		7.1	7.1	1
	Test	2013		8.1	0.3	7.9	8.4	3
		2016		8	0.2	7.8	8.2	3

Appendix F. Mean cover by vegetation structure class and herbaceous and woody plant height (mean, standard error, and frequency) for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Year	Area	Wildlife Habitat	Water Alone	Soil Alone	Litter Alone	Mosses Cover	Lichens Cover	Forbs Cover	Grasses Cover	Sedges Cover	Dwarf Shrub	Low and Tall Shrub	Woody Frequency (%)	Woody Height (cm)	Woody SE (cm)	Herb Frequency (%)	Herb Height (cm)	Herb SE (cm)
2013	Test	Barrens	17.74	70.16	2.69	0.81	0.00	3.49	0.81	1.61	0.81	2.15	40.000000	28.38	7.95	100	11.80	3.53
2013	Reference	Barrens	0.00	94.37	1.66	0.00	0.00	3.31	0.33	0.00	0.00	0.33	0.000000	NA	NA	100	11.13	4.31
2016	Test	Barrens	5.07	81.41	1.13	0.56	0.00	7.61	2.54	0.00	2.25	1.41	17.857143	28.60	14.46	100	12.71	2.62
2016	Reference	Barrens	1.66	86.42	8.61	0.00	0.00	2.98	0.33	0.00	0.00	0.00	0.000000	NA	NA	100	12.00	4.36
2013	Test	Deep Polygon Complex	22.83	0.22	40.16	41.28	2.81	5.85	0.22	20.70	6.41	6.64	55.952381	12.61	0.71	100	32.29	0.84
2013	Reference	Deep Polygon Complex	23.08	0.00	38.91	38.01	1.36	6.79	0.00	24.13	5.28	9.80	62.601626	15.68	0.96	100	35.80	1.14
2016	Test	Deep Polygon Complex	12.04	3.24	44.56	41.09	2.55	8.10	0.35	25.35	7.29	7.41	55.757576	13.59	0.91	100	27.91	0.76
2016	Reference	Deep Polygon Complex	11.46	1.36	46.00	45.25	1.66	7.39	0.15	24.28	6.33	8.90	60.975610	15.01	0.89	100	29.81	0.89
2013	Test	Dry Dwarf Shrub	0.00	0.00	46.67	25.33	12.00	5.33	2.67	17.33	24.00	17.33	93.333333	19.50	2.55	100	24.93	3.08
2013	Reference	Dry Dwarf Shrub	0.00	1.00	35.00	41.00	2.00	18.00	6.00	13.00	33.00	14.00	100.000000	15.82	2.12	100	26.06	2.70
2016	Test	Dry Dwarf Shrub	0.00	4.00	53.33	13.33	5.33	5.33	1.33	10.67	10.67	16.00	93.333333	11.14	2.46	100	21.20	1.90
2016	Reference	Dry Dwarf Shrub	0.00	0.00	33.00	38.00	1.00	12.00	4.00	21.00	34.00	11.00	100.000000	12.06	1.68	100	19.65	2.15
2013	Test	Dry Halophytic Meadow	0.00	50.00	32.50	0.00	0.00	7.50	9.17	0.00	0.83	0.00	4.166667	23.00	NA	100	34.54	4.71
2016	Test	Dry Halophytic Meadow	0.00	66.67	18.33	0.00	0.00	11.67	3.33	0.00	0.00	2.50	8.695652	60.50	0.50	100	27.00	3.95
2013	Reference	Moist Halophytic Dwarf Shrub	1.60	24.00	19.20	27.20	0.00	11.20	7.20	10.40	34.40	0.00	100.000000	5.46	1.00	100	18.58	1.72
2016	Reference	Moist Halophytic Dwarf Shrub	3.20	22.40	20.80	20.80	0.00	14.40	4.80	20.80	32.80	0.00	100.000000	6.75	1.52	100	16.00	2.25
2013	Test	Moist Herb Meadow	0.00	32.26	8.60	1.08	0.00	45.16	13.98	0.00	22.58	1.08	82.352941	6.07	1.67	100	24.29	2.47
2013	Reference	Moist Herb Meadow	0.00	39.51	8.64	6.17	0.00	28.40	12.35	2.47	0.00	28.40	87.500000	51.71	14.79	100	29.25	3.24
2016	Test	Moist Herb Meadow	0.00	32.26	10.75	1.08	0.00	30.11	7.53	2.15	26.88	1.08	88.235294	7.13	1.98	100	29.24	2.73
2016	Reference	Moist Herb Meadow	0.00	34.57	23.46	6.17	0.00	16.05	8.64	0.00	0.00	23.45	93.750000	48.20	10.41	100	28.44	2.18
2013	Test	Moist Low Shrub	0.77	9.42	28.81	40.06	1.26	20.80	2.60	12.79	11.45	25.58	94.539249	31.66	1.27	100	27.34	0.79
2013	Reference	Moist Low Shrub	1.42	6.76	29.09	38.69	0.36	22.12	3.41	19.35	11.81	24.89	97.500000	28.95	1.08	100	31.60	0.85
2016	Test	Moist Low Shrub	0.07	10.55	31.65	39.52	0.70	22.86	2.39	14.49	10.62	24.89	95.890411	32.43	1.53	100	24.21	0.71
2016	Reference	Moist Low Shrub	1.22	7.17	32.69	39.14	0.22	22.87	3.87	21.36	10.54	24.38	94.604316	28.86	1.06	100	26.14	0.69
2013	Test	Moist Sedge-Shrub Meadow	0.00	1.46	43.07	54.01	0.73	6.57	1.46	21.17	24.82	7.30	100.000000	13.86	1.31	100	26.93	1.96
2016	Test	Moist Sedge-Shrub Meadow	0.00	0.00	37.96	72.99	1.46	15.33	0.73	23.36	27.74	10.22	96.428571	13.30	1.50	100	23.04	1.64
2013	Test	Moist Tussock Tundra	7.14	0.00	34.82	25.89	3.57	15.18	0.89	35.71	12.50	16.96	86.956522	19.60	2.79	100	39.48	2.76
2016	Test	Moist Tussock Tundra	6.25	0.00	32.14	22.32	0.89	16.96	0.00	39.29	8.93	18.75	91.304348	17.76	2.64	100	32.30	2.17
2013	Test	Nonpatterned Wet Meadow	4.51	1.30	42.33	49.45	1.50	9.43	0.70	25.08	4.11	12.94	79.487179	22.69	1.11	100	33.11	0.86
2013	Reference	Nonpatterned Wet Meadow	5.98	1.24	40.14	56.91	1.01	13.66	2.48	23.06	6.99	10.41	76.717557	21.54	1.08	100	33.90	0.77
2016	Test	Nonpatterned Wet Meadow	0.40	2.81	49.35	57.07	0.80	11.63	1.30	24.67	5.72	10.93	76.530612	21.56	0.88	100	29.48	0.82
2016	Reference	Nonpatterned Wet Meadow	2.56	0.47	46.04	64.67	0.62	14.60	2.17	23.76	6.52	9.31	78.030303	22.65	1.42	100	29.72	0.71
2013	Test	Patterned Wet Meadow	5.61	0.03	44.29	53.18	2.53	8.64	0.99	25.85	6.78	9.19	70.029240	18.01	0.47	100	30.96	0.36
2013	Reference	Patterned Wet Meadow	8.14	0.16	42.83	54.48	1.47	13.19	0.65	23.53	7.57	9.12	78.278689	19.67	0.70	100	33.80	0.74
2016	Test	Patterned Wet Meadow	0.52	1.31	53.10	57.57	1.48	10.09	0.49	27.42	6.60	8.37	67.888563	18.14	0.83	100	27.31	0.34
2016	Reference	Patterned Wet Meadow	2.22	1.15	46.55	56.98	1.07	13.05	0.74	23.89	8.05	10.76	79.835391	19.60	0.77	100	28.83	0.58
2013	Reference	River or Stream	96.59	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	0.00	50.000000	21.00	NA	100	5.00	3.00
2016	Reference	River or Stream	97.98	1.01	1.01	0.00	0.00	1.01	0.00	0.00	0.00	0.00	100.000000	40.00	NA	100	12.00	NA

Appendix G. Mean cover, 75% and 95% confidence intervals by vegetation structure class for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Barrens	reference	Bare ground	98.36–98.56	98.21–98.71	98.46	90.22–91.32	89.42–92.12	90.77
	reference	Forbs	2.69–3.47	2.14–4.02	3.08	2.38–3.16	1.82–3.72	2.77
	reference	Grasses	0.27–0.35	0.20–0.42	0.31	3.31–4.39	2.54–5.16	3.85
	reference	Litter	2.31–2.61	2.10–2.82	2.46	8.02–9.22	7.16–10.08	8.62
	reference	Salix	0.27–0.35	0.20–0.42	0.31	0.00–0.00	0.00–0.00	0
	reference	Soil	98.36–98.56	98.21–98.71	98.46	90.22–91.32	89.42–92.12	90.77
	reference	Tall shrub	0.27–0.35	0.20–0.42	0.31	0.00–0.00	0.00–0.00	0
	reference	Total live vascular	3.49–4.51	2.74–5.26	4	6.54–7.92	5.56–8.90	7.23
	reference	Water	0.00–0.00	0.00–0.00	0	1.32–1.76	1.01–2.07	1.54
	test	Bare ground	69.16–71.56	67.43–73.29	70.36	89.50–90.76	88.58–91.68	90.13
	test	Dryas	0.69–0.89	0.55–1.03	0.79	0.00–0.00	0.00–0.00	0
	test	Dwarf shrub	0.97–1.19	0.82–1.34	1.08	6.93–7.99	6.16–8.76	7.46
	test	Forbs	6.65–7.89	5.75–8.79	7.27	12.73–14.31	11.59–15.45	13.52
	test	Grasses	0.54–0.64	0.46–0.72	0.59	2.65–3.03	2.38–3.30	2.84
	test	Litter	10.65–12.31	9.46–13.50	11.48	5.94–7.20	5.04–8.10	6.57
	test	Low shrub	7.79–9.47	6.58–10.68	8.63	2.32–2.80	1.99–3.13	2.56
	test	Mosses	2.59–3.37	2.03–3.93	2.98	2.22–3.04	1.63–3.63	2.63
	test	Salix	8.28–9.96	7.07–11.17	9.12	9.84–11.04	8.99–11.89	10.44
	test	Sedges	2.68–3.18	2.32–3.54	2.93	0.00–0.00	0.00–0.00	0
	test	Soil	69.16–71.56	67.43–73.29	70.36	89.50–90.76	88.58–91.68	90.13
	test	Tall shrub	0.16–0.22	0.12–0.26	0.19	0.35–0.49	0.26–0.58	0.42
	test	Total live vascular	20.86–23.54	18.92–25.48	22.2	25.98–28.46	24.19–30.25	27.22
	test	Water	15.12–17.00	13.77–18.35	16.06	3.49–4.09	3.07–4.51	3.79
Deep Open Water with Islands or Polygonized Margins	reference	Water	100.00–100.00	100.00–100.00	100	100.00–100.00	100.00–100.00	100
	test	Litter	4.34–6.18	3.02–7.50	5.26	4.34–6.18	3.02–7.50	5.26
	test	Mosses	4.34–6.18	3.02–7.50	5.26	2.17–3.09	1.51–3.75	2.63
	test	Sedges	2.17–3.09	1.51–3.75	2.63	4.34–6.18	3.02–7.50	5.26
	test	Total live vascular	2.17–3.09	1.51–3.75	2.63	4.34–6.18	3.02–7.50	5.26
	test	Water	93.81–95.65	92.49–96.97	94.73	93.81–95.65	92.49–96.97	94.73

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Deep Open Water without Islands	reference	Water	NA	NA	100	NA	NA	100
	test	Forbs	2.14–2.86	1.63–3.37	2.5	2.14–2.86	1.63–3.37	2.5
	test	Litter	0.00–0.00	0.00–0.00	0	2.14–2.86	1.63–3.37	2.5
	test	Sedges	2.14–2.86	1.63–3.37	2.5	2.14–2.86	1.63–3.37	2.5
	test	Total live vascular	4.29–5.71	3.27–6.73	5	4.29–5.71	3.27–6.73	5
	test	Water	94.29–95.71	93.27–96.73	95	100.00–100.00	100.00–100.00	100
Deep Polygon Complex	reference	Algae	0.31–0.41	0.24–0.48	0.36	0.00–0.00	0.00–0.00	0
	reference	Bare ground	0.26–0.34	0.20–0.40	0.3	5.74–6.10	5.47–6.37	5.92
	reference	Dryas	3.09–3.31	2.93–3.47	3.2	3.59–3.79	3.45–3.93	3.69
	reference	Dwarf shrub	4.98–5.26	4.77–5.47	5.12	6.24–6.54	6.03–6.75	6.39
	reference	Forbs	6.57–6.97	6.27–7.27	6.77	7.40–7.72	7.16–7.96	7.56
	reference	Grasses	0.00–0.00	0.00–0.00	0	0.12–0.16	0.09–0.19	0.14
	reference	Lichens	1.27–1.41	1.18–1.50	1.34	1.56–1.70	1.45–1.81	1.63
	reference	Litter	60.75–61.85	59.96–62.64	61.3	70.40–71.32	69.73–71.99	70.86
	reference	Liver	0.67–0.77	0.60–0.84	0.72	1.41–1.55	1.32–1.64	1.48
	reference	Low shrub	10.09–10.61	9.73–10.97	10.35	9.14–9.60	8.81–9.93	9.37
	reference	Mosses	38.08–39.30	37.19–40.19	38.69	45.27–46.35	44.49–47.13	45.81
	reference	Salix	9.97–10.47	9.62–10.82	10.22	8.95–9.39	8.63–9.71	9.17
	reference	Sedges	23.67–24.23	23.27–24.63	23.95	24.00–24.64	23.53–25.11	24.32
	reference	Soil	0.26–0.34	0.20–0.40	0.3	1.31–1.47	1.19–1.59	1.39
	reference	Total live vascular	48.49–49.61	47.68–50.42	49.05	49.41–50.71	48.47–51.65	50.06
	reference	Water	41.03–42.39	40.05–43.37	41.71	16.25–17.21	15.55–17.91	16.73
	test	Algae	0.31–0.43	0.24–0.50	0.37	0.19–0.23	0.16–0.26	0.21
	test	Bare ground	0.59–0.69	0.52–0.76	0.64	7.69–8.11	7.39–8.41	7.9
	test	Dryas	4.17–4.47	3.95–4.69	4.32	4.42–4.72	4.21–4.93	4.57
	test	Dwarf shrub	6.11–6.43	5.88–6.66	6.27	6.98–7.32	6.75–7.55	7.15
	test	Forbs	5.40–5.72	5.16–5.96	5.56	7.87–8.33	7.54–8.66	8.1
	test	Grasses	0.26–0.32	0.21–0.37	0.29	0.26–0.32	0.21–0.37	0.29
	test	Lichens	2.43–2.61	2.29–2.75	2.52	2.08–2.26	1.96–2.38	2.17
	test	Litter	58.91–59.99	58.15–60.75	59.45	69.26–70.30	68.52–71.04	69.78
	test	Liver	0.17–0.21	0.14–0.24	0.19	0.17–0.21	0.14–0.24	0.19
	test	Low shrub	5.85–6.13	5.65–6.33	5.99	7.29–7.59	7.07–7.81	7.44
	test	Mosses	40.35–41.33	39.65–42.03	40.84	42.35–43.37	41.61–44.11	42.86
	test	Salix	5.30–5.56	5.11–5.75	5.43	7.35–7.65	7.14–7.86	7.5
	test	Sedges	20.42–21.06	19.96–21.52	20.74	27.32–28.24	26.66–28.90	27.78
	test	Soil	0.59–0.69	0.52–0.76	0.64	2.09–2.33	1.91–2.51	2.21

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Deep Polygon Complex	test	Total live vascular	40.92–41.98	40.17–42.73	41.45	53.26–54.50	52.37–55.39	53.88
(continued)	test	Water	36.18–37.36	35.33–38.21	36.77	13.67–14.75	12.89–15.53	14.21
Dry Dwarf Shrub	reference	Bare ground	1.40–2.02	0.96–2.46	1.71	2.53–3.37	1.93–3.97	2.95
	reference	Dryas	13.85–14.75	13.21–15.39	14.3	8.20–9.04	7.60–9.64	8.62
	reference	Dwarf shrub	32.25–35.19	30.13–37.31	33.72	28.10–31.08	25.95–33.23	29.59
	reference	Forbs	21.78–25.52	19.10–28.20	23.65	12.39–14.73	10.71–16.41	13.56
	reference	Grasses	5.58–6.38	5.00–6.96	5.98	3.98–4.78	3.41–5.35	4.38
	reference	Lichens	2.15–2.79	1.69–3.25	2.47	1.47–2.11	1.01–2.57	1.79
	reference	Litter	70.70–72.72	69.25–74.17	71.71	79.80–82.50	77.87–84.43	81.15
	reference	Liver	0.00–0.00	0.00–0.00	0	0.69–0.99	0.47–1.21	0.84
	reference	Low shrub	13.47–14.85	12.47–15.85	14.16	14.22–15.76	13.10–16.88	14.99
	reference	Mosses	38.13–41.75	35.51–44.37	39.94	33.88–38.40	30.64–41.64	36.14
	reference	Salix	17.71–19.21	16.63–20.29	18.46	16.62–18.94	14.95–20.61	17.78
	reference	Sedges	8.50–10.66	6.95–12.21	9.58	15.88–18.76	13.82–20.82	17.32
	reference	Soil	1.40–2.02	0.96–2.46	1.71	2.53–3.37	1.93–3.97	2.95
	reference	Total live vascular	86.34–90.64	83.23–93.75	88.49	79.64–82.86	77.32–85.18	81.25
	test	Bare ground	0.00–0.00	0.00–0.00	0	3.46–4.54	2.68–5.32	4
	test	Dryas	18.88–21.12	17.26–22.74	20	8.97–9.69	8.45–10.21	9.33
	test	Dwarf shrub	22.88–25.12	21.26–26.74	24	10.49–10.85	10.23–11.11	10.67
	test	Forbs	4.85–5.81	4.17–6.49	5.33	4.97–5.69	4.45–6.21	5.33
	test	Grasses	2.49–2.85	2.23–3.11	2.67	1.15–1.51	0.89–1.77	1.33
	test	Lichens	11.69–12.31	11.24–12.76	12	4.85–5.81	4.17–6.49	5.33
	test	Litter	84.68–85.98	83.75–86.91	85.33	79.18–80.82	77.99–82.01	80
	test	Low shrub	16.68–17.98	15.75–18.91	17.33	15.69–16.31	15.24–16.76	16
	test	Mosses	23.93–26.73	21.90–28.76	25.33	12.24–14.42	10.66–16.00	13.33
	test	Salix	16.97–17.69	16.45–18.21	17.33	16.85–17.81	16.17–18.49	17.33
	test	Sedges	16.61–18.05	15.58–19.08	17.33	10.31–11.03	9.79–11.55	10.67
	test	Soil	0.00–0.00	0.00–0.00	0	3.46–4.54	2.68–5.32	4
	test	Total live vascular	65.27–68.07	63.24–70.10	66.67	44.00–44.00	44.00–44.00	44
Dry Halophytic Meadow	reference	Bare ground	92.90–93.30	92.61–93.59	93.1	100.00–100.00	100.00–100.00	100
	reference	Forbs	1.15–1.51	0.89–1.77	1.33	16.55–18.35	15.27–19.63	17.45
	reference	Grasses	3.89–4.57	3.39–5.07	4.23	5.19–5.95	4.64–6.50	5.57
	reference	Litter	6.61–6.95	6.37–7.19	6.78	2.59–2.97	2.31–3.25	2.78
	reference	Soil	92.90–93.30	92.61–93.59	93.1	100.00–100.00	100.00–100.00	100
	reference	Total live vascular	5.19–5.95	4.64–6.50	5.57	23.44–25.26	22.14–26.56	24.35

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Dry Halophytic Meadow (continued)	test	Bare ground	71.71–74.29	69.86–76.14	73	92.96–93.70	92.43–94.23	93.33
	test	Dwarf shrub	0.57–0.77	0.42–0.92	0.67	0.00–0.00	0.00–0.00	0
	test	Forbs	5.60–6.40	5.01–6.99	6	8.48–10.18	7.26–11.40	9.33
	test	Grasses	7.63–8.59	6.95–9.27	8.11	2.42–2.92	2.05–3.29	2.67
	test	Litter	40.56–41.88	39.62–42.82	41.22	19.64–21.32	18.43–22.53	20.48
	test	Salix	0.57–0.77	0.42–0.92	0.67	1.70–2.30	1.26–2.74	2
	test	Soil	71.71–74.29	69.86–76.14	73	92.96–93.70	92.43–94.23	93.33
	test	Tall shrub	0.00–0.00	0.00–0.00	0	1.70–2.30	1.26–2.74	2
	test	Total live vascular	14.32–15.24	13.66–15.90	14.78	13.68–15.66	12.25–17.09	14.67
Grass Marsh	reference	Forbs	17.32–19.50	15.75–21.07	18.41	26.33–28.61	24.70–30.24	27.47
	reference	Grasses	26.47–30.85	23.31–34.01	28.66	31.50–37.48	27.20–41.78	34.49
	reference	Litter	0.00–0.00	0.00–0.00	0	3.99–5.15	3.15–5.99	4.57
	reference	Mosses	1.08–1.54	0.76–1.86	1.31	18.37–24.47	13.99–28.85	21.42
	reference	Sedges	0.00–0.00	0.00–0.00	0	2.95–4.19	2.07–5.07	3.57
	reference	Total live vascular	43.92–50.22	39.38–54.76	47.07	62.01–69.05	56.93–74.13	65.53
	reference	Water	68.50–76.88	62.47–82.91	72.69	98.83–99.17	98.58–99.42	99
Human Modified	reference	Bare ground	0.00–0.00	0.00–0.00	0	2.94–4.46	1.83–5.57	3.7
	reference	Dryas	0.00–0.00	0.00–0.00	0	6.61–10.05	4.13–12.53	8.33
	reference	Dwarf shrub	0.00–0.00	0.00–0.00	0	8.62–11.76	6.37–14.01	10.19
	reference	Forbs	0.00–0.00	0.00–0.00	0	1.47–2.23	0.92–2.78	1.85
	reference	Grasses	0.00–0.00	0.00–0.00	0	1.47–2.23	0.92–2.78	1.85
	reference	Litter	89.96–93.36	87.53–95.79	91.66	73.65–77.09	71.17–79.57	75.37
	reference	Low shrub	0.00–0.00	0.00–0.00	0	1.47–2.23	0.92–2.78	1.85
	reference	Mosses	28.31–30.01	27.09–31.23	29.16	60.17–63.17	58.01–65.33	61.67
	reference	Salix	0.00–0.00	0.00–0.00	0	1.47–2.23	0.92–2.78	1.85
	reference	Sedges	23.26–32.30	16.76–38.80	27.78	24.61–29.47	21.11–32.97	27.04
	reference	Soil	0.00–0.00	0.00–0.00	0	2.94–4.46	1.83–5.57	3.7
	reference	Total live vascular	33.22–47.34	23.06–57.50	40.28	43.12–49.10	38.82–53.40	46.11
	test	Bare ground	NA	NA	NA	NA	NA	20
	test	Litter	NA	NA	NA	NA	NA	84
	test	Low shrub	NA	NA	NA	NA	NA	12
	test	Mosses	NA	NA	NA	NA	NA	8
	test	Salix	NA	NA	NA	NA	NA	12
	test	Sedges	NA	NA	NA	NA	NA	20
	test	Total live vascular	NA	NA	NA	NA	NA	36

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Moist Halophytic Dwarf Shrub	reference	Bare ground	58.53–63.33	55.08–66.78	60.93	59.33–63.15	56.58–65.90	61.24
	reference	Dwarf shrub	38.26–40.26	36.82–41.70	39.26	32.52–33.02	32.16–33.38	32.77
	reference	Forbs	13.24–15.20	11.83–16.61	14.22	11.11–12.89	9.83–14.17	12
	reference	Grasses	5.95–6.59	5.49–7.05	6.27	8.37–9.95	7.23–11.09	9.16
	reference	Litter	32.60–34.26	31.40–35.46	33.43	37.94–42.24	34.86–45.32	40.09
	reference	Liver	0.57–0.77	0.43–0.91	0.67	0.00–0.00	0.00–0.00	0
	reference	Mosses	20.73–24.61	17.94–27.40	22.67	15.86–18.80	13.75–20.91	17.33
	reference	Salix	38.26–40.26	36.82–41.70	39.26	32.52–33.02	32.16–33.38	32.77
	reference	Sedges	7.92–9.42	6.83–10.51	8.67	16.12–18.54	14.38–20.28	17.33
	reference	Soil	58.53–63.33	55.08–66.78	60.93	59.33–63.15	56.58–65.90	61.24
	reference	Total live vascular	68.45–71.07	66.56–72.96	69.76	70.93–74.27	68.52–76.68	72.6
	reference	Water	1.70–2.30	1.28–2.72	2	2.28–3.06	1.71–3.63	2.67
	test	Bare ground	95.75–96.61	95.13–97.23	96.18	66.14–69.08	64.02–71.20	67.61
	test	Dwarf shrub	27.35–30.09	25.38–32.06	28.72	35.02–39.02	32.15–41.89	37.02
	test	Forbs	17.18–17.78	16.74–18.22	17.48	6.19–8.13	4.79–9.53	7.16
	test	Grasses	1.82–2.62	1.24–3.20	2.22	13.88–15.90	12.43–17.35	14.89
	test	Litter	24.43–24.95	24.06–25.32	24.69	42.16–43.60	41.13–44.63	42.88
	test	Mosses	0.66–0.94	0.45–1.15	0.8	2.05–2.95	1.40–3.60	2.5
	test	Salix	27.35–30.09	25.38–32.06	28.72	35.02–39.02	32.15–41.89	37.02
	test	Soil	95.75–96.61	95.13–97.23	96.18	66.14–69.08	64.02–71.20	67.61
	test	Total live vascular	48.14–50.92	46.15–52.91	49.53	57.07–61.07	54.18–63.96	59.07
Moist Herb Meadow	reference	Bare ground	86.04–88.68	84.13–90.59	87.36	61.34–63.92	59.49–65.77	62.63
	reference	Forbs	30.39–32.97	28.55–34.81	31.68	12.57–14.29	11.34–15.52	13.43
	reference	Grasses	9.75–10.95	8.88–11.82	10.35	8.60–9.64	7.86–10.38	9.12
	reference	Litter	18.66–20.60	17.27–21.99	19.63	41.70–42.78	40.91–43.57	42.24
	reference	Low shrub	19.27–20.09	18.67–20.69	19.68	16.05–16.89	15.45–17.49	16.47
	reference	Mosses	8.61–10.41	7.31–11.71	9.51	10.15–12.77	8.27–14.65	11.46
	reference	Salix	25.63–26.09	25.30–26.42	25.86	21.13–22.17	20.37–22.93	21.65
	reference	Sedges	3.77–4.65	3.13–5.29	4.21	0.00–0.00	0.00–0.00	0
	reference	Soil	86.04–88.68	84.13–90.59	87.36	61.34–63.92	59.49–65.77	62.63
	reference	Tall shrub	7.70–8.82	6.89–9.63	8.26	4.87–5.47	4.43–5.91	5.17
	reference	Total live vascular	77.83–78.87	77.07–79.63	78.35	43.12–45.30	41.56–46.86	44.21
	test	Bare ground	92.58–93.54	91.90–94.22	93.06	73.08–75.80	71.13–77.75	74.44
	test	Dwarf shrub	18.91–21.27	17.22–22.96	20.09	26.55–29.55	24.39–31.71	28.05
	test	Forbs	41.67–43.11	40.63–44.15	42.39	24.78–26.40	23.61–27.57	25.59
	test	Fungi	1.97–2.79	1.38–3.38	2.38	0.00–0.00	0.00–0.00	0

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Moist Herb Meadow (continued)	test	Grasses	13.30–14.78	12.24–15.84	14.04	8.59–9.13	8.21–9.51	8.86
	test	Litter	17.09–19.13	15.62–20.60	18.11	36.06–39.40	33.67–41.79	37.73
	test	Low shrub	1.72–2.44	1.21–2.95	2.08	1.72–2.44	1.21–2.95	2.08
	test	Mosses	0.56–0.78	0.39–0.95	0.67	1.97–2.79	1.38–3.38	2.38
	test	Salix	21.17–23.19	19.71–24.65	22.18	28.73–31.55	26.69–33.59	30.14
	test	Sedges	0.00–0.00	0.00–0.00	0	2.65–3.45	2.07–4.03	3.05
	test	Soil	92.58–93.54	91.90–94.22	93.06	73.08–75.80	71.13–77.75	74.44
	test	Total live vascular	83.76–86.96	81.45–89.27	85.36	70.17–73.85	67.51–76.51	72.01
Moist Low Shrub	reference	Algae	0.05–0.07	0.04–0.08	0.06	0.05–0.07	0.04–0.08	0.06
	reference	Bare ground	21.39–22.49	20.61–23.27	21.94	18.23–19.13	17.57–19.79	18.68
	reference	Dryas	4.66–4.94	4.46–5.14	4.8	3.55–3.79	3.39–3.95	3.67
	reference	Dwarf shrub	10.85–11.35	10.48–11.72	11.1	9.59–10.05	9.25–10.39	9.82
	reference	Forbs	21.29–21.91	20.85–22.35	21.6	21.76–22.32	21.36–22.72	22.04
	reference	Fungi	0.00–0.00	0.00–0.00	0	0.05–0.07	0.04–0.08	0.06
	reference	Grasses	3.63–3.83	3.48–3.98	3.73	5.04–5.50	4.70–5.84	5.27
	reference	Lichens	0.30–0.34	0.26–0.38	0.32	0.29–0.35	0.25–0.39	0.32
	reference	Litter	63.44–64.38	62.76–65.06	63.91	71.08–71.94	70.46–72.56	71.51
	reference	Liver	0.34–0.38	0.30–0.42	0.36	0.18–0.22	0.15–0.25	0.2
	reference	Low shrub	22.51–23.21	22.02–23.70	22.86	22.57–23.21	22.12–23.66	22.89
	reference	Mosses	37.28–38.24	36.59–38.93	37.76	38.95–40.11	38.12–40.94	39.53
	reference	Salix	27.14–27.80	26.68–28.26	27.47	25.70–26.32	25.25–26.77	26.01
	reference	Sedges	17.97–18.65	17.49–19.13	18.31	19.99–20.77	19.42–21.34	20.38
	reference	Soil	21.39–22.49	20.61–23.27	21.94	18.18–19.08	17.52–19.74	18.63
	reference	Tall shrub	1.06–1.26	0.92–1.40	1.16	0.36–0.44	0.31–0.49	0.4
	reference	Total live vascular	83.35–84.67	82.40–85.62	84.01	83.63–84.73	82.84–85.52	84.18
	reference	Water	3.77–4.27	3.40–4.64	4.02	2.67–3.19	2.29–3.57	2.93
	test	Algae	0.09–0.13	0.07–0.15	0.11	0.00–0.00	0.00–0.00	0
	test	Bare ground	20.11–21.15	19.37–21.89	20.63	18.69–19.65	17.99–20.35	19.17
	test	Dryas	5.77–6.15	5.50–6.42	5.96	3.15–3.37	2.99–3.53	3.26
	test	Dwarf shrub	11.98–12.46	11.63–12.81	12.22	11.06–11.54	10.72–11.88	11.3
	test	Forbs	22.85–23.51	22.37–23.99	23.18	25.21–25.95	24.67–26.49	25.58
	test	Fungi	0.00–0.00	0.00–0.00	0	0.12–0.16	0.09–0.19	0.14
	test	Grasses	2.54–2.72	2.41–2.85	2.63	2.33–2.49	2.22–2.60	2.41
	test	Lichens	1.56–1.74	1.44–1.86	1.65	0.52–0.60	0.46–0.66	0.56
	test	Litter	63.50–64.28	62.93–64.85	63.89	67.84–68.54	67.35–69.03	68.19
	test	Liver	0.10–0.12	0.08–0.14	0.11	0.00–0.00	0.00–0.00	0
	test	Low shrub	24.01–24.67	23.53–25.15	24.34	24.99–25.65	24.50–26.14	25.32

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Moist Low Shrub (continued)	test	Mosses	38.72–39.64	38.06–40.30	39.18	37.45–38.39	36.78–39.06	37.92
	test	Salix	29.40–30.06	28.93–30.53	29.73	30.41–31.11	29.92–31.60	30.76
	test	Sedges	12.70–13.20	12.35–13.55	12.95	14.35–14.91	13.94–15.32	14.63
	test	Soil	20.11–21.15	19.37–21.89	20.63	18.69–19.65	17.99–20.35	19.17
	test	Tall shrub	1.50–1.82	1.27–2.05	1.66	1.03–1.19	0.90–1.32	1.11
	test	Total live vascular	80.04–81.30	79.13–82.21	80.67	84.63–86.17	83.53–87.27	85.4
	test	Water	2.78–3.10	2.56–3.32	2.94	0.28–0.34	0.23–0.39	0.31
Moist Sedge-Shrub Meadow	reference	Dryas	NA	NA	15.38	NA	NA	0
	reference	Dwarf shrub	NA	NA	38.46	NA	NA	23.08
	reference	Forbs	NA	NA	23.08	NA	NA	23.08
	reference	Lichens	NA	NA	15.38	NA	NA	7.69
	reference	Litter	NA	NA	46.15	NA	NA	38.46
	reference	Mosses	NA	NA	84.62	NA	NA	92.31
	reference	Salix	NA	NA	23.08	NA	NA	23.08
	reference	Sedges	NA	NA	7.69	NA	NA	7.69
	reference	Total live vascular	NA	NA	69.23	NA	NA	53.85
	test	Bare ground	5.71–7.93	4.11–9.53	6.82	3.80–5.28	2.73–6.35	4.54
	test	Dryas	8.89–9.51	8.45–9.95	9.2	11.91–12.91	11.19–13.63	12.41
	test	Dwarf shrub	22.10–23.46	21.13–24.43	22.78	33.83–36.89	31.64–39.08	35.36
	test	Forbs	5.35–6.19	4.75–6.79	5.77	12.93–13.95	12.19–14.69	13.44
	test	Grasses	1.45–1.83	1.17–2.11	1.64	0.42–0.58	0.30–0.70	0.5
	test	Lichens	0.42–0.58	0.30–0.70	0.5	0.89–1.11	0.74–1.26	1
	test	Litter	67.45–71.01	64.90–73.56	69.23	71.75–73.49	70.51–74.73	72.62
	test	Liver	0.00–0.00	0.00–0.00	0	0.42–0.58	0.30–0.70	0.5
	test	Low shrub	7.01–8.07	6.24–8.84	7.54	11.29–12.71	10.26–13.74	12
	test	Mosses	53.71–56.93	51.39–59.25	55.32	72.24–74.40	70.69–75.95	73.32
	test	Salix	12.02–13.12	11.24–13.90	12.57	28.53–32.03	26.01–34.55	30.28
	test	Sedges	17.83–19.89	16.34–21.38	18.86	19.89–21.31	18.88–22.32	20.6
	test	Soil	5.71–7.93	4.11–9.53	6.82	3.80–5.28	2.73–6.35	4.54
	test	Total live vascular	57.25–61.21	54.41–64.05	59.23	84.74–87.06	83.08–88.72	85.9
	test	Water	1.90–2.64	1.37–3.17	2.27	0.00–0.00	0.00–0.00	0
Moist Tall Shrub	reference	Bare ground	87.15–89.31	85.60–90.86	88.23	48.00–51.60	45.40–54.20	49.8
	reference	Forbs	16.53–19.47	14.42–21.58	18	14.98–17.10	13.46–18.62	16.04
	reference	Grasses	8.80–11.14	7.11–12.83	9.97	13.21–14.67	12.16–15.72	13.94
	reference	Litter	26.30–27.56	25.39–28.47	26.93	75.38–76.84	74.33–77.89	76.11
	reference	Low shrub	3.04–3.96	2.38–4.62	3.5	4.06–5.94	2.72–7.28	5

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Moist Tall Shrub	reference	Mosses	2.85–3.75	2.19–4.41	3.3	8.12–10.08	6.71–11.49	9.1
(continued)	reference	Salix	27.36–29.30	25.97–30.69	28.33	34.02–37.58	31.46–40.14	35.8
	reference	Sedges	0.00–0.00	0.00–0.00	0	2.81–3.63	2.22–4.22	3.22
	reference	Soil	87.15–89.31	85.60–90.86	88.23	48.00–51.60	45.40–54.20	49.8
	reference	Tall shrub	26.19–28.47	24.56–30.10	27.33	31.34–35.26	28.51–38.09	33.3
	reference	Total live vascular	56.85–60.75	54.04–63.56	58.8	71.74–78.92	66.58–84.08	75.33
Moist Tussock Tundra	test	Bare ground	0.00–0.00	0.00–0.00	0	0.64–0.92	0.44–1.12	0.78
	test	Dryas	4.58–5.66	3.79–6.45	5.12	4.71–5.81	3.92–6.60	5.26
	test	Dwarf shrub	9.65–10.87	8.78–11.74	10.26	7.68–8.84	6.85–9.67	8.26
	test	Forbs	11.47–12.49	10.73–13.23	11.98	14.92–17.12	13.35–18.69	16.02
	test	Grasses	0.64–0.92	0.44–1.12	0.78	0.00–0.00	0.00–0.00	0
	test	Lichens	2.32–2.96	1.87–3.41	2.64	0.41–0.59	0.28–0.72	0.5
	test	Litter	69.01–71.71	67.07–73.65	70.36	77.25–79.71	75.48–81.48	78.48
	test	Low shrub	14.43–16.03	13.27–17.19	15.23	11.70–13.38	10.48–14.60	12.54
	test	Mosses	23.87–26.79	21.77–28.89	25.33	17.82–19.64	16.50–20.96	18.73
	test	Salix	17.37–19.37	15.94–20.80	18.37	13.66–15.42	12.39–16.69	14.54
	test	Sedges	40.95–44.47	38.41–47.01	42.71	35.92–40.12	32.89–43.15	38.02
	test	Soil	0.00–0.00	0.00–0.00	0	0.64–0.92	0.44–1.12	0.78
	test	Total live vascular	94.11–99.83	90.01–103.93	96.97	79.29–88.19	72.89–94.59	83.74
	test	Water	24.79–29.33	21.54–32.58	27.06	7.02–8.98	5.60–10.40	8
Nonpatterned Wet Meadow	reference	Algae	0.11–0.13	0.09–0.15	0.12	0.00–0.00	0.00–0.00	0
	reference	Bare ground	3.64–4.18	3.25–4.57	3.91	6.32–6.76	6.00–7.08	6.54
	reference	Dryas	3.20–3.44	3.04–3.60	3.32	2.21–2.39	2.08–2.52	2.3
	reference	Dwarf shrub	7.26–7.74	6.90–8.10	7.5	6.07–6.45	5.80–6.72	6.26
	reference	Forbs	14.21–14.85	13.74–15.32	14.53	14.42–15.06	13.96–15.52	14.74
	reference	Grasses	2.48–2.68	2.33–2.83	2.58	2.69–2.97	2.50–3.16	2.83
	reference	Lichens	1.06–1.20	0.96–1.30	1.13	0.45–0.51	0.40–0.56	0.48
	reference	Litter	67.61–68.41	67.03–68.99	68.01	71.33–72.05	70.80–72.58	71.69
	reference	Liver	1.00–1.14	0.90–1.24	1.07	0.28–0.32	0.24–0.36	0.3
	reference	Low shrub	10.80–11.38	10.39–11.79	11.09	7.88–8.22	7.64–8.46	8.05
	reference	Mosses	53.19–54.21	52.45–54.95	53.7	62.04–63.10	61.29–63.85	62.57
	reference	Salix	13.89–14.49	13.45–14.93	14.19	10.74–11.12	10.46–11.40	10.93
	reference	Sedges	22.23–22.77	21.85–23.15	22.5	25.07–25.85	24.50–26.42	25.46
	reference	Soil	3.64–4.18	3.25–4.57	3.91	5.35–5.79	5.04–6.10	5.57
	reference	Tall shrub	0.57–0.71	0.46–0.82	0.64	0.29–0.35	0.25–0.39	0.32
	reference	Total live vascular	60.68–61.70	59.94–62.44	61.19	59.22–60.42	58.36–61.28	59.82

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Nonpatterned Wet Meadow (continued)	reference	Water	14.91–15.77	14.28–16.40	15.34	4.39–5.05	3.91–5.53	4.72
	test	Bare ground	3.02–3.58	2.61–3.99	3.3	6.56–7.30	6.04–7.82	6.93
	test	Dryas	1.52–1.68	1.40–1.80	1.6	2.49–2.75	2.29–2.95	2.62
	test	Dwarf shrub	3.84–4.12	3.64–4.32	3.98	4.85–5.27	4.56–5.56	5.06
	test	Forbs	9.10–9.54	8.79–9.85	9.32	11.23–11.65	10.94–11.94	11.44
	test	Grasses	0.62–0.78	0.52–0.88	0.7	1.06–1.18	0.98–1.26	1.12
	test	Lichens	1.70–1.84	1.59–1.95	1.77	0.70–0.80	0.64–0.86	0.75
	test	Litter	69.51–70.29	68.96–70.84	69.9	74.90–75.62	74.39–76.13	75.26
	test	Liver	1.03–1.17	0.94–1.26	1.1	0.76–0.96	0.61–1.11	0.86
	test	Low shrub	14.52–15.18	14.04–15.66	14.85	10.99–11.53	10.61–11.91	11.26
	test	Mosses	50.84–51.94	50.05–52.73	51.39	56.09–57.21	55.29–58.01	56.65
	test	Salix	15.63–16.31	15.14–16.80	15.97	12.77–13.35	12.35–13.77	13.06
	test	Sedges	25.46–26.34	24.84–26.96	25.9	24.89–25.53	24.43–25.99	25.21
	test	Soil	3.02–3.58	2.61–3.99	3.3	5.96–6.70	5.43–7.23	6.33
	test	Tall shrub	0.16–0.22	0.12–0.26	0.19	0.00–0.00	0.00–0.00	0
	test	Total live vascular	57.09–58.37	56.17–59.29	57.73	57.34–58.32	56.64–59.02	57.83
	test	Water	16.09–17.05	15.40–17.74	16.57	0.97–1.15	0.84–1.28	1.06
Patterned Wet Meadow	reference	Algae	0.00–0.00	0.00–0.00	0	0.06–0.08	0.05–0.09	0.07
	reference	Bare ground	2.57–3.05	2.22–3.40	2.81	7.38–7.94	6.98–8.34	7.66
	reference	Dryas	4.30–4.50	4.14–4.66	4.4	3.84–4.12	3.64–4.32	3.98
	reference	Dwarf shrub	7.64–7.96	7.40–8.20	7.8	8.03–8.43	7.75–8.71	8.23
	reference	Forbs	13.00–13.44	12.68–13.76	13.22	13.09–13.53	12.78–13.84	13.31
	reference	Grasses	0.53–0.59	0.49–0.63	0.56	0.91–1.07	0.80–1.18	0.99
	reference	Lichens	1.39–1.49	1.31–1.57	1.44	0.87–0.95	0.82–1.00	0.91
	reference	Litter	67.09–67.61	66.70–68.00	67.35	74.12–74.78	73.66–75.24	74.45
	reference	Liver	0.66–0.74	0.61–0.79	0.7	0.93–1.07	0.83–1.17	1
	reference	Low shrub	8.75–9.03	8.54–9.24	8.89	11.23–11.63	10.94–11.92	11.43
	reference	Mosses	52.16–53.10	51.49–53.77	52.63	56.35–57.31	55.65–58.01	56.83
	reference	Salix	10.52–10.82	10.30–11.04	10.67	14.14–14.60	13.80–14.94	14.37
	reference	Sedges	23.16–23.60	22.84–23.92	23.38	23.64–24.10	23.32–24.42	23.87
	reference	Soil	2.57–3.05	2.22–3.40	2.81	6.47–7.03	6.07–7.43	6.75
	reference	Total live vascular	56.32–57.32	55.59–58.05	56.82	60.62–61.64	59.88–62.38	61.13
	reference	Water	20.19–20.95	19.66–21.48	20.57	2.95–3.23	2.74–3.44	3.09
	test	Algae	0.03–0.03	0.02–0.04	0.03	0.00–0.00	0.00–0.00	0
	test	Bare ground	0.31–0.33	0.29–0.35	0.32	6.27–6.59	6.05–6.81	6.43
	test	Dryas	3.75–3.89	3.64–4.00	3.82	3.74–3.88	3.64–3.98	3.81
	test	Dwarf shrub	6.64–6.82	6.51–6.95	6.73	6.54–6.72	6.40–6.86	6.63

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Patterned Wet Meadow (continued)	test	Forbs	8.75–8.95	8.61–9.09	8.85	10.46–10.70	10.29–10.87	10.58
	test	Fungi	0.03–0.03	0.02–0.04	0.03	0.04–0.06	0.04–0.06	0.05
	test	Grasses	1.07–1.13	1.03–1.17	1.1	0.48–0.52	0.45–0.55	0.5
	test	Lichens	2.41–2.51	2.33–2.59	2.46	1.48–1.56	1.43–1.61	1.52
	test	Litter	70.66–71.00	70.41–71.25	70.83	79.43–79.71	79.23–79.91	79.57
	test	Liver	0.41–0.45	0.39–0.47	0.43	0.65–0.69	0.62–0.72	0.67
	test	Low shrub	9.47–9.69	9.32–9.84	9.58	8.70–8.90	8.57–9.03	8.8
	test	Mosses	53.02–53.46	52.71–53.77	53.24	56.99–57.51	56.62–57.88	57.25
	test	Salix	11.49–11.71	11.33–11.87	11.6	10.64–10.84	10.49–10.99	10.74
	test	Sedges	26.42–26.76	26.17–27.01	26.59	27.62–27.94	27.38–28.18	27.78
	test	Soil	0.31–0.33	0.29–0.35	0.32	5.06–5.36	4.84–5.58	5.21
	test	Tall shrub	0.04–0.06	0.03–0.07	0.05	0.00–0.00	0.00–0.00	0
	test	Total live vascular	55.59–56.17	55.18–56.58	55.88	56.62–57.20	56.20–57.62	56.91
	test	Water	17.78–18.26	17.45–18.59	18.02	0.80–0.90	0.73–0.97	0.85
River or Stream	reference	Algae	0.00–0.00	0.00–0.00	0	0.85–1.15	0.63–1.37	1
	reference	Bare ground	0.00–0.00	0.00–0.00	0	3.09–4.19	2.30–4.98	3.64
	reference	Forbs	3.36–4.64	2.43–5.57	4	0.85–1.15	0.63–1.37	1
	reference	Litter	0.00–0.00	0.00–0.00	0	1.54–2.10	1.15–2.49	1.82
	reference	Soil	0.00–0.00	0.00–0.00	0	3.09–4.19	2.30–4.98	3.64
	reference	Total live vascular	3.36–4.64	2.43–5.57	4	0.85–1.15	0.63–1.37	1
	reference	Water	96.56–97.22	96.09–97.69	96.89	95.81–96.91	95.02–97.70	96.36
	test	Bare ground	0.00–0.00	0.00–0.00	0	34.58–46.12	26.28–54.42	40.35
	test	Litter	0.00–0.00	0.00–0.00	0	2.70–3.96	1.79–4.87	3.33
	test	Soil	0.00–0.00	0.00–0.00	0	34.58–46.12	26.28–54.42	40.35
	test	Water	100.00–100.00	100.00–100.00	100	50.95–61.69	43.22–69.42	56.32
Shallow Open Water with Islands or Polygonized Margins	test	Litter	0.00–0.00	0.00–0.00	0	1.78–2.38	1.36–2.80	2.08
	test	Mosses	0.00–0.00	0.00–0.00	0	1.78–2.38	1.36–2.80	2.08
	test	Water	100.00–100.00	100.00–100.00	100	97.61–98.21	97.19–98.63	97.91

Appendix G. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2016 75% CI	2016 95% CI	2016 Mean Cover
Tapped Lake with High-water Connection	reference	Water	NA	NA	0	NA	NA	100
	test	Forbs	NA	NA	12.5	NA	NA	0
	test	Litter	NA	NA	12.5	NA	NA	0
	test	Low shrub	NA	NA	12.5	NA	NA	0
	test	Salix	NA	NA	12.5	NA	NA	0
	test	Total live vascular	NA	NA	25	NA	NA	0
	test	Water	NA	NA	87.5	NA	NA	100

Appendix H1. Datafile listing and summary statistics for ground surface elevation (m) measured at Thaw Elevation Monitoring Locations in Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

				Minimum		Maximum		Mean		SE		n	
TreatArea	Direction	point_type	ecotype	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Reference	North	Thaw Elev Point	Coastal Barrens	101.9	101.4	135.3	117.3	118.3	109.3	9.6	7.9	3	2
Reference	North	Thaw Elev Point	Coastal Dry Elymus Meadow	45.7	136.5	45.7	184.2	45.7	160.3		23.8	1	2
Reference	North	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	186.6	184.6	186.6	184.6		184.6			1	1
Reference	North	Thaw Elev Point	Human Modified Low Shrub	204.6	198.1	204.6	198.1					1	1
Reference	North	Thaw Elev Point	Lowland Deep-polygon Complex	228.5	221.1	323.6	327.2			8.6	9.1	14	14
Reference	North	Thaw Elev Point	Lowland Wet Sedge Meadow	226.4	216.2	301.1	296.1			13.5	14.3	5	5
Reference	North	Thaw Elev Point	Lowland Wet Sedge-Willow Meadow	256.0	252.5	256.0	252.5	256.0	252.5			1	1
Reference	North	Thaw Elev Point	Riverine Deep-polygon Complex	213.4	205.3	250.9	245.6			5.1	5.5	7	7
Reference	North	Thaw Elev Point	Riverine Moist Low Willow Shrub	197.1	191.4	295.0	290.5	233.2	230.1	22.8	22.5	4	4
Reference	North	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	179.8	182.2	249.9	242.9			8.3	7.5	8	8
Reference	North	Thaw Elev Point	Riverine Wet Sedge Meadow	175.2	167.3	293.2	286.1	242.2	238.4	11.7	11.1	10	10
Reference	North	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	181.8	204.2	285.9	289.3			4.7	4.2	23	23
Reference	North	Veg Start Point	Coastal Barrens	14.9	52.0	87.8	156.5	52.7	87.4	21.1	34.5	3	3
Reference	North	Veg Start Point	Coastal Moist Willow Dwarf Shrub	73.4	72.8	169.5	168.2	121.5	120.5	48.1	47.7	2	2
Reference	North	Veg Start Point	Lowland Deep-polygon Complex	216.0	218.1	275.8	268.9	245.7	241.2	12.1	10.6	5	5
Reference	North	Veg Start Point	Lowland Wet Sedge Meadow	245.3	243.1	245.3	243.1	245.3	243.1			1	1
Reference	North	Veg Start Point	Riverine Deep-polygon Complex	229.6	217.6	230.9	220.5	230.3	219.1	0.7	1.4	2	2
Reference	North	Veg Start Point	Riverine Dry Dryas Dwarf Shrub	212.5	214.8	212.5	214.8	212.5	214.8			1	1
Reference	North	Veg Start Point	Riverine Moist Low Willow Shrub	121.2	110.7	229.3	221.1	189.6	181.2	34.4	35.4	3	3
Reference	North	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	111.2	105.7	278.4	273.5	198.1	190.8	26.1	25.5	7	7
Reference	North	Veg Start Point	Riverine Wet Sedge Meadow	182.7	178.4	297.4	295.4	238.8	235.0	16.8	17.2	6	6
Reference	North	Veg Start Point	Riverine Wet Sedge-Willow Meadow	215.8	215.8	255.9	242.6	235.5	231.7	6.4	4.5	5	5
Reference	North	Veg Start Point	Upland Moist Low Willow Shrub	210.1	214.4	210.1	214.4	210.1	214.4			1	1
Reference	North	Cut Bank	Lowland Moist Low Willow Shrub	285.4	266.0	285.4	266.0					1	1
Reference	North	Cut Bank	Riverine Moist Low Willow Shrub	224.7	202.3	224.7	202.3	224.7	202.3			1	1
Reference	North	Cut Bank	Riverine Moist Low Willow-Sedge Meadow	222.2	30.9	236.6	234.8	229.4	142.6	7.2	41.4	2	5
Reference	North	Water Edge	Coastal Barrens	13.5	-17.8	31.9	6.7	22.7	-4.2	9.2	7.2	2	3
Reference	North	Water Edge	Coastal Moist Willow Dwarf Shrub	2.4	9.7	2.4	146.5	2.4	78.1		68.4	1	2

Appendix H1. Continued.

TreatArea	Direction	point_type	ecotype	Minimum 2013	Minimum 2016	Maximum 2013	Maximum 2016	Mean 2013	Mean 2016	SE 2013	SE 2016	n 2013	n 2016
Reference	North	Water Edge	Lowland Deep-polygon Complex	230.3	200.7	230.3	237.7				4.5	2	8
Reference	North	Water Edge	Lowland Lake		210.3		214.7		212.5		2.2		2
Reference	North	Water Edge	Lowland Moist Low Willow Shrub	13.5		13.5		13.5				1	
Reference	North	Water Edge	Riverine Deep-polygon Complex		204.6		217.6		210.5		1.9		6
Reference	North	Water Edge	Riverine Grass Marsh		142.5		145.5		143.8		0.9		3
Reference	North	Water Edge	Riverine Moist Low Willow Shrub	-118.3	34.0	13.5	18			65.9	44.4	2	3
Reference	North	Water Edge	Riverine Moist Low Willow-Sedge Meadow	13.5	9.7	13.5	144.9	13.5	48.9		32.3	2	4
Reference	North	Water Edge	Riverine Wet Sedge Meadow		143.0		222.8		179.8		23.2		3
Reference	North	Water Edge	Riverine Wet Sedge-Willow Meadow	-118.3	189.5	197.1	189.5	39.4	189.5	157.7		2	1
Reference	North	Water Edge	Tidal River	3.0	2.9	3.0	25.1	3.0	11.6		3.7	1	5
Reference	South	Thaw Elev Point	Coastal Barrens	100.6	76.0	154.5	137.9	115.4	94.5	13.1	14.7	4	4
Reference	South	Thaw Elev Point	Human Modified Wet Meadow	360.1	344.9	360.1	344.9	360.1	344.9			1	1
Reference	South	Thaw Elev Point	Lowland Deep-polygon Complex	369.3	369.9	369.3	369.9	369.3	369.9			1	1
Reference	South	Thaw Elev Point	Lowland Moist Sedge-Shrub Meadow	413.3	402.2	413.3	402.2					1	1
Reference	South	Thaw Elev Point	Lowland Wet Sedge Meadow	381.4	373.1	424.7	424.6	408.8	400.9	5.1	5.3	8	8
Reference	South	Thaw Elev Point	Riverine Moist Herb Meadow	254.7	243.6	254.7	243.6	254.7	243.6			1	1
Reference	South	Thaw Elev Point	Riverine Moist Low Willow Shrub	293.5	279.0	393.0	377.8	348.5	340.2	14.2	14.2	7	7
Reference	South	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	397.8	396.1	401.2	416.7	399.5		1.7	10.3	2	2
Reference	South	Thaw Elev Point	Riverine Wet Sedge Meadow	193.6	178.3	434.3	428.2	365.8	355.4	14.3	15.3	20	20
Reference	South	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	327.6	320.7	432.8	425.6	393.2	386.2	4.8	4.9	27	27
Reference	South	Thaw Elev Point	Upland Dry Dryas Dwarf Shrub	463.4	451.9	497.6	49	480.5	470.9	17.1	19.1	2	2
Reference	South	Thaw Elev Point	Upland Moist Low Willow Shrub	456.6	444.0	47	458.8			6.7	7.4	2	2
Reference	South	Veg Start Point	Coastal Barrens	68.5	39.5	145.1	148.2			38.3	54.4	2	2
Reference	South	Veg Start Point	Human Modified Wet Meadow	388.5	389.9	388.5	389.9	388.5	389.9			1	1
Reference	South	Veg Start Point	Lowland Deep-polygon Complex	361.7	348.5	371.5	36	366.6	354.3	4.9	5.7	2	2
Reference	South	Veg Start Point	Lowland Wet Sedge Meadow	386.9	376.0	429.9	413.7	402.2	390.5	1	9.1	4	4
Reference	South	Veg Start Point	Riverine Moist Herb Meadow	257.7	246.9	286.1	280.3		263.6	14.2	16.7	2	2
Reference	South	Veg Start Point	Riverine Moist Low Willow Shrub	259.5	255.2	415.6	402.6	352.9	346.4	28.2	27.0	5	5
Reference	South	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	299.1	286.8	424.7	425.7	377.1	371.0	28.7	31.1	4	4
Reference	South	Veg Start Point	Riverine Moist Tall Willow Shrub	216.9	206.5	216.9	206.5		206.5			1	1

Appendix H1. Continued.

TreatArea	Direction	point_type	ecotype	Minimum 2013	Minimum 2016	Maximum 2013	Maximum 2016	Mean 2013	Mean 2016	SE 2013	SE 2016	n 2013	n 2016
Reference	South	Veg Start Point	Riverine Wet Sedge Meadow	349.8	336.4	425.3	420.2	381.0	371.2	10.8	12.0	6	6
Reference	South	Veg Start Point	Riverine Wet Sedge-Willow Meadow	334.6	325.0	415.4	402.7	385.8	376.6	7.8	7.6	10	10
Reference	South	Veg Start Point	Upland Moist Low Willow Shrub	537.6	525.4	537.6	525.4	537.6	525.4			1	1
Reference	South	Cut Bank	Coastal Barrens		92.8		515.2		214.9		63.2		6
Reference	South	Cut Bank	Riverine Moist Herb Meadow		230.7		271.4		251.1		20.3		2
Reference	South	Cut Bank	Riverine Moist Low Willow Shrub	338.1	312.2	435.5	411.9	399.9	346.8	31.0	14.4	3	7
Reference	South	Cut Bank	Riverine Moist Low Willow-Sedge Meadow		170.6		367.2		250.8		42.0		4
Reference	South	Cut Bank	Riverine Moist Tall Willow Shrub		297.2		297.2		297.2				1
Reference	South	Cut Bank	Riverine Wet Sedge Meadow		216.6		252.3		234.4		17.8		2
Reference	South	Cut Bank	Riverine Wet Sedge-Willow Meadow		279.2		321.8		295.9		13.2		3
Reference	South	Cut Bank	Upland Dry Dryas Dwarf Shrub	496.9	484.7	496.9	484.7	496.9	484.7			1	1
Reference	South	Cut Bank	Upland Moist Low Willow Shrub	452.9	307.0	452.9	307.0	452.9	307.0			1	1
Reference	South	Water Edge	Coastal Barrens	-5.5	7.1	29.3	8	19.7	45.4	5.7	9.5	6	10
Reference	South	Water Edge	Lowland Lake	356.1	348.2	356.1	351.7	356.1	35		1.8	2	2
Reference	South	Water Edge	Riverine Moist Low Willow Shrub	12.3	209.0	12.3	209.0	12.3	209.0			1	1
Reference	South	Water Edge	Riverine Moist Low Willow-Sedge Meadow	168.7	150.6	168.7	210.4	168.7	189.5		19.5	1	3
Reference	South	Water Edge	Riverine Wet Sedge Meadow		203.4		211.1		208.2		1.7		4
Reference	South	Water Edge	Riverine Wet Sedge-Willow Meadow	144.1	130.3	163.6	333.3	153.8	189.1	9.7	48.3	2	4
Reference	South	Water Edge	Tidal River	22.0	9.7	30.4	74.4	26.8	34.3	2.5	12.4	3	6
Reference	South	Water Edge	Upland Dry Dryas Dwarf Shrub	12.3		12.3		12.3				1	
Test	North	Thaw Elev Point	Coastal Barrens	43.3	42.4	201.6	201.0	135.2	125.7	33.5	31.6	5	5
Test	North	Thaw Elev Point	Coastal Dry Elymus Meadow	360.7	358.4	360.7	358.4	360.7	358.4			1	1
Test	North	Thaw Elev Point	Lowland Deep-polygon Complex	288.8	283.1	290.7	283.2	289.8	283.1	1.0		2	2
Test	North	Thaw Elev Point	Lowland Wet Sedge Meadow	308.9	298.8	308.9	298.8	308.9	298.8			1	1
Test	North	Thaw Elev Point	Riverine Deep-polygon Complex	283.2	264.2	325.2	320.3	299.2	292.0	6.7	8.2	7	7
Test	North	Thaw Elev Point	Riverine Moist Low Willow Shrub	182.5	161.5	263.4	259.7	222.9	210.6	40.5	49.1	2	2
Test	North	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	261.5	252.6	342.4	331.5	305.4	297.0	16.7	16.6	4	4
Test	North	Thaw Elev Point	Riverine Wet Sedge Meadow	269.9	250.7	405.4	389.2	311.2	300.3	6.7	6.7	30	30
Test	North	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	228.6	215.8	394.4	391.2	310.8	299.8	13.1	13.3	16	16

Appendix H1. Continued.

TreatArea	Direction	point_type	ecotype	Minimum 2013	Minimum 2016	Maximum 2013	Maximum 2016	Mean 2013	Mean 2016	SE 2013	SE 2016	n 2013	n 2016
Test	North	Thaw Elev Point	Upland Moist Low Willow Shrub	336.5	331.5	446.6	440.2	391.6	385.9	55.0	54.4	2	2
Test	North	Thaw Elev Point	Upland Moist Tussock Meadow	277.5	272.6	277.5	272.6	277.5	272.6			1	1
Test	North	Veg Start Point	Coastal Barrens	104.5	80.6	193.4	192.1	149.0	136.3	44.4	55.8	2	2
Test	North	Veg Start Point	Human Modified Wet Meadow		241.4		241.4		241.4				1
Test	North	Veg Start Point	Lowland Deep-polygon Complex	278.2	271.3	278.2	271.3	278.2	271.3			1	1
Test	North	Veg Start Point	Lowland Wet Sedge Meadow	266.1	260.8	306.5	294.5	286.3	277.7	20.2	16.8	2	2
Test	North	Veg Start Point	Riverine Deep-polygon Complex	284.6	279.7	287.9	280.1	286.3	279.9	1.7	0.2	2	2
Test	North	Veg Start Point	Riverine Moist Low Willow Shrub	405.6	400.8	405.6	400.8	405.6	400.8			1	1
Test	North	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	239.1	234.7	288.5	283.2	263.5	256.4	7.3	7.5	7	7
Test	North	Veg Start Point	Riverine Wet Sedge Meadow	238.5	220.8	355.5	354.7	288.6	280.9	6.8	6.6	20	19
Test	North	Veg Start Point	Riverine Wet Sedge-Willow Meadow	264.4	255.9	382.9	377.6	316.3	309.7	11.1	11.8	10	10
Test	North	Veg Start Point	Upland Moist Low Willow Shrub	296.8	283.1	509.9	500.6	378.4	371.7	35.8	36.1	5	5
Test	North	Veg Start Point	Upland Moist Tussock Meadow	357.5	351.8	357.5	351.8	357.5	351.8			1	1
Test	North	Cut Bank	Coastal Barrens		73.1		271.2		193.0		42.2		4
Test	North	Cut Bank	Coastal Dry Elymus Meadow		245.9		319.3		282.6		36.7		2
Test	North	Cut Bank	Riverine Moist Low Willow Shrub		49.4		263.7		209.8		20.7		10
Test	North	Cut Bank	Riverine Moist Low Willow-Sedge Meadow		179.7		228.6		204.2		24.4		2
Test	North	Cut Bank	Riverine Wet Sedge-Willow Meadow	311.5	315.5	311.5	345.6	311.5	334.3		9.5	1	3
Test	North	Cut Bank	Tidal River		94.8		94.8		94.8				1
Test	North	Cut Bank	Upland Moist Low Willow Shrub		282.6		282.6		282.6				1
Test	North	Water Edge	Coastal Barrens	8.8	2.6	8.8	78.4	8.8	38.3		22.0	1	3
Test	North	Water Edge	Coastal Lake	37.9	34.4	37.9	34.4	37.9	34.4			2	2
Test	North	Water Edge	Riverine Grass Marsh	142.4	103.5	144.9	109.2	143.7	106.4	1.2	2.8	2	2
Test	North	Water Edge	Riverine Lake	142.3	106.6	144.9	108.4	143.2	107.4	0.9	0.4	3	4
Test	North	Water Edge	Riverine Moist Low Willow Shrub	142.4	92.5	142.4	103.9	142.4	98.2		5.7	1	2
Test	North	Water Edge	Riverine Moist Low Willow-Sedge Meadow	-10.5	8.3	-10.5	20.6	-10.5	14.4		6.1	1	2
Test	North	Water Edge	Riverine Wet Sedge Meadow		273.1		332.7		302.7		16.2		4
Test	North	Water Edge	Riverine Wet Sedge-Willow Meadow	0.8		0.8		0.8				1	
Test	North	Water Edge	Tidal River	-9.0	7.5	8.8	58.0	-3.1	35.4	6.0	13.0	3	4
Test	South	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	160.2	169.2	188.9	186.2	174.6	177.7	14.3	8.5	2	2

Appendix H1. Continued.

TreatArea	Direction	point_type	ecotype	Minimum 2013	Minimum 2016	Maximum 2013	Maximum 2016	Mean 2013	Mean 2016	SE 2013	SE 2016	n 2013	n 2016
Test	South	Thaw Elev Point	Lowland Deep-polygon Complex	299.6	295.5	328.9	328.2	308.4	305.9	2.7	3.2	10	10
Test	South	Thaw Elev Point	Lowland Wet Sedge Meadow	298.0	295.7	40	397.6	328.2	323.0	18.7	19.2	5	5
Test	South	Thaw Elev Point	Lowland Wet Sedge-Willow Meadow	330.7	319.2	357.3	344.9	344.0	332.0	13.3	12.9	2	2
Test	South	Thaw Elev Point	Riverine Deep-polygon Complex	318.8	314.0	318.8	314.0	318.8	314.0			1	1
Test	South	Thaw Elev Point	Riverine Moist Low Willow Shrub	204.6	203.0	327.1	325.0	270.8	274.5	35.7	36.7	3	3
Test	South	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	251.1	262.1	277.9	301.1	264.9	280.5	7.8	11.3	3	3
Test	South	Thaw Elev Point	Riverine Moist Sedge-Shrub Meadow	269.0	261.8	305.4	295.7	289.0	281.5	9.5	8.3	4	4
Test	South	Thaw Elev Point	Riverine Wet Sedge Meadow	256.0	251.8	377.3	375.2	312.1	307.8	4.8	4.8	36	36
Test	South	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	252.9	250.5	335.2	317.8	290.8	283.0	7.0	6.1	12	12
Test	South	Thaw Elev Point	Upland Moist Tussock Meadow	235.3	230.7	319.6	314.5	286.0	282.6	25.8	26.2	3	3
Test	South	Veg Start Point	Coastal Barrens	45.8	41.6	112.5	132.3	78.5	81.2	19.3	26.8	3	3
Test	South	Veg Start Point	Coastal Moist Willow Dwarf Shrub	187.3	188.3	187.3	188.3	187.3	188.3			1	1
Test	South	Veg Start Point	Human Modified Wet Meadow		323.0		323.0		323.0				1
Test	South	Veg Start Point	Lowland Deep-polygon Complex	297.0	290.4	347.2	300.5	306.9	294.9	8.1	1.8	6	5
Test	South	Veg Start Point	Lowland Wet Sedge Meadow	285.7	281.7	327.1	319.2	299.8	296.0	13.6	11.7	3	3
Test	South	Veg Start Point	Lowland Wet Sedge-Willow Meadow	339.7	330.3	339.7	330.3	339.7	330.3			1	1
Test	South	Veg Start Point	Riverine Deep-polygon Complex	289.8	285.4	293.3	29	291.6	287.7	1.8	2.3	2	2
Test	South	Veg Start Point	Riverine Moist Herb Meadow	174.8	172.7	253.4	251.9	214.1	212.3	39.3	39.6	2	2
Test	South	Veg Start Point	Riverine Moist Low Willow Shrub	203.8	204.5	256.9	255.6	237.9	238.0	17.1	16.7	3	3
Test	South	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	283.3	268.5	346.8	346.6	302.9	294.4	14.8	17.7	4	4
Test	South	Veg Start Point	Riverine Moist Sedge-Shrub Meadow	382.9	372.1	382.9	372.1	382.9	372.1			1	1
Test	South	Veg Start Point	Riverine Wet Sedge Meadow	162.0	156.8	347.9	343.9	294.8	287.4	9.0	9.1	21	21
Test	South	Veg Start Point	Riverine Wet Sedge-Willow Meadow	258.0	242.7	341.4	329.5	296.3	288.3	13.3	13.9	6	6
Test	South	Veg Start Point	Upland Moist Tussock Meadow	324.6	319.9	324.6	319.9	324.6	319.9			1	1
Test	South	Cut Bank	Coastal Barrens		94.5		233.8		160.1		28.6		4
Test	South	Cut Bank	Riverine Moist Low Willow Shrub	266.7	145.1	309.1	332.1	294.1	237.9	13.7	17.9	3	13
Test	South	Cut Bank	Riverine Moist Low Willow-Sedge Meadow		258.3		268.0		264.5		3.1		3
Test	South	Cut Bank	Riverine Wet Sedge-Willow Meadow		280.1		332.8		308.8		15.4		3
Test	South	Water Edge	Coastal Barrens	8.5	11.2	8.5	77.3	8.5	45.5		14.4	1	4
Test	South	Water Edge	Lowland Deep-polygon Complex		260.2		295.8		276.7		2.5		13

Appendix H1. Continued.

				Minimum		Maximum		Mean		SE		n	
TreatArea	Direction	point_type	ecotype	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Test	South	Water Edge	Lowland Lake		241.7		283.9		267.7		8.4		6
Test	South	Water Edge	Riverine Deep-polygon Complex		281.0		281.0		281.0				1
Test	South	Water Edge	Riverine Grass Marsh	139.8	104.7	139.8	235.4	139.8	170.1		65.4	1	2
Test	South	Water Edge	Riverine Lake	135.2	102.4	300.8	250.7	205.8	158.1	26.2	25.8	6	8
Test	South	Water Edge	Riverine Moist Low Willow Shrub	5.5	31.2	244.1	244.6	145.5	108.8	40.3	37.1	5	5
Test	South	Water Edge	Riverine Moist Low Willow-Sedge Meadow	255.8	21.7	255.8	240.8	255.8	96.1		72.4	1	3
Test	South	Water Edge	Riverine Wet Sedge-Willow Meadow	141.6	198.5	300.8	289.9	228.8	251.4	46.6	21.4	3	4
Test	South	Water Edge	Tidal River	0.8	19.5	8.5	96.3	4.6	66.9	1.3	16.3	6	5
Test	South	Water Edge	Upland Moist Tussock Meadow		199.9		199.9		199.9				1

Appendix H2. Datafile listing and summary statistics for thaw depth (cm) measured at Thaw Elevation Monitoring Locations in Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

				Minimum		Maximum		Mean		SE		n	
Area	Direction	point_type	ecotype	2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Reference	North	Thaw Elev Point	Coastal Barrens	97	74	120	98	110.3	86.0	6.9	12.0	3	2
Reference	North	Thaw Elev Point	Coastal Dry Elymus Meadow	146	69	146	114	146.0	91.5		22.5	1	2
Reference	North	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	68	61	68	61	68.0	61.0			1	1
Reference	North	Thaw Elev Point	Human Modified Low Shrub	63	57	63	57	63.0	57.0			1	1
Reference	North	Thaw Elev Point	Lowland Deep-polygon Complex	38	27	57	50	47.2	38.3	1.9	1.8	14	14
Reference	North	Thaw Elev Point	Lowland Wet Sedge Meadow	40	25	61	49	49.8	39.6	3.9	4.3	5	5
Reference	North	Thaw Elev Point	Lowland Wet Sedge-Willow Meadow	37	32	37	32	37.0	32.0			1	1
Reference	North	Thaw Elev Point	Riverine Deep-polygon Complex	34	26	58	47	43.0	37.6	2.8	2.8	7	7
Reference	North	Thaw Elev Point	Riverine Moist Low Willow Shrub	40	34	73	66	57.3	49.3	7.7	8.1	4	4
Reference	North	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	47	40	71	64	56.6	49.6	2.7	3.1	8	8
Reference	North	Thaw Elev Point	Riverine Wet Sedge Meadow	36	26	53	44	45.3	34.5	1.8	1.9	10	10
Reference	North	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	30	26	62	56	46.7	38.9	1.5	1.5	23	23
Reference	North	Veg Start Point	Coastal Barrens	101	76	106	97	103.0	86.0	1.5	6.1	3	3
Reference	North	Veg Start Point	Coastal Moist Willow Dwarf Shrub	57	58	70	73	63.5	65.5	6.5	7.5	2	2
Reference	North	Veg Start Point	Lowland Deep-polygon Complex	40	32	51	44	43.8	37.2	2.0	2.3	5	5
Reference	North	Veg Start Point	Lowland Wet Sedge Meadow	43	40	43	40	43.0	4			1	1
Reference	North	Veg Start Point	Riverine Deep-polygon Complex	38	39	46	40	42.0	39.5	4.0	0.5	2	2
Reference	North	Veg Start Point	Riverine Dry Dryas Dwarf Shrub	60	55	60	55	6	55.0			1	1
Reference	North	Veg Start Point	Riverine Moist Low Willow Shrub	50	46	64	69	57.3	56.7	4.1	6.7	3	3
Reference	North	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	5	41	67	67	47.0	51.0	7.6	3.6	7	7
Reference	North	Veg Start Point	Riverine Wet Sedge Meadow	37	35	61	46	45.3	39.8	3.4	2.2	6	6
Reference	North	Veg Start Point	Riverine Wet Sedge-Willow Meadow	37	36	53	48	44.8	42.0	3.2	2.2	5	5

Appendix H2. Continued.

Area	Direction	point_type	ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Reference	North	Veg Start Point	Upland Moist Low Willow Shrub	62	61	62	61	62.0	61.0			1	1
Reference	North	Cut Bank	Lowland Moist Low Willow Shrub	45		45		45.0				1	
Reference	North	Cut Bank	Riverine Moist Low Willow Shrub	89		89		89.0				1	
Reference	North	Cut Bank	Riverine Moist Low Willow-Sedge Meadow	80		82		81.0		1.0		2	
Reference	North	Water Edge	Coastal Barrens	99		99		99.0				1	
Reference	North	Water Edge	Riverine Wet Sedge-Willow Meadow	64		64		64.0				1	
Reference	South	Thaw Elev Point	Coastal Barrens	86	67	111	90	98.0	80.3	5.3	4.9	4	4
Reference	South	Thaw Elev Point	Human Modified Wet Meadow	52	41	52	41	52.0	41.0			1	1
Reference	South	Thaw Elev Point	Lowland Deep-polygon Complex	54	24	54	24	54.0	24.0			1	1
Reference	South	Thaw Elev Point	Lowland Moist Sedge-Shrub Meadow	30	22	30	22	3	22.0			1	1
Reference	South	Thaw Elev Point	Lowland Wet Sedge Meadow	44	28	52	39	48.0	36.1	1.1	1.2	7	8
Reference	South	Thaw Elev Point	Riverine Moist Herb Meadow	102	92	102	92	102.0	92.0			1	1
Reference	South	Thaw Elev Point	Riverine Moist Low Willow Shrub	33	24	114	94	71.9	56.9	10.4	8.5	7	7
Reference	South	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	49	34	49	43	49.0	38.5		4.5	2	2
Reference	South	Thaw Elev Point	Riverine Wet Sedge Meadow	32	26	103	62	52.8	36.8	3.4	1.9	20	20
Reference	South	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	27	22	59	51	45.0	34.6	1.9	1.4	27	27
Reference	South	Thaw Elev Point	Upland Dry Dryas Dwarf Shrub	50	41	102	77	76.0	59.0	26.0	18.0	2	2
Reference	South	Thaw Elev Point	Upland Moist Low Willow Shrub	28	25	46	31	37.0	28.0	9.0	3.0	2	2
Reference	South	Veg Start Point	Coastal Barrens	96	77	107	89	101.5	83.0	5.5	6.0	2	2
Reference	South	Veg Start Point	Human Modified Wet Meadow	50	39	50	39	5	39.0			1	1
Reference	South	Veg Start Point	Lowland Deep-polygon Complex	43	36	46	37	44.5	36.5	1.5	0.5	2	2
Reference	South	Veg Start Point	Lowland Wet Sedge Meadow	47	27	49	42	47.8	36.5	0.5	3.4	4	4
Reference	South	Veg Start Point	Riverine Moist Herb Meadow	103	89	105	92	104.0	90.5	1.0	1.5	2	2

Appendix H2. Continued.

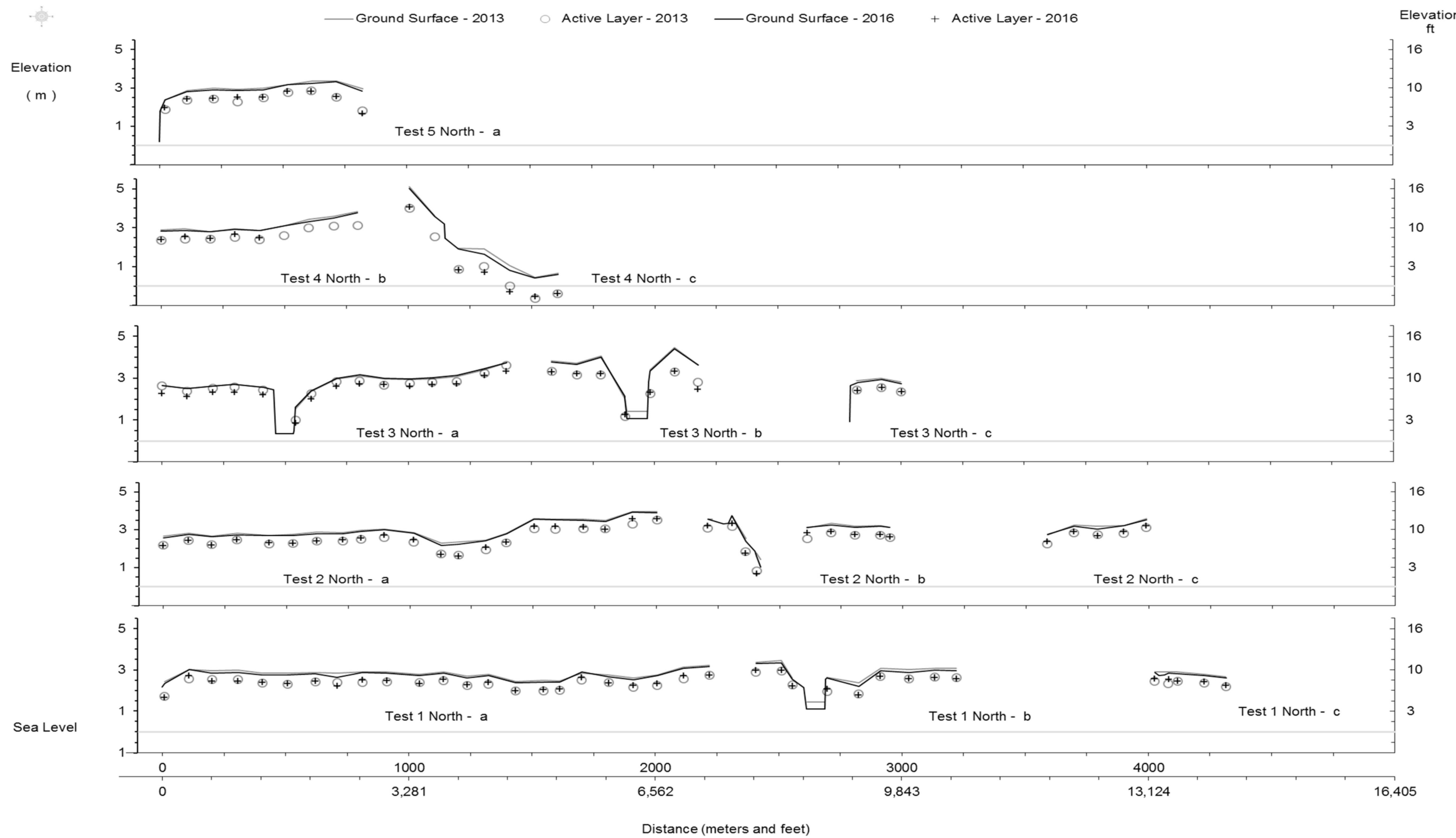
Area	Direction	point_type	ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Reference	South	Veg Start Point	Riverine Moist Low Willow Shrub	37	32	92	77	65.0	54.8	9.0	8.7	5	5
Reference	South	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	40	28	59	55	51.3	4	4.0	5.6	4	4
Reference	South	Veg Start Point	Riverine Moist Tall Willow Shrub	133	97	133	97	133.0	97.0			1	1
Reference	South	Veg Start Point	Riverine Wet Sedge Meadow	44	29	53	39	49.7	36.0	1.3	1.6	6	6
Reference	South	Veg Start Point	Riverine Wet Sedge-Willow Meadow	38	30	62	52	46.2	38.3	2.7	2.2	10	10
Reference	South	Veg Start Point	Upland Moist Low Willow Shrub	120	101	120	101	12	101.0			1	1
Reference	South	Cut Bank	Riverine Moist Low Willow Shrub	80		91		87.0		3.5		3	
Reference	South	Cut Bank	Upland Dry Dryas Dwarf Shrub	129		129		129.0				1	
Reference	South	Cut Bank	Upland Moist Low Willow Shrub	113		113		113.0				1	
Reference	South	Water Edge	Lowland Lake	74		74		74.0				1	
Reference	South	Water Edge	Tidal River	105		105		105.0				1	
Test	North	Thaw Elev Point	Coastal Barrens	85	76	108	98	96.0	91.8	4.5	4.0	5	5
Test	North	Thaw Elev Point	Coastal Dry Elymus Meadow	108		108		108.0				1	
Test	North	Thaw Elev Point	Lowland Deep-polygon Complex	42	30	48	35	45.0	32.5	3.0	2.5	2	2
Test	North	Thaw Elev Point	Lowland Wet Sedge Meadow	43	37	43	37	43.0	37.0			1	1
Test	North	Thaw Elev Point	Riverine Deep-polygon Complex	40	30	54	44	45.1	35.0	1.6	2.2	7	7
Test	North	Thaw Elev Point	Riverine Moist Low Willow Shrub	68	53	82	77	75.0	65.0	7.0	12.0	2	2
Test	North	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	38	27	51	46	44.0	33.5	2.7	4.3	4	4
Test	North	Thaw Elev Point	Riverine Wet Sedge Meadow	35	26	65	44	47.8	35.5	1.3	0.9	30	30
Test	North	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	42	34	70	62	52.1	40.3	1.8	1.7	16	16
Test	North	Thaw Elev Point	Upland Moist Low Willow Shrub	84	77	117	108	100.5	92.5	16.5	15.5	2	2
Test	North	Thaw Elev Point	Upland Moist Tussock Meadow	40	31	40	31	4	31.0			1	1
Test	North	Veg Start Point	Coastal Barrens	105	109	108	112	106.5	110.5	1.5	1.5	2	2

Appendix H2. Continued.

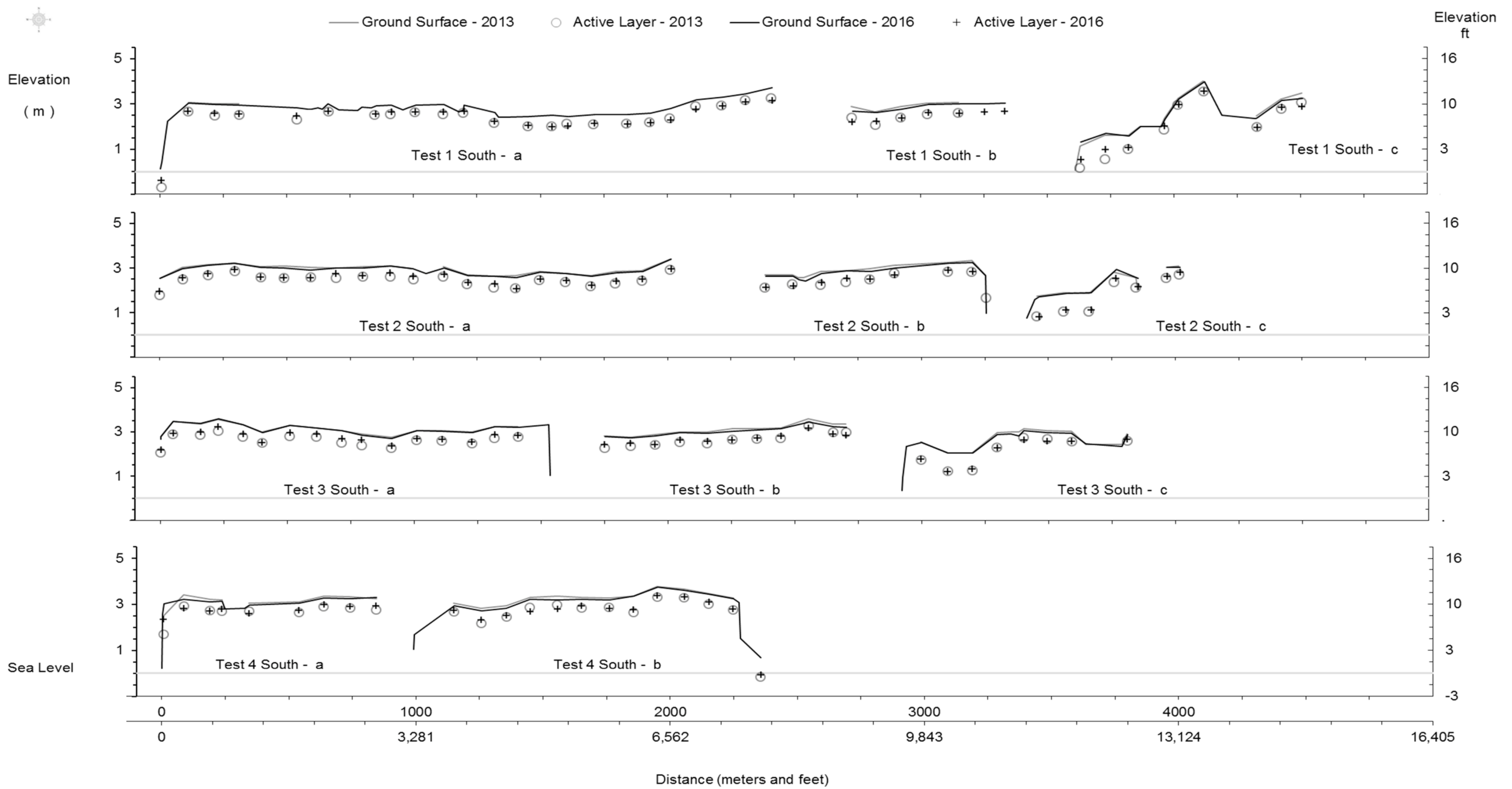
Area	Direction	point_type	ecotype	Minimum 2013	Minimum 2016	Maximum 2013	Maximum 2016	Mean 2013	Mean 2016	SE 2013	SE 2016	n 2013	n 2016
Test	North	Veg Start Point	Human Modified Wet Meadow		33		33		33.0				1
Test	North	Veg Start Point	Lowland Deep-polygon Complex	40	39	40	39	4	39.0			1	1
Test	North	Veg Start Point	Lowland Wet Sedge Meadow	44	36	48	38	46.0	37.0	2.0	1.0	2	2
Test	North	Veg Start Point	Riverine Deep-polygon Complex	44	34	50	39	47.0	36.5	3.0	2.5	2	2
Test	North	Veg Start Point	Riverine Moist Low Willow Shrub	90	79	90	79	9	79.0			1	1
Test	North	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	34	30	72	70	52.3	47.3	5.3	5.6	7	7
Test	North	Veg Start Point	Riverine Wet Sedge Meadow	43	30	55	45	47.5	38.4	0.9	0.9	20	19
Test	North	Veg Start Point	Riverine Wet Sedge-Willow Meadow	31	29	55	50	47.8	40.2	2.2	1.9	10	10
Test	North	Veg Start Point	Upland Moist Low Willow Shrub	70	63	115	118	98.2	98.8	9.3	1	5	5
Test	North	Veg Start Point	Upland Moist Tussock Meadow	48	31	48	31	48.0	31.0			1	1
Test	North	Cut Bank	Riverine Wet Sedge-Willow Meadow	85		85		85.0				1	
Test	South	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	85	71	104	76	94.5	73.5	9.5	2.5	2	2
Test	South	Thaw Elev Point	Lowland Deep-polygon Complex	39	29	56	45	46.8	33.7	1.6	1.5	10	10
Test	South	Thaw Elev Point	Lowland Wet Sedge Meadow	34	31	46	54	42.2	39.2	2.2	4.0	5	5
Test	South	Thaw Elev Point	Lowland Wet Sedge-Willow Meadow	40	37	41	45	40.5	41.0	0.5	4.0	2	2
Test	South	Thaw Elev Point	Riverine Deep-polygon Complex	47	36	47	36	47.0	36.0			1	1
Test	South	Thaw Elev Point	Riverine Moist Low Willow Shrub	43	42	83	84	59.3	57.0	12.1	13.5	3	3
Test	South	Thaw Elev Point	Riverine Moist Low Willow-Sedge Meadow	60	39	80	67	70.7	55.3	5.8	8.4	3	3
Test	South	Thaw Elev Point	Riverine Moist Sedge-Shrub Meadow	36	22	42	43	39.5	32.8	1.5	4.9	4	4
Test	South	Thaw Elev Point	Riverine Wet Sedge Meadow	32	24	72	59	46.1	35.9	1.2	1.0	36	36
Test	South	Thaw Elev Point	Riverine Wet Sedge-Willow Meadow	31	24	66	60	48.8	40.8	3.2	2.6	12	12
Test	South	Thaw Elev Point	Upland Moist Tussock Meadow	43	30	49	40	47.0	33.7	2.0	3.2	3	3

Appendix H2. Continued.

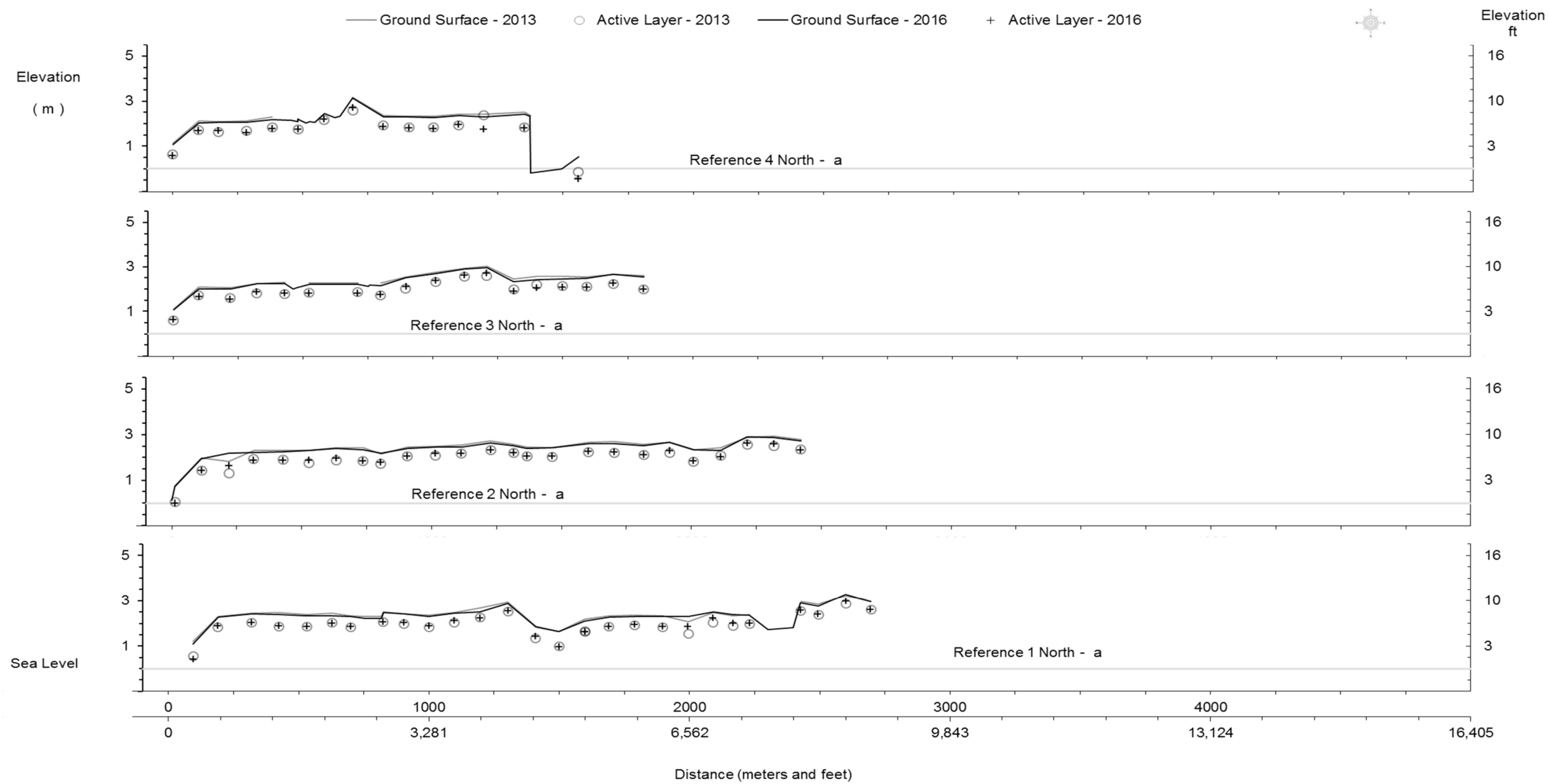
Area	Direction	point_type	ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2016	2013	2016	2013	2016	2013	2016	2013	2016
Test	South	Veg Start Point	Coastal Barrens	93	77	114	81	100.7	79.0	6.7	1.2	3	3
Test	South	Veg Start Point	Coastal Moist Willow Dwarf Shrub	81	76	81	76	81.0	76.0			1	1
Test	South	Veg Start Point	Human Modified Wet Meadow		35		35		35.0				1
Test	South	Veg Start Point	Lowland Deep-polygon Complex	35	26	47	35	40.7	32.0	2.0	1.8	6	5
Test	South	Veg Start Point	Lowland Wet Sedge Meadow	41	37	47	39	44.3	38.0	1.8	0.6	3	3
Test	South	Veg Start Point	Lowland Wet Sedge-Willow Meadow	47	41	47	41	47.0	41.0			1	1
Test	South	Veg Start Point	Riverine Deep-polygon Complex	47	24	52	39	49.5	31.5	2.5	7.5	2	2
Test	South	Veg Start Point	Riverine Moist Herb Meadow	80	76	91	92	85.5	84.0	5.5	8.0	2	2
Test	South	Veg Start Point	Riverine Moist Low Willow Shrub	43	39	78	72	65.3	57.0	11.2	9.6	3	3
Test	South	Veg Start Point	Riverine Moist Low Willow-Sedge Meadow	46	33	58	54	5	45.7	2.7	6.4	4	3
Test	South	Veg Start Point	Riverine Moist Sedge-Shrub Meadow	56	58	56	58	56.0	58.0			1	1
Test	South	Veg Start Point	Riverine Wet Sedge Meadow	38	35	61	52	48.9	4	1.0	1.0	21	21
Test	South	Veg Start Point	Riverine Wet Sedge-Willow Meadow	44	37	58	49	49.3	40.8	2.2	1.8	6	6
Test	South	Veg Start Point	Upland Moist Tussock Meadow	29	25	29	25	29.0	25.0			1	1
Test	South	Cut Bank	Riverine Moist Low Willow Shrub	56		100		76.3		12.8		3	
Test	South	Water Edge	Riverine Moist Low Willow Shrub		39		39		39.0				1



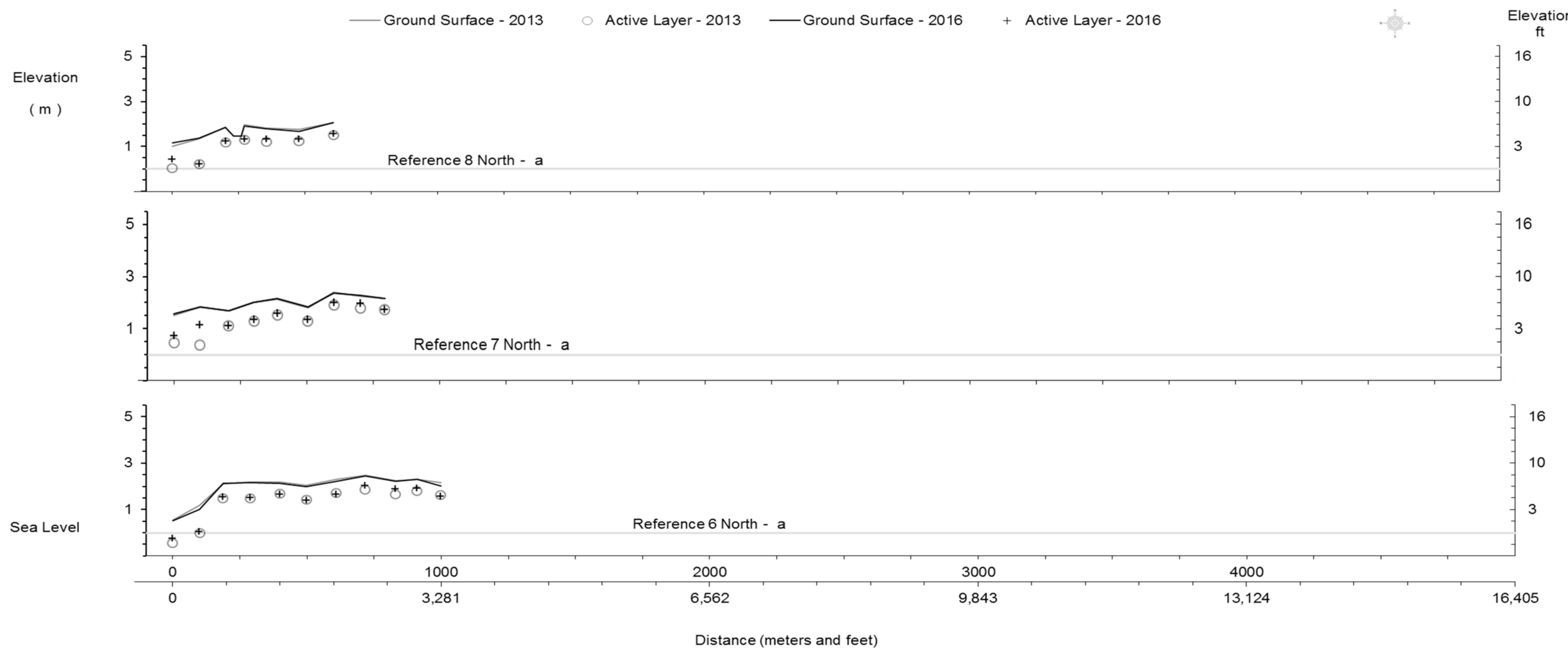
Appendix I1. Cross section of ground surface elevation and thaw depth along transects in the Test North Area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



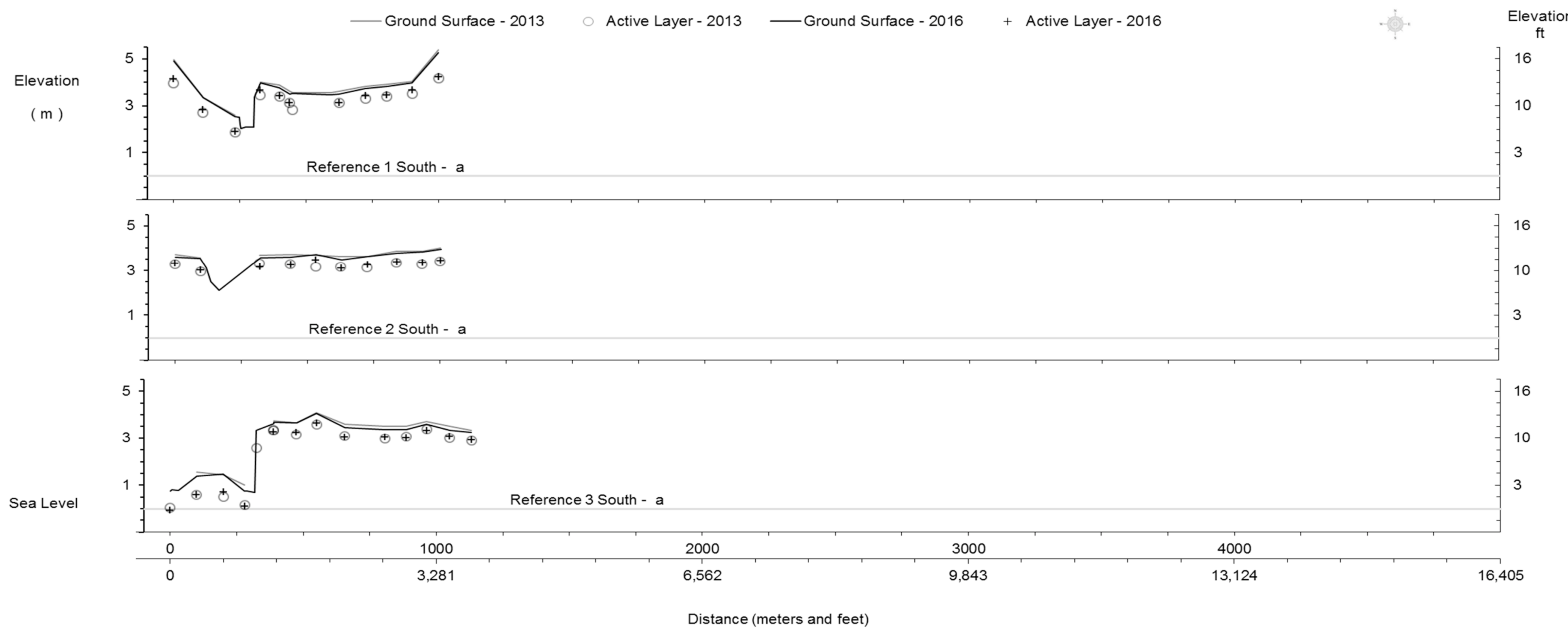
Appendix I2. Cross section of ground surface elevation and thaw depth along transects in the Test South Area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



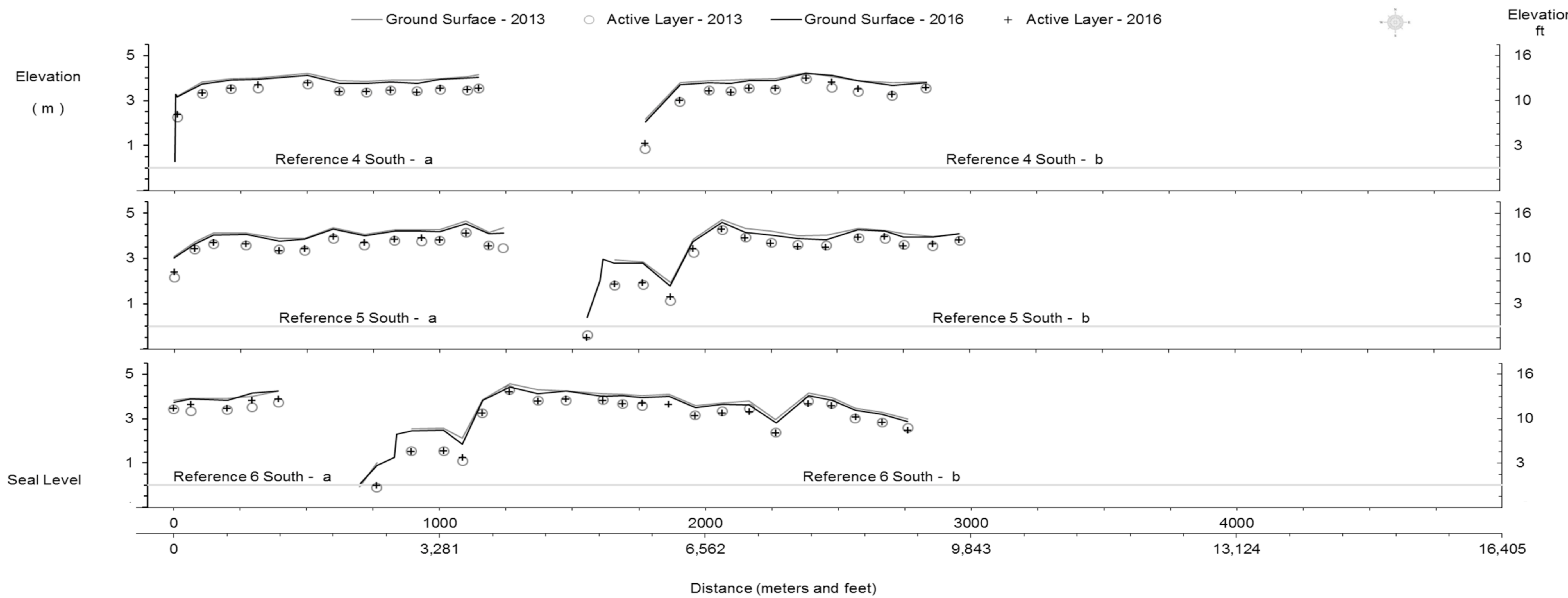
Appendix J1. Cross section of ground surface elevation and thaw depth along transects (1–4) in the Reference North Area Transects, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix J2. Cross section of ground surface elevation and thaw depth along transects (6–8) in the Reference North Area Transects, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix J3. Cross section of ground surface elevation and thaw depth along transects (1–3) in the Reference South Area Transects, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.



Appendix J4. Cross section of ground surface elevation and thaw depth along transects (4–6) in the Reference South Area Transects, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

Appendix K. Detailed ground cover summary statistics by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2016.

sample_year	area_title	vtc_title	min_cov_percent	max_cov_percent	avg_cov_percent	n_cov_percent
2013	Reference	Fungi	1.3	1.3	1	1
2013	Reference	Herbaceous Litter	2.6	97.4	26	60
2013	Reference	Lichens	1.3	9.2	3	8
2013	Reference	Liverworts	1.3	6.6	3	11
2013	Reference	Mineral Soil	1.0	100.0	36	34
2013	Reference	Mosses	1.3	93.4	49	64
2013	Reference	Tussock	1.3	2.6	2	2
2013	Reference	Vascular Base	1.3	14.5	4	63
2013	Reference	Water	1.3	100.0	29	41
2013	Reference	Woody Litter	1.3	1.3	1	2
2016	Reference	Herbaceous Litter	1.3	82.9	29	70
2016	Reference	Lichens	1.3	11.8	4	7
2016	Reference	Liverworts	1.3	6.6	2	18
2016	Reference	Mineral Soil	1.3	100.0	25	48
2016	Reference	Mosses	5.3	97.4	54	67
2016	Reference	Organic Soil	1.3	27.6	9	11
2016	Reference	Tussock	1.3	1.3	1	1
2016	Reference	Vascular Base	1.3	7.9	3	58
2016	Reference	Water	1.3	38.7	13	12
2016	Reference	Wildlife Scat	1.3	1.3	1	7
2016	Reference	Woody Litter	1.3	4.0	2	8
2013	Test	Algae	1.3	5.3	3	3
2013	Test	Herbaceous Litter	1.3	80.3	24	93
2013	Test	Lichens	1.3	14.5	4	18
2013	Test	Liverworts	1.3	21.1	4	8
2013	Test	Mineral Soil	1.3	100.0	44	26
2013	Test	Mosses	1.3	92.1	48	94
2013	Test	Tussock	1.3	1.3	1	1
2013	Test	Vascular Base	1.3	14.5	4	86
2013	Test	Water	1.3	100.0	33	66
2013	Test	Woody Litter	1.3	5.3	2	5

Appendix K. Continued.

sample_year	area_title	vtc_title	min_cov_percent	max_cov_percent	avg_cov_percent	n_cov_percent
2016	Test	Algae	2.6	2.6	3	1
2016	Test	Gravel	2.6	2.6	3	1
2016	Test	Herbaceous Litter	1.3	77.6	31	98
2016	Test	Lichens	1.3	13.2	4	17
2016	Test	Liverworts	1.3	4.0	2	15
2016	Test	Mineral Soil	1.3	100.0	32	49
2016	Test	Mosses	1.3	89.5	51	97
2016	Test	Organic Soil	1.3	54.0	10	19
2016	Test	Tussock	4.0	4.0	4	1
2016	Test	Vascular Base	1.3	9.2	4	85
2016	Test	Water	1.3	100.0	33	13
2016	Test	Wildlife Scat	1.3	2.6	1	9
2016	Test	Woody Litter	1.3	4.0	2	9