2019 Habitat Monitoring and Assessment
CD5 Development Project

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Fairbanks and Anchorage, Alaska

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CD5 DEVELOPMENT PROJECT

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EXECUTIVE SUMMARY

This report presents the results of the 2019 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 Special Stipulation #1. The specific objectives of the 2019 CD5 Habitat Monitoring Study were to: 1) conduct the second year of post-construction data collection and monitoring of climate and habitat in the CD5 Habitat Monitoring Study Area; 2) analyze and summarize 2019 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 2018 high-resolution aerial imagery and 2019 field data; and 4) present findings at an agency and stakeholder meeting in February 2020.

The 2019 CD5 Habitat Monitoring Study includes two components: local climate monitoring and habitat monitoring. For each of these components, ABR collected and assessed data from this second post-construction monitoring event 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, 2013–2019, as these are the months during which the habitat monitoring field work occurred. Snowfall and snow depth data were also summarized for the winter months preceding field work.

For the habitat monitoring component, ABR completed several tasks. Habitat-monitoring field surveys were conducted 11 July–6 August 2019 during which habitat-monitoring locations were accessed via helicopter 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 2019 to assess potential changes in thaw depth and ground surface elevation through time, per the Monitoring Plan

The baseline map Integrated Terrain Unit (ITU) mapping was updated using high-resolution imagery acquired 13 July 2018; imagery acquired 16 August 2017 was used as the basis for map updates for areas that were cloud-covered in the 2018 imagery. The updated mapping was then used to perform a landscape change analysis as indicated in the Monitoring Plan. This second 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 and regionally across the Beaufort Coastal Plain.

ABR performed a wildlife habitat analysis, 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 2019 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 significant interaction between Area and year for willow (*Salix*) cover. In Patterned Wet Meadow, *Salix* cover increased substantially between 2013 and 2019 in the Reference Area (from 10.7 to 16.8%), but only slightly in the Test Area (from 11.6 to 12.1%). While the cause of this increase and how it differs by area is unknown, it bears increased scrutiny in future monitoring efforts because *Salix* provides important habitat (forage and cover) for many wildlife species.

The vegetation plot assessment data analysis methods follow directly from the Monitoring Plan. Specifically, vegetation data from both Test and References Areas in 2019 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 80% of Vegetation Plots (144 plots) had not changed in plant species composition between 2013 and 2019, 6% (10 plots) showed a change, and 14% (25 plots) were flagged as potentially changing species composition between 2013 and 2019. Of the 10 plots that showed changes in species composition, 3 were Upland Sandy Alkaline Moist Low Willow Shrub, which is characterized by low willow vegetation on inactive sand dunes. Environmental variables related to riverine processes of flooding, sedimentation, and deeper thaw depths, suggest that these plots are expressing a higher degree of riverine activity (i.e. more flooding) in 2019. These changes occurred in both the Test and Reference areas north and south of the CD5 Road, indicating the observed changes are unrelated to the CD5 Road. The remaining 7 plots that changed are all wet (4 Wet Sedge Meadow Tundra and 3 Wet Sedge-Willow Tundra), and all but 1 Wet Sedge Meadow plot are located in Test Areas. The changes at the Wet Sedge Meadow Tundra plots were attributable to increases in the cover of sedges (*Carex* sp. and *Eriophorum* sp.), and 3 of the Wet Sedge Meadow Tundra plots showed minor subsidence since 2013. The changes at 2 of the Wet Sedge-Willow Tundra plots correspond to predicted increases in elevation and less frequent flooding, with increases in *Salix reticulata* and *Equisetum* spp. The 1 remaining Wet Sedge-Willow Tundra plot was flagged as disturbed by avian grazing, and while species richness increased, total vascular cover declined by 9.2% in 2019. In summary, the total number of Vegetation Plots identified as having changed in species composition between 2013 and 2019 is small (6% 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 stayed the same or increased between 2013 and 2019 in both Test and Reference areas, 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, 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. However, surface organic thickness was significantly thinner in 2019 than in 2013, with increased variability.

In summary, the results of the 2019 Habitat Monitoring showed very little ecosystem change between 2013 and 2019. Broad-scale changes that were observed between years, including the decrease of standing water and mineral soil cover, and increase in moss cover were observed in both Reference and Test Areas, and hence not attributable to the CD5 Road. Rather, differences in break-up flooding between 2013 and 2019 is the primary causal factor lending to the differences observed. The changes in *Salix* cover in Patterned Wet Meadow habitat, namely *Salix* cover increasing in both Areas but more rapidly in the reference area, warrant increased scrutiny in future monitoring efforts. The CD5 Habitat Monitoring Study effort is scheduled to be conducted again in 2024.

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ACKNOWLEDGMENTS

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1.0 INTRODUCTION

1.1 BACKGROUND

As a condition of the permit to develop the CD5 Project 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 and 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 industrial development activities in North Slope wetlands, rivers, and streams, and more than 10 years of oil and gas extraction in the Colville River Delta (CRD), impacts resulting from gravel placement on tundra, and effects of bridges across rivers and streams are well understood.

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). As discussed with federal management 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, the overall goals of the CD5 Habitat Monitoring Study include (1) determine if placement of gravel results in alteration to wildlife habitats upstream and/or downstream of the CD5 road; (2) quantify plant communities and habitat in permanent plots established upstream and downstream of the road to identify changes through time based on comparisons 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 habitats, geomorphology (soils, permafrost, thaw depth), and sedimentation/erosion over time; and (4) through periodic monitoring of vegetation and hydrology, identify intermediate change trends that, to the extent possible, corroborate sedimentation and erosion predictions.

The 2019 effort was focused on collecting the second 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 2019 CD5 Habitat Monitoring Study were to:

1. Conduct the second year of post-construction data collection and monitoring of climate and habitat in the CD5 Habitat Monitoring Study Area;
2. Analyze and summarize 2019 field data in comparison to the 2013 baseline data, update the Integrated Terrain Unit (ITU) mapping in the CD5 Habitat Monitoring Study Area, based on 2018 high-resolution aerial imagery and 2019 field data, and prepare summary reports and maps; and
3. Present findings at an agency and stakeholder meeting in February 2020.

1.3 CD5 HABITAT MONITORING STUDY AREA

This study was conducted in the CD5 Habitat Monitoring Study Area, which is located along the Niġliq Channel in the southwestern portion of the 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. 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 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. The Test Areas are limited to an area within approximately 1.9 km of the CD5 road. 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.

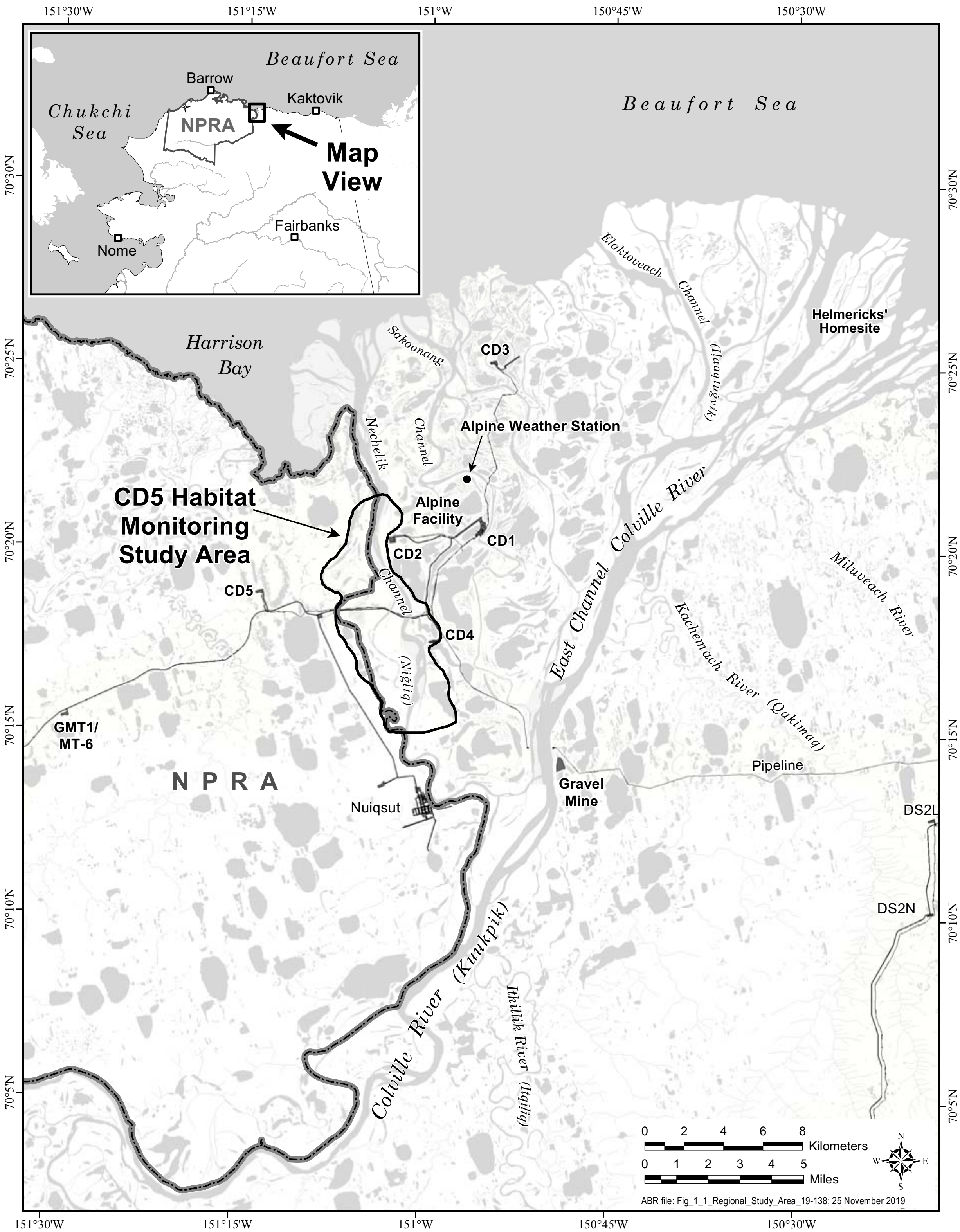

Figure 1.1 Overview map showing the location of the CD5 Habitat Monitoring Study Area on the Colville River Delta, northern Alaska, 2013–2019.

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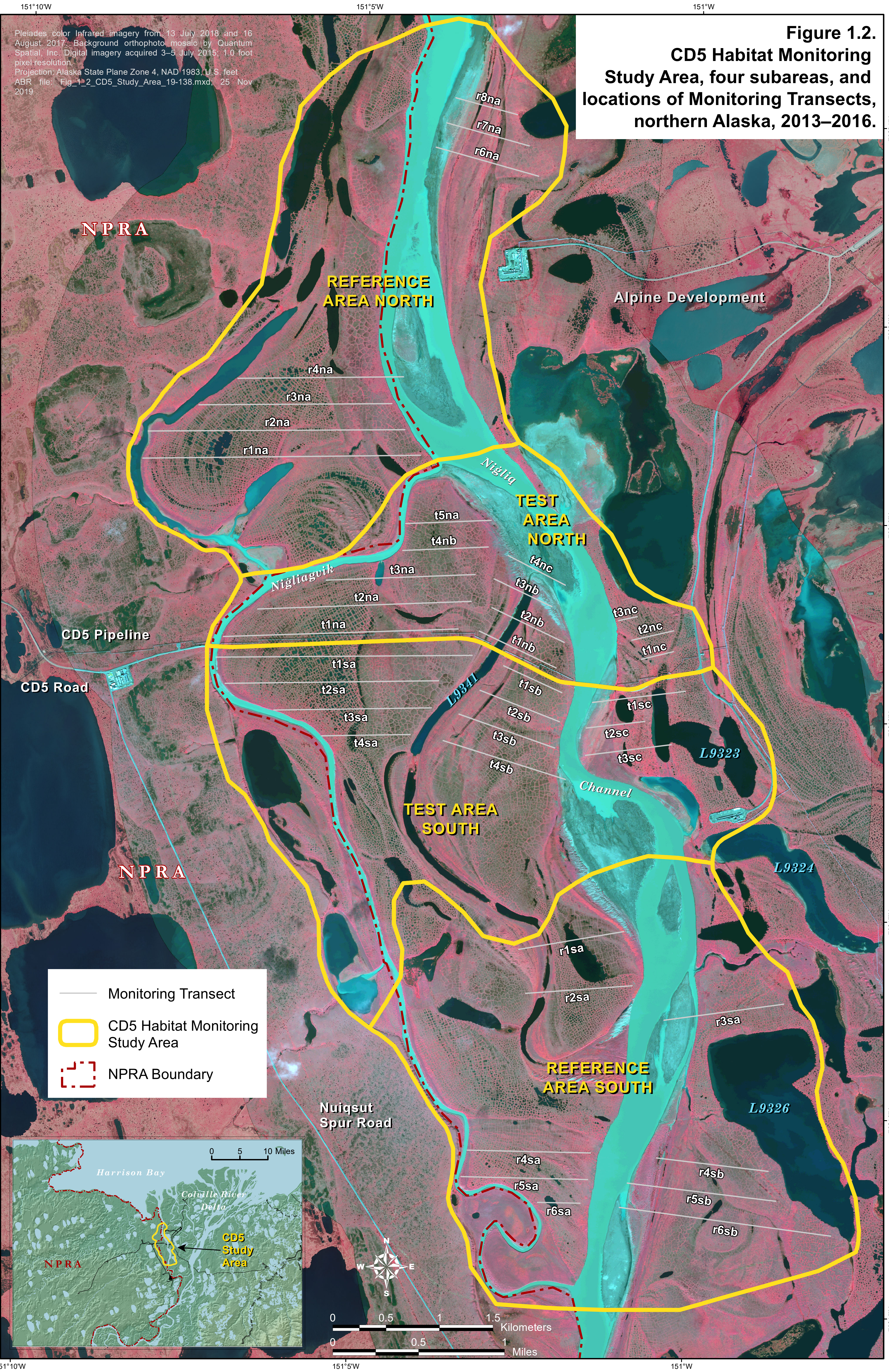

Figure 1.2. CD5 Habitat Monitoring Study Area, four subareas, and locations of Monitoring Transects, northern Alaska, 2013–2016.

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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 and/or climate change 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, 2013–2019, 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 2019). 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 summarizing by 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. Precipitation data were suspiciously low for 2019, so precipitation data from the Colville Village weather station was used instead. The first snow-free date in spring was estimated by finding the first day of the year on which 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 summarized 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 2019 field season and compared with similarly aggregated snow depth and cumulative snowfall data from nearby stations.

The 95th percentile for snow depth was chosen 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 2019), 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. 2012) 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 2019 thaw seasons (1 May–1 October) are presented in Figure 2.1. The 2019 thaw season started in the third week of May and daily high temperatures were consistently above freezing by 1 June. Overall temperatures in May 2019 were similar both to 2013 and the 2013–2019 average (Figure 2.2). Despite the near normal temperatures in May 2019, the first snow-free date of the year did not occur until 13 June (Table 2.1), possibly because of a deeper snowpack (see Section 2.3.3). June, July, and August temperatures were all close

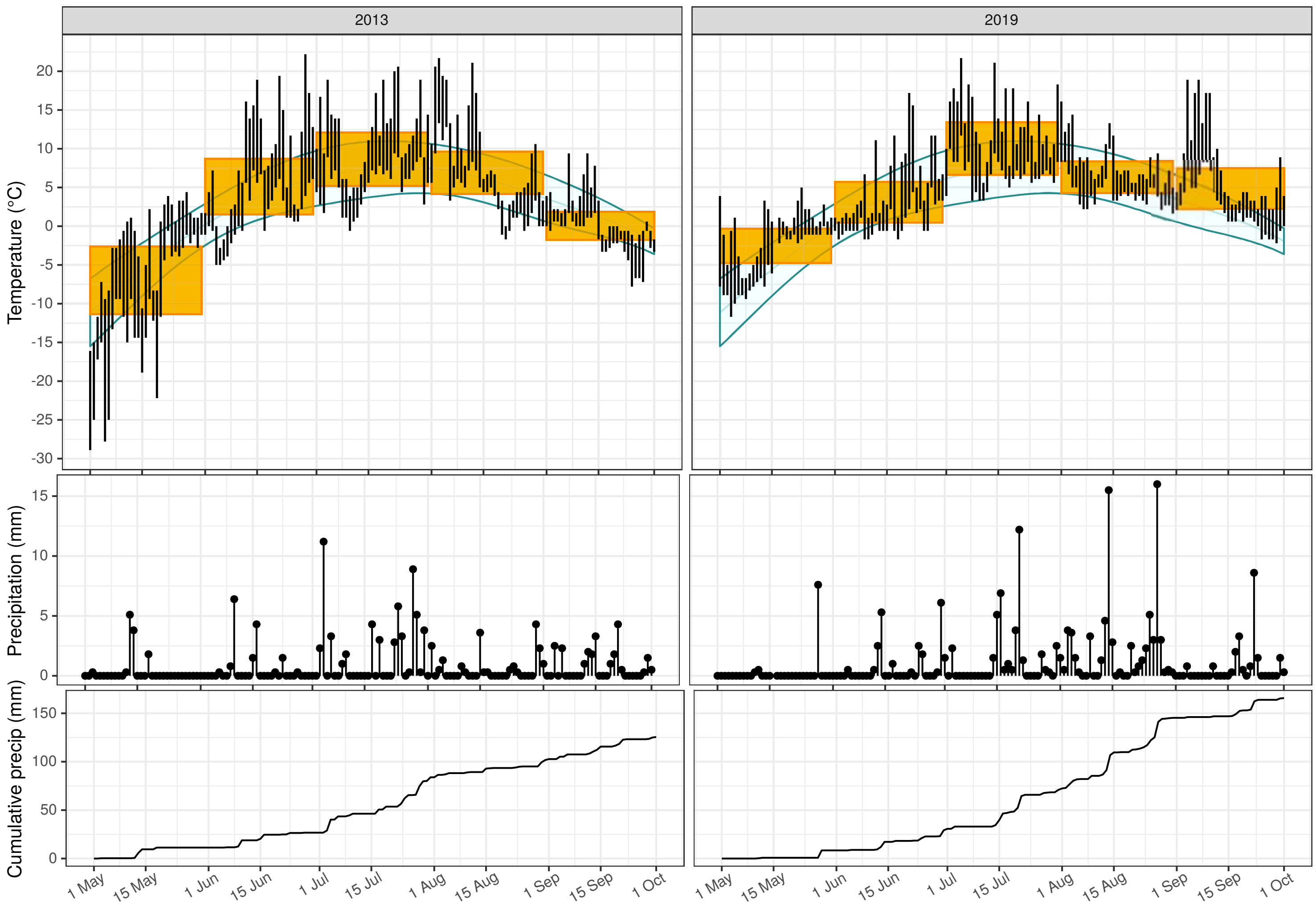

Figure 2.1 Charts summarizing temperature and precipitation data from the Colville River weather station, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019. (Top) daily minimum and maximum temperature (black bars), monthly average high and low temperature (orange boxes), and 1981-2010 Climate Normal temperatures (light blue). (Middle) Daily precipitation (mm). (Bottom) Cumulative precipitation from 1 May–1 October.

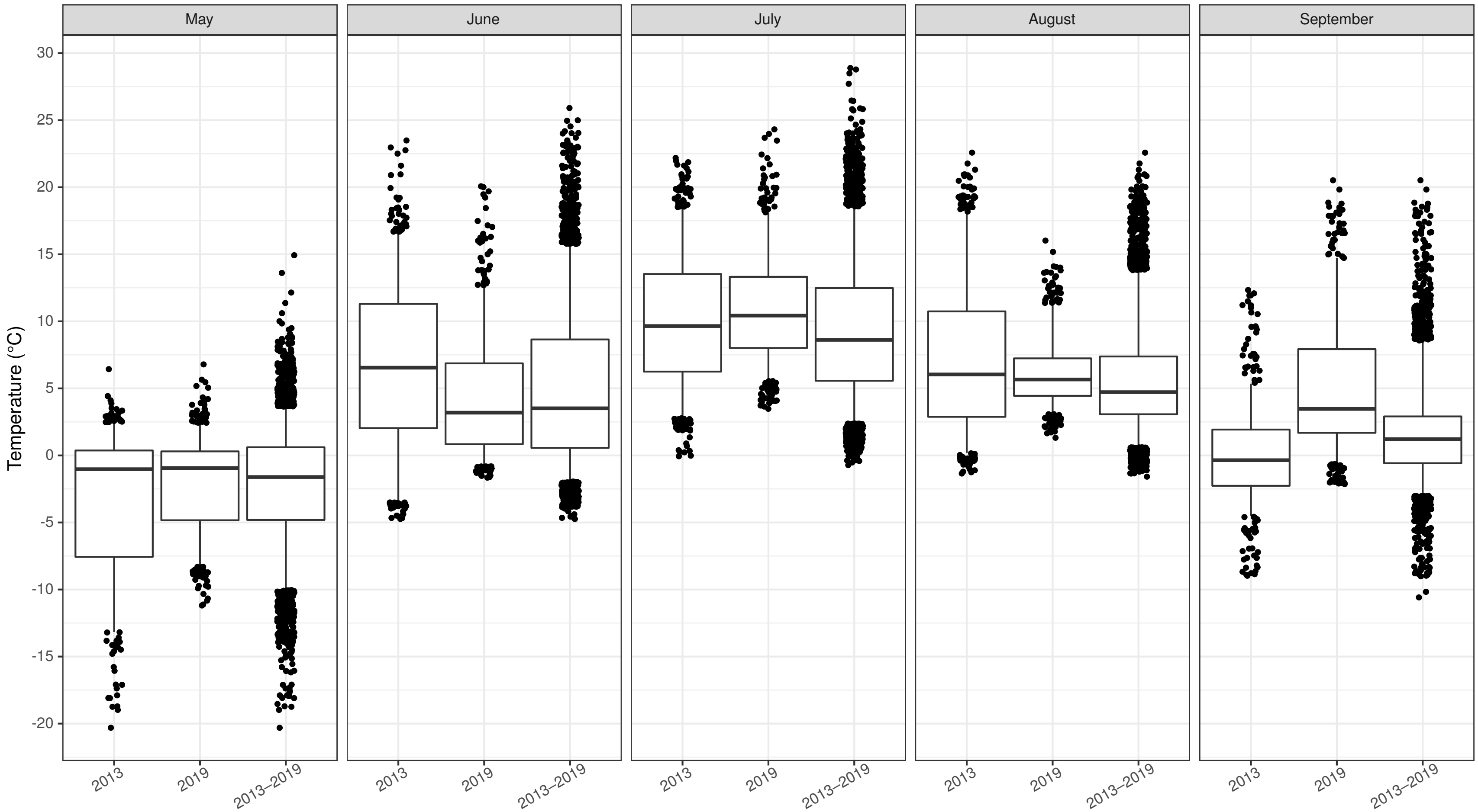

Figure 2.2 Boxplots summarizing monthly temperature distribution for the months May through September, 2013, 2019, and all years (2013–2019), Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019. Boxes represent the 25%–75% quartiles, the horizontal line through each box is the mean value, lines above and below the boxes extend to 5% and 95%, and the dots represent the remaining extreme temperatures.

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, 2013–2019.

Year	CD5 Alpine	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
2017	2017-06-19	2017-05-26	2017-06-03
2018	2018-06-13	2018-06-08	2018-06-20
2019	2019-06-13	2019-05-23	2019-06-06

to normal in 2019, but September was significantly warmer than both 2013 and the 2013–2019 average. Freeze-up in 2019 was much later than average, and mean daily temperatures in 2019 remained above freezing into early October.

Total summer rainfall in 2019 at the Colville Village station was 165.7 mm, significantly higher than the 124.5 mm that fell in 2013 and the 2013–2019 average of 125.3 mm (Table 2.2). June was the driest of the summer months in 2019; most of the precipitation in the 2019 thaw season came in August, with almost twice as much precipitation (74.4 mm) as the next rainiest month (July, 41.7 mm). In contrast, almost half of the summer precipitation in 2013 fell in July. The 1981–2010 climate normal at the Colville Village station for total precipitation during the thaw season is 84.1 mm, which suggests that the CRD is becoming wetter in the summer.

2.3.2 WIND

Winds during the thaw season are predominantly east-northeasterly in the CD5 Study Area, except in September when winds also come from the west-southwest (Figure 2.3). Winds in 2019 mostly followed this pattern except in August, when westerly winds were prevalent. Wind speeds in 2019 were usually in the low category, as is normal, with well over half of all observations between 1–5 mps (Table 2.3). In May, however, the frequency of medium and high wind speeds was much greater, accounting for more than 55% of observations. On 20 July, the region experienced a significant wind event with sustained winds in excess of 15 mps and gusts measured above 25 mps at Alpine and nearby climate stations.

2.3.3 WINTER SNOWPACK

The 2018–2019 winter snowpack depth in the CD5 Study Area (482.4 mm) was higher than in any other year of the study (2013–2019) (Table 2.4). Snowpack depth during the winter season at the Colville Village station (381 mm) was also significantly higher in 2019.

2.3.4 WATER BALANCE

Evapotranspiration rates in 2019 were slightly lower than the 2013–2019 average evapotranspiration for all summer (May–August) months except July, when rates were essentially normal (Table 2.5).

The combination of a deeper snowpack, later snowmelt, and above-normal May–July precipitation, and slightly below-normal evapotranspiration rates likely contributed to somewhat wetter soil moisture conditions in 2019 compared with the previous field sampling year in 2016. However, soil moisture conditions in 2019 were somewhat drier than in 2013, when a massive spring breakup flood inundated the CD5 Study Area for several days. The instrumental measurements collected in 2019 were corroborated by field observations made during the habitat monitoring field effort during July and August 2019.

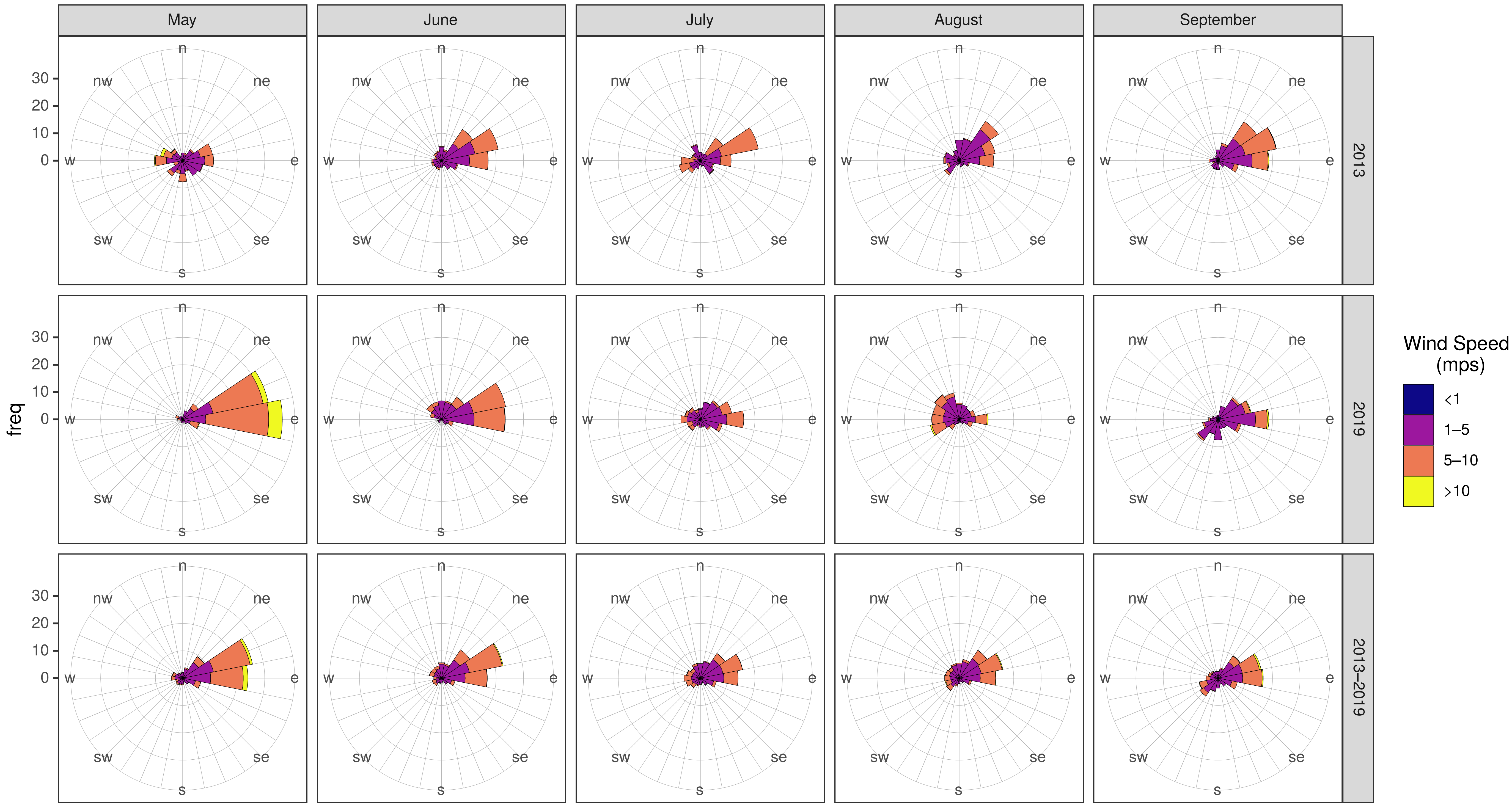

Figure 2.3 Charts summarizing monthly wind speed and direction for the months May through September, 2013, 2019, and all years (2013–2019), Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

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Table 2.2 Monthly summer precipitation totals in mm, 2013, 2019 and average monthly totals (2013 and 2019), Colville Village Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Period	2013	2019	2013–2019
May	11.3	8.4	7.4
June	15.4	20.8	15.6
July	57.2	41.7	29.1
August	17.8	74.4	45.3
September	23.8	20.4	27.9
TOTAL	125.5	165.7	125.3

Table 2.3 Categorized wind speed frequency by month for 2013, 2019, and average for 2013 and 2019, 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	3.0	70.8	24.5	1.7
May 2019	3.4	41.0	48.7	7.0
May 2013–2019	4.2	57.4	35.5	3.0
June 2013	4.2	69.0	26.8	
June 2019	3.3	62.1	34.4	0.1
June 2013–2019	2.9	61.7	34.7	0.7
July 2013	2.8	59.4	37.5	0.3
July 2019	5.1	72.4	21.9	0.5
July 2013–2019	3.9	68.3	27.4	0.4
August 2013	6.7	76.7	16.5	
August 2019	6.5	65.3	27.0	1.2
August 2013–2019	4.3	66.4	28.5	0.9
September 2013	4.3	66.9	28.3	0.4
September 2019	9.4	79.0	10.7	0.8
September 2013–2019	5.6	66.9	26.2	1.3

Table 2.4 Maximum snow depth (95th percentile, mm) at the Alpine Weather station and the Colville Village station, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Winter Year	CD5 Alpine Snowpack (mm)	Colville Village Snowpack (mm)
2012–2013		305
2013–2014	415.00	305
2014–2015	352.00	279
2015–2016	156.00	203
2016–2017	236.00	254
2017–2018	277.00	254
2018–2019	482.35	381

Table 2.5 Average daily reference evapotranspiration (mm per day) by month for 2013, 2019, and average for 2013–2019, Alpine Weather Station, CD5 Habitat Monitoring Study Area, northern Alaska.

Month	2013	2019	2013–2019
May	1.52	1.17	1.27
June	2.69	2.07	2.27
July	2.47	2.52	2.51
August	1.95	1.19	1.36

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 categories that reflect use by birds and mammals (Jorgenson et al. 1997a). The CRD is a complex environment with many interacting biotic and abiotic landscape elements (Wells et al. 2014), which makes long-term habitat monitoring in this environment 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 changes. 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 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 so that impacts are not anticipated.

3.3.1.A Permanent Habitat Monitoring Transects

Permanent Habitat Monitoring Transects (referred to 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 (e.g., veg_cover) are written in bold and italics, and database table field names (e.g., plot_id) are written in italics. Dot notation is used to specify a field name in a specific table; for example, 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 (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 2 spatial scales, including (1) the local plant 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 naming conventions used to identify Integrated Plots (superplot_id) were:

- 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, and 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".

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 from 23–27 May 2019. ABR staff participated in gage surveys and assisted with preparations for discharge measurements. During the daily field operations, ABR field staff recorded observations and photo- and video-documented breakup activities. Photographs were taken using an 8 megapixel iPhone 6 camera system with 1.5µ pixels and *ƒ*/2.2 aperture. Videos were taken using the iPhone 6 video system with 1080p HD video recording (30 fps or 60 fps). Field notes were digitized and archived with spring breakup photos.

3.3.2.B Habitat Monitoring

Habitat-monitoring field surveys were conducted from 10 July–6 August 2019. Three crews of 4 people, each crew consisting of 2 botanists, 1 soil scientist, and 1 bear guard, completed the habitat-monitoring fieldwork. All crews were based out of the Alpine Oil Facilities on the CRD. Field crews accessed the study area via bus, truck, or helicopter, and then walked to each Integrated Plot. Prior to these surveys, an ABR avian crew performed ground nest searches in the CD5 Study Area to ensure that no Spectacled Eider (*Somateria fischeri*) or Steller's Eider (*Polysticta stelleri*) nests would be disturbed during the monitoring effort, in accordance with USACE and federal Biological Opinion (BO) requirements. Nest searches were performed during 17–21 June and 24–26 June; no nests of these or other ESA-protected species were found (Shook and Johnson 2019).

Habitat-monitoring field crews (Habitat Crews) worked with UMIAQ Environmental, LLC (UMIAQ; formerly LCMF Engineering) to precisely locate the Integrated Plots established in 2013 (Figure 3.1). ABR supplied UMIAQ with the GPS locations for all Vegetation Plot Start Points, Habitat Plot Centers, and Habitat Plot Line End Points before field surveys began. Habitat Crews met with UMIAQ in the field to review the layout of the Integrated Plots on site (Figure 3.2), and to discuss how best to avoid trampling vegetation in the plots. Working ahead of the Habitat Crews, UMIAQ walked the Monitoring Transects using Real Time Kinematic (RTK) GPS equipment to relocate the Vegetation Plot Start Point, Vegetation Plot End Point, Habitat Plot Center, and Habitat Plot Line End Points at each Integrated Plot. Pin flags placed at each of the above locations served as temporary markers for the Habitat Crews.

3.2.2.B.i. Vegetation Plots

Habitat Crew leaders used GPS units and digital field maps 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 sampling gear were placed well away from the plot to avoid trampling in the plot area.

<u>Monumentation</u>

In 2013, Vegetation Plot Start Points were permanently monumented by burying a Surv-Kap® magnetic marker 20 cm below the soil surface, and inserting a survey nail with bright pink survey whiskers and an aluminum tag labeled with the plot_id (e.g., t1na-0000-veg) at the surface. In 2016, a second survey nail with bright blue whiskers and an aluminum tab with plot_id + END (e.g., t1na-0000-veg END) was placed at each Vegetation Plot End Point to further facilitate the precise relocation of each plot. Prior to the 2019 field effort, UMIAQ surveyors placed temporary pin flags at the survey nails marking the Vegetation Plot Start and End Points; this enabled Habitat Crews to quickly relocate Vegetation Plots and avoid trampling vegetation inside the plot. At a few plots, the survey nails could not be found (e.g., due to sedimentation or physical disturbance by ice gouging during spring breakup). 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. Before field sampling, Habitat Crews temporarily set wooden lath next to the survey nail for use in photographic documentation of each Vegetation Plot. A 30-m tape (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 or survey nail was used to hold the meter tape temporarily in place for the Vegetation Plot Start Point Photo.

<u>Vegetation Plot Photographs</u>

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

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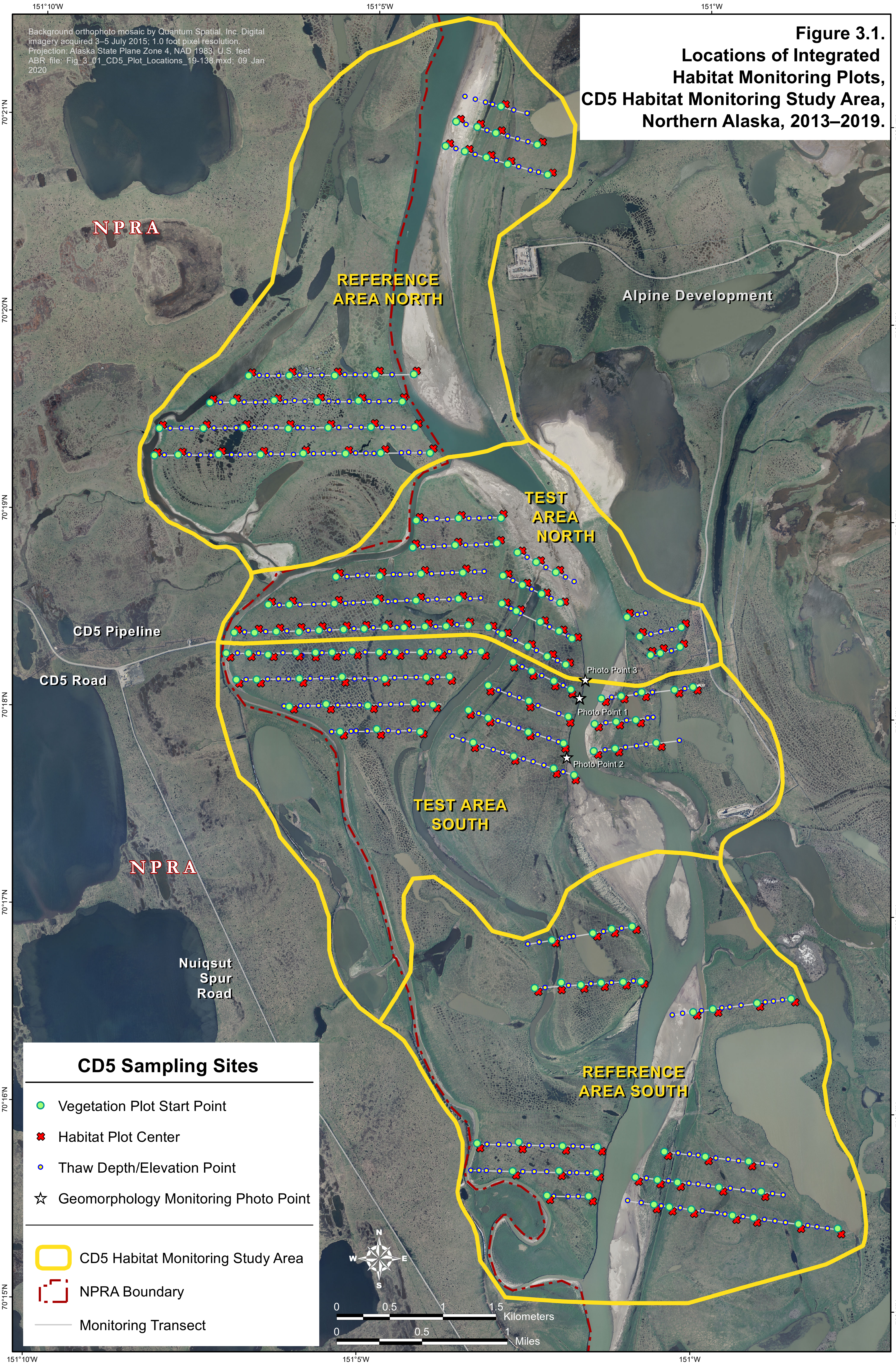

Figure 3.1. Locations of Integrated Habitat Monitoring Plots, CD5 Habitat Monitoring Study Area, Northern Alaska, 2013–2019.

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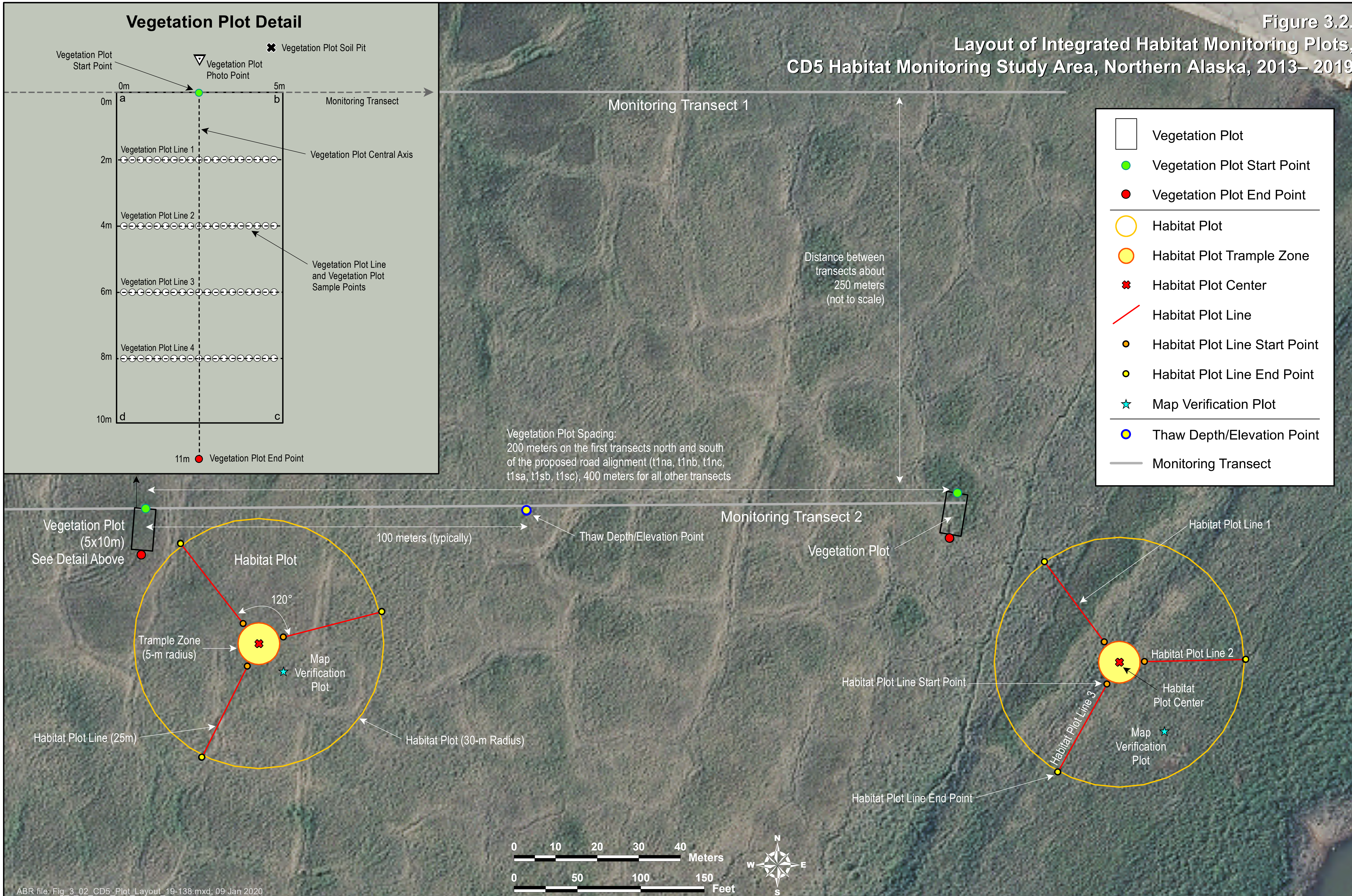

Figure 3.2.
Layout of Integrated Habitat Monitoring Plots,
CD5 Habitat Monitoring Study Area, Northern Alaska, 2013– 2019
Vegetation Plot Detail
Vegetation Plot Soil Pit
Vegetation Plot Start Point
Vegetation Plot Photo Point
0m
5m
a
b
Monitoring Transect
Vegetation Plot Central Axis
Vegetation Plot Line 1
Vegetation Plot Line 2
Vegetation Plot Line 3
Vegetation Plot Line 4
2m
4m
6m
8m
10m
d
c
Vegetation Plot Line and Vegetation Plot Sample Points
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
Monitoring Transect 2
Vegetation Plot (5x10m)
See Detail Above
100 meters (typically)
Thaw Depth/Elevation Point
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 3
Habitat Plot Line Start Point
Habitat Plot Center
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 E S W
ABR file: Fig_3_02_CD5_Plot_Layout_19-138.mxd; 09 Jan 2020

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length. All photographs were taken without zoom and photograph file-size was standardized to 23 MB. All equipment, packs, and crew members 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 ABR-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 those above with the meter tape at the 15-m mark (Figure 3.2 inset, corner "d"). These corners were adjusted to ensure that the 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 the rectangular vegetation plot 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 laser beam intersects with a live or dead plant part or ground cover class (e.g., bare soil) are recorded. 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.

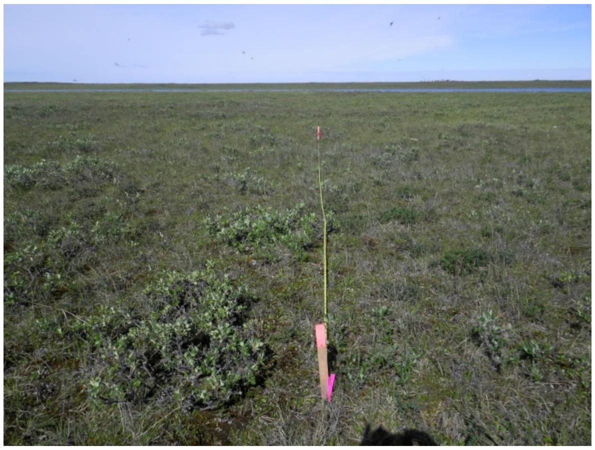
A meter tape was used to establish the Vegetation Plot Lines at 2-m increments along the long axis of the Vegetation Plots, starting at 2 m and ending at 8 m (Figure 3.2). The Vegetation Plot Lines were set up perpendicular to the Central Axis of the Vegetation Plot using meter marks on the meter tape,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

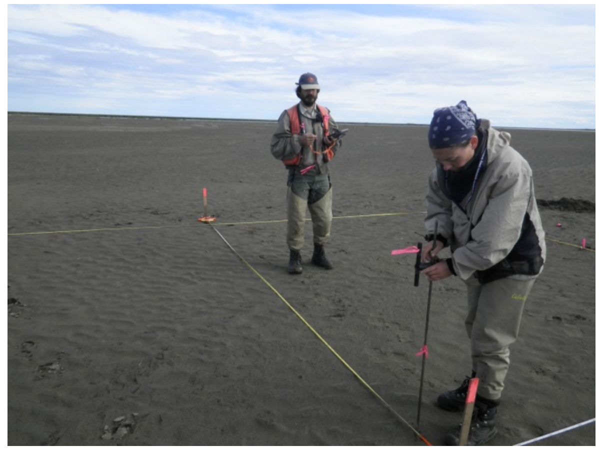
All field data were recorded digitally in the field (Figure 3.3, middle right) using a standardized data entry form on an Android tablet computer designed to upload data to a relational database (PostgreSQL). Point-intercept protocols for Vegetation Plots were as follows:

At each sampling point:

- The laser pointer was directed down unless vegetation existed that was taller than the laser pointer mount (~1.0 m; primarily willow shrubs), in which case the laser pointer was first directed up to record hits above the laser pointer mount, and then directed down to records hits below the mount
- The frost probe with laser pointer was oriented such that the laser pointer mount is pointing toward the far end of the vegetation plot and thus perpendicular to the vegetation plot sampling lines
- Lines were sampled by starting at the western most end and working east on each line.
- Canopy Hits
    - All hits were recorded beginning at the highest hit and proceeding downward to the ground cover (last hit).
    - 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. The exception to this was dead (previous growing season) leaf tips of *Eriophorum angustifolium,* which when hit were counted as standing dead using the “dead” hit modifier (see below, Hit Modifiers).
    - All laser hits count, including “glancing blows” (though not reflected light, which was most obvious when vegetation was wet)
    - In windy conditions the botanists at first waited a few seconds for a lull before calling out hits, next the botanists attempted to use their bodies to block the wind. If neither of these worked, then the botanist performing the point intercept sampling closed their eyes for 1–2 seconds and quickly opened them. If a hit with the laser beam was observed immediately upon opening their eyes then it was counted, if not, then no hit was counted.
- Hit modifiers
    - Hit modifiers were used to indicate something unique about a specific hit.
    - Allowable hit modifiers included:
        - **Base:** used to indicate a hit of the lowest part of the stem of a plant as it emerges from the ground
        - **Canopy:** used to indicate a hit of a ground cover type that is legitimately not the last hit (e.g., litter “rafted” by floodwaters and deposited in the canopy of a shrub).
        - **Collect:** used to indicate that a plant species that was hit during point intercept sampling was later collected (for positive identification) outside the plot area.
        - **Dead:** also referred to as “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.



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 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, 2013–2019.

        - 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 genus (if known) or lifeform (forb, shrub, etc.).
        - A dead branch on live shrub is considered standing dead
    - **Stem:** used to indicate stem hits of woody species and only for non-photosynthetic woody parts.
    - **Stressed:** used to indicate hits of plant parts displaying signs of stress (e.g., yellowing).
    - **Trace:** used during point intercept sampling to indicate a trace species recorded using the point intercept app that was not hit with the laser.
    - **Tuss:** used to indicate a hit of the abiotic portion of a tussock
    - **Underwater:** used to indicate a hit of a live vascular or nonvascular plant that is underwater.
- Heights
    - ABR recorded heights following the Bureau of Land Management Assessment, Inventory & Monitoring (BLM AIM) protocol (Herrick et al. 2017), with modifications from NPRA (Boucher et al. 2016).
    - Height measurements and species for the tallest live woody and herbaceous plants were collected at every fifth sample point (starting with the first point on each line).
    - The tallest attached plant part that intersected an imaginary cylinder of 15-cm radius 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.
    - Plant-height minimum (when a plant was present) was set at 1 cm. The minimum height was recorded even if actual plant height was <1 cm.
    - Flowering heads of *Cassiope* and *Dryas* and other dwarf shrubs with flowering parts that are taller than the leaves and stems were not be measured for vegetation heights; instead we measured the height of the highest leaf or non-flowering stem.
    - When either a woody or herbaceous species (or both) were absent at point where heights are recorded, -999 was recorded.
- Water Depths
    - Water depth was recorded from the point on the water surface intersected by the laser beam, 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 0.4 in (1 cm). The minimum depth was recorded even if actual depth was <1 cm.
  - If water occurred below litter, the depth of water was measured if it fell on a point where heights and water depth were measured.
  - When water was present at the point, the plant heights were measured from the soil surface beneath the water.
- Ground Cover Hits (i.e. bottom hit)
  - Only 1 ground cover class hit is allowed at each point, with the exception of a ground cover class suspended in a plant's canopy (see 'Canopy' modifier, above), e.g., rafted litter.
  - Allowable last hits:
    - Abiotic ground cover classes. Common classes included:
      - **Algae:** simple, non-vascular commonly aquatic plants
      - **Fungi:** i.e., mushrooms
      - **Debris:** human refuse, i.e., trash
      - **Gravel:** rocks ranging from >2–76 mm in diameter
      - **Limnic:** reddish, iron-rich organic material typically found in wet low-center ice wedge polygons (see below 'Limnic material vs. mineral soil hits', for additional details.
      - **Litter:** detached dead organic material (see below 'Litter' for additional details)
      - **Scat:** animal fecal droppings, generic (scat) or animal specific (e.g., ptarmigan scat)
      - **Soil:** mineral soil
      - **Water:** standing or flowing water
      - **Woodlit:** detached woody debris >5mm
    - Bryophytes and lichens
    - "Base" hits of vascular plants (see above, Hit Modifiers section)
    - Underwater hits of live vascular and nonvascular species (see above, Hit Modifiers section)
  - Litter
    - Litter was defined as any dead organic material detached at the base.
    - Dead non-vascular plants were recorded as "litter" with no modifier.
    - Dead plants that were attached but appressed to the soil surface were also considered litter.
    - Only hits of live nonvascular vegetation were recorded below litter.
  - Organic vs. mineral soil hits were recorded separately to distinguish between sediment deposited during overbank flood events and other types of exposed soil. Organic soil hits included most commonly "limnic materials."
    - **Limnic material**: reddish, iron-rich organic material typically found in wet low-center ice wedge polygons. When rubbed between the thumb and index finger limnic materials will feel slippery and very smooth.
    - **Mineral soil:** consists of various proportions of sand, silt, and clay with <20% organic carbon content. When rubbed between the thumb and index finger mineral soils will often feel slightly to extremely gritty.
  - Bryophytes and Lichens (collectively referred to as nonvascular plants or nonvasculars)
    - In Vegetation Plots, nonvascular 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 nonvasculars, hits were recorded in broad categories (e.g., foliose and fruiticose lichen, *Sphagnum*, other mosses, etc.) and then 3–5 of the most common mosses and lichens were collected as vouchers. Voucher specimens were collected from outside the plot area.

- ■ In Habitat Plots (see the Habitat Plots section below), 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.
- ■ Live hits of bryophytes that occurred under litter were allowed.

- ○ For the last hit at a point, priority was given to partial hits of live nonvasculars over partial hits of non-vegetated classes (e.g., mineral soil). Therefore if any part of the laser beam hit a nonvascular then the hit was counted as a nonvascular hit.

Vegetation Plot Trace Search

Trace species included all vascular species and up to 3–5 dominant nonvascular species located within the vegetation plot that were not recorded using the point-intercept method along the vegetation plot lines. We conducted the trace species search within the boundary of the vegetation plot after the point intercept sampling was completed.

The following steps were followed when performing the trace search:

- All voucher specimen collections were made outside the vegetation plot boundary after the trace search was complete. During the trace search all species for which a specimen was desired were flagged in the data collection app. If needed, pin flags were used during the trace search to temporarily mark species in the vegetation plot if a specimen was desired.
- For a given plot, a 5 minute timer was started (e.g., on a wrist watch) concurrent with the start of the trace search
    - ○ After the 5 minutes had passed, a 2.5 minute timer was started.
    - ○ Over the next 2.5 minutes, if no new species were encountered then the trace search was terminated. If a new species was encountered, then the 2.5 minute timer was started over again each time a species was encountered until 2.5 minutes had passed since the last new species had been encountered.
    - ○ If 20 minutes of total search time had past and the team was still searching (per the above criteria), then the trace search was terminated.
    - ○ Thus a minimum of 7.5 minutes, and a maximum of 20 minutes was spent on the trace species search. In most cases, the trace search took 7.5–15 minutes.

General Environment Data

Soil scientists on each crew were responsible for collecting general site data at each Vegetation Plot. Geomorphic variables, such as physiography (e.g., Riverine) and surface geomorphology (e.g., Delta Active Overbank Deposit) were recorded if they differed from the terrestrial (Table 3.1), aquatic (Table 3.2), or surface form (Table 3.3) units that were described in 2016. Topographic and site variables were collected, including aspect, slope, microrelief, and the distance and azimuth from the veg plot corner where the soil was sampled. The collection of vegetation variables included vegetation structure (e.g., Low Shrub), the 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 25 cm deep (Figure 3.4), located outside the Vegetation Plot and at least 1 m radius away from the 2013 and

Table 3.1 Standard classification system developed for classifying and mapping terrestrial geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

Code	Geomorphology Unit
Cs	Solifluction Deposit
Esa	Eolian Active Sand Deposit
Esda	Eolian Active Sand Dune
Esdb*	Eolian Abandoned 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
Fhl	Lowland Headwater Floodplain
Fto	Old Alluvial Terrace
Ftr	Recent Alluvial Terrace
Hfg	Gravel Fill
Ltdi	Delta Thaw Basin, Ice-rich
Ltdn	Delta Thaw Basin, Ice-poor
Ltic	Thaw Basin, Ice-rich Center
Ltim	Thaw Basin, Ice-rich Margin
Ltiu	Thaw Basin, Ice-rich Undifferentiated

*Class described in field but not mapped.

Table 3.2 Standard classification system developed for classifying and mapping aquatic geomorphic units in the CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

Code	Geomorphology Unit
W*	Water
Weldc	Brackish Deep Tapped Lake, Connected
Wert	Tidal River
Wldcrh	Deep Tapped Riverine Lake, High-water Connection
Wldir	Deep Isolated Riverine Lake
Wldirt*	Deep Isolated Riverine Thaw Lake
Wldit	Deep Isolated Thaw Lake
Wlscr*	Shallow Connected Riverine Lake
Wlsip*	Shallow Isolated Lake, deep polygon center
Wlsir	Shallow Isolated Riverine Lake
Wlsit	Shallow Isolated Thaw Lake
Wr*	Rivers and Streams
Wrln*	Lower Perennial River, non-glacial

*Class described in field but not mapped.

Table 3.3 Standard classification system developed for classifying and mapping surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

Code	Surface Form
Dt	Water Tracks
Ek	Streaked Dune
El*	Eolian Linear Dunes
En	Dune, undifferentiated
Es	Small Dune
F*	Flat or fluvial related
Fbl*	Lateral Bar
Fbm*	Mid-Channel Bar
Fc*	Channel, Swale or Gut
Fe*	Tread
Fer*	Floodplain Step
Fi*	Interfluv or Flat Bank
Fm*	Flats Margins
Fn*	Nonpatterned
Hm	Human Modified
N	Nonpatterned
Na*	not available
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
Sb	Bluffs or Banks
Tb	Beads
Tm	Mixed Thermokarst Pits and Polygons
W	Water
Wi	Lake with Islands
NULL*	NULL

*Class described in field but not mapped.

Table 3.4 Standard classification system developed for classifying and mapping vegetation in the CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

Code	Vegetation
Bbg	Barren
Bpv	Partially Vegetated
Hfds	Seral Herbs
Hfmm*	Mixed Herbs
Hgdl	Elymus
Hgmsht*	Moist Sedge-Herb Meadow Tundra
Hgmss	Moist Sedge-Shrub Tundra
Hgmst*	Moist Sedge Meadow Tundra
Hgmswt*	Moist Sedge-Willow Tundra
Hgmt	Tussock Tundra
Hgmtd*	Tussock Tundra-Dryas
Hgw*	Wet Graminoid Meadow
Hgwfg	Fresh Grass Marsh
Hgwfs	Fresh Sedge Marsh
Hgwsl*	Subarctic Lowland Sedge Wet Meadow
Hgwst	Wet Sedge Meadow Tundra
Hgwswt	Wet Sedge-Willow 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
W	Water
Wb	Brackish Water
Wf	Fresh Water
Xp	Deep Polygon Complex

*Class described in field but not mapped.

Table 3.5 Standard classification system developed for classifying and mapping disturbances in the CD5 Habitat Monitoring Study area, northern Alaska, 2019.

Code	Disturbance
A	Absent (no recent disturbance)
Hfd*	Dust
Hfgp	Gravel Pad
Hfgr	Gravel Road
Hs*	Structures and Debris
Hseb	Elevated Bridge
Hsep	Elevated Pipeline
Hti	Snow/Ice pads and roads
Htin*	Ice Road or Pad
Na*	Animals, Wildlife
Nabg*	Avian grazing
Nge	Eolian (Wind)
Ngf*	Fluvial
Ngfd	Fluvial deposition
Ngfe	Fluvial erosion/Channel migration
Ngt	Thermokarst
Nsk	Salt killed vegetation

*Class described in field but not mapped.

2016 soil sampling locations (Figure 3.3, middle left). Additionally, 2019 soil sites were selected to reflect the same microtopographic position and similar hydrology as the 2013 and 2016 soil sample locations. Efforts were made to reduce disturbance to the site by incorporating modifications to the soil sample depth (e.g., from 40 cm in 2013 to 25–30 cm deep in 2019) and restricting data collected to a reduced set of variables.

Soil plugs and excavated soil material were placed on tarps to protect the ground surface during sampling (Figure 3.4). 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 25–30 cm of the soil plug or pit:

- Soil descriptions including horizons, horizon depths, soil texture, boundary 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 (see Office Methods section),
- Soil moisture
- Depth to saturated soil,
- Hydric soil indicator (i.e., reduced iron)
- Depth to water table above or below ground surface,
- Thickness of surface organic matter (see Office Methods section),
- Dominant source of organic material (i.e., peat type)
- Depth to frozen ground (see RTK Surveys below),
- 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. 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 (Figure 3.4). The cardinal direction (from the corner to the soil plot), and the

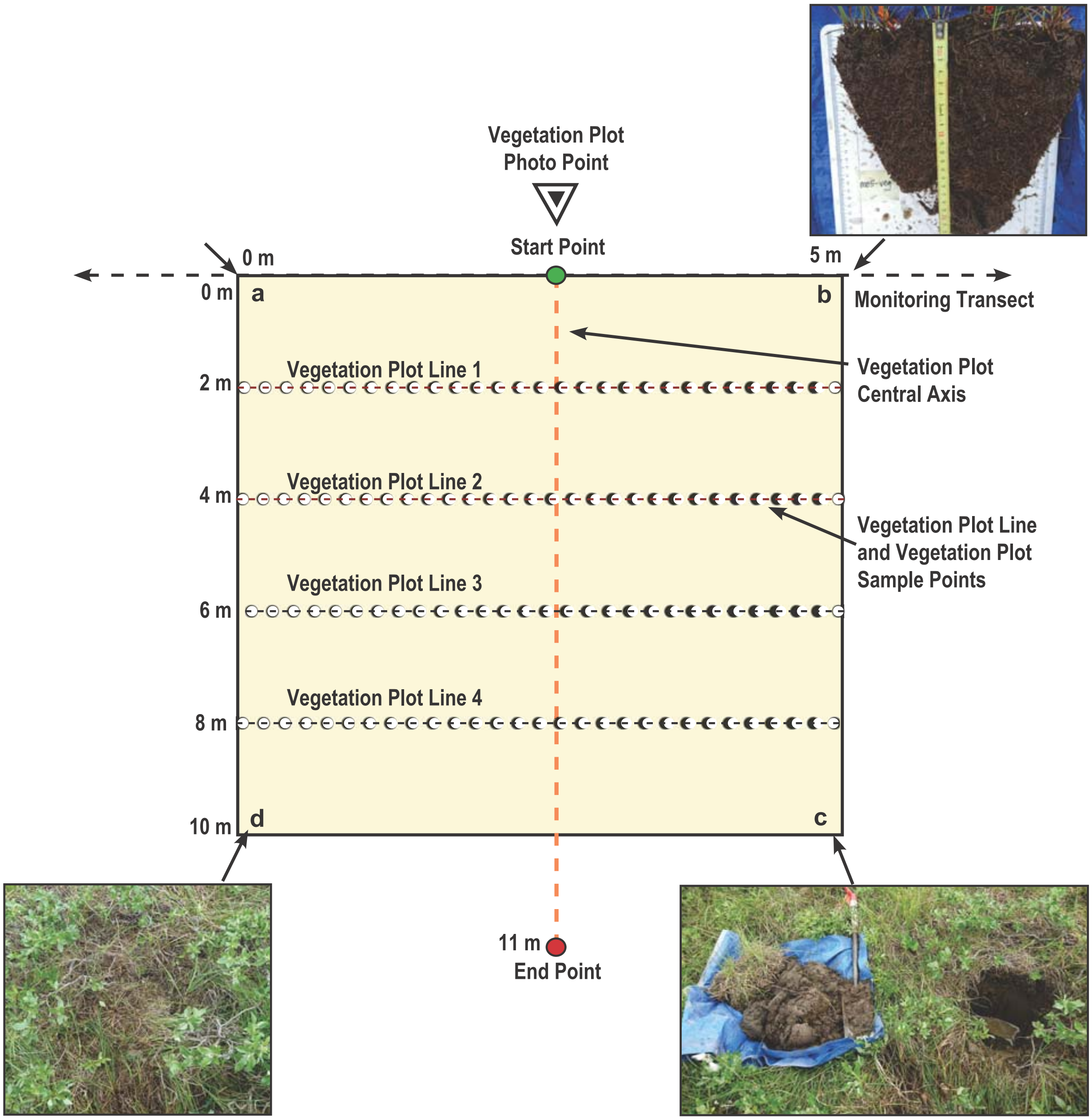


Figure 3.4 Diagram illustrating an example placement of the 2019 soil plug or pit with respect to the vegetation plot (a), a photo of a representative soil plug (b), a photo of a soil pit (c) when a plug could not be used, and an example of a remediated soil pit (d), CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

closest Vegetation Plot corner (Figure 3.4) were recorded with the general environment data.

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 plant 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 Boucher et al. 2016).

<u>Monumentation</u>

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, UMIAQ 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.

<u>Habitat Plot Setup</u>

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.

<u>Habitat Plot Line Photographs</u>

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

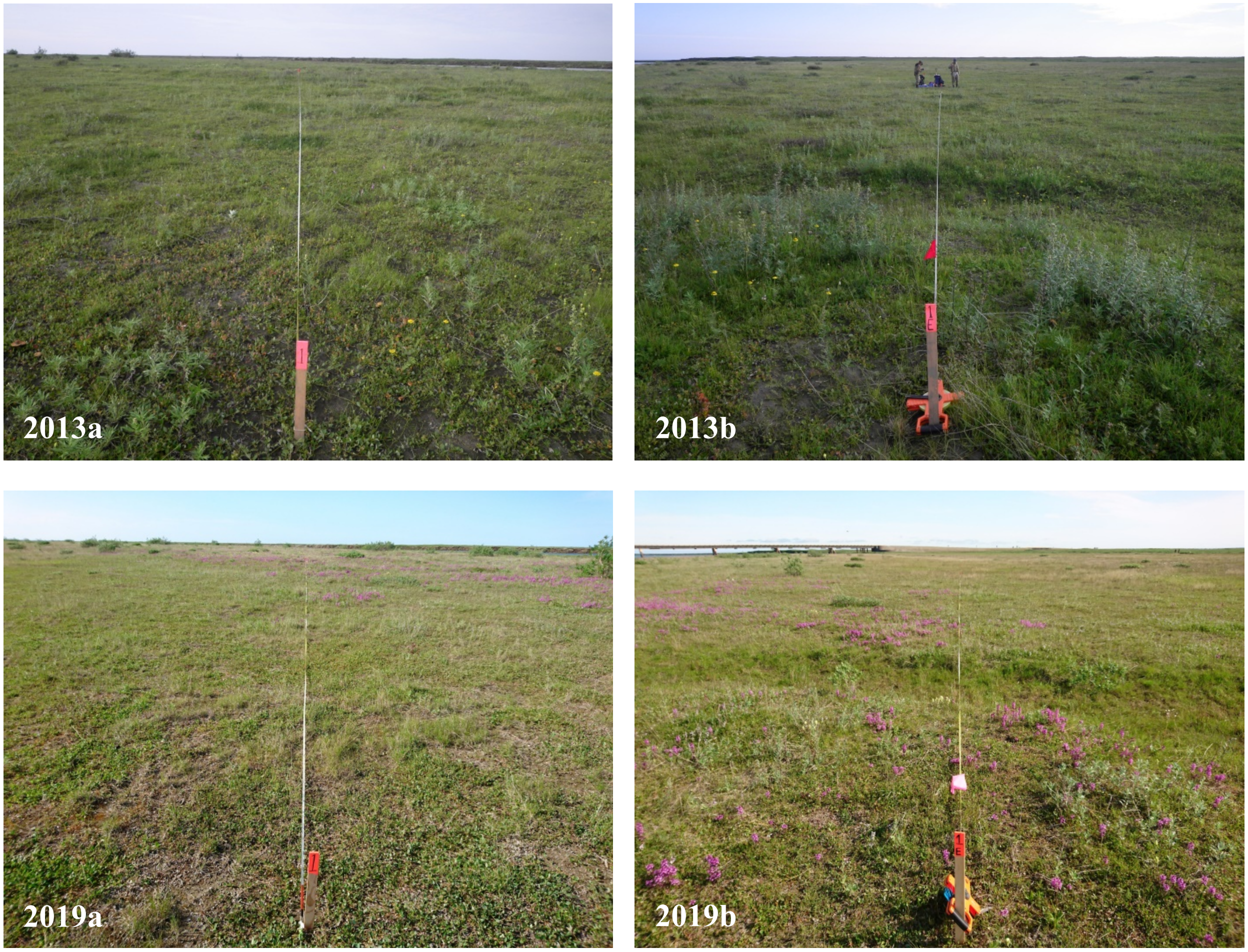


Figure 3.5 Examples of Habitat Plot Line Start Point (a) and Habitat Plot Line End Point (b) photographs from plot t2sc-0000-hab, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

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.

<u>Habitat Plot Lines</u>

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.

<u>Map Verification Plots</u>

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.

3.2.2.B.iii. Real Time Kinematic (RTK) Surveys

<u>Survey Preparation</u>

UMIAQ 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, UMIAQ 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 UMIAQ 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 2019 survey will allow UMIAQ to duplicate similar results over the life of the project.

<u>Elevation and Thaw Depth Survey</u>

To assess potential changes in thaw depth and ground surface elevation through time, per the Monitoring Plan (ABR and Baker 2013), UMIAQ conducted the surveys during the second and third weeks of July 2019 (note that the RTK surveys were conducted in the first and second weeks of August in 2013). While traversing each monitoring transect, UMIAQ 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.

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

We undertook three geomorphology monitoring activities in 2019. First, ABR staff described an undisturbed soil plug or profile adjacent to each 2013 Vegetation Plot Soil Pit. Detailed soil descriptions, including surface organic horizon thickness, were recorded for monitoring of sedimentation and erosion. 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 (i.e., wood and litter deposited during high-water events) was opportunistically recorded as photo observations in the Integrated Monitoring Plots. Third, three geomorphology monitoring repeat photography points (herein, Geomorphology Monitoring Photo Points) were photographed (Figures 3.6–3.8). Repeat photography is a rapid and effective method for documenting landscape changes over time. Two of the Geomorphology Monitoring Photo Points were first established in 2013 south of the CD5 road along the west bank of the Niġliq

Figure 3.6 Photographs from the Geomorphology Monitoring Photo Point 1, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019. Photographs include Photo Point 1 at 110º in 1.a) 2013, 1.b) 2016, and 1.c) 2019; and Photo Point 1 at 190º in 2.a) 2013, 2.b) 2016, and 2.c) 2019.

2013 2016 2019

2013 Photo Point 2 at 154° 2016 Photo Point 2 at 154° 2019 Photo Point 3 at 154°

Figure 3.7 Photographs from the Geomorphology Monitoring Photo Point 2, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019. Photographs include Photo Point 2 at 154º degrees in 1.a) 2013, 1.b) 2016, and 1.c) 2019.

2016 2019

2016 Photo Point 3 at 329°   2019 Photo Point 3 at 329°

2016 Photo Point 3 at 149°   2019 Photo Point 3 at 149°

Figure 3.8 Photographs from the Geomorphology Monitoring Photo Point 3, CD5 Habitat Monitoring Study Area, northern Alaska, 2016–2019. Photographs include Photo Point 3 at 329º degrees in 1.a) 2016, and 1.b) 2019; and Photo Point 3 at 149º degrees in 2.a) 2016, and 2.b) 2019. This point was added in 2016 to monitor for landscape change from the Niġliq Channel. There is no 2013 photo because the bridge that this photo was taken from had not yet been constructed.

Channel. The third Geomorphology Monitoring Photo Point was established in 2016 on the western end of the newly constructed Niġliq Channel Bridge. In 2019, ABR staff navigated to each Geomorphology Monitoring Photo Point using a handheld GPS, ascertained the approximate azimuth of the original photographs using a compass, and then replicated the precise field-of-view of the original photographs by triangulating persistent, easily recognized features (e.g., infrastructure, nearby shrub patches) that were evident in the earlier photography (Hall 2002). Although the Geomorphology Monitoring Photo Point established in 2013 had been monumented by survey nails, the survey nails were no longer visible in 2019, likely because they had been removed by cutbank erosion. The Geomorphology Monitoring Photo Point on the Niġliq Channel Bridge, however, is easily relocated and should remain so in the future.

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 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.

We calculated total soil surface organic thickness in the upper 40 cm, dominant soil texture in the upper 40 cm, dominant mineral soil texture in the upper 40 cm, and a confidence value from the soil horizon data using a database views for all plots 2013–2019. The confidence value was calculated as soil pit depth (cm)/40 cm. The calculated values in the views were used to update the relevant data attributes in the project database tables for plots with a confidence value ≥75%. In addition we calculated soil surface organic thickness in the upper 20 cm (herein, surface organic thickness) from the soil horizon data for use in the 2019 vegetation assessment broad-scale monitoring of geomorphology. This was necessary to provide a consistent maximum surface organic depth given the change in minimum sampling depth from 40 cm in 2013, to 25–30 cm in 2019 (see Field Surveys: Habitat Monitoring, above).

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 Fairbanks Herbarium (vascular plants) and Brian Heitz at the University of Alaska Anchorage (non-vasculars). The species determinations were used in the PostgreSQL project database to update the preliminary species codes assigned to voucher specimens in the field. Plant taxonomic nomenclature was based on Viereck and Little (2007) for trees and shrubs, Skinner et al. (2012) for grasses, and Hultén (1968) for all other vascular taxa. Nomenclature for bryophytes (mosses and liverworts) and lichens followed the National Plants Database (USDA NRCS 2019). Appendix A provides a comprehensive list of vascular and nonvascular plant taxa identified in the CD5 Habitat Study Area 2013–2019; the year(s) each was encountered in; the number of occurrences of each across all years, which taxa have voucher specimens; State, Federal, and Global rankings for rare and sensitive taxa (ACCS 2019); and the Alaska invasiveness rankings (AKEPIC 2019) for non-native taxa. Appendix B provides a synonymy table between plant taxonomic names used by ABR and those accepted by the Integrated Taxonomic Information System (ITIS 2019). All vascular and nonvascular plant specimens are curated at the UAA Herbarium.

3.3.3.B Integrated Terrain Unit (ITU) Mapping

In 2013, ABR performed baseline ecological mapping for the CD5 Study Area using an existing ecological classification system that was developed for the Central Beaufort Coastal Plain (CBCP; see below). The 2013 mapping effort described landscape conditions that were 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, the ecological mapping was updated by overlaying the baseline map units onto more recent high-resolution imagery, which was then used to perform a landscape change analysis as indicated in the Monitoring Plan (ABR and Baker 2013). The mapping was first updated in 2016 using imagery acquired 3–5 July 2015 (Wells et al. 2017), and again in 2019 using imagery acquired 13 July 2018; imagery acquired 16 August 2017 was used as the basis for map updates for areas that were cloud-covered in the 2018 imagery. This report discusses the map updates and landscape change analysis based on the 2018 imagery.

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 2018 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. 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 2019 map update effort, we adjusted map units as needed to reflect changes in landscape conditions evident in 2018 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 13 July 2018 was compared with 2012 imagery using the "swipe" and "flicker layer" tools 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 Niġliq 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 channels that may be flooded seasonally (i.e., with a high-water connection) or permanently (i.e., a low-water connection). We also reviewed all map units for which a disturbance class had been assigned during prior mapping efforts to assess whether the disturbed area had changed in size, or if vegetation had recovered from the historical disturbance. We used GIS shapefiles of ice road and pad locations since 2012, by year, to identify potential areas of new disturbance. 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 2018.

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 2019

Table 3.6 Standard classification system developed for classifying and mapping landscape change mechanisms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2012–2018.

Disturbance regime	Description
Absent	No detectable change in ecosystem conditions during the 2012–2018 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 2012–2018.
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 2012–2018.
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 2012–2018, usually associated with flood events.
Inundation	Increased water level in tapped lakes.
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 inaccuracies 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 CBCP classification and mapping represent nearly 20 years of ELS efforts in northern Alaska, including the CRD (Jorgenson et al. 1997a) and northeastern NPRA (Jorgenson et al. 2002 and 2003). 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.

Map Ecotypes represent local-scale ecosystems that are classified by aggregating ITUs that possess 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 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 the 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 because species composition was similar (e.g., open and closed shrub).

We updated the baseline Map Ecotype and wildlife habitat maps by recoding the updated ITUs using a cross-reference table between ITU code, Map Ecotype, and wildlife habitat. During the 2019 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).

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

<u>Point-intercept Data Summaries</u>

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, Boucher et al. 2016), 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).

<u>Vegetation Plot Assessment</u>

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 the 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 2019 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.

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

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 2019.

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.

withheld from the analysis were assessed by comparing the Viereck et al. (1992) Level IV vegetation class assigned to the plot in 2013 and 2019. 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 2019. 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 2019 transformed Vegetation Plot datasets were then ingested in R statistical software. We partitioned the dataset into 2 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 2019 plots classified as wet Plot Ecotypes in 2013 (referred to herein as the "2013/2019 wet Plot Ecotype sub-dataset"), and
4. 2013 and 2019 plots classified as moist Plot Ecotypes in 2013 (referred to herein as the "2013/2019 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 2013/2019 wet Plot Ecotype and 2013/2019 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 2013/2019 wet pl9t Ecotype (herein "2013/2019 wet NMDS") and 2013/2019 moist Plot Ecotype (herein "2013/2016 moist NMDS") sub-datasets as 3-dimensional, dynamic plots. The rgl function allows the user to rotate the plots graphically so as to view the plots 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 2019 plots (see below).

We plotted the "2013/2019 moist NMDS" and "2013/2019 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 2019 (e.g., plot_id t1na-0200-veg sampled in 2019) plots in the 2013/2019 moist NMDS and 2013/2019 wet NMDS, respectively. The ordination distance between the 2013 and 2019 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 2019 plot.

- Not changed: plots with a NMDS distance between the 2013 and 2019 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 2019 plot of 2x stdev >3x stdev medoid distance for their respective 2013 cluster were considered to have shifted in species composition between 2013 and 2019 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 2019 plot greater than the 3x stdev medoid distance for their respective 2013 cluster were flagged as having changed in species composition between 2013 and 2019.

Plots flagged as having changed were then plotted in the NMDS diagrams with arrows pointing from the 2013 plot to the 2019 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 per Reynoldson et al. (2001).

<u>Non-metric Multidimensional Scaling (NMDS): Ecological Gradients and Vegetation Plot Assessment</u>

The R function ordisurf() from the vegan package was used to fit a subset of environmental variables to the 2013/2019 moist and 2013/2019 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 in the upper 20 cm of the soil profile (**env_data_-for_veg_plot_analy_view.***soil_surforg_in_upper_20cm*),
- 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 ID (plot.**area_id**)
- Study 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.

<u>Species Richness by Study Area, Plot Ecotype, and Sample Year</u>

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.

We tested the relationship between species richness, search time, and total live cover (TLC) by preparing linear regression models of species richness as a function search time, search time and TLC, and the interaction between search time and TLC. We then prepared a bubble chart of species richness as a function of search time, with bubble size representing TLC grouped into 3 classes: <50%, 50–150%, and >150%.

<u>Detailed Ground Cover Class Assessment</u>

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 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 2018 CD5 ITU Mapping, and each Habitat Line Point was assigned to the its 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 the first and most recent monitoring years (2013 and 2019) for both Test and Reference Areas, and a repeated measures analysis was performed using the nlme package (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.iii. 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 ITU map to reflect natural and anthropogenic changes to ecosystem conditions that occurred since the baseline imagery was collected in summer 2012. All map revisions (i.e., where field observations indicated that the original ITU assigned to a map unit was inaccurate) were applied to both the baseline 2012 map and the updated 2018 map.

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 Ecotypes, and wildlife habitats as of July 2018. From these summaries, we calculated the percent change in area (+/-) of each class that occurred in the Test and Reference Areas, excluding 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 ≥5%. For these classes, we assessed whether the percent change in the Test Areas exceeded the percent change in the Reference Area by ≥5% and then evaluated the likelihood that CD5 infrastructure played a role in the landscape change.

3.3.3.C.iv. 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. 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 thaw depth and elevation cross section diagrams. Thaw depth and elevation point data from the Vegetation Plot Start Points and Thaw Depth/Elevation 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 2019, with visible differences representing physical change (e.g., erosion, deposition). Thaw depth in 2013 and 2019 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.v. 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 of the soil profile 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 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 2019. 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 thickening of the surface organics through time indicates less frequent or an absence of sedimentation. The results of 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 2019 spring breakup flood progression for the Colville River was reported by Baker (2019). ABR field staff observed peak conditions in the delta from 24–26 May 2019. Breakup was characterized by Baker (2019) as a short-duration, low-magnitude event with minimal ice jamming effects. Floodwaters were primarily confined to active and inactive channel deposits, with minimal overbank flooding. Channel ice was observed at the Niġliq Bridge on May 24. There was minimal ice scour noted from ice floes in vegetated active and inactive channel deposits once the temporary ice jam released on May 25. Channel ice was observed upstream of the Nigliagvik Bridge during peak flow, however no ice jams or overbank flooding were recorded. Baker (2019) reported that peak stage at MON1C in 2019 was six days prior to the historical average. The earlier breakup date in the CRD is likely attributed to air temperatures being generally higher than average during the spring season (Baker 2019).

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 9 and 3 clusters for the moist and wet plots, respectively (Figures 3.9 and 3.10). The average cluster medoid distances are presented in Table 3.8. For the 2013 moist Plot Ecotype sub-dataset, cluster 2 had 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 had the highest average distance from the medoid (0.39 ordination distance) and the highest standard deviation (0.26), indicating that plots in this cluster are relatively diverse in species composition when compared to the other 8 clusters. Cluster 2 had only 2 plots in it, one of which is the medoid; thus the standard deviation metrics could not be calculated for this cluster. 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 0.20 and 0.25 and standard deviation ranging between 0.08 and 0.11. This indicates that the 2013 wet Plot Ecotypes are similarly variable in species composition within each cluster.

Of the total 179 vegetation plots, 161 plots were included in the vegetation analysis and 18 plots were withheld, based on the criteria described in section 3.3.3.C.i Vegetation Plot Analysis, above. The 18 plots withheld from the analysis were all classified as the same Viereck et al. (1992) Level IV vegetation class in 2013 and 2019 and, based on vegetation class alone, did not change between years. Of the 161 vegetation plots included in the vegetation analysis, 126 plots did not change in species composition between 2013 and 2019, based on the vegetation assessment analysis. In combination, a total of 144 vegetation plots (126+18) or 80% did not change in species composition between 2013 and 2019. The NMDS ordination distances separating the 2013 and 2019 plots for those plots with a distance greater than 2 times the standard deviation of the 2013 cluster medoid distance are presented in Table 3.9. A total of 2 plots from the 2013/2019 moist Plot Ecotype sub-dataset and 23 plots from the 2013/2019 wet Plot Ecotype sub-dataset had ordination distances separating the 2013 and 2019 plots of 2x stdev > 3x stdev the medoid distance of the 2013 clusters. These 25 plots represent 14% of the total 179 Vegetation Plots and have been flagged in the database as having potentially changed in species composition between 2013 and 2019. Of these 25 plots, 17 occurred in the Test Areas (plot_id starting with “t”), and 8 in Reference Areas (plot_id starting with “r”). Of those in the Test Areas, 7 plots were located on the first transect north or south of the road (plot_id starting with “t1”), and 5 plots were located on the second 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 7 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. As noted above, 8 plots, or 32% of plots flagged for potential change, 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 2024 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 3 plots from the 2013/2019 moist Plot Ecotype sub-dataset and 7 plots from the 2013/2019 wet Plot Ecotype sub-dataset had an

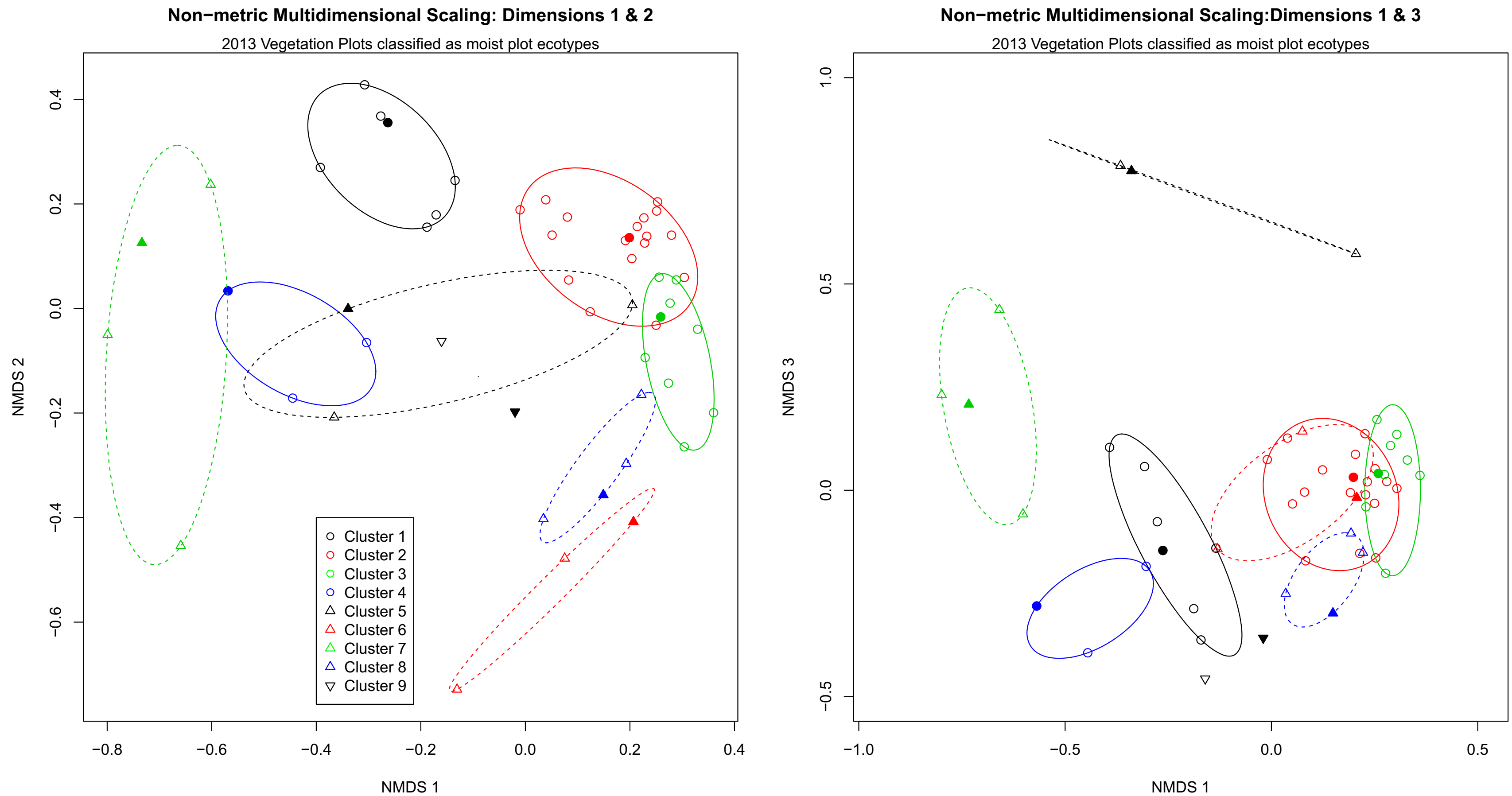


Figure 3.9 Non-metric Multidimensional Scaling diagram of 2013 Vegetation Plots classified as moist plot ecotypes with Partitioning Around Medoids 9-cluster solution symbolized.

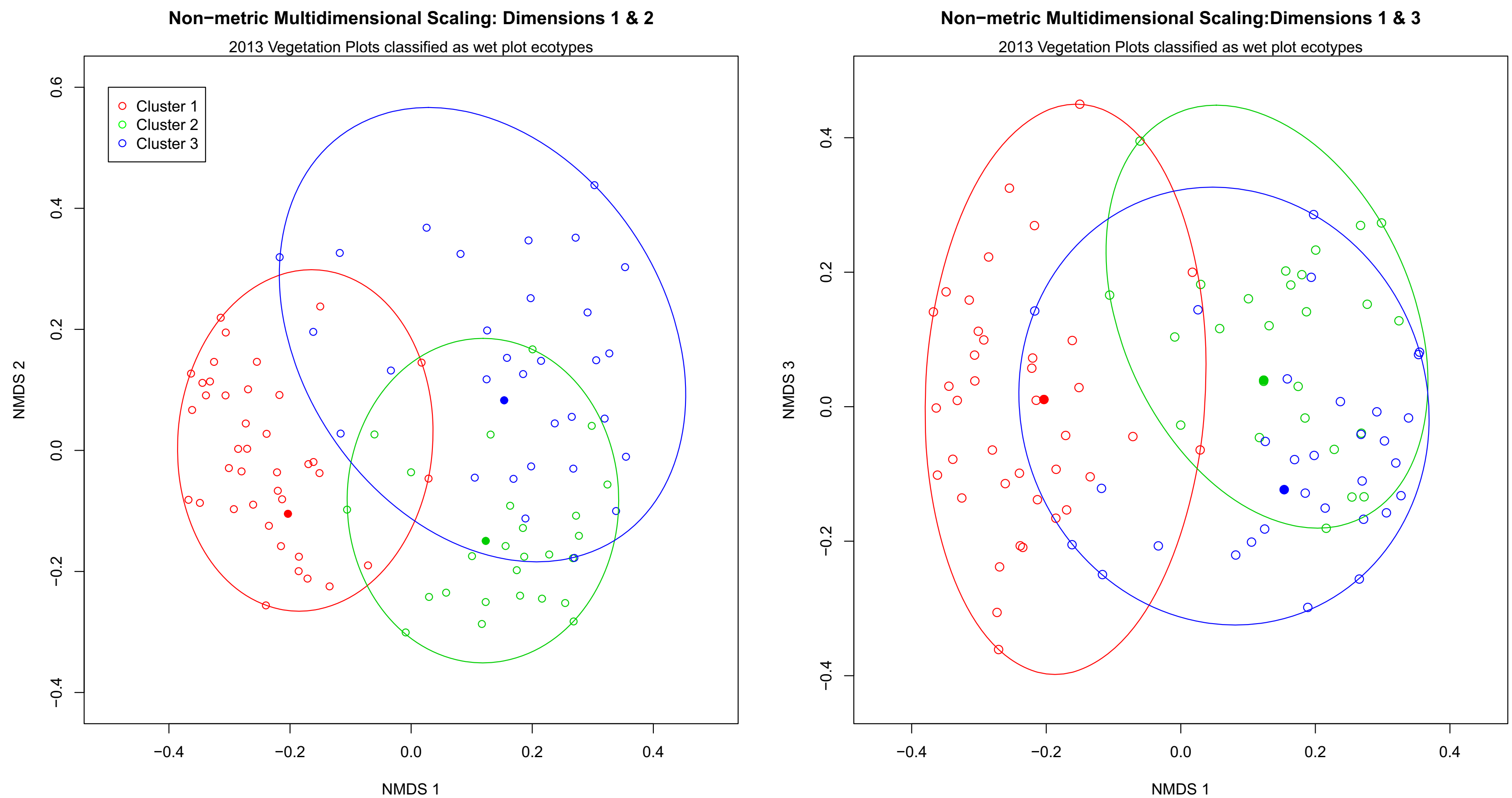


Figure 3.10 Non-metric Multidimensional Scaling diagram of 2013 Vegetation Plots classified as wet plot ecotypes with Partitioning Around Medoids 3-cluster solution symbolized.

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	0.22	0.09	0.17	0.26
	2	0.14	0.07	0.14	0.20
	3	0.16	0.07	0.14	0.21
	4	0.28	0.02	0.05	0.07
	5	0.39	0.26	0.52	0.79
	6	0.35	0.19	0.37	0.56
	7	0.38	0.23	0.45	0.68
	8	0.20	0.06	0.12	0.18
	9	0.22	NULL	NULL	NULL
Wet Ecotypes	1	0.23	0.11	0.22	0.33
	2	0.20	0.09	0.17	0.26
	3	0.25	0.12	0.23	0.35

ordination distance separating the 2013 and 2019 plots of >3x stdev of the medoid distance of the 2013 clusters. These 10 plots represent 6% of the total 179 Vegetation Plots and are considered to have changed in species composition between 2013 and 2019. These plots have been flagged in the database and will be reassessed in 2024 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 2019 (Figures 3.11 and 3.12). Two of the 3 moist plots that changed between years, t3nb-0200-veg and t3nb-0400-veg are from the third transect north of the road in the Test Area. The third plot, r1sa-1800-veg, is from Reference Area South. These 3 plots represent all the plots in the CD5 Habitat Monitoring dataset classified into the Plot Ecotype Upland Sandy Alkaline Moist Low Willow Shrub, which is characterized by low willow vegetation on inactive sand dunes. The results of the indirect gradient analysis for the 2013/2019 moist NMDS ordination found the strongest fits for the continuous variables Soil Thaw Depth, Water Depth, Site pH, and Surface Organic Thickness in upper 20 cm (Figures 3.13 and 3.14; Table 3.10). Plot Ecotype and Study Area were the significant ($p < 0.001$) categorical variables in the 2013/2019 moist NMDS ordination. Comparing the direction of movement of the three plots (Figure 3.11) with the fitted contour surfaces from the GAMs (Figures 3.13 and 3.14) shows that movement of plots t3nb-0400-veg and r1sa-1800-veg down on axis 1 corresponds to deeper thaw and water table 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 horizons); and deeper thaw depths related to the latent heat of river water

Table 3.9 Ordination distances between 2013 and 2019 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 2019.

Distance Class	Ecotype Group	Plot ID	Cluster	2x St.Dev.	3x St.Dev.	Ordination Distance
2x Standard Deviation	moist	r1na-2150-veg	2	0.136	0.204	0.141
	moist	t2na-1800-veg	3	0.14	0.209	0.19
	wet	r2sa-0836-veg	1	0.217	0.326	0.264
	wet	r3na-1015-veg	2	0.175	0.262	0.175
	wet	r3na-1400-veg	2	0.175	0.262	0.221
	wet	r3sa-0800-veg	1	0.217	0.326	0.28
	wet	r3sa-1132-veg	2	0.175	0.262	0.214
	wet	r4sb-0386-veg	3	0.233	0.35	0.279
	wet	r6sb-0600-veg*	3	0.233	0.35	0.284
	wet	t1na-2000-veg*	1	0.217	0.326	0.308
	wet	t1nb-0799-veg	1	0.217	0.326	0.283
	wet	t1nc-0600-veg	1	0.217	0.326	0.291
	wet	t1sa-0410-veg*	1	0.217	0.326	0.29
	wet	t1sa-1600-veg	2	0.175	0.262	0.216
	wet	t1sa-1824-veg*	1	0.217	0.326	0.253
	wet	t1sb-0200-veg*	3	0.233	0.35	0.252
	wet	t2na-0633-veg*	1	0.217	0.326	0.29
	wet	t2sa-0200-veg	2	0.175	0.262	0.196
	wet	t2sa-1400-veg	1	0.217	0.326	0.229
	wet	t2sa-1800-veg*	1	0.217	0.326	0.292
	wet	t3na-0000-veg*	3	0.233	0.35	0.27
	wet	t3sa-1550-veg	1	0.217	0.326	0.317
	wet	t3sc-0599-veg	2	0.175	0.262	0.18
	wet	t4nb-0400-veg	1	0.217	0.326	0.241
	wet	t4sb-1000-veg	1	0.217	0.326	0.257
3x Standard Deviation	moist	r1sa-1800-veg	4	0.048	0.072	0.177
	moist	t3nb-0200-veg	4	0.048	0.072	0.214
	moist	t3nb-0400-veg	4	0.048	0.072	0.107
	wet	r3na-0611-veg	1	0.217	0.326	0.624
	wet	t1na-0600-veg	1	0.217	0.326	0.368
	wet	t1nc-0296-veg	2	0.175	0.262	0.288
	wet	t1nc-0400-veg*	2	0.175	0.262	0.294
	wet	t1sa-2200-veg*	3	0.233	0.35	0.398
	wet	t2sb-0400-veg	1	0.217	0.326	0.334
	wet	t4sa-1200-veg*	2	0.175	0.262	0.32

*Plots flagged by Wells et al. (2017) as having potentially changed in species composition between 2013 and 2016.

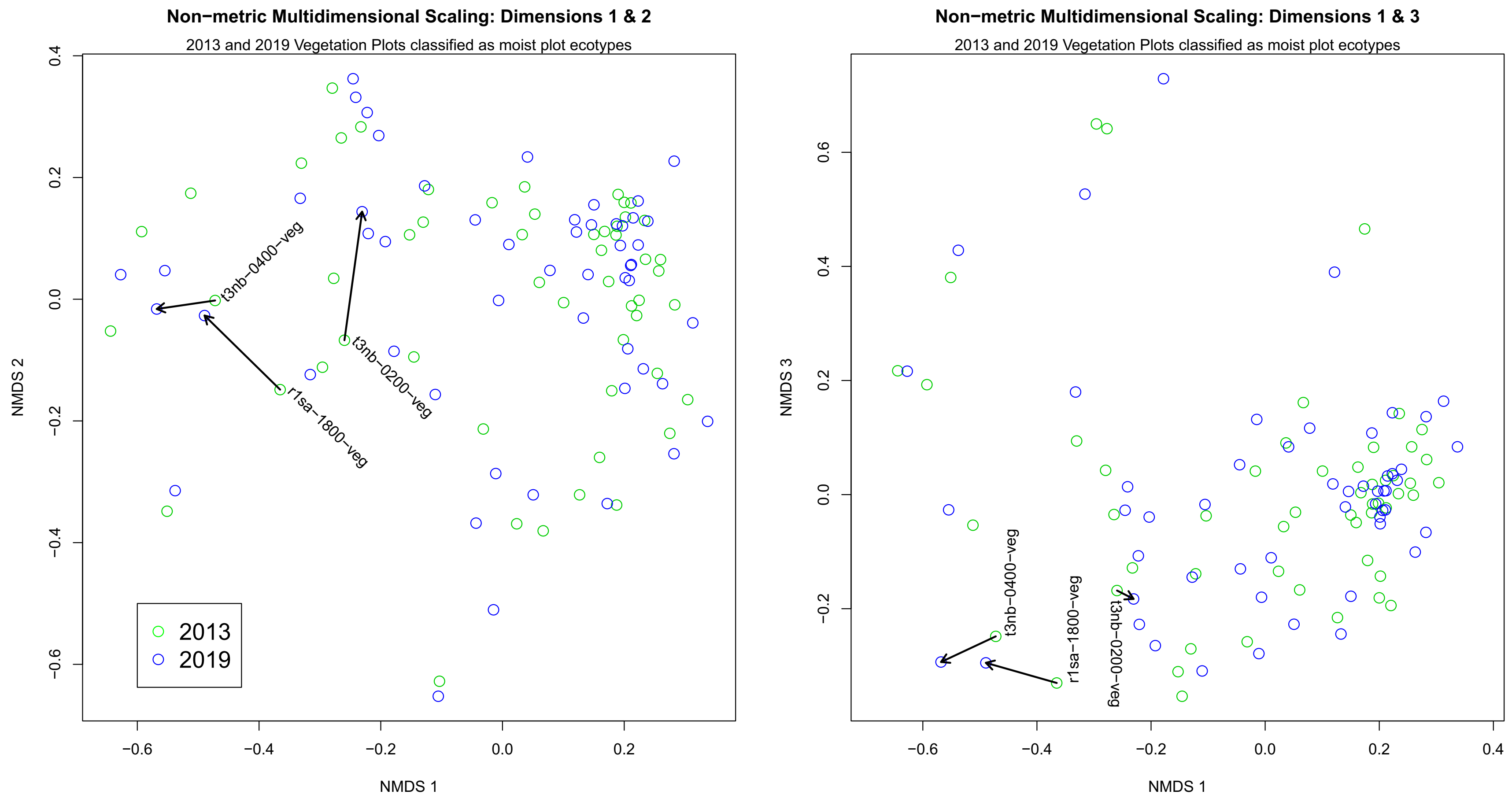


Figure 3.11 Non-metric Multidimensional Scaling diagram of the combined 2013/2019 Vegetation Plots classified as moist plot ecotypes with study year symbolized.

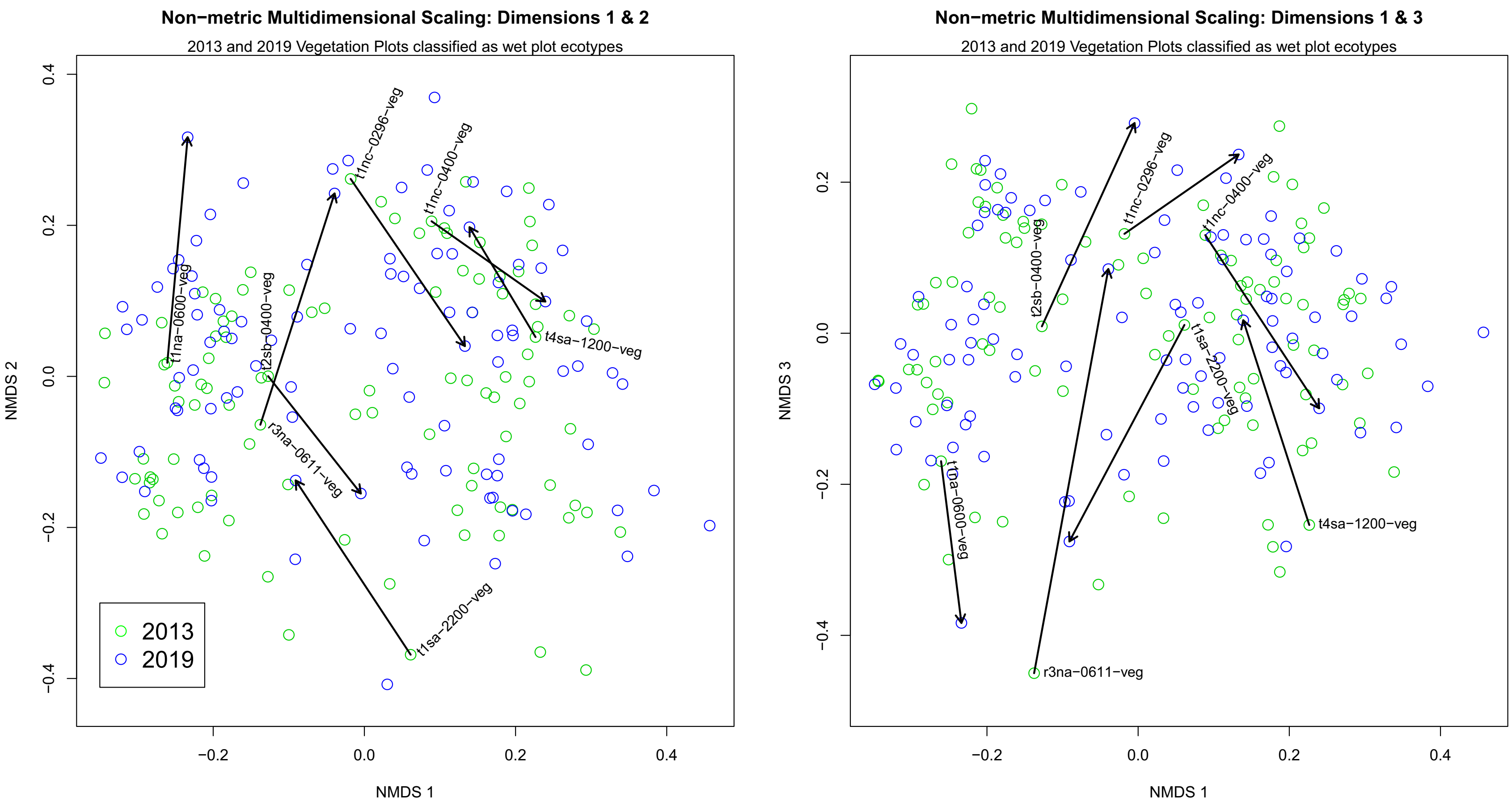


Figure 3.12 Non-metric Multidimensional Scaling diagram of the combined 2013/2019 Vegetation Plots classified as wet plot ecotypes with study year symbolized.

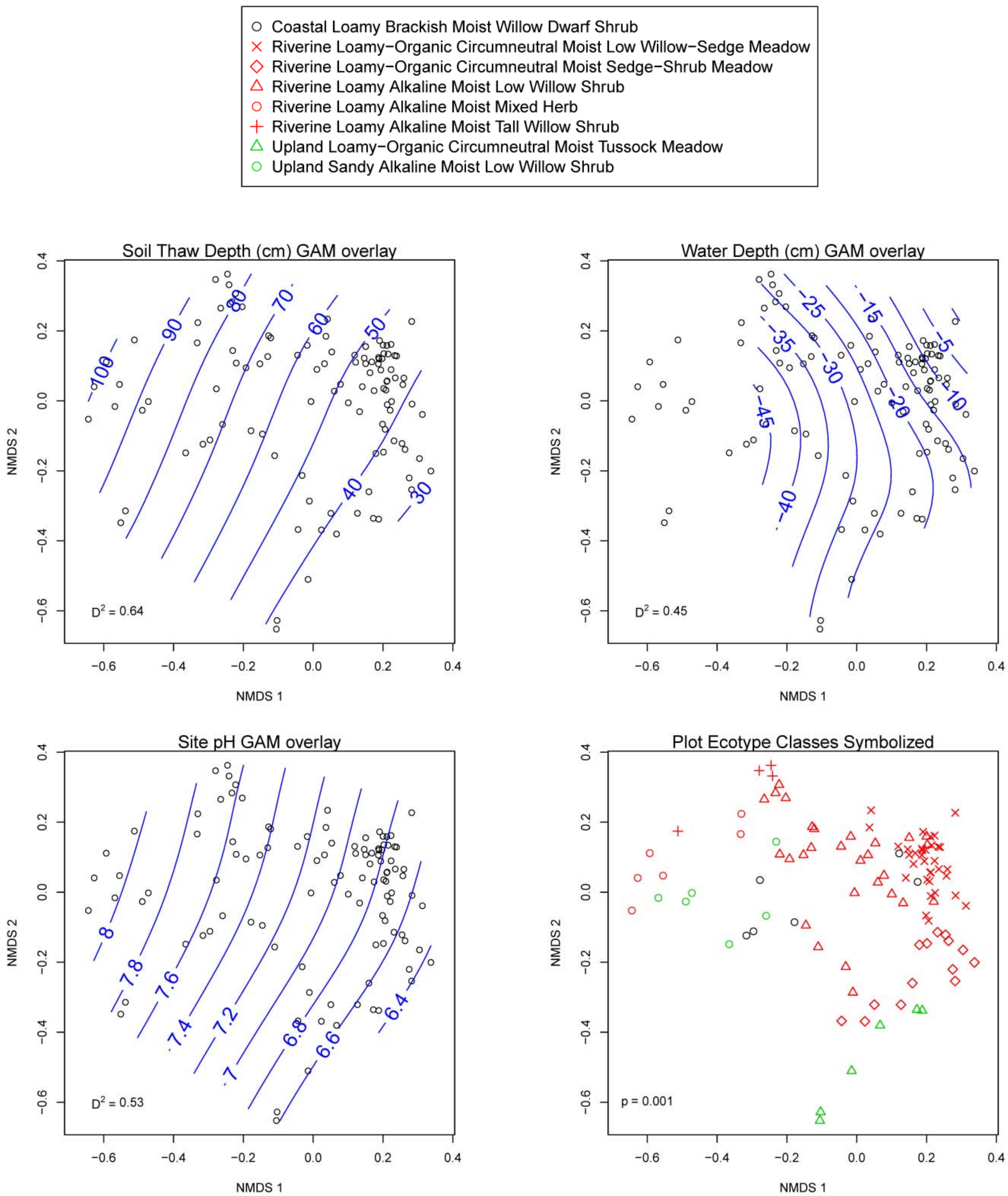


Figure 3.13 Plots of dimensions 1 and 2 for the Non-metric Multidimensional Scaling of the combined 2013/2016 Vegetation Plots classified as moist plot ecotypes with Soil Thaw Depth, Soil Surface Organic Thickness, and Site pH Generalized Additive Model contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

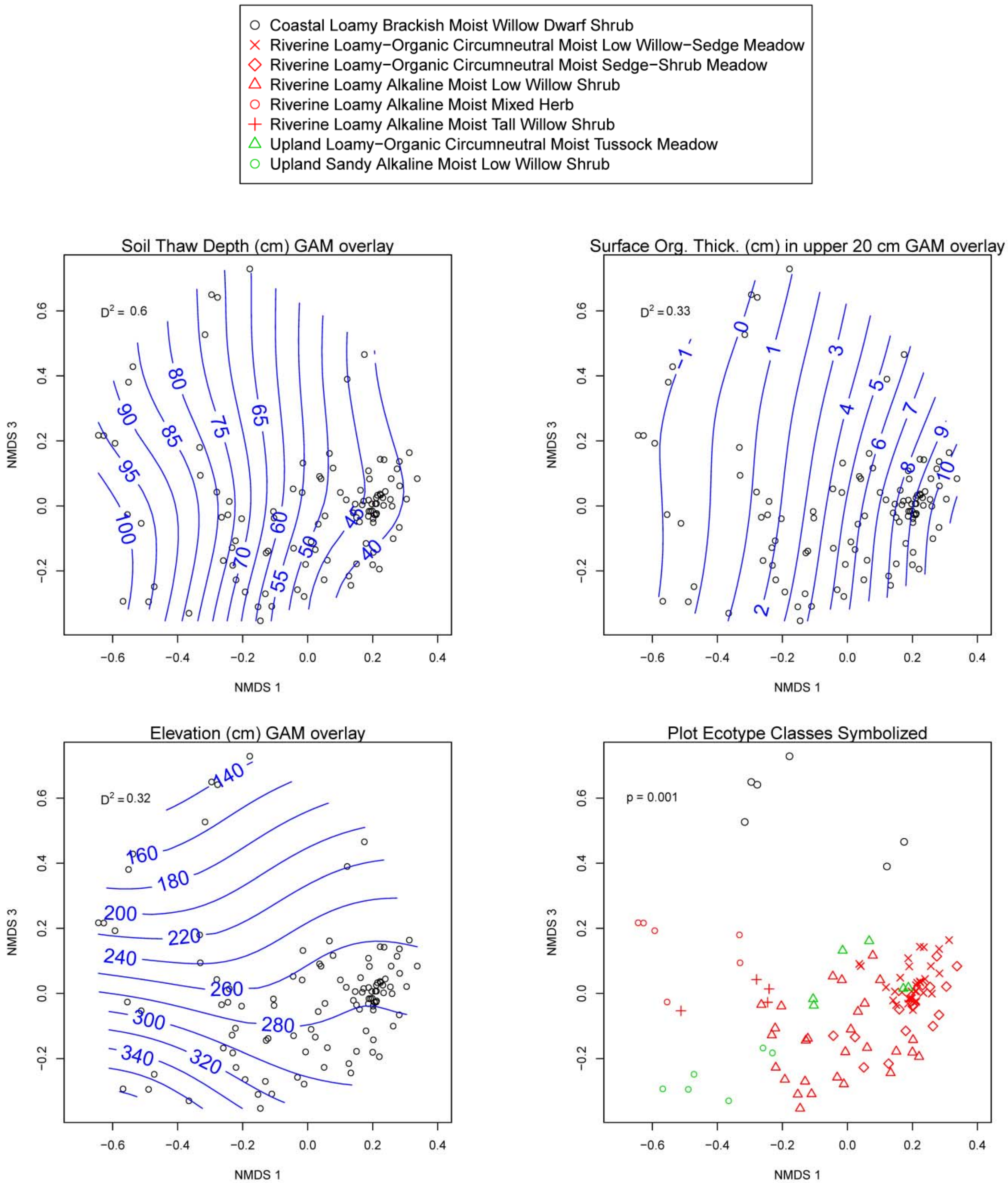


Figure 3.14 Plots of dimensions 1 and 3 for the Non-metric Multidimensional Scaling of the combined 2013/2019 Vegetation Plots classified as moist plot ecotypes with Soil Thaw Depth, Soil Surface Organic Thickness, and Site pH Generalized Additive Model contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

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 2019.

Ecotype Group	Environmental Variable	nmds_object	NMDS X-dimension	NMDS Y-dimension	P-Value	Deviance-squared	R Squared
moist	lat_dd83	vegln_m_nmds	1	2	<0.001	0.23	0.20
	long_dd83	vegln_m_nmds	1	2	0.004	0.19	0.15
	distance_cd5_rd_m	vegln_m_nmds	1	2	<0.001	0.24	0.19
	thaw_depth_cm	vegln_m_nmds	1	2	<0.001	0.64	0.62
	soil_surforg_in_upper_20cm	vegln_m_nmds	1	2	<0.001	0.48	0.45
	water_depth_cm	vegln_m_nmds	1	2	<0.001	0.45	0.41
	site_ph_calc	vegln_m_nmds	1	2	<0.001	0.53	0.51
	lat_dd83	vegln_m_nmds	1	3	<0.001	0.21	0.18
	long_dd83	vegln_m_nmds	1	3	<0.001	0.31	0.26
	elev_cm	vegln_m_nmds	1	3	<0.001	0.32	0.29
	thaw_depth_cm	vegln_m_nmds	1	3	<0.001	0.60	0.58
	soil_surforg_in_upper_20cm	vegln_m_nmds	1	3	<0.001	0.33	0.31
	water_depth_cm	vegln_m_nmds	1	3	<0.001	0.41	0.37
	site_ph_calc	vegln_m_nmds	1	3	<0.001	0.48	0.46
	lat_dd83	vegln_m_nmds	2	3	<0.001	0.17	0.14
	elev_cm	vegln_m_nmds	2	3	<0.001	0.28	0.27
	distance_cd5_rd_m	vegln_m_nmds	2	3	<0.001	0.16	0.13
	thaw_depth_cm	vegln_m_nmds	2	3	<0.001	0.32	0.27
	soil_surforg_in_upper_20cm	vegln_m_nmds	2	3	<0.001	0.37	0.33
	water_depth_cm	vegln_m_nmds	2	3	<0.001	0.35	0.31
	site_ph_calc	vegln_m_nmds	2	3	<0.001	0.31	0.27

Table 3.10 Continued.

Ecotype Group	Environmental Variable	nmds_object	NMDS X-dimension	NMDS Y-dimension	P-Value	Deviance-squared	R Squared
wet	lat_dd83	vegln_w_nmds	1	2	<0.001	0.12	0.11
	long_dd83	vegln_w_nmds	1	2	<0.001	0.24	0.22
	elev_cm	vegln_w_nmds	1	2	<0.001	0.27	0.26
	soil_surforg_in_upper_20cm	vegln_w_nmds	1	2	<0.001	0.17	0.16
	water_depth_cm	vegln_w_nmds	1	2	<0.001	0.24	0.22
	site_ph_calc	vegln_w_nmds	1	2	<0.001	0.12	0.10
	long_dd83	vegln_w_nmds	1	3	<0.001	0.12	0.11
	soil_surforg_in_upper_20cm	vegln_w_nmds	1	3	<0.001	0.17	0.16
	water_depth_cm	vegln_w_nmds	1	3	<0.001	0.22	0.20
	long_dd83	vegln_w_nmds	2	3	<0.001	0.17	0.15
	elev_cm	vegln_w_nmds	2	3	<0.001	0.20	0.19

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 (i.e., more frequent flooding) in 2019 than in 2013. The movement of t3nb-0400-veg higher on axis 2 placing it closer to plots in the Plot Ecotype Riverine Loamy Alkaline Moist Low Willow Shrub, which suggests this plot is also expressing a higher degree of riverine activity in 2019 than 2013. The notable change in species cover between years was a decrease in *Astragalus alpinus* in all three plots from an average of 31.6% in 2013 to 19.4% in 2019. Species richness in the Plot Ecotype Upland Sandy Alkaline Moist Low Willow Shrub remained approximately the same or increased in 2019 relative to 2013 in both Reference and Test Areas (Appendix C). Additionally, litter decreased and moss cover increased in 2019 relative to 2013 in this Plot Ecotype in both Reference and Test Areas (see below, Detailed Ground Cover Class and Environment Assessment). The similar changes observed across all plots in this Plot Ecotype suggest a trend may be developing in this Plot Ecotype towards vegetation more similar to the Plot Ecotype Riverine Loamy Alkaline Moist Low Willow Shrub. However, the changes occurred in both the Test and Reference Areas on both the north- and south-sides of the CD5 Road, thus indicating that the observed changes are unrelated to the road. The 3 plots will be evaluated again in 2024 to determine if the observed changes continue into the future.

Six of the 7 wet plots that changed between years were from Test Areas: t1na-0600-veg, t1nc-0296-veg, t1nc-0400-veg, t1sa-2200-veg, t2sb-0400-veg, and t4sa-1200-veg; and 1 plot was from the Reference Area: r3na-0611-veg. Of the 6 Test Area plots, 4 were located on the first transects north or south of the road, and 1 each were located on the second and fourth transects south of the CD5 road. Four of the seven plots: t1na-0600-veg, t1sa-2200-veg, and t2sb-0400-veg, were classified as Wet Sedge Meadow Tundra, while the other 3 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, Water Depth, and Surface Organic Thickness in upper 20 cm (Figures 3.15 and 3.16; Table 3.10). Plot Ecotype ($p < 0.001$) and Study Area ($p < 0.013$) were the significant categorical variables. Four plots moved up along axis 2 in 2019: t1na-0600-veg, r3na-0611-veg, t1sa-2200-veg, and t4sa-1200-veg; while the other 3 plots moved down on axis 2. Comparing the direction of movement of the 3 plots classified as Wet Sedge Meadow Tundra (Figure 3.12) with the fitted contour surfaces from the GAMs (Figures 3.15 and 3.16) we found that the 3 plots (t1na-0600-veg, t1sa-2200-veg, and r3na-0611-veg) moved up along axis 2, while plot t2sb-0400-veg moved down along axis 2. The elevation GAM (Figure 3.15, upper left panel) revealed that axis 2 represents an elevation gradient, with lower elevations predicted at the top of axis 2 and higher elevations predicted at the bottom. Axis 2 also represents a gradient in soil pH (Figure 3.15, lower left) with higher pH predicted lower on axis 2. Thus, the vegetation at the plots that moved up on axis 2 in 2019 are more representative of lower elevation, more frequently flooded sites. The elevation at plots r3na-0611-veg, t1na-0600-veg, and t1sa-2200-veg has decreased since 2013 by 4.2, 7.6, and 9.6 cm, respectively, indicating minor subsidence has occurred at these sites over the past 6 years. The primary vegetative change between 2013 and 2019 at these 3 plots that was an increase in cover of *Eriophorum angustifolium* and/or *Carex aquatilis*, an indication that these sites were more productive in 2019 than 2013. Plot r3na-0611-veg also had the largest shift across axis 3 of the 7 plots in the wet Ecotype group that showed a change in vegetation species composition in 2019. This plot shifted up on axis 3 placing it closer to plots classified as Wet Sedge-Willow Tundra, a change most likely related to an increase in *Salix richardsonii* cover from trace in 2013 to 2.6% in 2019. Plot t2sb-0400-veg moved down along axis 2 in 2019 placing it closer to plots classified as Wet Sedge-Willow Tundra. This corresponds with a 2 times increase in *Salix richardsonii* cover in 2019 (5.3%) relative to 2013 (2.6%). In addition to the increase in willow cover in 2019 the cover of *Carex aquatilis* increased at this plot from 22.4% in 2013 to 30.3% in 2019.

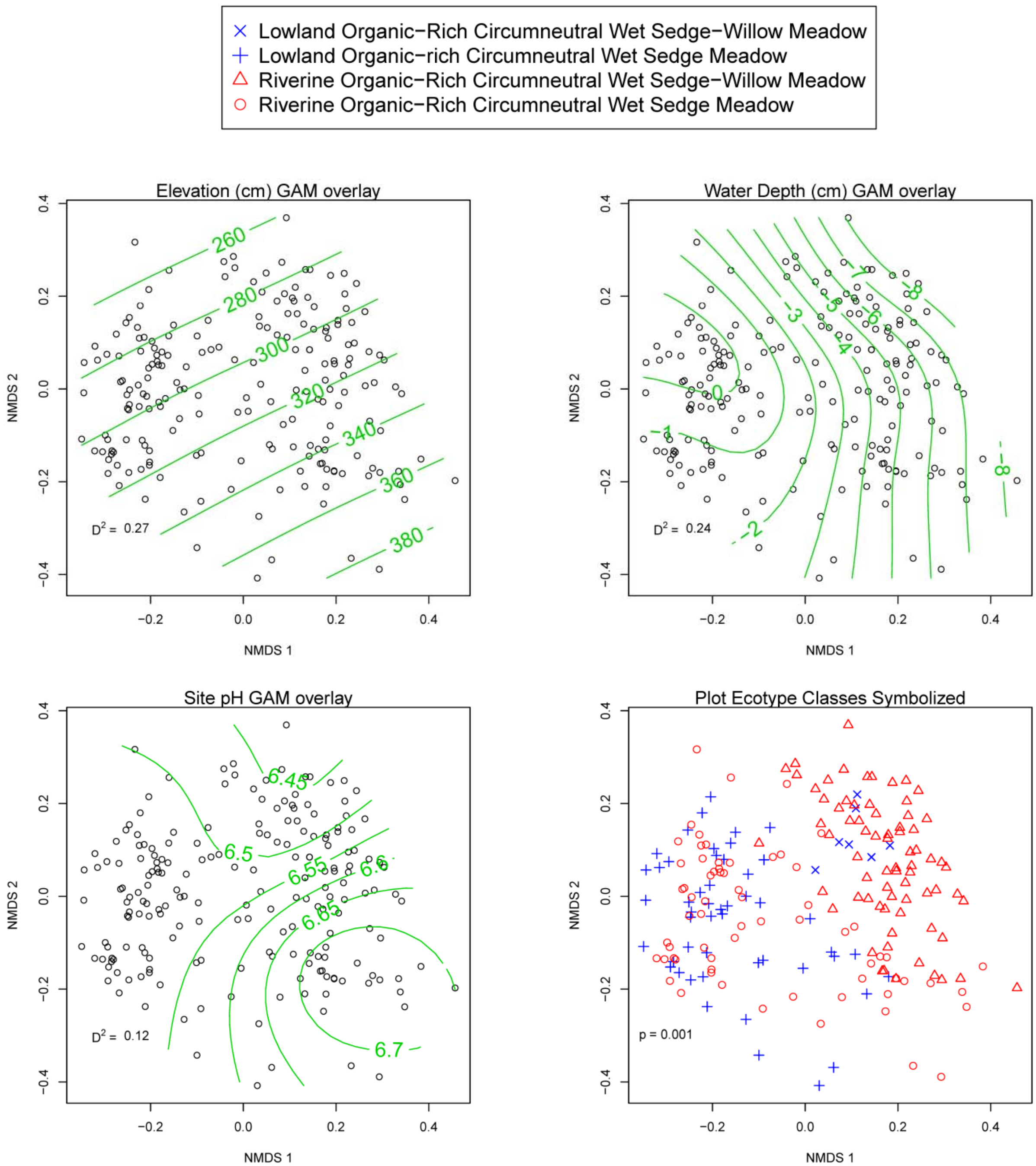


Figure 3.15 Plots of dimensions 1 and 2 for the Non-metric Multidimensional Scaling of the combined 2013/2019 Vegetation Plots classified as wet plot ecotypes with Elevation and Soil Surface Organic Thickness Generalized Additive Model contour surfaces overlaid; and Study Area and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

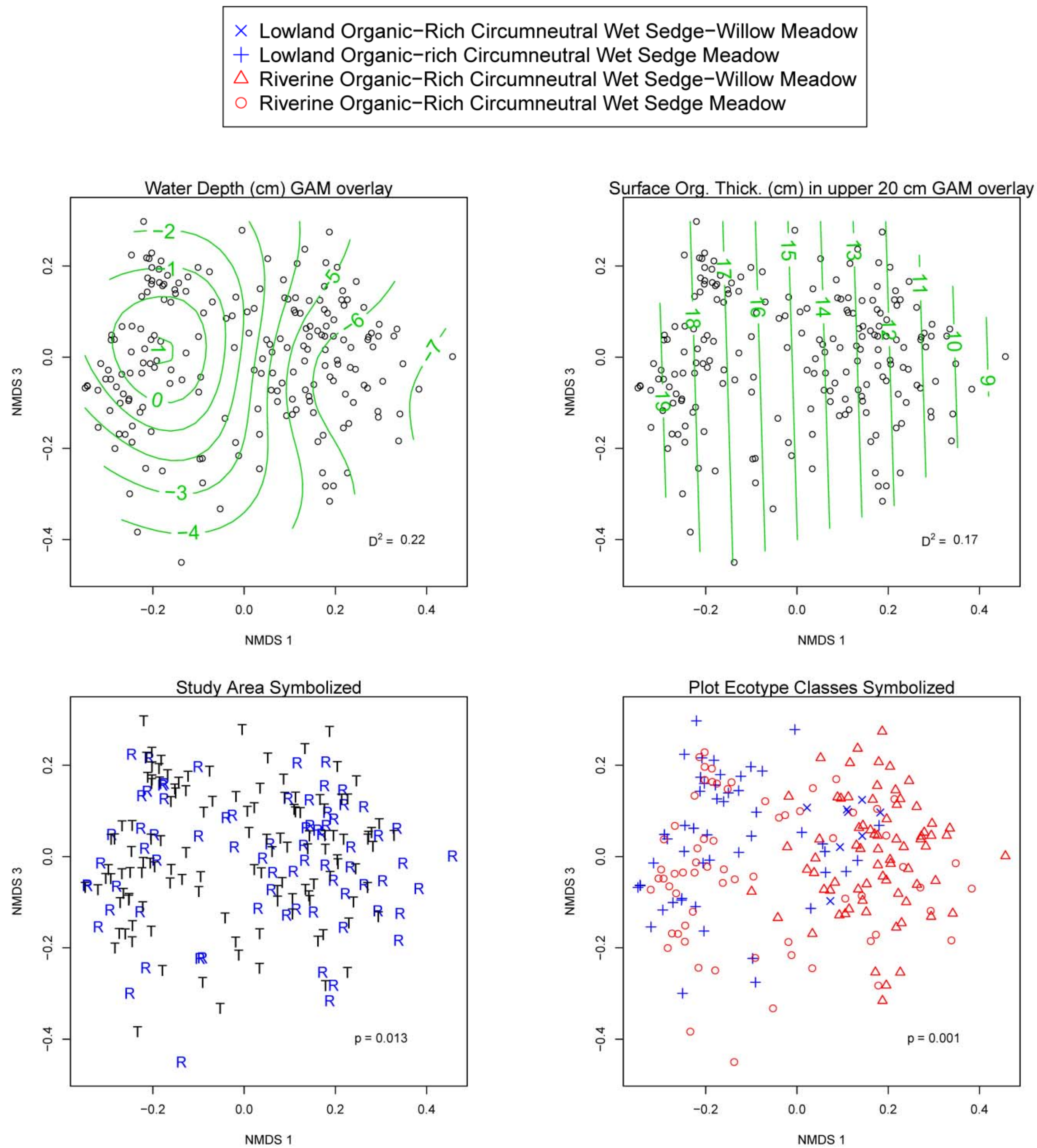


Figure 3.16 Plots of dimensions 1 and 3 for the Non-metric Multidimensional Scaling of the combined 2013/2019 Vegetation Plots classified as wet plot ecotypes with Water Depth, Soil Surface Organic Thickness; and Distance from CD5 Road generalized Additive Model contour surfaces overlaid; and Plot Ecotype Classes symbolized, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Of the 3 plots classified as Wet Sedge-Willow Meadow Tundra (Figure 3.12) 2 plots (t1nc-0296-veg and t1nc-0400-veg) moved down along axis 2, while the other plot (t4sa-1200-veg) moved up along axis 2. The downward movement along NMDS axis 1 at plots t1nc-0296-veg and t1nc-0400-veg (Figure 3.12) corresponds to a predicted increase in elevation and soil pH, and decrease in depth to water table (Figures 3.15 and 3.16). In deltaic environments, higher elevation sites are flooded less frequently than lower elevation sites, and soil moisture at higher elevation sites is drier than at lower elevation sites; thus the vegetation at these 2 plots is expressing a lower degree of riverine activity and drier soil conditions in 2019 than in 2013. This is reflected in an increase in the cover of *Salix reticulata* and *Equisetum* at both plots in 2019. Plot t4sa-1200-veg was flagged in 2019 has having been disturbed by avian grazing. At this plot the vascular and non-vascular species richness increased from 17 and 8 (respectively) in 2013, to 23 and 11 (respectively) in 2019. However, total vascular species cover at this plot declined by 9.2% in 2019.

A total of 13 Vegetation Plots were under ice roads or pads for at least 1 winter between monitoring years, of which none were identified to have changed in species composition (>3x stdev of medoid distance) between 2013 and 2019 (Table 3.11). Of the 25 plots that we identified to have potentially changed (2x stdev > 3x) only 1 plot (t1sa-0410-veg) was under an ice road or pad for at least one winter between monitoring years. This plot was under an ice pad during the 2013–2014 winter season and was also identified by Wells et al. (2017) to have potentially changed in species composition between 2013 and 2016. Wells et al. (2017) identified 2 Vegetation Plots (t2sb-0800-veg and r4sa-0809-veg) that had changed in species composition between 2013 and 2016 that also had ice roads or pads over them for at least 1 winter during that same period. In 2019 we found that these 2 plots were no longer identified to have changed in species composition. This indicates that the potential effects of ice roads and pads on the species composition of those 2 plots are no longer evident using the methods employed, and the species composition has shifted back towards that of the baseline conditions.

3.4.2.A.ii. Species Richness Assessment

Species richness by Area and year is summarized in Figure 3.17 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 C). The most notable decrease in vascular species richness between years was in the Ecotype Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow in the Reference Area, which had a reduction in vascular species richness from 17 in 2013 to 13 in 2019. The most notable decrease in non-vascular species richness between years was in the Ecotype Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow in the Reference Area, which had a reduction in non-vascular species richness from 16 in 2013 to 11 in 2019.

The Ecotypes Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow and Upland Loamy-Organic Circumneutral Moist Tussock Meadow had the highest overall average species richness in both Reference and Test Areas in 2013 and 2019 (Figure 3.17, Appendix C). Vascular species richness in the Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow Ecotype did not change beyond the range of variability between years in the Test and Reference Area, but non-vascular richness went down in 2019 (16 vs.11) in the Reference Area and increased by 12 in the Test Area (8 vs. 20), the second largest increase in non-vascular species richness in all Areas. The drop in non-vascular species richness in this Ecotype in the Reference Area represents the largest decrease in non-vascular species richness between years in all Areas (Figure 3.17, Appendix C). In the Ecotype Upland Loamy-Organic Circumneutral Moist Tussock Meadow, non-vascular species richness in the Test Area increased by 6 from 11 (± 1) to 17 (± 16), while vascular richness was unchanged. In Reference Areas, non-vascular richness increased dramatically (5 vs. 23) for this Ecotype, while vascular richness was unchanged. 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 in all Areas, is related to a

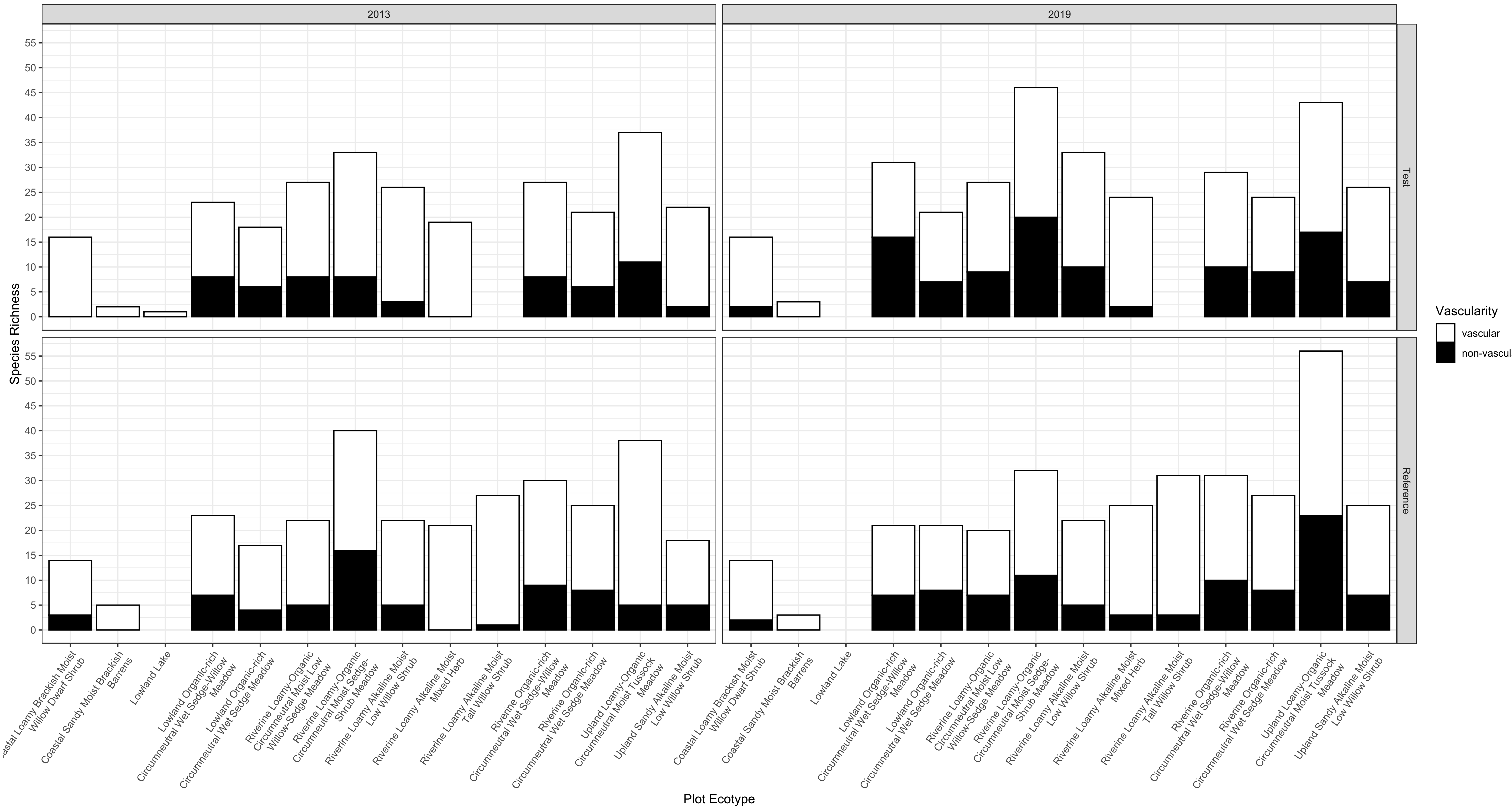


Figure 3.17 Mean vascular and non-vascular species richness for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2013 and 2019.

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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 2019.

	Winter Season					
Plot ID	2013–2014	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019
r4sa-0809-veg		Ice Road	Ice Road			
r4sa-1153-veg			Ice Pad			
r4sb-0800-veg	Ice Road	Ice Road*	Ice Road*		Ice Road	Ice Road
r5sb-0000-veg					Ice Road	
t1na-1029-veg		Ice Road				
t1na-1424-veg		Ice Road				
t1na-1600-veg		Ice Road				
t1na-1800-veg		Ice Road				
t1sa-0200-veg	Ice Pad					
t1sa-0410-veg	Ice Pad					
t1sb-0420-veg	Ice Pad					
t1sc-0875-veg	Ice Pad	Ice Road		Ice Pad		Ice Pad
t2sb-0800-veg	Ice Road					

* Estimate less than 15% of plot covered by ice road or ice pad.

more thorough trace species search in 2019 compared to 2013. Additionally there is only one plot (r2na-1200-veg) assigned to the Plot Ecotype Upland Loamy-Organic Circumneutral Moist Tussock Meadow in the Reference Area which precludes us from calculating an average and standard deviation as a measure of variability. In 2019, we timed the trace searches at Vegetation Plots allowing us to determine the degree to which species richness is a function of time spent searching (See Methods: Vegetation Plot Trace Search, above). The time spent searching for trace species at plot r2na-1200-veg in 2019 was 20 minutes, the maximum allowable search time. Trace searches were not timed in 2013, hence we have no means of comparing the 2 years based on search time. However, given that the time spent searching in 2019 was the maximum allowed suggests that the large increase in non-vascular species richness in 2019 was at least in part related to a longer trace search.

We found a significant positive relationship between species richness, search time, and TLC (Figure 3.18). Search time and TLC were both significant, while the interaction effect was not. The model had an R^2 of 0.51 suggesting that while the relationship is moderately strong, about half of the variability in the relationship is yet unexplained. The linear model that only included search time had a lower R^2 (0.41) indicating that TLC is an important factor affecting species richness, but not as important as search time. The results of the linear regression are constrained on the lower and upper end by the minimum (7.5 min.) and maximum (20 min.) search times set by the field methods. For instance, the group of points in the lower left corner of Figure 3.18 with species richness <10, TLC <50, and a search time of 7.5 minutes. These are barrens and wet sedge vegetation with few species present, and at which most species were likely found within the first 2–3 minutes of searching. This suggests that a shorter

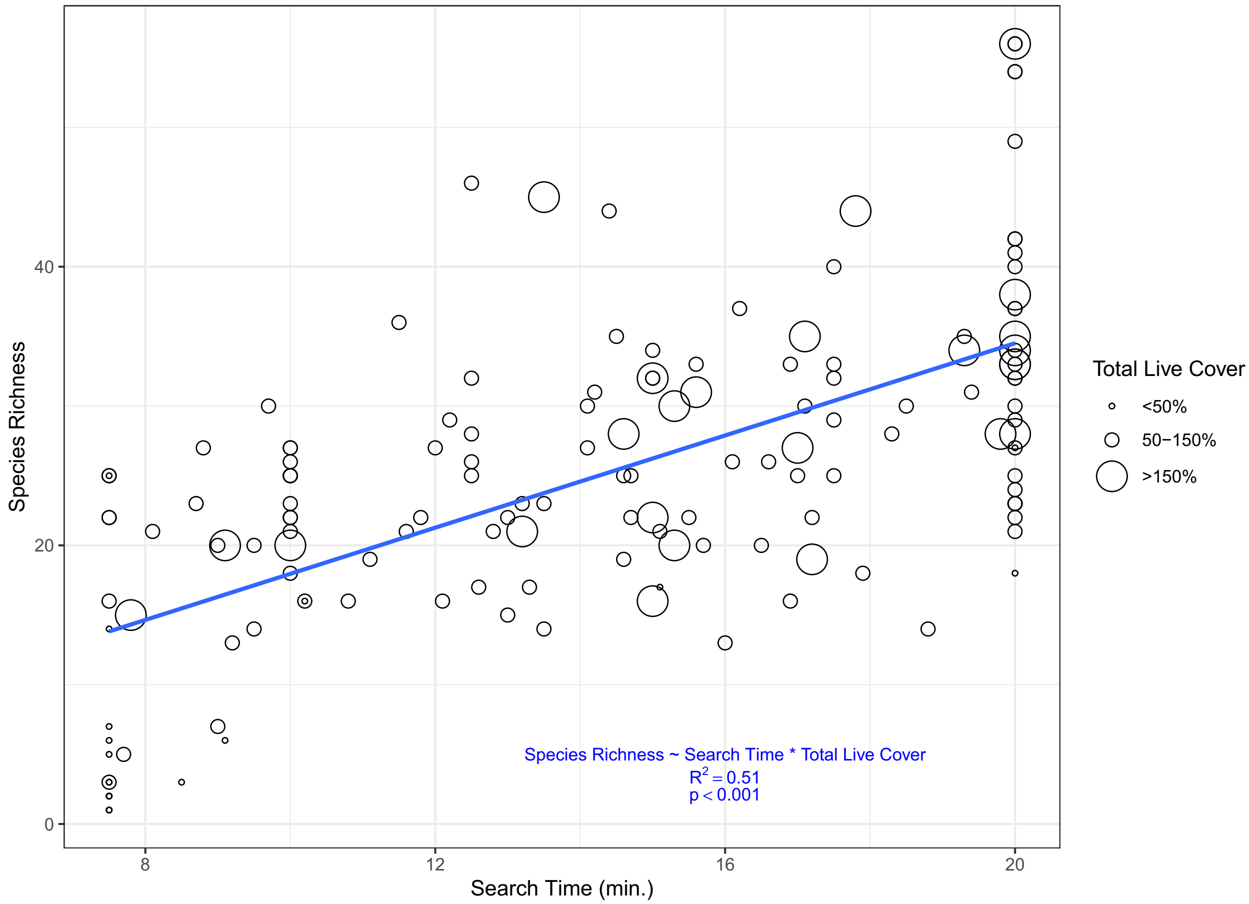


Figure 3.18 Species richness as a function of search time and total live cover in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2019.

minimum search time may be appropriate. Plots on the far right side of Figure 3.18 with moderately high species richness (20–30), and TLC <150 are plots at which the maximum search time of 20 minutes may have been insufficient to complete the trace search, suggesting that a longer maximum search time may be appropriate. The purpose of imposing time limits for the trace search were to standardize the trace search intensity between field teams, and to balance the amount of information gained (i.e., species encountered) against the time spent searching to optimize field time. The results of this analysis will be considered when discussing trace search methods for monitoring in 2024. An additional factor affecting the relationship between species richness, TLC, and the time spent searching is Plot Ecotype. For instance, all of the plots assigned to the Plot Ecotypes Coastal Sandy Moist Brackish Barrens and Lowland Organic-rich Circumneutral Sedge Marsh had a species richness <10, TLC < 50, and a search time of <9 minutes. Also, plots having a species richness >35 and search time between 17.5–20.0 minutes were nearly all in 1 of 3 Ecotypes: Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow, Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow, and Upland Loamy-Organic Circumneutral Moist Tussock Meadow.

The largest increase in vascular species richness between years (from 13 to 18) occurred in the Ecotype Upland Sandy Alkaline Moist Low Willow Shrub in the Reference Area (Figure 3.17, Appendix C). This Ecotype occurs on inactive (i.e., stabilized) sand dunes, which are also occasionally flooded by river water during spring breakup. Ecotypes with the lowest species richness in both Reference and Test Areas and between sample years included Coastal Loamy Brackish Moist Willow Dwarf Shrub and Coastal Sandy Moist Brackish Barrens, and Lowland Lake. The low species richness in these three Ecotypes is typical of extreme environments like 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.

3.4.2.A.iii. Detailed Ground Cover Class and Environment Assessment

Coastal Loamy Brackish Moist Willow Dwarf Shrub had mineral soil as the predominant ground cover in 2013 in all Areas (Appendix D-1). Whereas in 2019 litter or litter and mineral soil were the predominant ground covers in this Plot Ecotype. Both Reference and Test Areas had higher average cover percentages of mineral soil in 2013 (78 and 93%, respectively, Appendix E) than in 2019 (41 and 25%, respectively). Mosses were also present as a ground cover in all Areas and years. However, moss decreased in cover in Reference Areas between 2013 (22%) and 2019 (9%); and increased in cover in Test Areas between years (3 and 20%, respectively). Cover of water was observed only in the Reference Area in 2019, with an average cover of 9%. This Plot Ecotype occurs on frequently flooded, active and inactive channel deposits of the Colville River Delta, as such a surface organic horizon for Coastal Loamy Brackish Moist Willow Dwarf Shrub was absent in both Reference and Test Areas in both years (Appendix F). 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 approximately the same in 2019 as it was in 2013 in the Reference and Test 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 depth was shallower in 2019 than in 2013 in both Reference (45 cm and 64 cm, respectively) and Test (65 cm and 81 cm, respectively) Areas. The shallower thaw depths in 2019 are at least in part related to the earlier timing of the 2019 thaw depth surveys (mid-July) than in 2013 when thaw depths surveys were conducted in early- to mid-August when seasonal frost is typically nearing its maximum thaw extent. Water table depths in the Reference and Test Areas did not change substantially between 2013 and 2019 (Appendix F), but note that the water table is highly dynamic in this environment, which could influence future measurements.

Coastal Sandy Moist Brackish Barrens ground cover attributes were generally consistent between 2013 and 2019, but varied between Reference and Test Areas (Appendix D-2). Mineral soil was the predominant ground cover in all Areas and years (Appendix E), but varied between years within Areas. In Test Areas mineral soil was higher in 2013 than 2019 (99 and 78%, respectively), while in the Reference Areas mineral soil was approximately the same in 2013 and 2019 years (87 and 93%, respectively). Water was present in the Reference Area in both years (average cover 28–30%) and in the Test Area in 2019 (17%), but absent from the Test Area in 2013. 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 F). The average thaw depth decreased in both Test (103 cm in 2013 and 75 cm in 2019) and Reference (102 cm in 2013 and 59 cm in 2019) Areas between 2013 to 2019. The average water table depth in the Reference Area (-4 cm) was shallower than in the Test Area (-13 cm) in 2019, 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 2019 (Appendices D-3 and E). Average EC and pH rose remained approximately the same between 2013 and 2019 in this Plot Ecotype (Appendix F).

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

Area and is represented by a single plot (t1sc-0875-veg). Herbaceous litter and accounted for the greatest cover in both 2013 and 2019 (Appendix D-4), with lower values in 2013 (43%; Appendix E) than in 2019 (55%). Moss accounted for the second highest cover in both years; but moss decreased by 16% between 2013 and 2019. Lichen cover decreased by 7% between 2013 and 2019, and wildlife scat (specifically goose scat) and organic soil increased from zero in 2013 to 3% and 9%, respectively. Disturbance from avian grazing was observed at this plot in 2019 which explains the increase in wildlife scat and may in part explain the increase in organic soil resulting from the plucking of vegetation by geese for use as nesting material. This plot was also located under an ice pad during the winter of 2018–2019 (Table 3.11). However, plot t1sc-0875-veg did not change in species composition between 2013 and 2019 based on the results of the vegetation plot analysis discussed above.

Lowland Organic-rich Circumneutral Sedge Marsh was only located in the Test Area. Water was the predominant ground cover in both 2013 and 2019 (Appendix D-5), with a higher cover in 2019 (100%, Appendix E) than in 2013 (93%). Algae and vascular base were the only other ground covers observed in 2013, while water was the only ground cover observed in 2019. Between 2013 to 2019, EC increased slightly (+40 µS/cm), water depth increased from 15 cm to 21 cm above the soil surface, and thaw depth decreased from 47 cm in 2013 to 32 cm in 2019 (Appendix F).

Lowland Organic-rich Circumneutral Wet Sedge Meadow ground covers were similar between years within each Area (Appendix D-6). Water was observed in both Reference and Test Areas, with similar cover values in 2013 (57% and 45%, respectively; Appendix E) and in 2019 (53% and 43%, respectively). Mineral soil was absent in all years and Areas with the exception of the Test Area in 2019 where is present at 3% cover. Mosses were observed in both Reference and Test Areas, with slightly higher average cover values in the Reference Area than in the Test Area, and slightly lower average cover values in 2019 than in 2013. From 2013 to 2019, the average EC decreased slightly or remained approximately the same in both the Reference and Test Areas (Appendix F). Average water table depth remained approximately the same (± 1–2 cm) between 2013 to 2019 for both Reference (-9 cm) and Test Areas (-8 cm) paralleling the observed similarities in standing water cover. The average thaw depth was deeper in 2013 than in 2019 in both Reference and Test Areas, but varied little between Areas within the same year. Surface organic thickness in the upper 20 cm decreased slightly in both Reference and Test Areas in 2019 (-1.2 and -0.6 cm, respectively).

Moss was the predominant ground cover class in the Plot Ecotype Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow for all Areas and years (Appendix D-7). In 2013 average moss cover was slightly higher in the Reference Areas (68%; Appendix E) than Test Areas (64%), while in 2019 moss cover was the same (61%) in both Reference and Test Areas. Water was observed in both Reference and Test Areas in 2013 (average cover of 21% and 15%, respectively). In 2019, water was observed in both Reference and Test Areas (1 and 18%, respectively); however water decreased by 20% in the Reference Area between 2013 and 2019. Herbaceous litter cover remained approximately the same in the Test Area between 2013 and 2019 (19 and 16%, respectively). Herbaceous litter increased by 26% in the Reference Area in 2019, a result consistent with the reduction in water cover which would result in more litter exposed at the soil surface. The average pH in the Test Area (6.5 in 2013 and 6.3 in 2019) remained approximately the same as the pH in the Reference Area (6.9 in 2013 and 6.3 in 2019) (Appendix F). The water table depth did not change in the Reference Area between years (0 cm, i.e., at the soil surface), whereas the Test Area experienced an increase in the water table between 2013 and 2019 (+6 cm). Thaw depth was shallower in both the Reference and Test Areas in 2019 (23 cm and 36 cm, respectively) compared to 2013 (41 cm and 45 cm, respectively). In 2013 average pH and EC were greater in the Reference Area (6.9 and 400 µS/cm, respectively) than in the Test Area (6.5 and 293 µS/cm, respectively). Whereas in 2019 average pH and EC were approximately the same in both Areas.

Riverine Loamy Alkaline Moist Low Willow Shrub ground cover was generally similar between Areas and years, with the exceptions of average mineral soil cover which decreased 22% in the Reference Area in 2019, and liverwort cover which decreased by 6% in the Reference Area in 2019 (Appendix D-8). In contrast, mineral soil cover changed very little (+1%) in the Test Area in 2019. Moss (average 41–55%, Appendix E) and herbaceous litter (average 24–43%) were the predominant ground cover classes in both Areas and years. While cover of moss and herbaceous litter did fluctuate to some degree between years the changes were within the range of variability of this Plot Ecotype as measured by the standard deviation. 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 2019 (Appendix F). However, the average surface organic thickness decreased slightly from 2013 to 2019 in both the Reference (4.2 cm in 2013, and 1.2 cm in 2019) and Test Areas (3.8 cm in 2013 and 2.0 cm in 2019), a result consistent with the 2016 CD5 Habitat Monitoring Project (Wells et al. 2017), and likely a 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 Mixed Herb had mineral soil as the predominant ground cover class in both Areas and years (Appendix D-9). However mineral soil cover decreased in both Reference (-23%) and Test (-19%) Areas in 2019 (Appendix E). Herbaceous litter cover was observed in the Test Area in both years (14% and 32%, respectively) and in the Reference Area in 2019 (18%), reflecting an increase in both Areas in 2019. Moss cover also increased in both Reference (+9%) and Test (+6%) Areas in 2019. The decrease in mineral soil cover and increase in moss cover suggests a reduction in sedimentation across all Areas between 2013 and 2019. Mosses grow close to the ground and as such are one of the first to be buried and killed by sediment, thus when sedimentation frequency and/or intensity is reduced mosses can start to become established. 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 2019 (Appendix F). Average EC was approximately the same across all Areas and years, while pH was higher in 2013 in Reference and Test Areas (8.1 in both Areas), than in 2019 (7.7 in both Areas). 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 dynamic lower floodplain geomorphic positions. The thaw depth in the Reference Area in both 2013 and 2019 (105 cm and 90 cm, respectively) was consistently deeper than in the Test Area (86 cm and 76 cm, respectively). Additionally, both Reference and Test Areas had a shallower active layer in 2019 than 2013 in this Ecotype.

Riverine Loamy Alkaline Moist Tall Willow Shrub was only located in the Reference Area. Cover of mineral soil comprised the vast majority of ground cover observed in 2013 (average 83%, Appendix D-10, Appendix E), but in 2019 was notably lower (average 14%). In 2013, herbaceous litter and moss cover were relatively low (8% and 9%, respectively), whereas in 2019 the cover of herbaceous litter and moss increase substantially to 28% and 55%, respectively. Similar to the Plot Ecotype Riverine Loamy Alkaline Moist Mixed Herb the decrease in mineral soil cover and increase in moss cover suggests a reduction in sedimentation between 2013 and 2019. The Riverine Loamy Alkaline Moist Tall Willow Shrub Plot Ecotype is limited to frequently flooded, inactive channel deposits of the Colville River Delta. In dynamic environments such as these surface organic horizons are typically absent which was the case in both 2013 and 2019. The average thaw depth decreased from 2013 (118 cm) to 2019 (95 cm), average pH decreased from 8.2 to 7.2, and average EC increased from 430 to 1130 μS/cm (Appendix F). A water table was not encountered in the upper 40 cm of the soil profile in 2013, but in 2019 a water table was encountered in 25 cm below the soil surface. 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-Organic Circumneutral Moist Low Willow-Sedge Meadow ground cover saw an increase in water and a reduction of mineral soil between years in both Areas (Appendix D-11). In 2013, mineral soil cover was relatively low; however, it was absent in 2019 in both the Reference and Test Areas (average -3% and -5%, respectively). In 2019, water cover increased in both the Reference and Test Areas (average +13% and +11%, respectively) (Appendix E), which may be related to an increase in the average water table depth by 4 cm between years in both Areas (Appendix F). Mosses and herbaceous litter cover were the predominant ground cover classes in both Areas and years, however there was a slight increase in mosses in the 2019 Test Area. The increase in mosses in 2019 was within the variability of the standard deviation. This Plot Ecotype occurs predominantly on inactive overbank deposits. The average pH was similar between all Areas and years. Electrical conductivity has steadily dropped since 2013 in both Area, and similar to 2013 the Reference Area continues to trend higher than the Test Area.

This Plot Ecotype Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow occurs on inactive overbank deposits. Ground cover was predominantly mosses and herbaceous litter (Appendix D-12). Average moss cover was higher in the Reference Area (68% in both years) than in the Test Area (57% in 2013, 63% in 2019) (Appendix E). Conversely, average herbaceous litter cover was lower in the Reference Area (25% in 2013, 28% in 2019) than in the Test Area (35% in 2013, 26% in 2019). In both 2013 and 2019 water was observed in the Test Area and absent in the Reference Area. In 2013 lichens were only observed in the Test Area (avg. cover 4%), but were present in 2019 in both the Test and Reference Area (7% and 1%, respectively). The average EC decreased in the Reference Area from 2013 to 2019 (600 µS/cm to 360 µS/cm, respectively) and increased in the Test Area from 2013 to 2019 (360 µS/cm to 532 µS/cm, respectively, Appendix F). The water table was shallower in 2019 than in 2013 for both the Reference (-17 cm and -29 cm, respectively) and the Test Area (-19 cm and -27 cm, respectively). The increase of moss cover and presence of lichens in 2019 in both Areas, suggests an absence of major flood disturbance in this Ecotype.

Riverine Organic-rich Circumneutral Wet Sedge Meadow ground cover was dominated by herbaceous litter, moss, and water (Appendix D-13). Average cover of herbaceous litter increased slightly in 2019 from 2013 in the Reference (+2%, Appendix E) but decreased in the Test (-5%) Areas. The average moss cover increased similarly in both the Reference and Test Areas from 2013 to 2019 (+7% and +5%, respectively). Conversely, the average cover of water decreased between 2013 to 2019 for both the Reference and Test (-11% and -1%, respectively) Areas. Organic soil was not encountered in either Areas in 2013, but was present in both the Reference and Test Areas (avg. 9% and 4%, respectively) in 2019. Average mineral soil cover did not change appreciably between 2013 and 2019 in the Reference (5% and 6%, respectively) or Test Area (2% and 6%, respectively), but the increase was more pronounced in the Test Area. The Riverine Organic-rich Circumneutral Wet Sedge Meadow Plot Ecotype is common on inactive overbank deposits of the Colville River delta. The increase in organic soil at the surface between 2013 to 2019, particularly in the Reference Area, is likely related to the lower cover of water in 2019 which would result in a higher proportion of the ground surface exposed. The average surface organic thickness changed very little in the Reference Area from 2013 to 2019 (11.9% and 11.0%, respectively) and the decrease between years in the Test Area was well within the standard deviation (16.2% and 13.8%, respectively, Appendix F). The average thaw depth was shallower in 2019 compared to 2013 in both the Reference (34 cm and 45 cm, respectively) and Test Areas (38 cm and 48 cm, respectively). The average water table depth did not change in the Reference Area from 2013 to 2019, but slightly increased in the Test Area (-3 cm and -2 cm, respectively).

Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow ground cover was generally similar in the Test Area between years (Appendix D-14) except that exposed organic soil was not present in 2013, but was evident in 2019 (avg. 3%). The notable change in the Reference Area from 2013 to 2019 was a decrease in average herbaceous litter (19% to 13%) between years. The average mineral soil cover also decreased in the Reference Area from 10% in 2013 to 0% in 2019, however this was within the range of the standard deviation. Mosses were the predominant ground cover in both 2013 and 2019 in the Reference (65% and 76%, respectively) and Test (65% and 67%, respectively, Appendix E) Areas, followed by herbaceous litter in the Reference (19% and 13%, respectively) and Test (23% and 18%, respectively) Areas. The average water and lichen cover was the same in both years in the Test Area, but increased in the Reference Area (+3% and +2%, respectively) from 2013 to 2019. The Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow Plot Ecotype is common on inactive overbank deposits of the Colville River delta. Environmental variables like water table depth, EC, and pH were the same or similar from 2013 to 2019 in the Test Area, with the exception of thaw depth, which became shallower (47 cm and 34 cm, respectively, Appendix F). The shallower thaw depth from 2013 to 2019 was also reflected in the Reference Area and was coincidentally the same depths as the Test Area (47 cm and 34 cm, respectively). All other environmental attribute averages in the Reference Area decreased slightly from 2013 to 2019 including, surface organic thickness (14.3 cm to 11.6 cm, respectively), EC (517 µS/cm to 432 µS/cm, respectively), pH (6.8 to 6.6, respectively), except for the water table depth, which increased (-6 cm and -4 cm, respectively). Five plots in this Plot Ecotype were under an ice road during 1 or more winters over the past six years (Table 3.11), however none of these 5 plots were flagged as having changed in species composition.

Upland Loamy-Organic Circumneutral Moist Tussock Meadow ground cover was predominantly herbaceous litter and mosses (Appendix D-15). The sample size is low for this Ecotype in both the Reference (n=1) and Test (n=2) Areas so changes in average cover and environmental variables over time are more difficult to ascertain. Average cover of herbaceous litter was higher in the Reference Area (67% in 2013, 37% in 2019) than the Test Area (40% in 2013, 27% in 2019)(Appendix E). Average tussock cover was also higher in the Reference Area (3% in 2013, 11% in 2019) than the Test Area (0% in 2013, 3% in 2019). We surmise the decrease in herbaceous litter and the increase in tussock cover in both Areas and years is related to differing interpretations of what constitutes a tussock hit versus a litter hit by the field observers between years. The average cover of moss was lower in the Reference Area (13% in 2013, 37% in 2019) than in the Test Area (46% in 2013, 57% in 2019). Average cover of lichen increased in both Areas from 2013 to 2019 (9% to 11%, Reference and 9% to 14%, Test). 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 2019 (19 cm) at a single plot in the Reference Area appears to be the result of the high micro-opographic variability in this Plot Ecotype (Appendix F). The EC in the Reference Area remained higher in both 2013 than 2019 (590 µS/cm and 460 µS/cm, respectively) and higher than the Test Area (170 µS/cm and 175 µS/cm, respectively). The average water table depth was shallower in 2019 than in 2013 for both the Reference (-10 cm and -11 cm, respectively) and the Test Areas (-17 cm and -26 cm, respectively).

Upland Sandy Alkaline Dry Barrens was sampled in the Test Area only. Mineral soil was the predominant ground cover in both 2013 and 2019 (Appendix D-16) and the average percent cover of mineral soil was substantially higher in 2013 (96%) than in 2019 (68%) (Appendix E). Herbaceous litter had the second greatest average percent cover in both years, yet was substantially lower in 2013 (3%) than in 2019 (28%). This Plot Ecotype had no moss cover in 2013, but 4% average moss cover in 2019. The Upland Sandy Alkaline Dry Barrens Plot Ecotype is uncommon, occurring on active sand dune deposits. Sand dunes are dynamic geomorphic landforms that are regularly reshaped by wind events. Active, sandy, dune deposits can be difficult for vegetation to establish on, resulting in the absence of a surface organic horizon in both years (Appendix F). Notably, the thaw depth increased from 82 cm in 2013 to 100 cm in 2019, despite an earlier sampling period when seasonal frost was shallower, which differs from the other Ecotypes. The decrease in mineral soil cover in 2019 is related to the increase in litter and moss which overtop mineral soil. This suggests a decrease in the intensity of natural disturbances in the form of wind and flooding, which can physically remove litter and bury moss under sediment.

Upland Sandy Alkaline Moist Low Willow Shrub ground cover in both Areas and years was predominantly herbaceous litter (Appendix D-17). However, the average cover of herbaceous litter in the Test Area (41–50%) was substantially lower than that found in the Reference Area (75–97%) (Appendix E). Mineral soil was observed in the Reference Area only in 2019 (average 1% cover), but increased in the Test Area from 2013 to 2019 (31% to 37%, respectively). The average moss cover increased substantially in all Areas from 2013 to 2019 (1% to 22%, Reference and 17% to 33%, Test), but continues to be more abundant in the Test than the Reference 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 2019 (0.5 cm and 0 cm in Reference, and 0.3 cm and 0.2 cm in Test, respectively)(Appendix F). The one plot in this Ecotype in the Reference Area experienced a decrease in EC (450 µS/cm to 100 µS/cm) and very little change in pH (8.2 to 8.1) from 2013 to 2019. Similarly, the Test Area saw a slight decrease in EC (167 µS/cm to 123 µS/cm), while pH remained approximately the same (8.1 to 8.0) from 2013 to 2019. The thaw depth was shallower in 2019 compared to 2013 in both the Reference (90 cm and 120 cm, respectively) and Test Areas (68 cm and 105 cm, respectively).

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 3.19 and 3.20. In general, total live cover (TLC) stayed approximately the same or increased between 2013 and 2019 in both Reference and Test Areas and across all Plot Ecotypes. Increases in TLC were most commonly related to increases in moss and sedge cover, and in some cases increases in forb (e.g., Riverine Loamy Alkaline Moist Low Willow Shrub) and/or low shrub (e.g., Riverine Loamy Alkaline Moist Mixed Herb) cover. In 2013, TLC 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 2019, Riverine Loamy Alkaline Moist Low Willow Shrub again had the highest TLC in the Test Area; we attribute the higher cover value in this Plot Ecotype in 2019 to increase in forbs and mosses, and to a lesser extent, low shrubs. In the Reference Area, Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow was again the Plot Ecotype with the highest TLC in 2019, which saw an increase between years in sedge and moss cover, and a slight reduction in forb cover. Total live cover increased appreciably in Coastal Loamy Brackish Moist Willow Dwarf Shrub in the Reference Area in 2019, attributed predominantly to an increase in dwarf willow, grass, and sedge cover.

Total live vascular cover (TLVC) is similar to TLC except that bryophytes and lichens are excluded from the cover sum. Total live vascular cover remained approximately the same or increased between 2013 and 2019 in both Reference and Test Areas and across Ecotypes. Increases in TLVC were most commonly related to increases in sedge and low shrub cover (predominantly *Salix*). Two Plot Ecotypes were an exception to this rule, and experienced a decrease in TLVC: Riverine Loamy Alkaline Moist Tall Willow Shrub in the Reference Area and Upland Sandy Alkaline Moist Low Willow Shrub in the Test Area. The decrease in TLVC in Riverine Loamy Alkaline Moist Tall Willow Shrub in the Reference Area was primarily related to a large decrease in forb cover, and secondarily to a decrease in tall shrub cover. While TLVC decreased in this Plot Ecotype between 2013 and 2019, TLC increased slightly in 2019 due to a large increase in moss cover. The decrease in TLVC in Sandy Alkaline Moist Low Willow Shrub in the Test Area is related primary to a decrease in grass and forb cover. Similar to above, while TLVC decreased substantially in 2019 in this Plot Ecotype, the TLC remained approximately the same due to a large increase in moss cover between

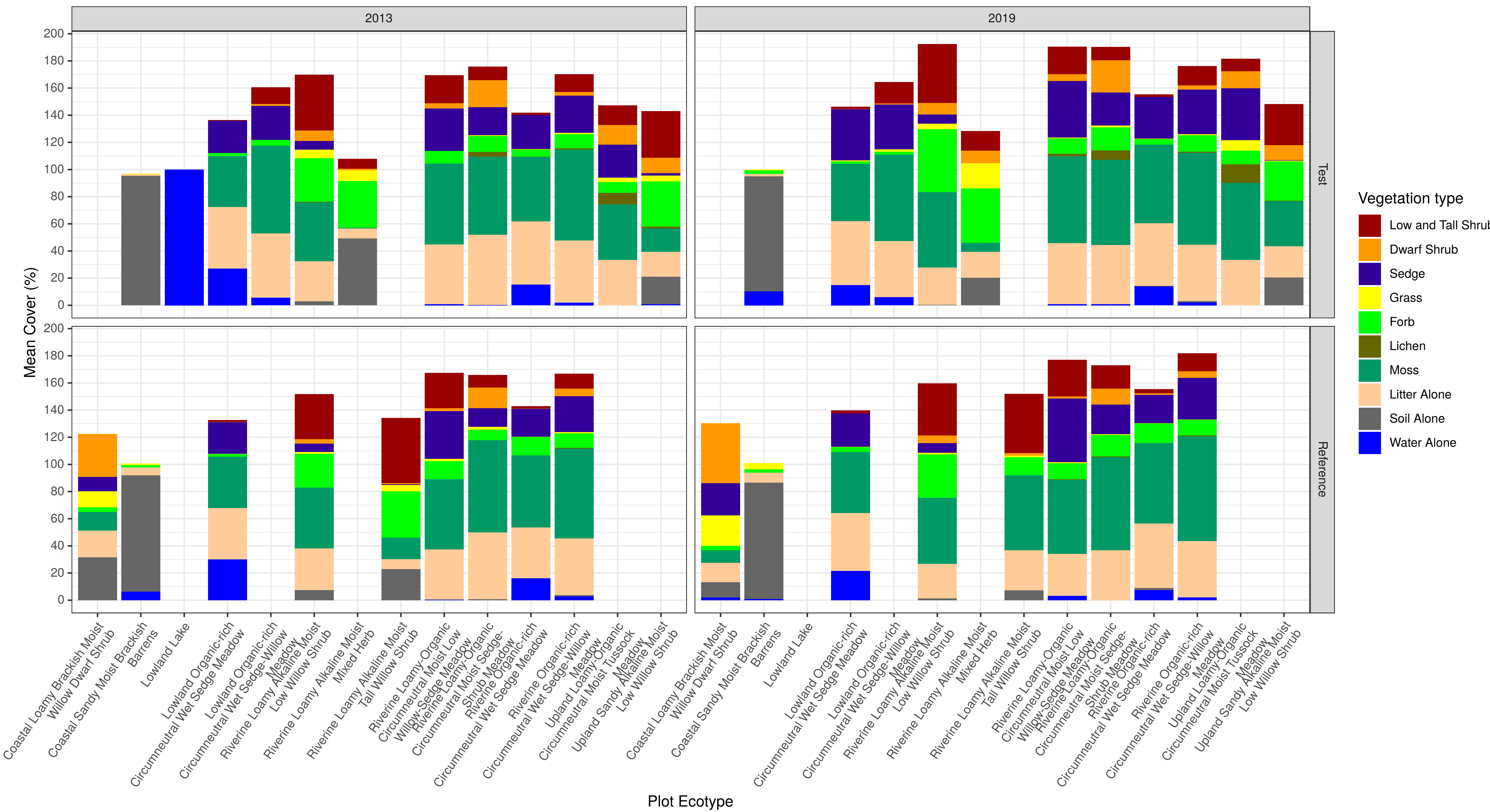


Figure 3.19 Mean cover by vegetation structure class for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska, Test and Reference Areas, 2013 and 2019.

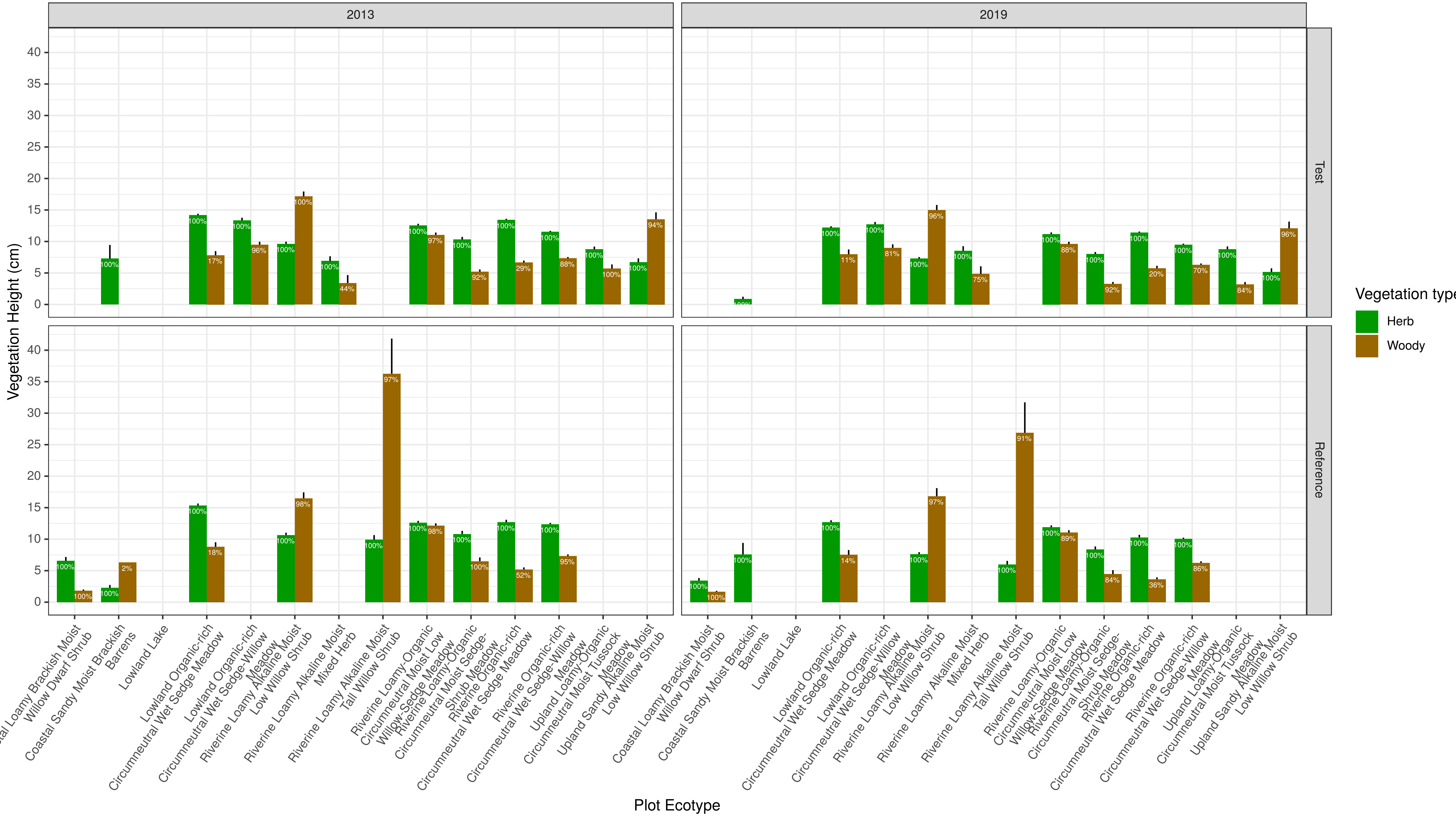


Figure 3.20 Herbaceous and woody plant height for common plot ecotype classes in the CD5 Habitat Monitoring Study Area, northern Alaska,Test and Reference Areas, 2013 and 2019.

years. All plots in the Plot Ecotype Sandy Alkaline Moist Low Willow Shrub in both Reference and Test Areas were also identified in the vegetation analysis (see above, Vegetation Assessment) as having changed in plant species composition between 2013 and 2019. In the Test Area, the Plot Ecotype with the greatest TLVC was Riverine Loamy Alkaline Moist Low Willow Shrub in both 2013 and 2019. This same Plot Ecotype also had the greatest TLC in the Test Area in both years. In the Reference Area, the Plot Ecotype with the greatest TLVC in 2013 was Riverine Loamy Alkaline Moist Tall Willow Shrub; however in 2019 this Plot Ecotype saw a decrease in TLVC as discussed above. In 2019, Coastal Loamy Brackish Moist Willow Dwarf Shrub was the Plot Ecotype with the greatest TLVC, attributed predominantly to an increase in dwarf willow, grass, and sedge cover. The Plot Ecotypes with the largest increases in TLVC in 2019 were (from largest to smallest): Riverine Loamy Alkaline Moist Mixed Herb in the Test Area, Coastal Loamy Brackish Moist Willow Dwarf Shrub in the Reference Area, and Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow in the Reference Area.

The bottom cover of the non-vegetated classes water, soil, litter, and moss are included in Figure 3.20 and mirror the results of the detailed ground cover class assessment (Appendices D and E). 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, slightly deeper water tables, and an increase in soil, litter, and non-vascular cover between 2013 and 2019. The higher water cover in 2013, despite the deeper snowpack, later snowmelt, higher than normal precipitation in May, June, and July, and slightly lower to normal evapotranspiration in 2019, is likely related to the more extensive break-up flooding in 2013 when most of the CD5 Study Area was flooded for up to several days (Baker 2013). In contrast, spring break-up was more subdued in 2019 and the CD5 Study Area was flooded less extensively (Baker 2019). Lower cover of standing water in 2019 resulted in a higher amount of exposed litter and mineral soil, which is expressed in the higher percentages of these ground cover classes in 2019. 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 2019. The Ecotypes Coastal Loamy Brackish Moist Willow Dwarf Shrub, 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 general trend in ground cover in 2019 for these Plot Ecotypes was a decrease in mineral soil, and an increase in litter and moss cover. 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 moss and litter cover in 2019 in several of these Plot Ecotypes is likely attributable to a combination of the more subdued breakup flooding in 2017, 2018, and 2019 as compared to 2013 (Baker 2013, 2017, 2018, 2019), 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, and lower rates of sedimentation allowing mosses to proliferate. 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 3.20. In general, herb and woody heights were slightly lower in 2019 in both Reference and Test Areas and across Ecotypes with few exceptions. Woody heights were approximately the same between years in the following Ecotypes: Coastal Loamy Brackish Moist Willow Dwarf Shrub, Lowland Organic-rich Circumneutral Wet Sedge Meadow, Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow, Riverine Loamy Alkaline Moist Low

Willow Shrub, and Riverine Loamy Alkaline Moist Mixed Herb. The most dramatic change in woody height in 2019 was in the Plot Ecotype Riverine Loamy Alkaline Moist Tall Willow Shrub, which continues a trend of decreasing woody height in this Plot Ecotype first observed in 2016. Herb heights were approximately the same between years in only 1 Plot Ecotype: Upland Loamy-Organic Circumneutral Moist Tussock Meadow. The lower woody and herbaceous heights observed in 2019 across nearly all Plot Ecotypes and Areas suggest a similar change in heights across both Areas. This change may in part be related to an inconsistency in the method for recording heights in 2019. The methods call for recording the height of the tallest woody and herbaceous plant within a 15 cm radius around the laser beam (See Methods: Field Surveys, above). However, in some instances a 15 cm diameter around the laser beam was used resulting from a miscommunication about methods early on in the field trip. This was resolved later in the trip such that all field crews were recording heights using the correct method.

3.4.2.B Habitat Assessment

3.4.2.B.i 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) a 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 98.0% of the non-water portion of the CD5 Study Area (see 3.4.2.C ITU Mapping, below).

Summaries of vegetation structure class cover and non-vegetated cover by wildlife habitat class and grouped by year and area are presented in Figure 3.21 and Appendix G (mean cover) and Appendix H (mean cover and confidence intervals). 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 Halophytic Dwarf Shrub and Moist Low Shrub also had appreciable soil alone cover. Litter alone was highest in Patterned Wet Meadow, Deep Polygon Complex, Nonpatterned Wet Meadow, Moist Sedge-Shrub Meadow, and Dry Dwarf Shrub. Cover of mosses was highest in Moist Sedge-Shrub Meadow, Nonpatterned Wet Meadow, and Patterned Wet Meadow. Lichen cover was generally absent to low across all wildlife habitats, but was highest in Dry Dwarf 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 Moist Halophytic Dwarf Shrub. Wildlife habitats with the highest cover of sedges included Moist Tussock Tundra, Nonpatterned Wet Meadow, and Patterned 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, Moist Tussock Tundra, and Dry Dwarf Shrub. These broad patterns are consistent in both years of the study (2013 and 2019) 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 3.22 and Appendix G. Woody vegetation frequency was highest in Moist Halophytic Dwarf Shrub, Moist Sedge-Shrub Meadow, Dry Dwarf Shrub, and Moist Low Shrub. Moist Herb Meadow and Moist Low Shrub were associated with some of the highest woody vegetation heights. Note that Tall Shrub habitat classes were relatively rare and were excluded from these results due to insufficient sample points. Herb frequency was universally high across all

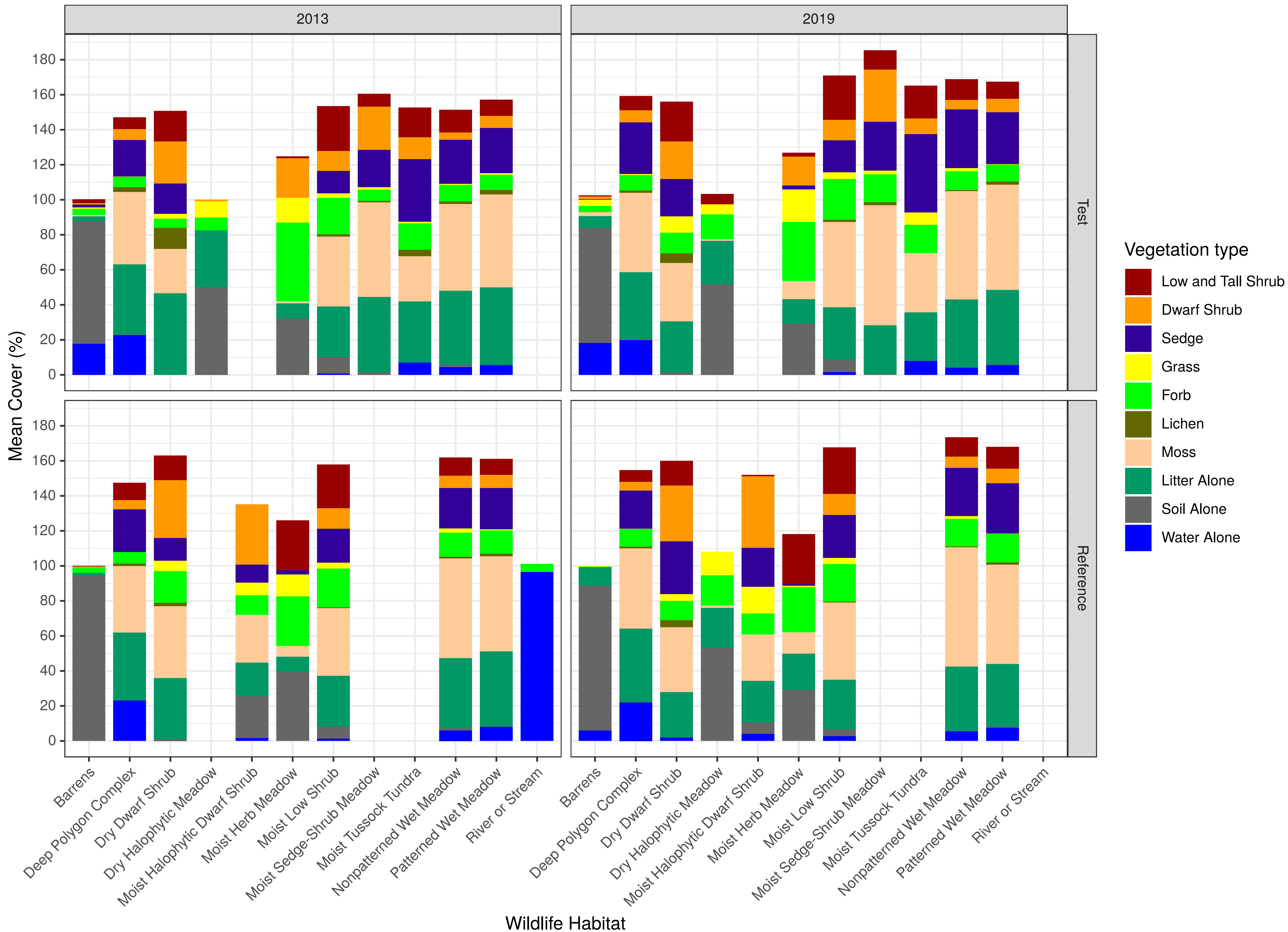


Figure 3.21 Mean cover by vegetation structure class for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

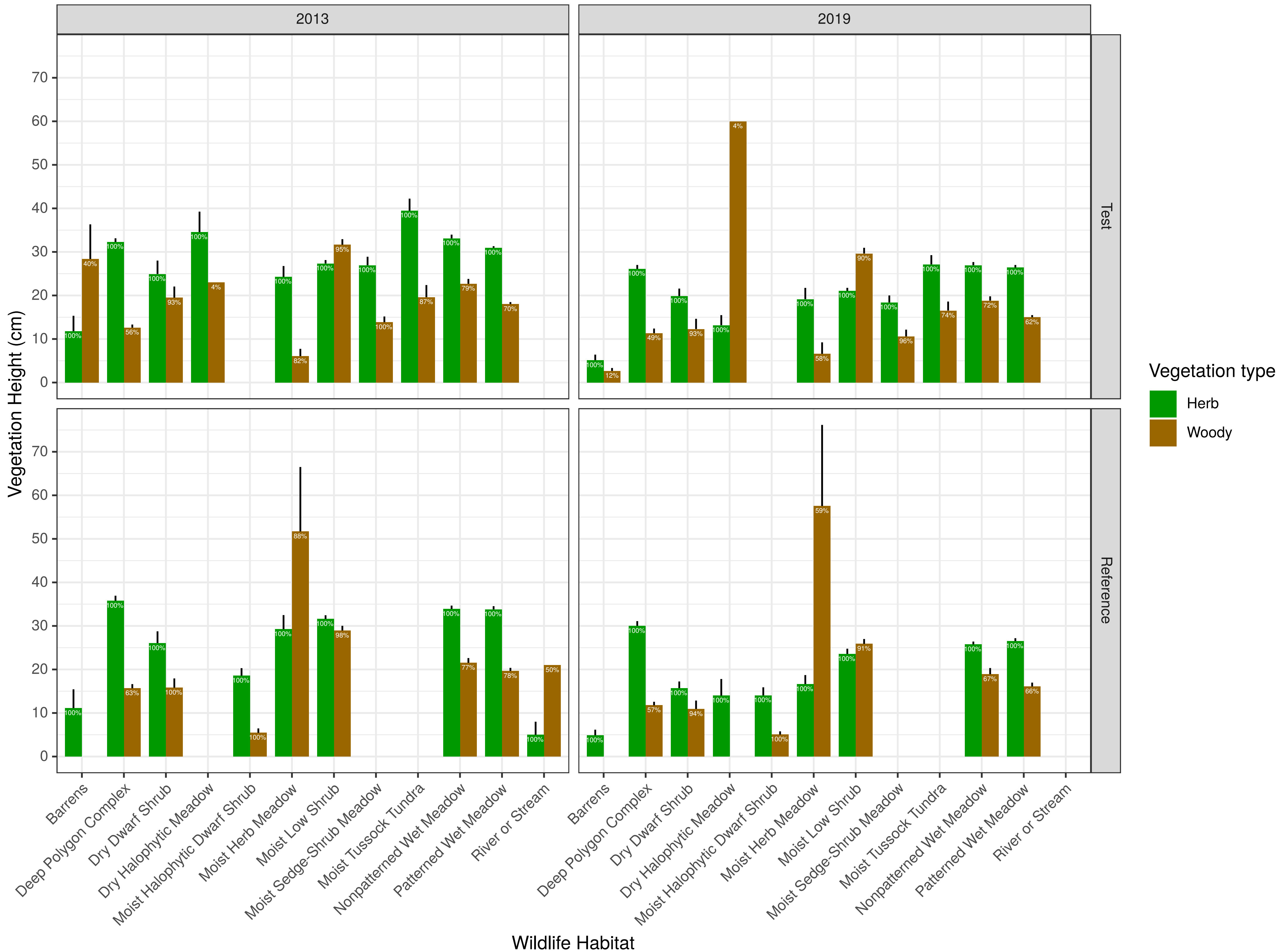


Figure 3.22 Herbaceous and woody plant height for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

habitats, and herb heights were highest in Moist Tussock Tundra, Deep Polygon Complex, Nonpatterned Wet Meadow, and Patterned Wet Meadow. 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 2019 for the Dry Halophytic Meadow habitat type (23 cm in 2013, 60 cm in 2019) represents a real increase in shrub height for this habitat, but as noted in the previous report (Wells et al. 2017), the increase occurred between 2013 and 2016 (60.5 cm in 2016) and heights have not continued to increase. Also note, 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.

3.4.2.B.ii 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 2019, and Test and Reference Areas (Figure 3.23 and Appendix H) 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 3.12). For the purposes of evaluating the effects of the CD5 project, the interaction effect is the important parameter because it signifies a change between 2013 and 2019 that was different in the Test Area than the Reference Area. For total live vascular cover, there were three significant interaction effects.

The year-effect response in the Deep Polygon Complex wildlife habitat is different between Test and Reference Areas, showing an increase in total live vascular cover in the Test Area, but a slight drop in the Reference Area. Both Dry Halophytic Meadow and Patterned Wet Meadow experienced a greater increase in total live vascular cover in the Reference Area compared with the Test Area.

There were also significant independent Area, and year effects in the Dry Halophytic Meadow wildlife habitat, possibly a result of a low number of plots within those habitats. Significant year effects were seen in Moist Halophytic Dwarf Shrub, Nonpatterned Wet Meadow, and Patterned Wet Meadow. All of these wildlife habitats showed large increases in total live vascular cover between 2013 and 2019.

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 3.13). Several significant Area effects were found, including higher cover of sedges and rushes in Moist Low Shrub for the Reference Area, and higher cover of both bare ground and mineral soil for the Reference Area in Barrens habitat (Figure 3.23).

Year effects between 2013 and 2019 occurred in a variety of habitats and structure classes. These include increases in mosses and liverworts cover in Deep Polygon Complex, Moist Low Shrub, and Nonpatterned Wet Meadow wildlife habitats, increases in sedges and rushes cover in Moist Low Shrub, Nonpatterned Wet Meadow, and Patterned Wet Meadow habitats, and increases in *Salix* cover in Patterned Wet Meadow. Decreasing cover between 2013 and 2019 occurred for bare ground in Barrens and Moist Halophytic Dwarf Shrub, and mineral soil in Barrens.

There are significant Area and year interaction effects, so not all of the differences between Test and Reference Areas can be explained by a year or an Area effect alone. *Salix* cover responded differently between Test and Reference Areas in 2013 and 2019 in both Moist Halophytic Dwarf Shrub and Patterned Wet Meadow wildlife habitats. In Patterned Wet Meadow habitat *Salix* cover increased from 10.7% to 16.8% between 2013 and 2019 in the Reference Area, but was only slightly higher (11.6% in 2013, 12.1% in 2019) in the Test Area. Similarly, in Moist Halophytic Dwarf Shrub habitat, *Salix* increased slightly in the Reference Area (39.3% to 40.4%) and dropped slightly in the Test Area (28.7% to 27.9%).

In Deep Polygon Complex wildlife habitats there was an interaction effect for the sedges and

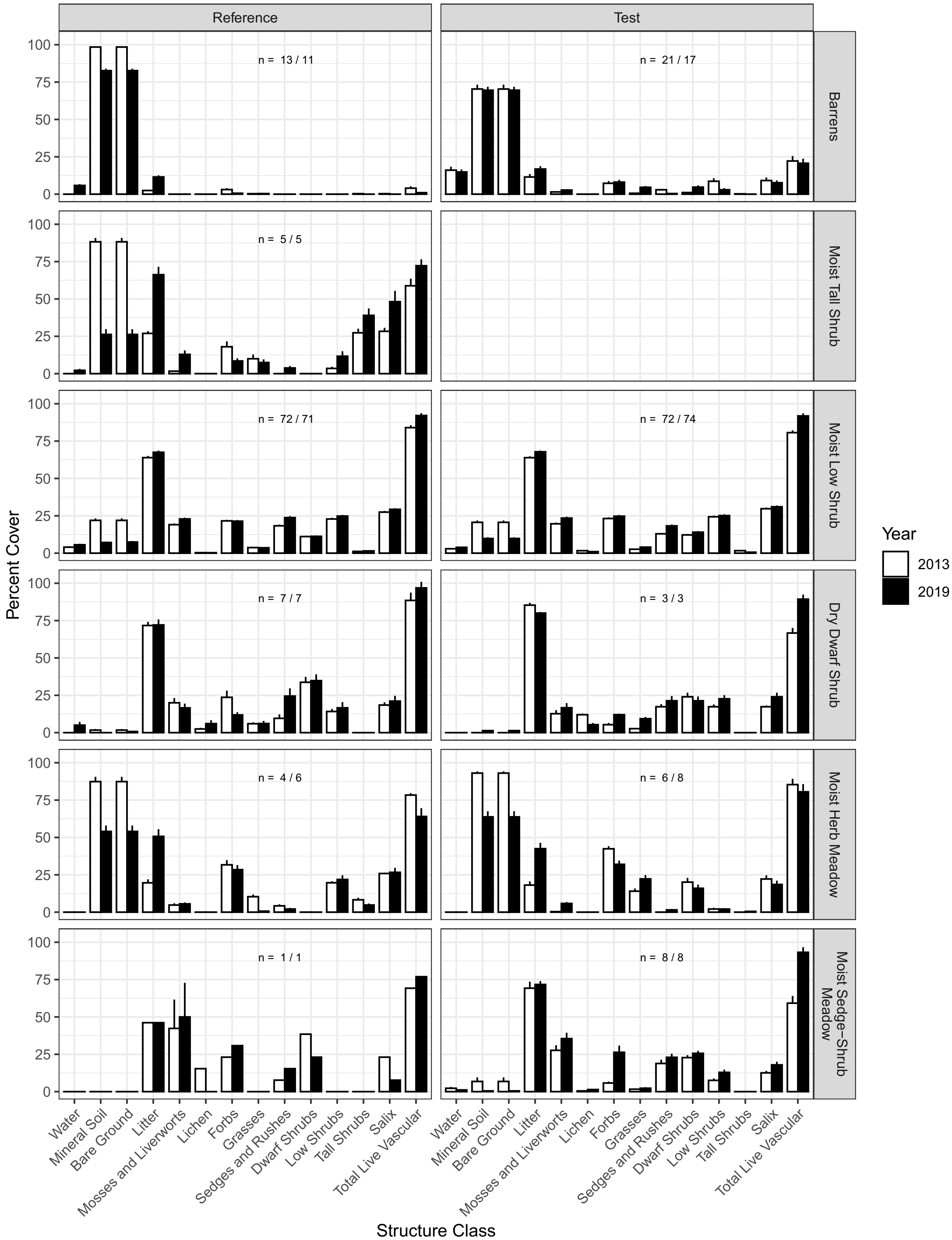


Figure 3.23 Mean cover and 95% confidence intervals by vegetation structure class, grouped by common wildlife habitat classes and Area classification in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

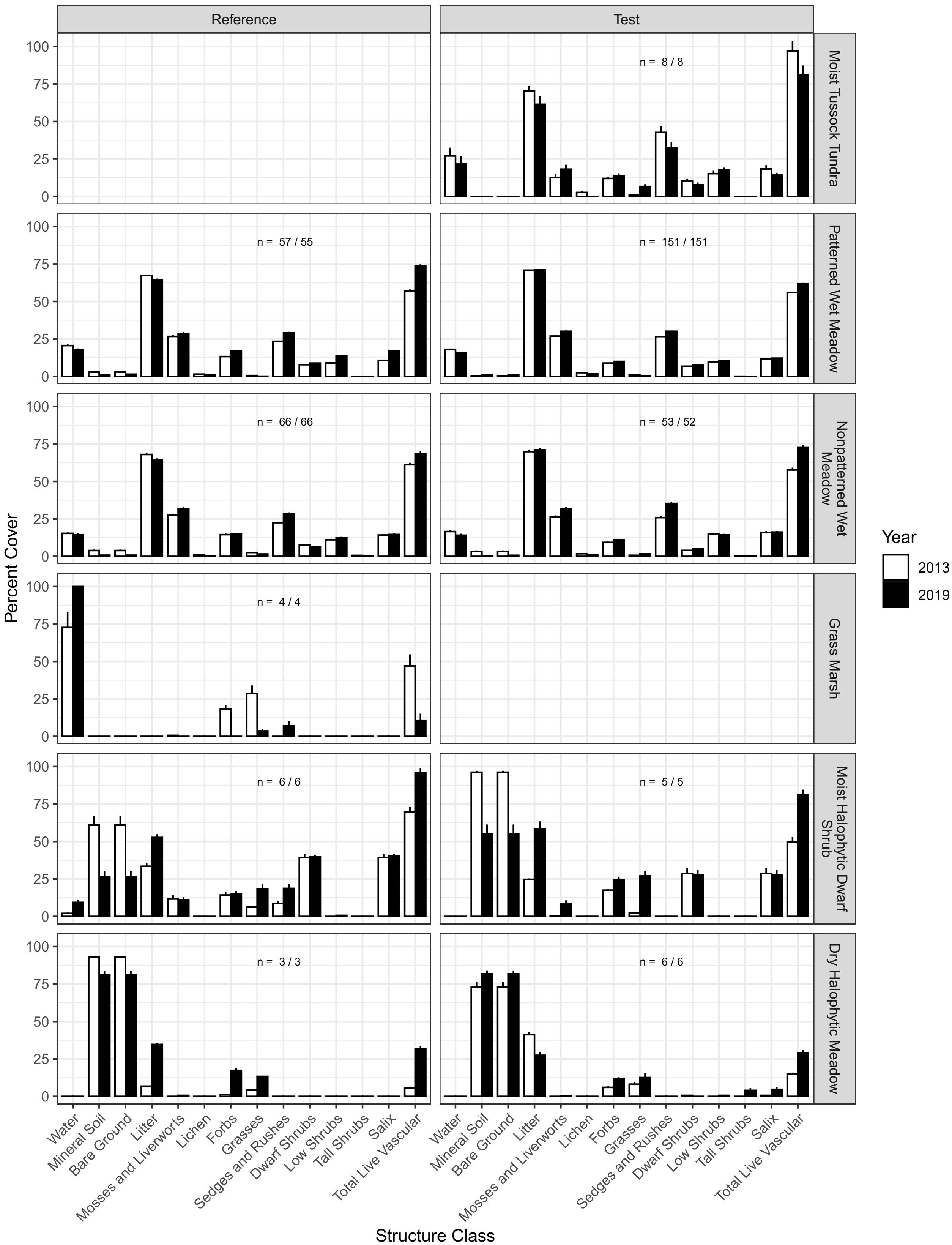


Figure 3.23 Continued.

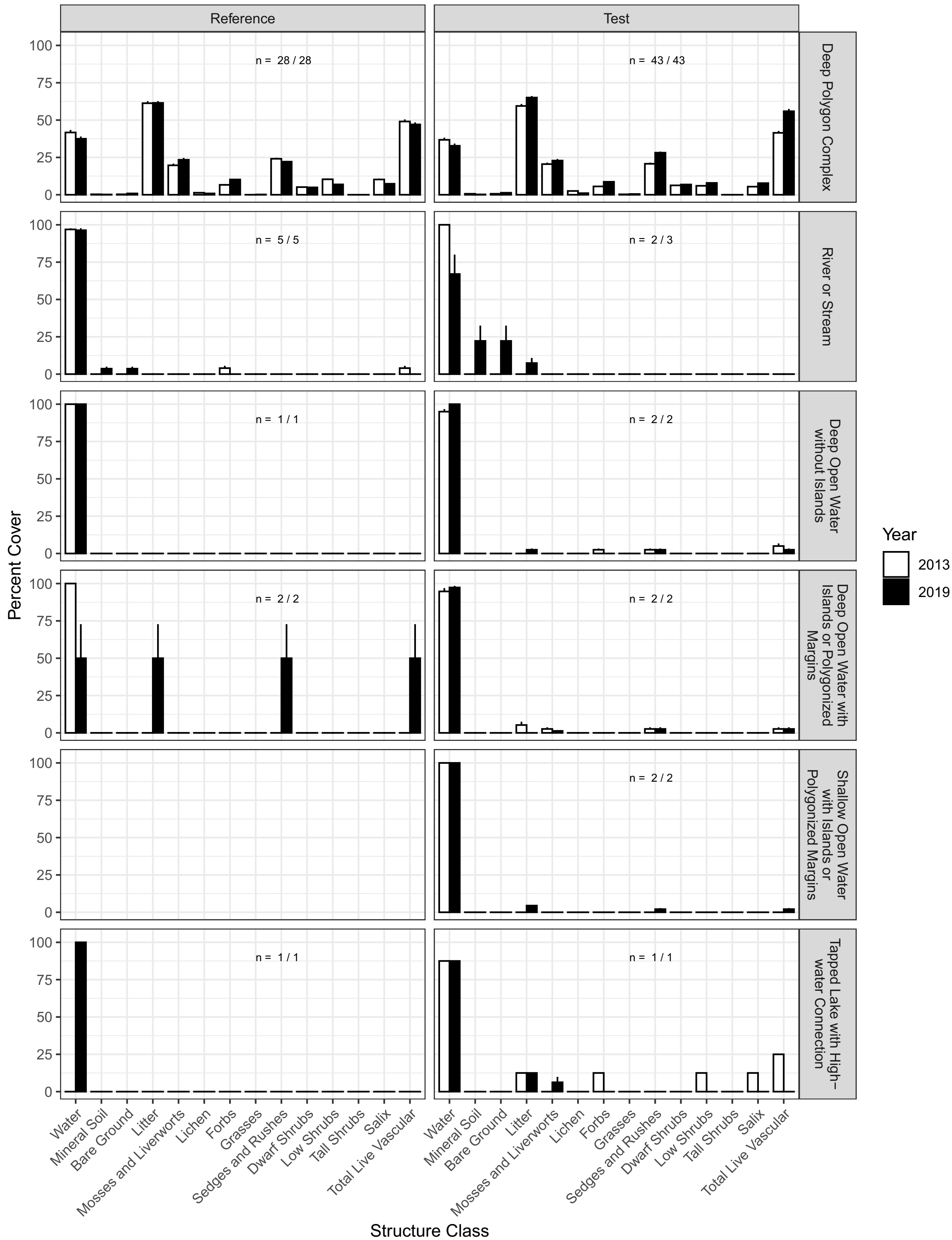


Figure 3.23 Continued.

Table 3.12 Significance 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 2019. Key to significance symbols: * $p < 0.5$; ** $p < 0.01$; *** $p < 0.001$.

Wildlife Habitat	Area	Year 2019	Area x 2019
Barrens	0.560	0.936	0.452
Deep Polygon Complex	0.376	0.603	0.001 **
Dry Dwarf Shrub	0.372	0.499	0.665
Dry Halophytic Meadow	0.035 *	0.002 **	0.020 *
Moist Halophytic Dwarf Shrub	0.517	0.001 **	0.320
Moist Herb Meadow	0.564	0.159	0.433
Moist Low Shrub	0.069	0.051	0.503
Moist Sedge-Shrub Meadow	0.959	0.678	0.404
Nonpatterned Wet Meadow	0.293	0.037 *	0.304
Patterned Wet Meadow	0.677	0.000 ***	0.043 *
River or Stream	0.498	0.311	0.600

Table 3.13 Significance of Area, Year, and Area × Year interaction on common vegetation structure classes by wildlife habitat from repeated measures analysis, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019. Key to significance symbols: * $p < 0.5$; ** $p < 0.01$; *** $p < 0.001$.

Wildlife Habitat	Structure Class	Area	Year 2019	Area × 2019
Barrens	Bare Ground	0.007 **	0.028 *	0.102
Barrens	Mineral Soil	0.007 **	0.028 *	0.102
Deep Polygon Complex	Mosses and Liverworts	0.508	0.033 *	0.360
Deep Polygon Complex	Sedges and Rushes	0.296	0.426	0.002 **
Moist Halophytic Dwarf Shrub	Bare Ground	0.096	0.013 *	0.899
Moist Halophytic Dwarf Shrub	Dwarf Shrub	0.674	0.102	0.011 *
Moist Halophytic Dwarf Shrub	Salix	0.652	0.082	0.010 **
Moist Halophytic Dwarf Shrub	Mineral Soil	0.096	0.013 *	0.899
Moist Low Shrub	Mosses and Liverworts	0.806	0.021 *	0.552
Moist Low Shrub	Sedges and Rushes	0.036 *	0.024 *	0.668
Moist Sedge-Shrub Meadow	Dwarf Shrub	0.169	0.071	0.047 *
Nonpatterned Wet Meadow	Mosses and Liverworts	0.119	0.000 ***	0.497
Nonpatterned Wet Meadow	Sedges and Rushes	0.980	0.049 *	0.191
Patterned Wet Meadow	Salix	0.652	0.001 ***	0.007 **
Patterned Wet Meadow	Sedges and Rushes	0.149	0.008 **	0.482

rushes structure class. Cover values decreased from 24.1% to 22.2% in the Reference Area between 2013 and 2019, but they increased from 20.7% to 28.2% in the Test Area.

Finally, dwarf shrub cover year changes were slightly different between Test and Reference Areas for Moist Halophytic Dwarf Shrub wildlife habitats. Cover slightly increased from 39.3% to 39.7% in the Reference Area, and slightly decreased from 28.7% to 27.9%. Despite being statistically significant in our analysis, these are very minor changes in cover.

Of these interaction effects, only the changes in cover for *Salix* in Patterned Wet Meadow habitat appear to be ecologically relevant. This same interaction effect was noted in the 2016 CD5 report, where *Salix* cover increased in the Reference Area, but declined in the Test Area. The pattern for 2019 includes cover increases in the Test Area, but not to the extent that *Salix* is increasing in the Reference Area. *Salix* cover changes are also significant for the between year coefficient, so it is clear that *Salix* is changing in this particular habitat both independently of Area, but also when Area is included. As we noted in 2016, this is a pattern that bears increased scrutiny in future monitoring assessments.

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 2018 and, where cloud cover obscured the ground in the 2018 imagery, we used imagery acquired in August 2017. 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 in the baseline map, with the exception of disturbance classes.

Geomorphic Units

Nineteen terrestrial geomorphic units are represented in the updated map, accounting for 79% of the CD5 Habitat Monitoring Study Area (Figure 3.24, Table 3.14). 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 7.5 to 9.8%. All other terrestrial geomorphic units cover <3% of the CD5 Study Area.

Seven aquatic geomorphic units collectively account for the remaining 21% of the CD5 Study Area (Figure 3.25, Table 3.15). As in both the 2012 and 2015 maps, 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 (6.5%). The remaining aquatic geomorphic units account for ≤2.1% each.

Surface Forms

Nineteen surface forms occur in the updated mapping (Figure 3.26, Table 3.16). As in both the 2012 and 2015 maps, the dominant surface forms were Disjunct Polygon Rims; Low-centered, Low-relief, Low-density Polygons; and Non-patterned, 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 7.5%. 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 3.27.

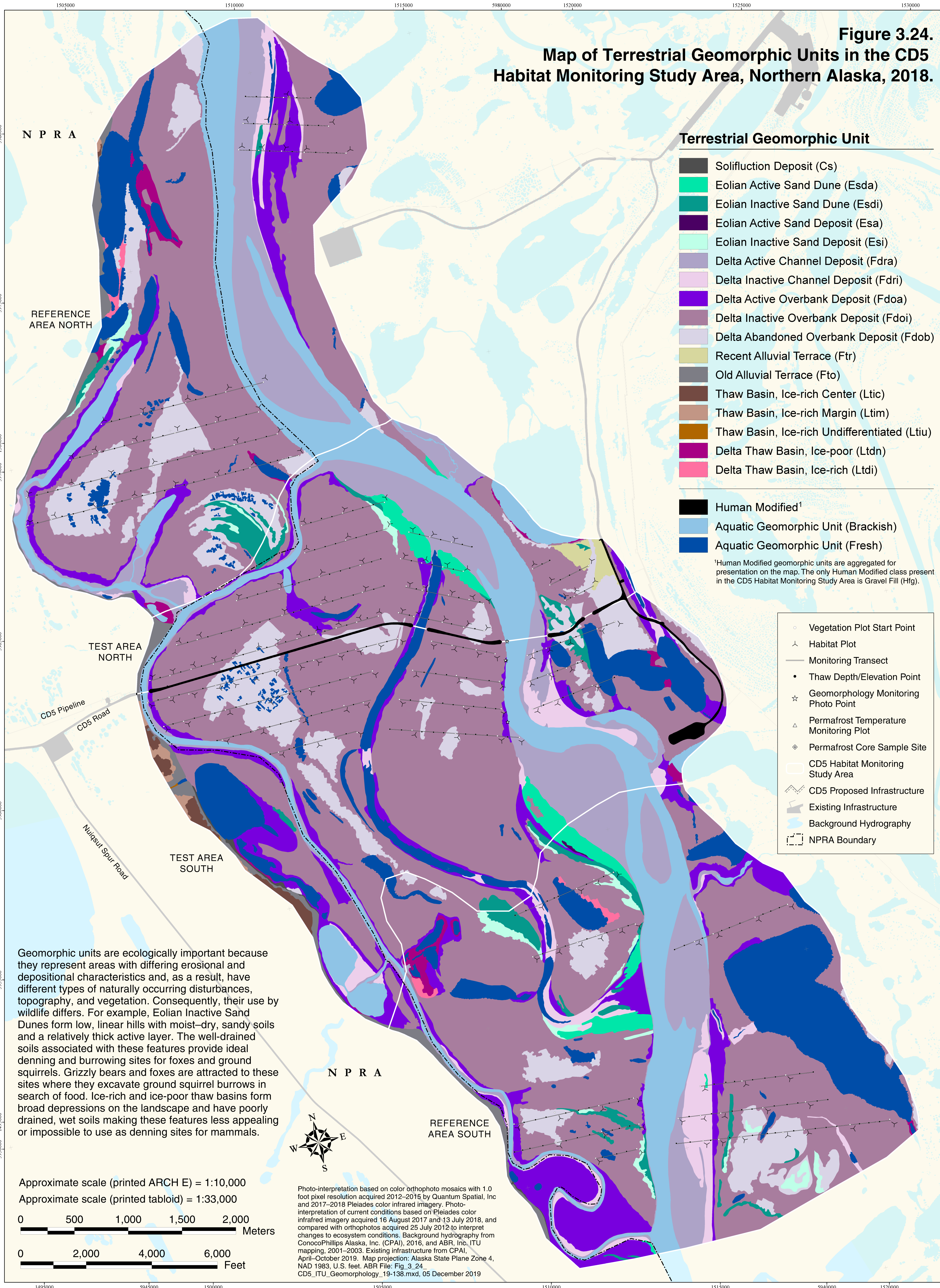
Vegetation

Twenty vegetation classes (Level IV, AVC) are represented in the updated mapping (Figure 3.28, Table 3.17). 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 11.3%, respectively. Other common vegetation classes include Fresh Water (9.4%), Open Low WIllow (7.9%), Deep Polygon Complex (6.3%), Barrens (8.2%), and Open Low Willow-Sedge Shrub Tundra (5.7%). All other vegetation classes combined account for slightly over 10% of the CD5 Study Area.

Disturbance

The updated mapping identified 10 disturbance classes within the CD5 Study Area (Figure 3.29, Tables 3.18 and 3.19). The disturbance classification includes one less anthropogenic category—Gravel Fill—than the

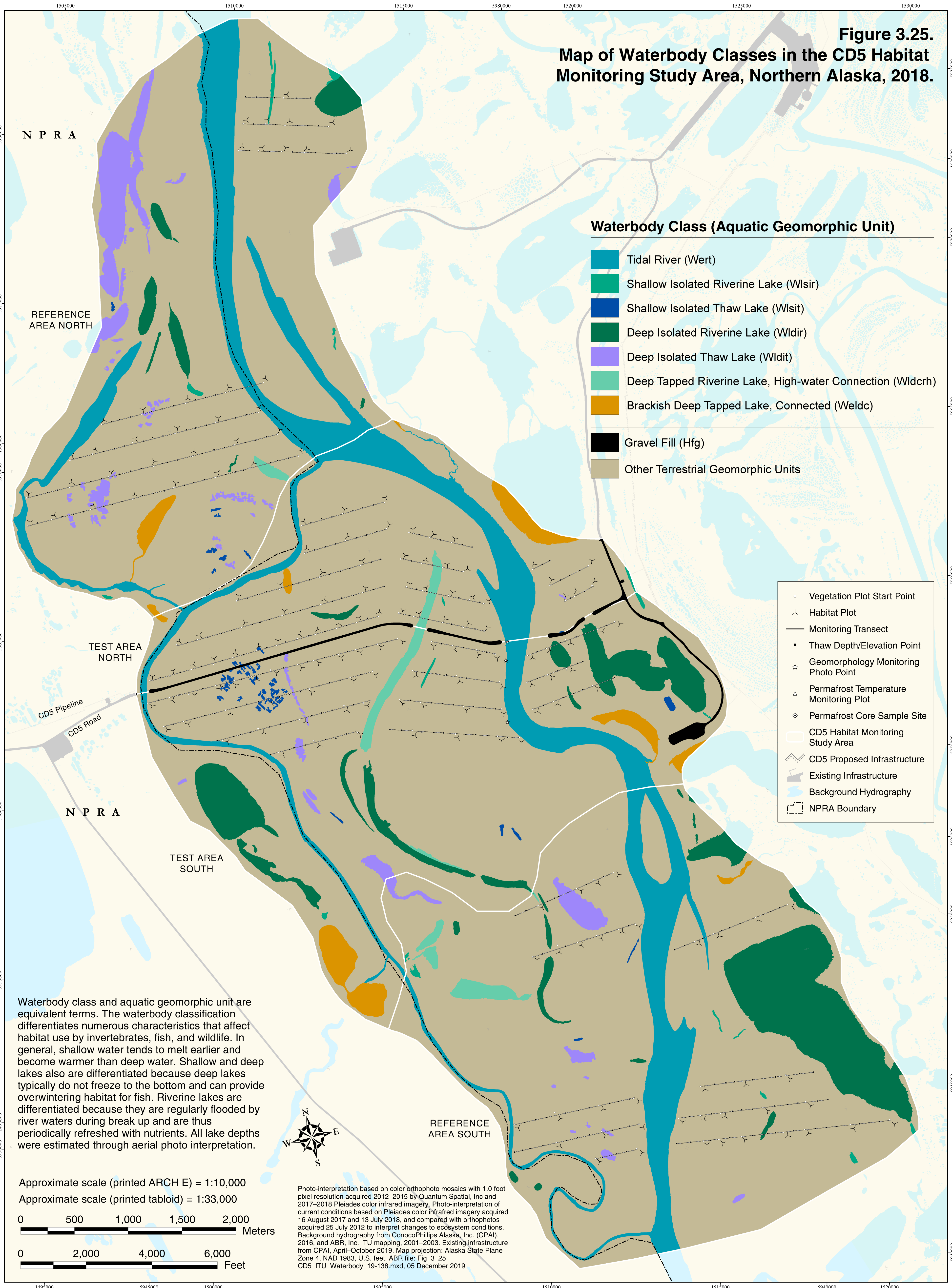
Figure 3.24. Map of Terrestrial Geomorphic Units in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.



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.

Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc and 2017–2018 Pleiades color infrared imagery. Photo-interpretation of current conditions based on Pleiades color infrafred imagery acquired 16 August 2017 and 13 July 2018, 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, April–October 2019. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR File: Fig_3_24_CD5_ITU_Geomorphology_19-138.mxd, 05 December 2019

Figure 3.25. Map of Waterbody Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.



Waterbody class and aquatic geomorphic unit are equivalent terms. The waterbody classification differentiates numerous characteristics that affect habitat use by invertebrates, fish, and wildlife. In general, shallow water tends to melt earlier and become warmer than deep water. Shallow and deep lakes also are differentiated because deep lakes typically do not freeze to the bottom and can provide overwintering habitat for fish. Riverine lakes are differentiated because they are regularly flooded by river waters during break up and are thus periodically refreshed with nutrients. All lake depths were estimated through aerial photo interpretation.

Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc and 2017–2018 Pleiades color infrared imagery. Photo-interpretation of current conditions based on Pleiades color infrafred imagery acquired 16 August 2017 and 13 July 2018, 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, April–October 2019. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_25_CD5_ITU_Waterbody_19-138.mxd, 05 December 2019

Table 3.14 Areal extent (ha) of terrestrial geomorphic units and the percent change in the total area of each unit between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Delta Abandoned Overbank Deposit	202	201.8	-0.1	144.7	144.7	0	346.7	346.5	-0.1
Delta Active Channel Deposit	256.5	256.1	-0.2	165	162.5	-1.5	421.5	418.6	-0.7
Delta Active Overbank Deposit	211	210.8	-0.1	109	108.9	-0.1	320	319.7	-0.1
Delta Inactive Channel Deposit	81.1	81.6	0.6	33	31.7	-3.9	114.1	113.3	-0.7
Delta Inactive Overbank Deposit	1106.3	1104.1	-0.2	793.9	792.9	-0.1	1900.2	1897	-0.2
Delta Thaw Basin, Ice-poor	18.9	18.9	0	6.3	5.8	-7.9	25.2	24.7	-2
Delta Thaw Basin, Ice-rich	7.5	7.5	0	0	0		7.5	7.5	0
Eolian Active Sand Deposit	0.5	0.5	0	0	0		0.5	0.5	0
Eolian Active Sand Dune	23.3	23.3	0	26.7	26.3	-1.5	50	49.6	-0.8
Eolian Inactive Sand Deposit	26.8	26.8	0	3.9	3.9	0	30.7	30.7	0
Eolian Inactive Sand Dune	44.8	44.8	0	19	19	0	63.8	63.8	0
Gravel Fill	0	0		7.9	8	1.3	7.9	8	1.3
Lowland Headwater Floodplain	0	0		<0.1	<0.1	0	<0.1	<0.1	0
Old Alluvial Terrace	31.4	31.2	-0.6	19.2	19.2	0	50.6	50.4	-0.4
Recent Alluvial Terrace	0	0		10.2	10.2	0	10.2	10.2	0
Solifluction Deposit	0.5	0.5	0	2.8	2.8	0	3.3	3.3	0
Thaw Basin, Ice-rich Center	0.3	0.3	0	11.8	11.8	0	12.1	12.1	0
Thaw Basin, Ice-rich Margin	0.5	0.5	0	5.1	5.1	0	5.6	5.6	0
Thaw Basin, Ice-rich Undifferentiated	0	0		0.2	0.2	0	0.2	0.2	0
Grand Total	2011.4	2008.8	-0.1	1358.8	1353	-0.4	3370.2	3361.8	-0.2

* The footprint of the CD5 road is not included.

Table 3.15 Areal extent (ha) of aquatic geomorphic units and the percent change in the total area of each unit between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Brackish Deep Tapped Lake, Connected	9.8	9.8	0	44.9	47.2	5.1	54.7	57	4.2
Deep Isolated Riverine Lake	176.7	177.4	0.4	101	99.7	-1.3	277.7	277.1	-0.2
Deep Isolated Thaw Lake	80.9	81.1	0.2	7.9	7.9	0	88.8	89	0.2
Deep Tapped Riverine Lake, High-water Connection	16.4	16.4	0	17.7	17.7	0	34.1	34.1	0
Shallow Isolated Riverine Lake	6.2	6.2	0	2.1	2.1	0	8.3	8.3	0
Shallow Isolated Thaw Lake	1.7	1.7	0	6.2	6.2	0	7.9	7.9	0
Tidal River	279.1	280.8	0.6	137.4	142.2	3.5	416.5	423	1.6
Grand Total	570.8	573.3	0.4	317.2	323	1.8	888	896.3	0.9

* The footprint of the CD5 road is not included.

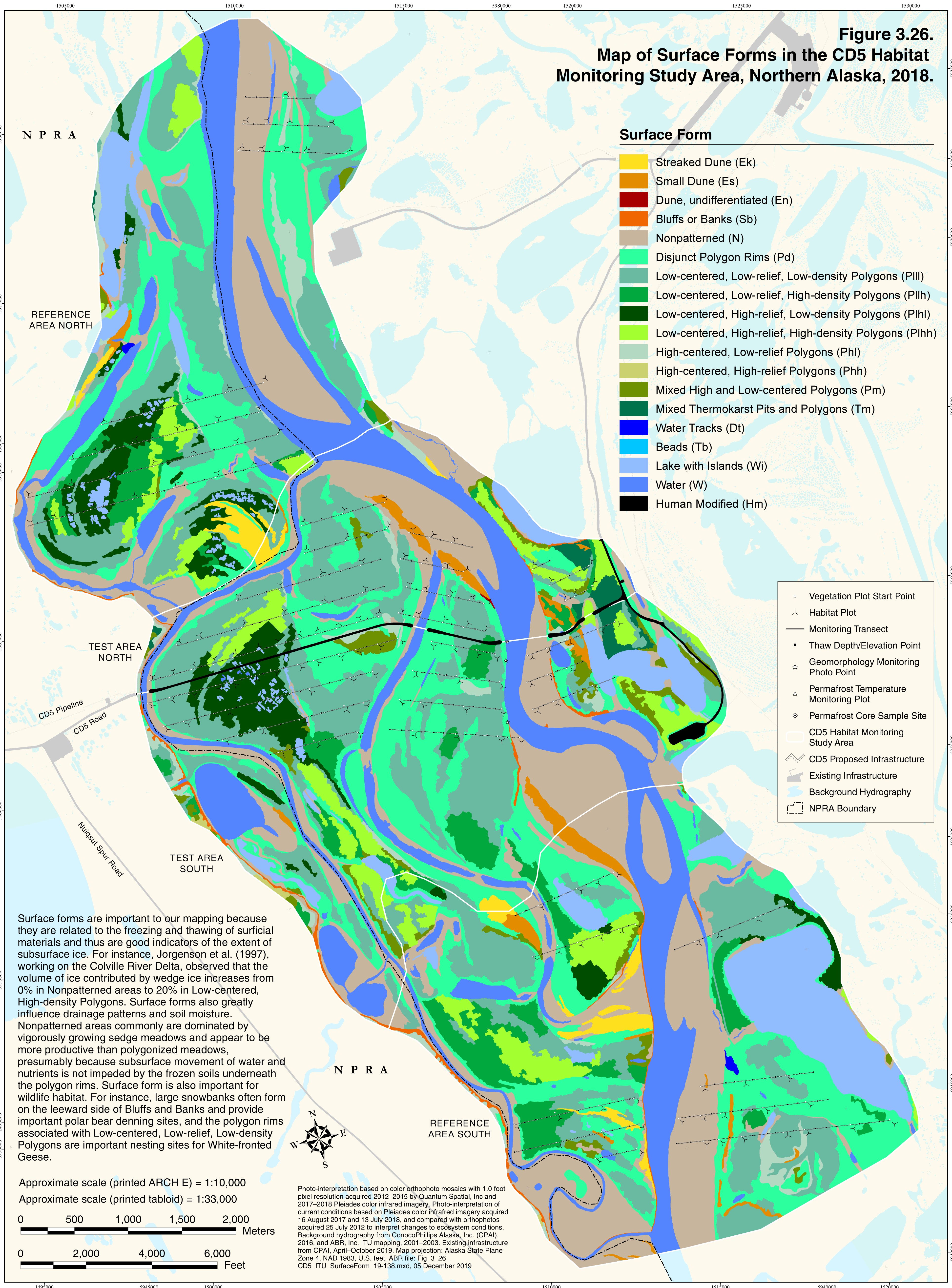
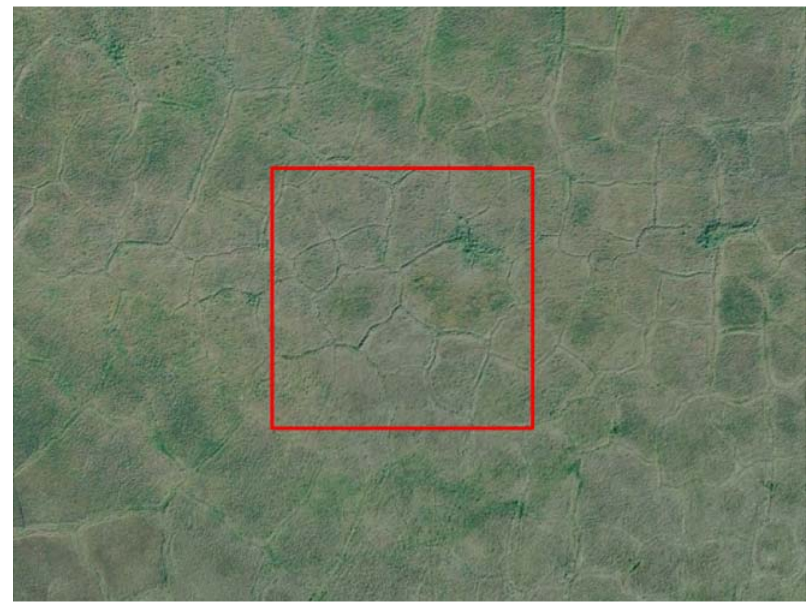


Figure 3.26.
Map of Surface Forms in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.
Surface Form
Streaked Dune (Ek)
Small Dune (Es)
Dune, undifferentiated (En)
Bluffs or Banks (Sb)
Nonpatterned (N)
Disjunct Polygon Rims (Pd)
Low-centered, Low-relief, Low-density Polygons (Plll)
Low-centered, Low-relief, High-density Polygons (Pllh)
Low-centered, High-relief, Low-density Polygons (Plhl)
Low-centered, High-relief, High-density Polygons (Plhh)
High-centered, Low-relief Polygons (Phl)
High-centered, High-relief Polygons (Phh)
Mixed High and Low-centered Polygons (Pm)
Mixed Thermokarst Pits and Polygons (Tm)
Water Tracks (Dt)
Beads (Tb)
Lake with Islands (Wi)
Water (W)
Human Modified (Hm)
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
TEST AREA SOUTH
REFERENCE AREA SOUTH
CD5 Pipeline
CD5 Road
Nuiqsut Spur Road
N P R A
Surface forms are important to our mapping because they are related to the freezing and thawing of surficial materials and thus are good indicators of the extent of subsurface ice. For instance, Jorgenson et al. (1997), working on the Colville River Delta, observed that the volume of ice contributed by wedge ice increases from 0% in Nonpatterned areas to 20% in Low-centered, High-density Polygons. Surface forms also greatly influence drainage patterns and soil moisture. Nonpatterned areas commonly are dominated by vigorously growing sedge meadows and appear to be more productive than polygonized meadows, presumably because subsurface movement of water and nutrients is not impeded by the frozen soils underneath the polygon rims. Surface form is also important for wildlife habitat. For instance, large snowbanks often form on the leeward side of Bluffs and Banks and provide important polar bear denning sites, and the polygon rims associated with Low-centered, Low-relief, Low-density Polygons are important nesting sites for White-fronted Geese.
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 and 2017–2018 Pleiades color infrared imagery. Photo-interpretation of current conditions based on Pleiades color infrafred imagery acquired 16 August 2017 and 13 July 2018, 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, April–October 2019. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_26_ CD5_ITU_SurfaceForm_19-138.mxd, 05 December 2019

Disjunct Polygon Rims (Pd)



High-centered, Low-relief Polygons (Phl)

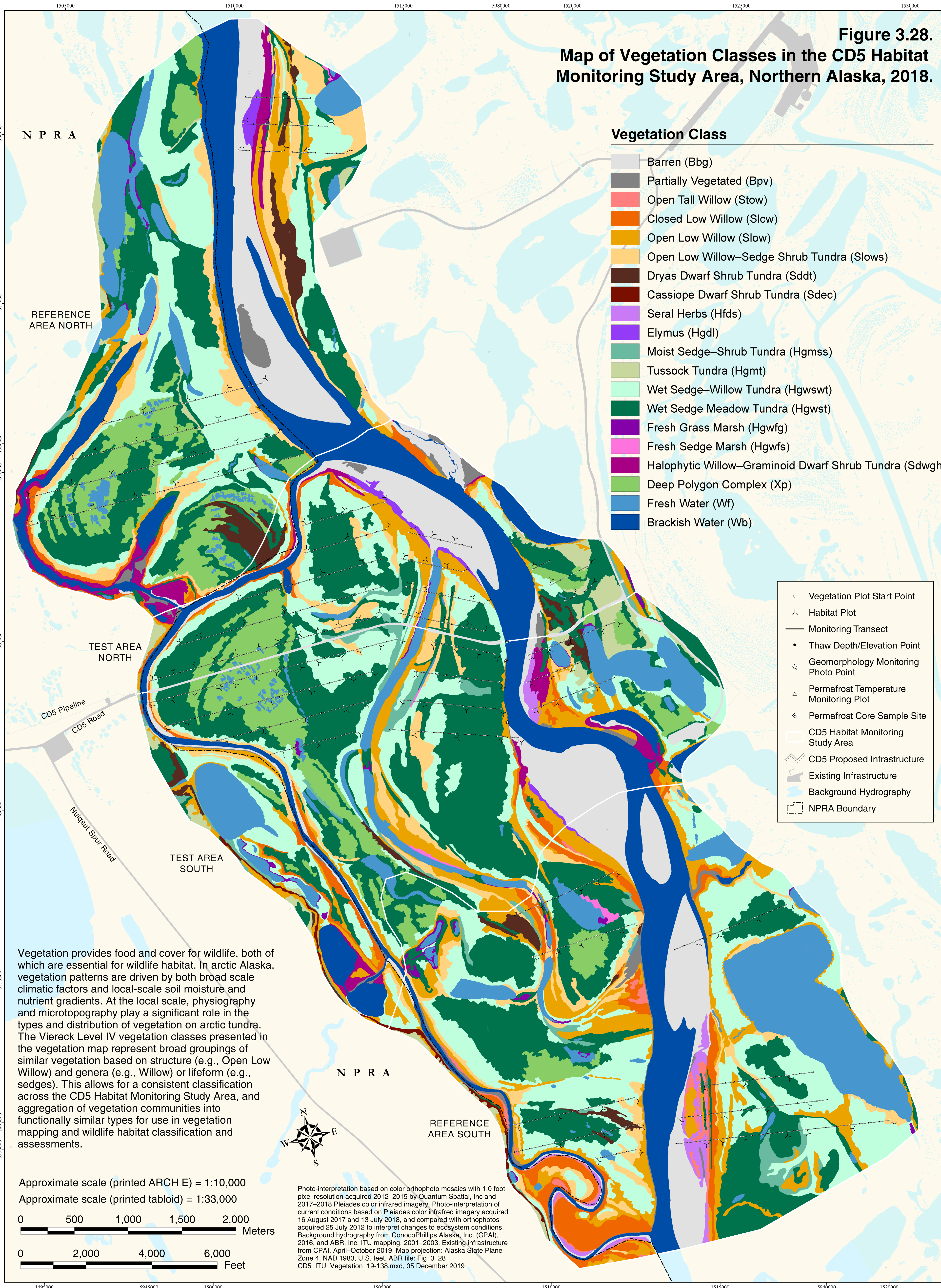
Low-centered, High-relief, High-density Polygons (Plhh)

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 3.27. Examples of common ice-wedge polygon surface forms in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019.



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.

Photo-interpretation based on color orthophoto mosaics with 1.0 foot pixel resolution acquired 2012–2015 by Quantum Spatial, Inc and 2017–2018 Pleiades color infrared imagery. Photo-interpretation of current conditions based on Pleiades color infrafred imagery acquired 16 August 2017 and 13 July 2018, 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, April–October 2019. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_28_ CD5_ITU_Vegetation_19-138.mxd, 05 December 2019

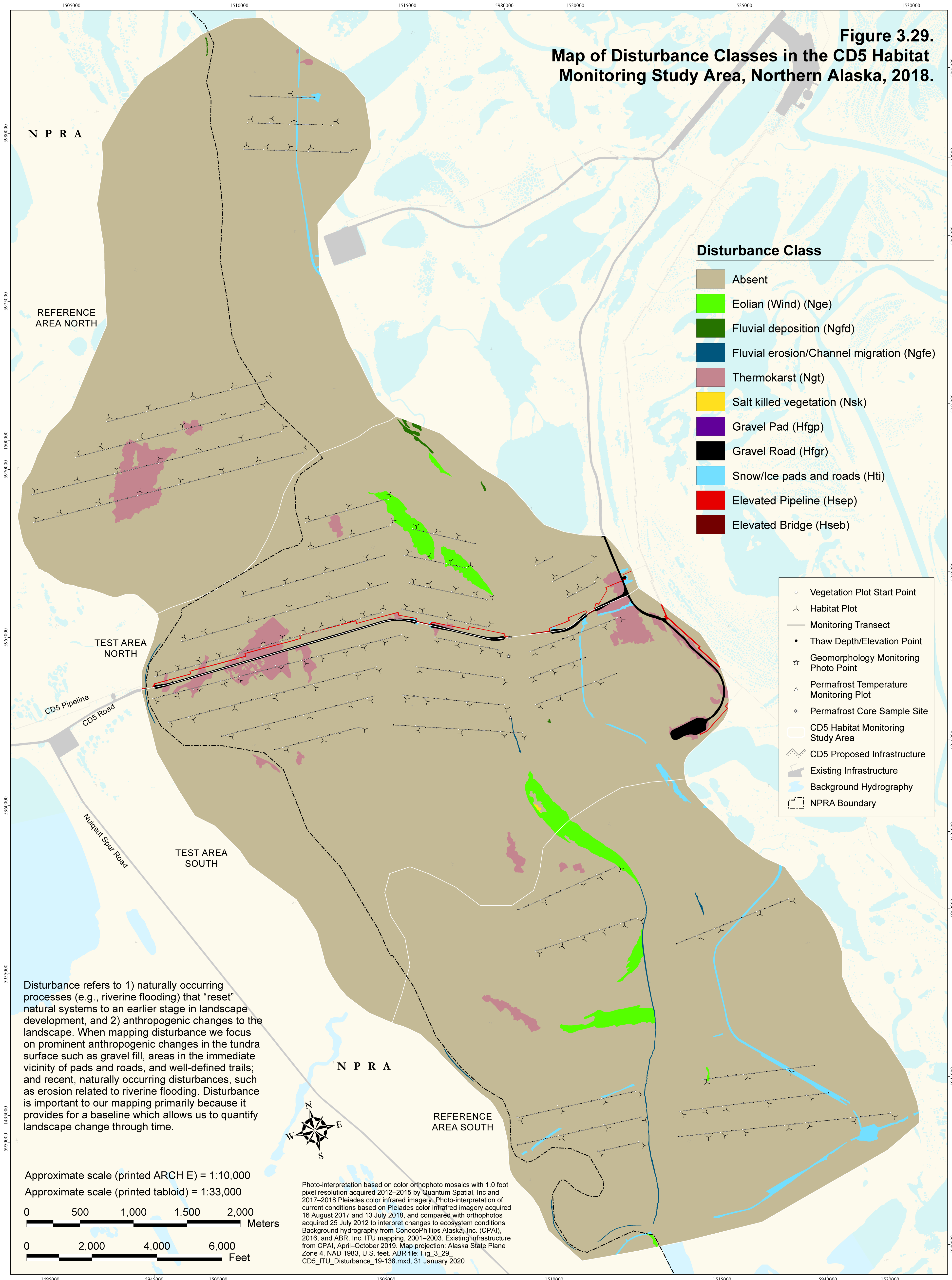


Figure 3.29.
Map of Disturbance Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.
Disturbance Class
Absent
Eolian (Wind) (Nge)
Fluvial deposition (Ngfd)
Fluvial erosion/Channel migration (Ngfe)
Thermokarst (Ngt)
Salt killed vegetation (Nsk)
Gravel Pad (Hfgp)
Gravel Road (Hfgr)
Snow/Ice pads and roads (Hti)
Elevated Pipeline (Hsep)
Elevated Bridge (Hseb)
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
TEST AREA SOUTH
REFERENCE AREA SOUTH
CD5 Pipeline
CD5 Road
Nuiqsut Spur Road
N P R A
Disturbance refers to 1) naturally occurring processes (e.g., riverine flooding) that "reset" natural systems to an earlier stage in landscape development, and 2) anthropogenic changes to the landscape. When mapping disturbance we focus on prominent anthropogenic changes in the tundra surface such as gravel fill, areas in the immediate vicinity of pads and roads, and well-defined trails; and recent, naturally occurring disturbances, such as erosion related to riverine flooding. Disturbance is important to our mapping primarily because it provides for a baseline which allows us to quantify landscape change through time.
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 and 2017–2018 Pleiades color infrared imagery. Photo-interpretation of current conditions based on Pleiades color infrafred imagery acquired 16 August 2017 and 13 July 2018, 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, April–October 2019. Map projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet. ABR file: Fig_3_29_CD5_ITU_Disturbance_19-138.mxd, 31 January 2020

Table 3.16 Areal extent (ha) of surface forms and the percent change in the total area of each class between 2012 and 2018 by Reference and Test area, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Beads	0	0		0	<0.1		0	<0.1	
Bluffs or Banks	13	13.2	1.5	14.6	13.4	-8.2	27.6	26.6	-3.6
Disjunct Polygon Rims	519.6	518.4	-0.2	310.4	310.3	0	830	828.7	-0.2
Dune, undifferentiated	0	0		0.3	0.3	0	0.3	0.3	0
High-centered, High-relief Polygons	0.4	0.4	0	3	3	0	3.4	3.4	0
High-centered, Low-relief Polygons	55.1	54.7	-0.7	33	32.6	-1.2	88.1	87.3	-0.9
Human Modified	0	0		7.9	7.9	0	7.9	7.9	0
Lake with Islands	240.9	241.7	0.3	75	75.6	0.8	315.9	317.3	0.4
Low-centered, High-relief, High-density Polygons	106	105.8	-0.2	84.2	84.1	-0.1	190.2	189.9	-0.2
Low-centered, High-relief, Low-density Polygons	92.5	92.5	0	68.5	68.5	0	161	161	0
Low-centered, Low-relief, High-density Polygons	131.3	131.2	-0.1	60.8	60.8	0	192.1	192	-0.1
Low-centered, Low-relief, Low-density Polygons	459.1	458.5	-0.1	366.4	366.4	0	825.5	824.9	-0.1
Mixed High and Low-centered Polygons	19.6	19.5	-0.5	45.5	45	-1.1	65.1	64.5	-0.9
Mixed Thermokarst Pits and Polygons	0.6	0.6	0	22.3	22.3	0	22.9	22.9	0
Nonpatterned	547.8	547.6	0	306.7	303.5	-1	854.5	851.1	-0.4
Small Dune	24.7	24.7	0	25.9	25.9	0	50.6	50.6	0
Streaked Dune	39.6	39.6	0	9.2	8.8	-4.3	48.8	48.4	-0.8
Water	329.9	331.6	0.5	242.1	247.4	2.2	572	579	1.2
Water Tracks	2	2	0	0	<0.1		2	2	0
Grand Total	2582.2	2582.2	0	1676	1676	0	4258.2	4258.2	0

* The footprint of the CD5 road is not included.

Table 3.17 Areal extent (ha) of vegetation classes and the percent change in the total area of each unit between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Barren	211.5	211.1	-0.2	140.9	139.7	-0.9	352.4	350.8	-0.5
Brackish Water	288.9	290.6	0.6	182.3	189.3	3.8	471.2	479.9	1.8
Cassiope Dwarf Shrub Tundra	5.6	5.6	0	3.3	3.3	0	8.9	8.9	0
Closed Low Willow	83.5	83.5	0	38.5	38	-1.3	122	121.5	-0.4
Deep Polygon Complex	144.5	144.4	-0.1	125.9	125.9	0	270.4	270.3	0
Dryas Dwarf Shrub Tundra	45	45	0	19	19	0	64	64	0
Elymus	3	5.4	80	7.6	7.6	0	10.6	13	22.6
Fresh Grass Marsh	10	10	0	5.2	4.5	-13.5	15.2	14.5	-4.6
Fresh Sedge Marsh	2.6	2.6	0	1.4	1.4	0	4	4	0
Fresh Water	271.9	272.7	0.3	128.6	128	-0.5	400.5	400.7	0
Halophytic Willow-Graminoid Dwarf Shrub Tundra	30.2	30.6	1.3	25.3	23	-9.1	55.5	53.6	-3.4
Moist Sedge-Shrub Tundra	23.4	23.4	0	30.1	29.8	-1	53.5	53.2	-0.6
Open Low Willow	197.6	196.6	-0.5	141.7	137.8	-2.8	339.3	334.4	-1.4
Open Low Willow-Sedge Shrub Tundra	171.3	170.4	-0.5	72.9	72.4	-0.7	244.2	242.8	-0.6
Open Tall Willow	15.5	15.5	0	0	0		15.5	15.5	0
Partially Vegetated	28.5	26.1	-8.4	10.6	13.2	24.5	39.1	39.3	0.5
Seral Herbs	18	18.1	0.6	4.9	4.9	0	22.9	23	0.4
Tussock Tundra	17.4	17.3	-0.6	37.7	37.6	-0.3	55.1	54.9	-0.4
Wet Sedge Meadow Tundra	521.6	521.6	0	442.2	442.7	0.1	963.8	964.3	0.1
Wet Sedge-Willow Tundra	492.4	491.7	-0.1	257.8	257.8	0	750.2	749.5	-0.1
Grand Total	2582.2	2582.2	0	1676	1676	0	4258.2	4258.2	0

* The footprint of the CD5 road is not included.

Table 3.18 Classification and description of disturbance regime categories in the CD5 Habitat Monitoring Study Area, northern Alaska, 2019.

Code	Disturbance	Description
A	Absent (no recent disturbance)	No disturbance within approximately a 5-year period.
Hfd*	Dust	Disturbed vegetation due to fugitive dust from adjacent gravel infrastructure.
Hfgp	Gravel Pad	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.
Hfgr	Gravel Road	Similar to above but the gravel here is placed as fill for roads.
Hs*	Structures and Debris	Anthropogenic debris (e.g. visqueen, buckets, etc.) deposited on the tundra by wind or water.
Hseb	Elevated Bridge	Bridges over distributaries of the Colville River Delta associated with the CD5 Road.
Hsep	Elevated Pipeline	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).
Hti	Snow/Ice pads and roads	Disturbed vegetation due to previous placement of snow (from plowed gravel pads) or ice roads and pads on tundra.
Na*	Animals, Wildlife	Vegetation is disturbed due to wildlife, typically caribou trampling and avian grazing.
Nge	Eolian (Wind)	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.
Ngf*	Fluvial	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.
Ngfd	Fluvial deposition	Fluvial disturbance associated with sediment deposition during and after flood events.
Ngfe	Fluvial erosion/Channel migration	Fluvial disturbance associated with the evolution of distributary channels on the Colville River delta, such as cutbank erosion.
Ngt	Thermokarst	The processes associated with the thawing permafrost that leads to local or widespread collapse, subsidence, erosion and instability of the ground surface.
Nsk	Salt killed vegetation	Coastal areas where saltwater intrusions from storm surges have killed much of the original terrestrial vegetation and where salt-tolerant plants are actively colonizing.

*Class observed in the field but not mapped.

Table 3.19 Areal extent (ha) of disturbance classes and the percent change in the total area of each class between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Absent	2541.1	2501.2	-1.6	1627.3	1578.3	-3.0	4168.4	4079.5	-2.1
Elevated Bridge	0	0		0	<0.1		0	<0.1	
Elevated Pipeline	0	0		1.2	4.1	241.7	1.2	4.1	241.7
Eolian (Wind)	23.3	23.3	0	26.3	26.3	0	49.6	49.6	0
Fluvial deposition	0	0.2		0	1.9		0	2.1	
Fluvial erosion/Channel migration	3.4	3.6	5.9	2.4	0.8	-66.7	5.8	4.4	-24.1
Gravel Pad	0	0		3.9	4.1	5.1	3.9	4.1	5.1
Gravel Road	0	0		4.0	3.9	-2.5	4.0	3.9	-2.5
Salt killed vegetation	<0.1	0		0.4	0.2	-50.0	0.4	0.2	-50.0
Snow/Ice pads and roads	9.2	20.5	122.8	0.6	4.4	633.3	9.8	24.9	154.1
Thermokarst	5.2	33.5	544.2	9.9	52.0	425.3	15.1	85.5	466.2
Grand Total	2582.2	2582.2	0	1676.0	1676.0	0	4258.2	4258.2	0

* The footprint of the CD5 road is not included.

2015 map (Table 3.19). This code is applied to a portion of the CD5 road permitted gravel fill, and the small amount (<0.1 ha) in the 2015 map is likely a result of geoprocessing anomaly, where a small sliver of this unit was not excluded from the analysis during a clip in ArcGIS. The disturbance class Gravel Road shows a 2.5% decrease (0.1 ha) throughout the study area, restricted to the Test Area. This is related to improvements along the CD4 road, where a portion of gravel fill was recoded from Gravel Road in 2012 to Gravel Pad in 2015. The vast majority of the CD5 Study Area has not undergone natural or anthropogenic disturbance since 2012; the areal extent of undisturbed ground is nearly 96% of the study area. Thermokarst, which refers to the subsidence of ice-rich ground after thawing, is the most common natural disturbance type (2% areal cover). The second most extensive disturbance class is Eolian (Wind) at 1.2%; this natural disturbance class was applied to active dunes as a revision to the map. Fluvial Deposition and Fluvial Erosion/Channel Migration are locally common disturbance classes adjacent to the Niġliq Channel (<0.2% combined coverage). Snow/Ice Pads and Roads was the most widespread anthropogenic disturbance class (0.6%).

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-nine Ecotypes are represented in the updated mapping for the CD5 Study Area (Table 3.20); this 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 3.30). Riverine Wet Sedge Meadow and Riverine Wet Sedge-Willow Meadow remain the dominant Ecotypes, with 19.4% and 17.1% areal cover, respectively (Table 3.20). Other common Map Ecotypes include Tidal River (9.9% areal cover), Coastal Barrens (8.8%), Riverine Moist Low Willow Shrub (7.9%), Riverine Lake (7.2%), and Riverine Moist Low Willow-Sedge Meadow (5.7%). All other Map Ecotypes account for less than 5% of the CD5 Study Area each.

Wildlife Habitat

Twenty-four wildlife habitat classes are represented in the updated mapping for the CD5 Study Area (Figure 3.31, Table 3.21). For detailed descriptions of the habitat, see Wells et al. (2014). As in the baseline mapping, the most extensive habitat types is Patterned Wet Meadow, with an areal cover of 26%. Other widespread terrestrial habitat classes remain include Moist Low Shrub (16.3% areal cover), Nonpatterned Wet Meadow (13.8%), Barrens (9.0%), and Deep Polygon Complex (6.3%). The aquatic habitat classes River or Stream (9.9%) and Deep Open Water with Islands or Polygonized Margins (6.7%) are also common. All other wildlife habitat classes had less than 2% areal cover each.

3.4.2.D Landscape Change Assessment

We evaluated natural and anthropogenic landscape change across the CD5 Study Area between 2012 and 2018 by updating the baseline ITU mapping using imagery acquired in July 2018. 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 3.32). Overall, only 2.6% (110.7 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 3.22).

Natural fluvial erosion and sedimentation along the Niġliq Channel accounted for many of the observed changes (Figure 3.33). Erosion was most apparent along sections of the Niġliq Channel where cutbank erosion claimed several meters of riverbank between 2012 and 2015, most likely in association with the very large spring breakup floods that occurred in 2013 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 (i.e., initiated since 2012) thermokarst associated with the surface forms Low-centered, High-relief, High-density Polygons and Low-centered, High-relief, Low-density Polygons on the geomorphic unit Delta Abandoned Overbank Deposits in the Test Areas adjacent to the CD5

Table 3.20 Areal extent (ha) of map ecotypes and the percent change in the total area of each ecotype between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Coastal Barrens	236.6	233.6	-1.3	143.7	143.2	-0.3	380.3	376.8	-0.9
Coastal Dry Elymus Meadow	3	5.4	80	7.6	7.6	0	10.6	13	22.6
Coastal Lake	9.8	9.8	0	44.9	47.2	5.1	54.7	57	4.2
Coastal Moist Willow Dwarf Shrub	30.2	30.6	1.3	25.3	23	-9.1	55.5	53.6	-3.4
Human Modified Barrens	0	0		7.9	8.5	7.6	7.9	8.5	7.6
Human Modified Dwarf Scrub	0.2	0.2	0	0	0.3		0.2	0.5	150
Human Modified Low Shrub	1.8	2.8	55.6	0.6	1.7	183.3	2.4	4.5	87.5
Human Modified Marsh	0	0		0	<0.1		0	<0.1	
Human Modified Moist Meadow	0	0		<0.1	1.1		<0.1	1.1	
Human Modified Waterbody	0	0		0	0.2		0	0.2	
Human Modified Wet Meadow	7.2	15.5	115.3	1.2	4.1	241.7	8.4	19.6	133.3
Lacustrine Grass Marsh	2.9	2.9	0	0.5	0.5	0	3.4	3.4	0
Lowland Deep-polygon Complex	105.7	105.5	-0.2	66.5	66.1	-0.6	172.2	171.6	-0.3
Lowland Lake	79.7	79.9	0.3	13.7	13.7	0	93.4	93.6	0.2
Lowland Moist Low Willow Shrub	6.1	6	-1.6	10.6	10.6	0	16.7	16.6	-0.6
Lowland Moist Sedge-Shrub Meadow	19.3	19.3	0	11.6	11.3	-2.6	30.9	30.6	-1
Lowland Sedge Marsh	2.2	2.2	0	0	0		2.2	2.2	0
Lowland Wet Sedge Meadow	83.4	82.9	-0.6	49	48.8	-0.4	132.4	131.7	-0.5
Lowland Wet Sedge-Willow Meadow	5.7	5.7	0	6.5	6.5	0	12.2	12.2	0
Riverine Deep-polygon Complex	38.8	38.8	0	59.4	59.1	-0.5	98.2	97.9	-0.3
Riverine Dry Dryas Dwarf Shrub	18.8	18.8	0	2.8	2.8	0	21.6	21.6	0

Table 3.20 Continued.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Riverine Grass Marsh	7.1	7.1	0	4.7	4	-14.9	11.8	11.1	-5.9
Riverine Lake	192.2	192.9	0.4	114.9	114.3	-0.5	307.1	307.2	0
Riverine Moist Barrens	0	0.3		0	1.2		0	1.5	
Riverine Moist Herb Meadow	18	18.1	0.6	4.9	4.9	0	22.9	23	0.4
Riverine Moist Low Willow-Sedge Meadow	169.9	169	-0.5	72.9	72.1	-1.1	242.8	241.1	-0.7
Riverine Moist Low Willow Shrub	212.8	210.9	-0.9	131.1	126.2	-3.7	343.9	337.1	-2
Riverine Moist Sedge-Shrub Meadow	4.2	4.2	0	18.5	18.1	-2.2	22.7	22.3	-1.8
Riverine Moist Tall Willow Shrub	14.9	14.9	0	0	0		14.9	14.9	0
Riverine Sedge Marsh	0.3	0.3	0	1.4	1.4	0	1.7	1.7	0
Riverine Wet Sedge Meadow	435.9	433.6	-0.5	392.1	391.2	-0.2	828	824.8	-0.4
Riverine Wet Sedge-Willow Meadow	481.7	475.6	-1.3	251.2	250.5	-0.3	732.9	726.1	-0.9
Tidal River	279.1	280.8	0.6	137.4	142.1	3.4	416.5	422.9	1.5
Upland Dry Barrens	3.4	3.4	0	0	0		3.4	3.4	0
Upland Dry Dryas Dwarf Shrub	26	26	0	16.2	15.9	-1.9	42.2	41.9	-0.7
Upland Dry Tall Willow Shrub	0.5	0.5	0	0	0		0.5	0.5	0
Upland Moist Cassiope Dwarf Shrub	5.6	5.6	0	3.3	3.3	0	8.9	8.9	0
Upland Moist Low Willow Shrub	61.9	61.8	-0.2	37.9	37.6	-0.8	99.8	99.4	-0.4
Upland Moist Tussock Meadow	17.4	17.3	-0.6	37.7	36.9	-2.1	55.1	54.2	-1.6
Grand Total	2582.2	2582.2	0	1676	1676	0	4258.2	4258.2	0

* The footprint of the CD5 road is not included.

Table 3.21 Areal extent (ha) of wildlife habitats and the percent change in the total area of each habitat between 2012 and 2018 by Reference and Test Area, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Barrens	240	237.2	-1.2	143.7	144.4	0.5	383.7	381.6	-0.5
Deep Open Water with Islands or Polygonized Margins	232.9	233.7	0.3	53.6	53	-1.1	286.5	286.7	0.1
Deep Open Water without Islands	20.4	20.4	0	52.1	52.1	0	72.5	72.5	0
Deep Polygon Complex	144.5	144.4	-0.1	125.8	125.2	-0.5	270.3	269.6	-0.3
Dry Dwarf Shrub	44.8	44.8	0	19	18.7	-1.6	63.8	63.5	-0.5
Dry Halophytic Meadow	3	5.4	80	7.6	7.6	0	10.6	13	22.6
Dry Tall Shrub	0.5	0.5	0	0	0		0.5	0.5	0
Grass Marsh	10	10	0	5.2	4.5	-13.5	15.2	14.5	-4.6
Human Modified	9.2	18.4	100	9.7	15.9	63.9	18.9	34.3	81.5
Moist Dwarf Shrub	5.6	5.6	0	3.3	3.3	0	8.9	8.9	0
Moist Halophytic Dwarf Shrub	30.2	30.6	1.3	25.3	23	-9.1	55.5	53.6	-3.4
Moist Herb Meadow	18	18.1	0.6	4.9	4.9	0	22.9	23	0.4
Moist Low Shrub	450.6	447.7	-0.6	252.5	246.5	-2.4	703.1	694.2	-1.3
Moist Sedge-Shrub Meadow	23.4	23.4	0	30.1	29.4	-2.3	53.5	52.8	-1.3
Moist Tall Shrub	14.9	14.9	0	0	0		14.9	14.9	0
Moist Tussock Tundra	17.4	17.3	-0.6	37.7	36.9	-2.1	55.1	54.2	-1.6
Nonpatterned Wet Meadow	374.9	369.4	-1.5	219.8	219.2	-0.3	594.7	588.6	-1
Patterned Wet Meadow	631.9	628.5	-0.5	479.1	477.8	-0.3	1111	1106.3	-0.4
River or Stream	279.1	280.8	0.6	137.4	142.1	3.4	416.5	422.9	1.5
Sedge Marsh	2.6	2.6	0	1.4	1.4	0	4	4	0
Shallow Open Water with Islands or Polygonized Margins	1.9	1.9	0	5.3	5.3	0	7.2	7.2	0

Table 3.21 Continued.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test* 2012	Test* 2018	Test* Delta (%)	Total* 2012	Total* 2018	Total* Delta (%)
Shallow Open Water without Islands	3.2	3.2	0	1.7	1.7	0	4.9	4.9	0
Tapped Lake with High-water Connection	13.5	13.5	0	15.8	15.8	0	29.3	29.3	0
Tapped Lake with Low-water Connection	9.8	9.8	0	44.9	47.2	5.1	54.7	57	4.2
Grand Total	2582.2	2582.2	0	1676	1676	0	4258.2	4258.2	0

* The footprint of the CD5 road is not included.

Table 3.22 Areal extent of landscape change mechanisms that affected Reference and Test Areas between 2015 and 2018, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2018	Reference % of total	Test* 2018	Test* % of total	Total* 2018	Total* % of total
Absent	2532.2	98.1	1615.3	96.4	4147.5	97.4
Anthropogenic-Ice Road Or Pad	11.3	0.4	2.1	0.1	13.4	0.3
Fluvial Erosion	1.1	0	2.8	0.2	3.9	0.1
Fluvial Sedimentation	0	0	0.8	0	0.8	0
Other	0	0	1.8	0.1	1.8	0
Succession	8.2	0.3	10.9	0.7	19.1	0.4
Thermokarst (Ngt)	29.3	1.1	42.3	2.5	71.6	1.7
Grand Total	2582.2	100	1676.0	100	4258.2	100

* The footprint of the CD5 road is not included.

road and in portions of the Reference Area (Figure 3.34). This combination of geomorphic unit and surface form represents some of the oldest and most ice-rich, and thus most sensitive to thermokarst, areas of the Colville River delta (Jorgenson et al. 1997b). The thermokarst in these areas was largely related to ice-wedge degradation and expressed in the imagery and on the ground as a widening and flooding of low-center polygon troughs, and as thaw pits at the intersection of ice-wedges. Thermokarst was also mapped in small (<0.8 ha), isolated areas along the CD4 road south of the CD4/CD5 road intersection. Ice-wedge degradation is among the most common secondary impacts of road construction in ice-rich permafrost on the North Slope (Raynolds et al. 2014). However, the occurrence of ice-wedge degradation in both the Test and Reference Areas in the 2018 mapping, and at approximately the same percent increase in area (Table 3.19), suggests that the onset of thermokarst since 2012 is not entirely attributable to the CD5 road. An important contributing factor is likely to include the finding that annual mean Arctic air temperatures have exceeded all previous records for the past 6 years (2014–2019) (Overland et al. 2019). Additionally, a long-term, regional trend in ice-wedge degradation has been detected across the Alaskan Arctic (Frost et al. 2018), thus the thermokarst detected in the CD5 study area is also likely part of this broader trend. Lastly, precipitation for that portion of the 2012 water year between 1 Oct. 2011 and 15 July 2012 was slightly less than the 1980–2010 climate normals, while the 2018 water year between 1 Oct. 2017 and 15 July 2018 was ~50% above normal. The wetter climatic conditions in 2018 relative to 2012 may be a confounding factor in some cases in the interpretation of thermokarst based on the observation of wider, more flooded troughs in the 2018 imagery. This is because the appearance of flooded troughs may simply be the result of the greater precipitation in 2018. However, if this were the case then ice-wedge polygon troughs across much of the CD5 study area would appear wetter in the 2018, which they do not (Figure 3.34). The areas mapped as thermokarst disturbance in 2019 will be reassessed in 2024 to determine if they have stabilized or if the thermokarst has continued to expand.. Succession was evident in areas where vegetation had colonized recent Delta Active Channel Deposits, and in places where vegetation recovered within the footprint of Snow/Ice Pads and Roads.

Human activities, including construction of CD5 infrastructure and winter ice roads, created

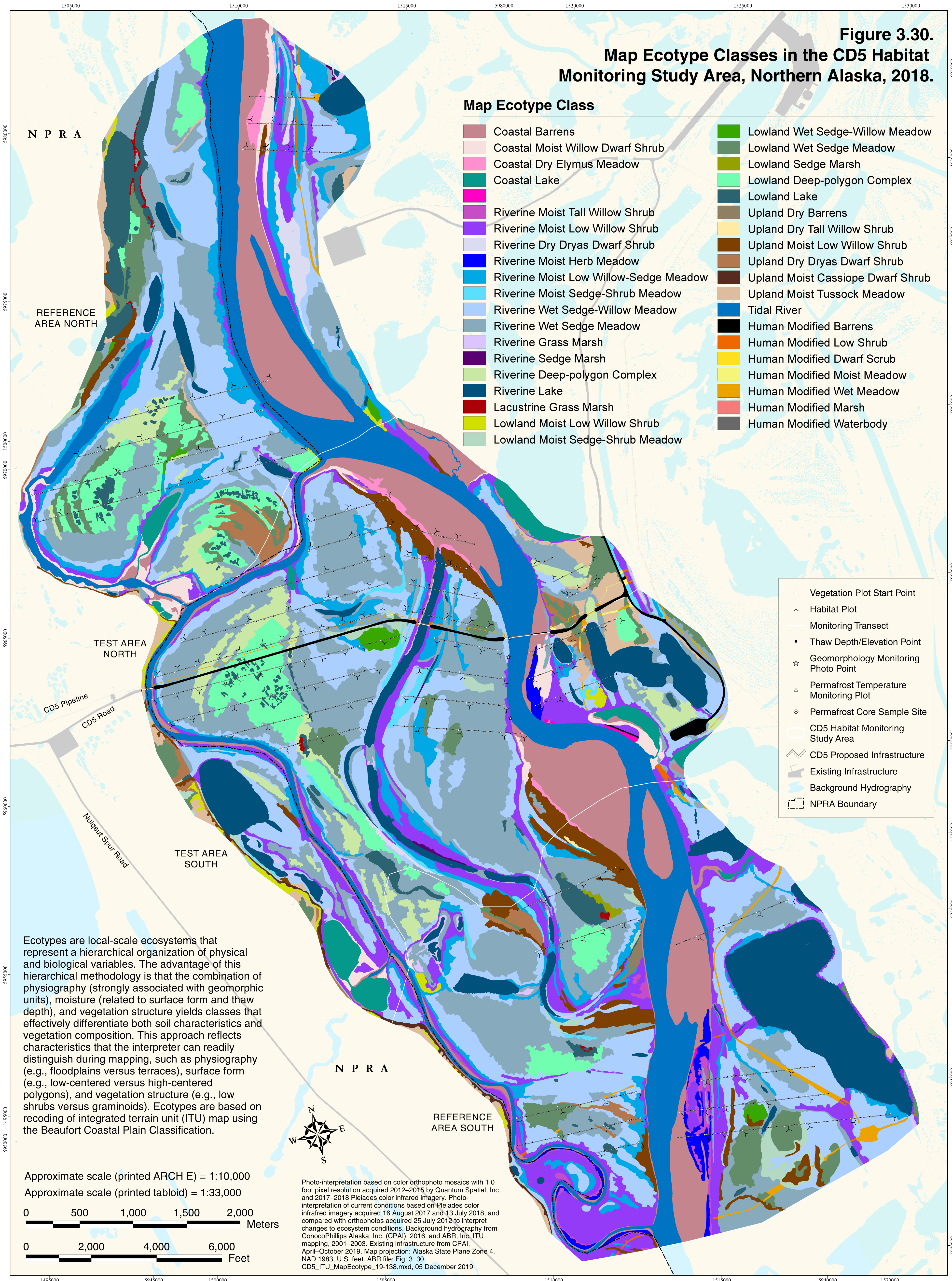


Figure 3.30. Map Ecotype Classes in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.

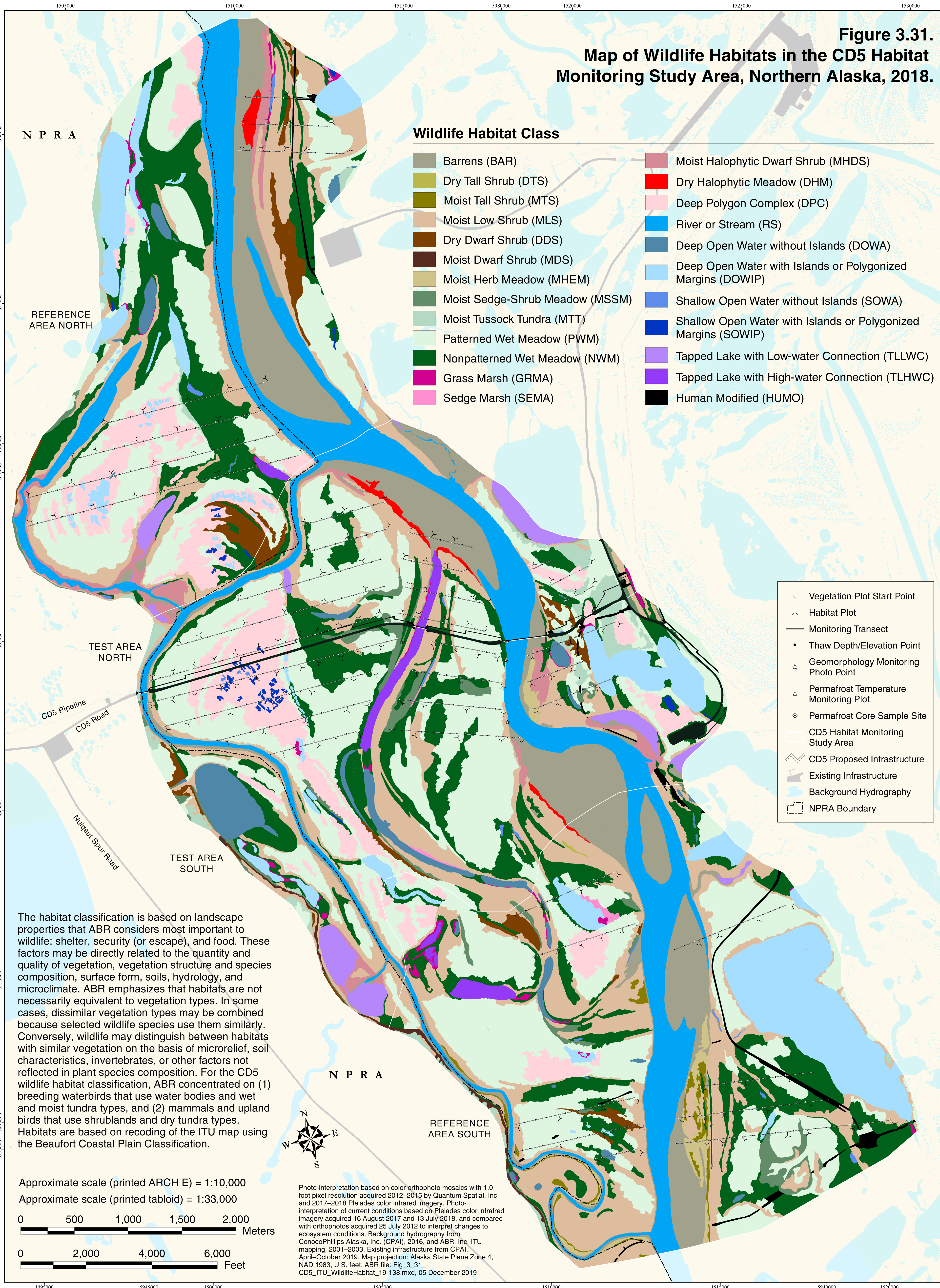


Figure 3.31. Map of Wildlife Habitats in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2018.

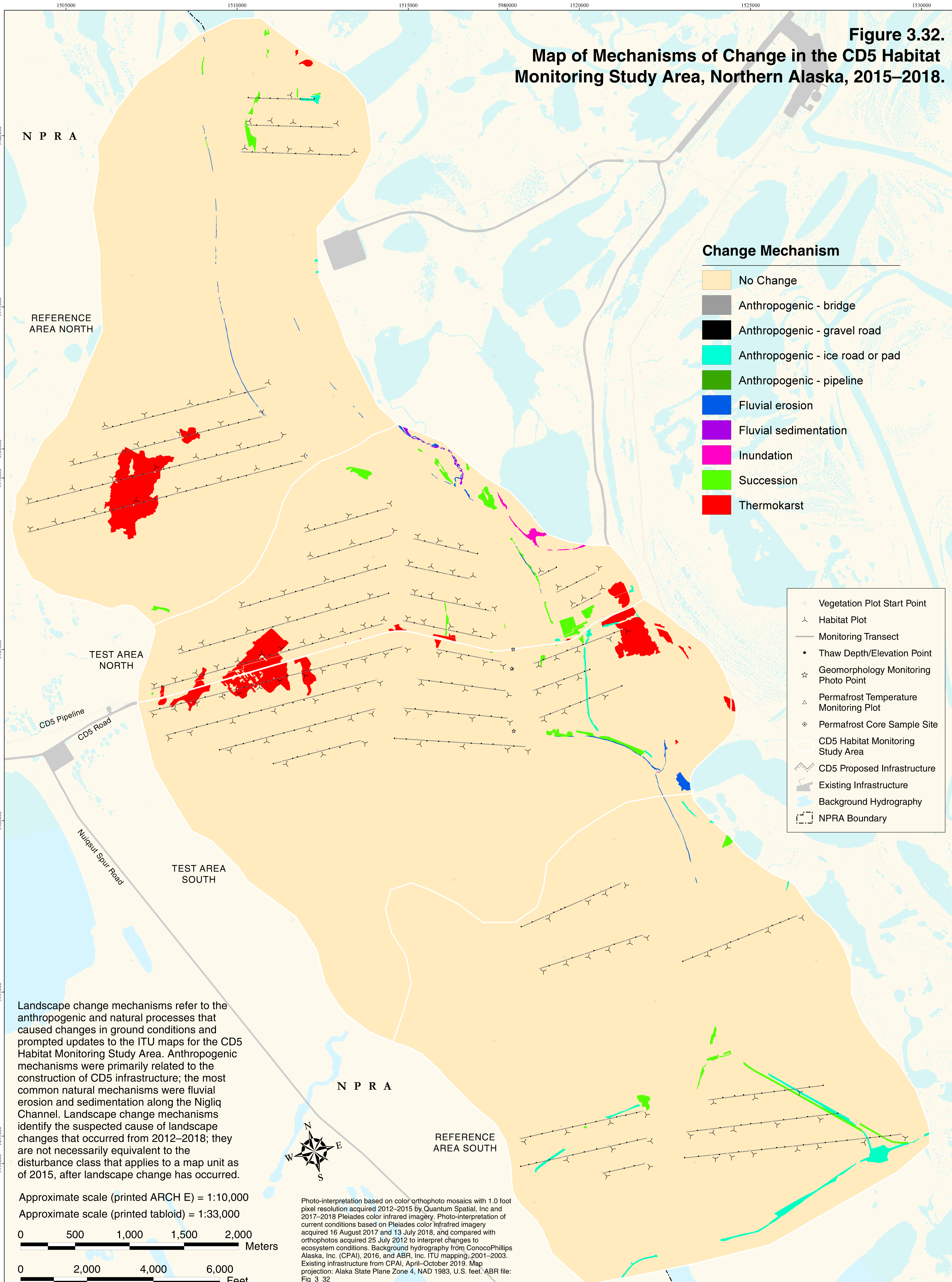


Figure 3.32. Map of Mechanisms of Change in the CD5 Habitat Monitoring Study Area, Northern Alaska, 2015–2018.

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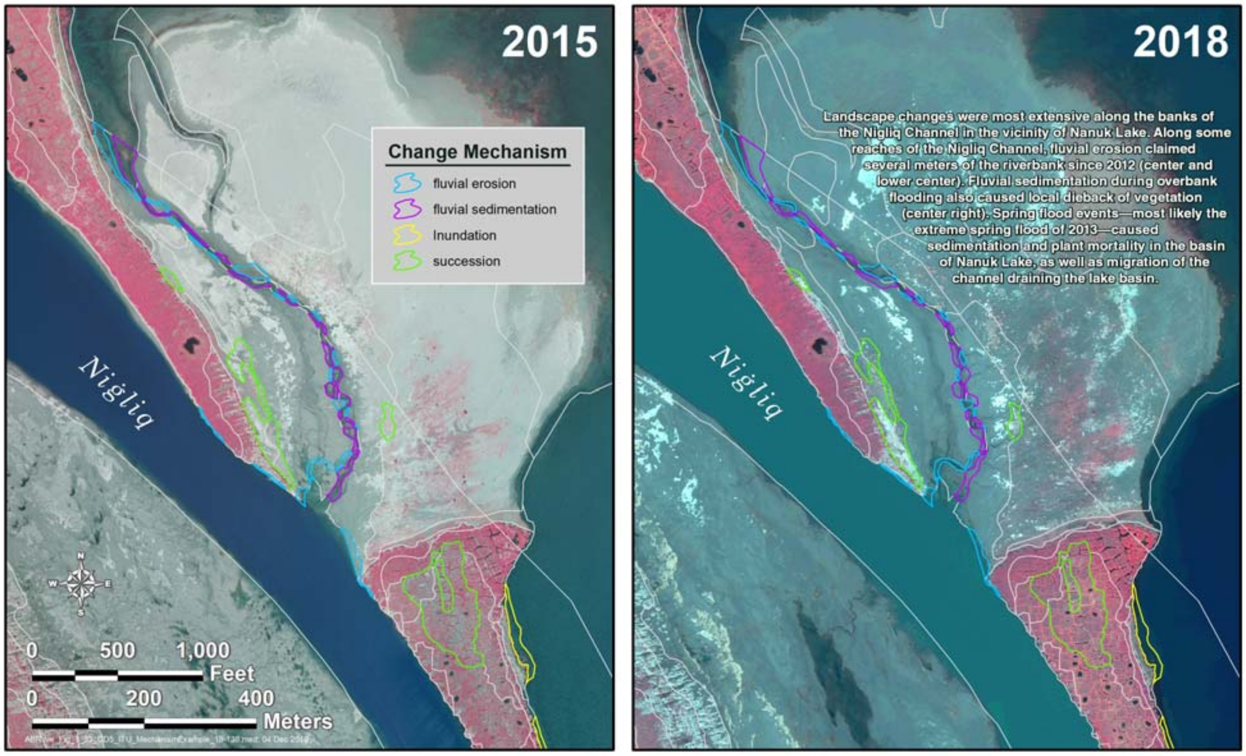

Figure 3.33 Example of landscape change resulting from fluvial processes along Niġliq Channel near Nanuk Lake, CD5 Habitat Monitoring Study Area, northern Alaska, 2015 and 2018.

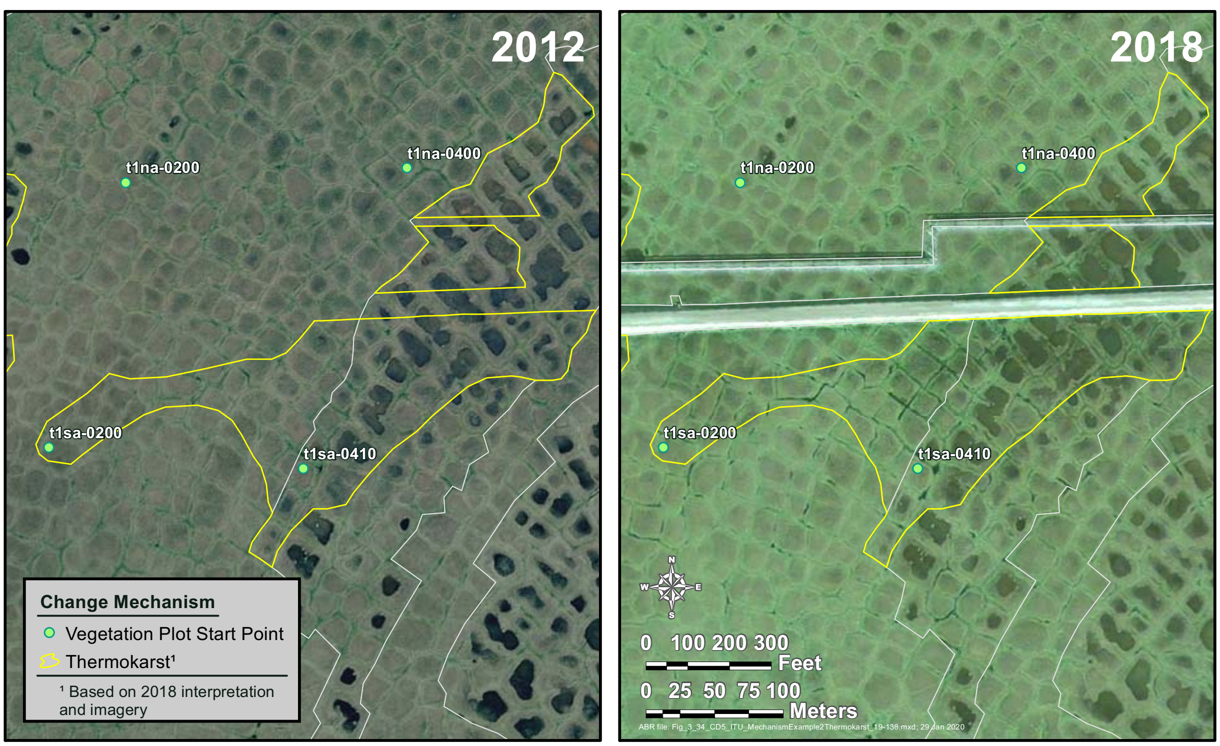

Figure 3.34 Example of landscape change resulting from thermokarst near the CD5 Road, CD5 Habitat Monitoring Study Area, northern Alaska, 2012 and 2018.

linear changes in both the Reference and Test Areas. 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. Construction of elevated structures (e.g., 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 2018, and no class changed in extent by more than 5%. On a percent basis, the largest change in terrestrial geomorphic units across the CD5 Study Area was a 2.0% decrease in the extent of Ice-poor Delta Thaw Basin (from 25.2 to 24.7 ha) (Table 3.14), which is coincident with the most substantial change to aquatic geomorphic units, a 4.2% increase in the extent of Connected Brackish Deep Tapped Lake (from 54.7 to 57.0 ha) (Table 3.15). All of this change occurred along the southwestern shore of Nanuk Lake in the South Test Area. While tapped lakes are dynamic systems, the southwestern shore of Nanuk Lake was consistently inundated in 2015, 2017, and 2018 imagery with visible aquatic vegetation (possibly *Sparganium* sp.); the presence of aquatic vegetation suggests that this inundation is not ephemeral. The second largest change in terrestrial geomorphic units across the CD5 Study Area was a 1.3% increase in the extent of Gravel Fill (from 7.9 to 8.0 ha) (Table 3.14). All of this change occurred within the Test Area and is associated with new permitted pullouts along the CD4 road; Gravel Fill associated with the CD5 road is being assessed separately for monitoring purposes (see below). Among aquatic geomorphic units, the second most extensive change observed across the CD5 Study Area was a 1.6% increase in the extent of Tidal River (Table 3.15). 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. No terrestrial or aquatic geomorphic units changed in area by more than 1% within the Reference Area.

Surface Forms

Similar to geomorphic unit, changes to surface forms were rare between 2012 and 2018 and no class changed in extent by more than 5% across the CD5 Study Area (Table 3.16). However, compensatory increases and decreases in the extent of one surface form—Bluffs or Banks—occurred within the Reference and Test Areas, respectively. The extent of Bluffs or Banks decreased by 8.2% in the Test Area (from 14.6 to 13.4 ha), but increased 1.5% in the Reference Area (from 13.0 to 13.2 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 across the entire CD5 Study Area was a 1.2% increase in Water, resulting from river channel migration and thermokarst along lakeshores and inundation of the southwestern shores of Nanuk Lake.

Vegetation

Changes in vegetation class were more prevalent than changes in geomorphic unit and surface form in the CD5 Study Area (Table 3.17). Across the CD5 Study Area, we observed areal changes exceeding 5% for one vegetation class—Elymus (+22.6%). 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. The only other change in the Reference Area exceeding 5% was an 8.4% decrease in Partially Vegetated, which was replaced by Elymus as described above. Within the Test Area, we observed changes in excess of 5% for three vegetation classes: Fresh Grass Marsh (-13.5%, from 5.2 to 4.5 ha), Halophytic Willow-Graminoid Dwarf

Shrub Tundra (-9.1%, from 25.3 to 23.0 ha) and Partially Vegetated (+24.5%, from 10.6 to 13.2 ha). Neither Fresh Grass Marsh nor Halophytic Willow-Graminoid Dwarf Shrub Tundra are common in the CD5 Study Area (<2.0% areal cover combined). The decrease in Fresh Grass Marsh occurred at a single location, along the margin of a tapped lake immediately south of the CD4 pad. The outlet of this tapped lake appears to have been enlarged by fluvial erosion outside of the CD5 Study Area, leading to lower water levels and a loss of Fresh Grass Marsh. The changes in Halophytic Willow-Graminoid Dwarf Shrub Tundra 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 slightly more than 3% 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 241.7% (from 1.2 to 4.1 ha), Thermokarst increased 285.4% (from 15.1 to 58.2 ha), Snow/Ice Pads and Roads increased 154% (from 9.8 to 24.9 ha), and Gravel Pad increased 5.1% (from 3.9 to 4.1 ha) (Table 3.19). The increase in Elevated Pipeline was entirely within the Test Area due to the construction of the CD5 pipeline. Increased thermokarst was observed in the Test Area (425.3%; from 9.9 to 52.0 ha), predominantly adjacent to the CD5 road, and in Reference Area North (544.2%; from 5.2 to 33.5 ha), where increased surface water in thermokarst pits and polygonal troughs was visible in aerial imagery, and where field observations in 2019 documented thermokarst pits and evidence of subsidence including submerged willow and dead or dying submerged tussocks. Increases in the extent of the Snow/Ice Pads and Roads disturbance class were documented in both Test Areas, adjacent to CD5 infrastructure (+633%; from 0.6 to 4.4 ha) and Reference Areas (+123%; from 9.2 to 20.5 ha). Areas where the footprint of an ice road or pad was no longer visible in the aerial imagery presumably due to a recovery of vegetation, litter, and standing dead vegetation, were removed from the disturbance class Snow/Ice Pads and Roads. The increase in Gravel Pad occurred within the Test Area and is associated with pullouts along the CD4 road; Gravel Fill associated with the CD5 road is being assessed separately for monitoring purposes. The anthropogenic disturbance classes Elevated Pipeline and Snow/Ice Pads and Roads generally resulted in partial mortality and/or delayed green-up of vegetation, rather than transitions from one vegetation class to another, while Thermokarst typically involves an increase in surface water and may be associated with a change from one vegetation class to another.

Changes in the extent of natural disturbance classes included a 50% decrease in the rare class Salt-killed Vegetation (from 0.4 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 (4.4 ha in the updated map); its overall extent declined 24.1% across the CD5 Study Area. Most of the decline occurred in the Test Area (-66.7%; from 2.4 to 0.8 ha) but this was partially offset by an increase in extent in the Reference Area (+5.9%; from 3.4 to 3.6 ha).

Map Ecotypes

Of the 39 Ecotypes mapped across the CD5 Study Area, 6 underwent changes in extent that exceeded +/-5%: Coastal Dry Elymus Meadow (+22.6%), Human Modified Barrens (+7.6%), Human Modified Dwarf Scrub (+150%), Human Modified Low Shrub (+87.5%), Human Modified Wet Meadow (+133%), and Riverine Grass Marsh (-5.9%) (Table 3.20). 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 above for the Elymus vegetation class.

The increase in Human Modified Barrens occurred entirely in the Test Area and was related to road improvements along the CD4 road and within the footprint of an ice road near the CD4 Pad. Human Modified Dwarf Scrub, Human Modified Low Shrub, and Human Modified Wet Meadow are rare classes (0.5 ha, 4.5 ha, and 19.6 ha respectively, in 2018 mapping) and the large percent increases in the areal extent of these Ecotypes pertained to localized changes associated with bridge and pipeline construction, and Snow/Ice Pads and Roads 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 22.6% (10.6 to 13 ha) and Human Modified increased 81.5% (18.9 to 34.3 ha) (Table 3.21). 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, as described for the Elymus vegetation class above. Human Modified increased in both the Reference Area (100% increase, from 9.2 to 18.4 ha) and the Test Area (64% increase, from 9.7 to 15.9 ha) and was associated with Snow/Ice Pads and Roads and linear sections of tundra that lie beneath the CD5 pipeline and bridges. Within the Test Area, Grass Marsh decreased by 13.5% (from 5.2 to 4.5 ha) due to lower water levels in a tapped lake, as described above for the Fresh Grass Marsh vegetation type. Moist Halophytic Dwarf Scrub decreased in extent by 9.1% (from 25.3 to 23.0 ha) due to fluvial sedimentation near the Niġliq Channel bridge (see Vegetation section, above). Tapped Lake with Low-water Connection increased 5.1% (from 44.9 to 47.2 ha), as described above for the geomorphic unit Connected Brackish Deep Tapped Lake. Human Modified increased 63.9% (from 9.7 to 15.8 ha) in the Test Area due to the construction of CD5 infrastructure and Snow/Ice Pads and Roads in previously undisturbed wildlife habitats.

CD5 Infrastructure

The CD5 infrastructure was not present when the baseline 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 reflected in 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 evident in both the Reference and Test Areas in association with ice roads and ice pads. The total extent of anthropogenic disturbance classes, including the CD5 road, is presented in Table 3.23.

Assessment of CD5 Infrastructure Indirect Effects

This report summarizes results from the second monitoring effort following baseline studies conducted in 2019 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 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

Table 3.23 Areal extent (ha) of anthropogenic disturbance classes in 2012 and 2018 including the CD5 road for Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska.

Title	Reference 2012	Reference 2018	Reference Delta (%)	Test 2012	Test 2018	Test Delta (%)	Total 2012	Total 2018	Total Delta (%)
Elevated Bridge	0	0		0	0.4		0	0.4	
Elevated Pipeline	0	0		1.2	4.1	241.7	1.2	4.1	241.7
Gravel Pad	0	0		3.9	4.1	5.1	3.9	4.1	5.1
Gravel Road	0	0		4.0	13.0	225.0	4.0	13.0	225.0
Snow/Ice pads and roads	9.2	20.5	122.8	0.6	4.4	633.3	9.8	24.9	154.1
Grand Total	9.2	20.5	122.8	9.8	26.0	165.3	19.0	46.5	144.7

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. Three natural disturbance classes changed in extent by >5%: Salt-killed Vegetation, Fluvial Erosion/Channel Migration, and Thermokarst. 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, 2015, or 2018 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. Thermokarst changed in extent by >5%, but the changes were consistent in magnitude between the Test and Reference Areas. In both Areas thermokarst was expressed by degrading ice wedged resulting in a widening and flooding of ice-wedge polygon troughs and the development of flooded pits at the intersection of ice wedges. Additionally, while the absolute area of thermokarst in the Test Area exceeds that of the Reference Area by 18.5 ha (<1% of the total study area), the percent change in the area of thermokarst between 2012 and 2018 was greater in the Reference Area (544.2%) than in the Test Area (425.3%). There were also changes to six 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 second 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 2013 and 2019 ground surface elevation are presented in Appendix I-1, and thaw depth are presented in Appendix I-2. Cross sections of ground surface elevation and thaw depth along the monitoring transects in the Test and Reference Areas are presented in Appendices J and K, respectively. Differences between years within the Reference Area reflect natural variation but can be used to better understand changes that may occur in the Test Area.

Ground surface elevation and thaw depth were measured at 227 locations in the Reference Area in 2019 (1 location on the east shoreline of the Niġliq Channel [Reference 5 South b transect] had been eroded into the river) and at 257 locations in the Test Area. Minimum ground surface elevations measured in 2019 in both the Reference (0.53 m) and Test (0.51 m) areas both occurred in Coastal Barrens. Maximum ground surface elevation for both the Reference (5.36 m) and Test (5.06 m) areas occurred in Upland Moist Low Willow Shrub. In 2019, minimum thaw depths were observed in Riverine Wet Sedge-Willow Meadow (16 cm) in the Reference Area and in Riverine Moist Sedge-Shrub Meadow (17 cm) in the Test Area. Maximum thaw depths were observed in Riverine Moist Tall Willow Shrub (119 cm) in the Reference Area and Coastal Dry Elymus Meadow (104 cm) in the Test Area.

Ground surface elevation (Table 3.24) and thaw depth (Table 3.25) were summarized by

Table 3.24 Mean, standard error (SE), and sample size (n) for measurements of ground surface elevation (m) above British Petroleum Mean Sea Level summarized by map ecotype class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

	Reference						Test					
	Mean		SE		n		Mean		SE		n	
Ecotype	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Coastal Barrens	1.3	0.9	0.2	0.1	12	10	1.2	1.2	0.2	0.2	10	10
Coastal Dry Elymus Meadow	1.8	1.6		0.1	1	3	3.6	3.6			1	1
Coastal Moist Willow Dwarf Shrub	2.3	1.5	0.8	0.3	3	3	1.8	1.8	0.1	0.1	3	3
Human Modified Low Shrub	2.0	2.0			1	1						
Human Modified Wet Meadow	3.7	3.4	0.1	0.5	2	4		2.4				1
Lowland Deep-polygon Complex	2.7	2.8	0.1	0.1	22	22	3.0	3.0	0.0	0.0	19	19
Lowland Moist Sedge-Shrub Meadow	4.1	4.1			1	1						
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	2.6	2.5			1	1	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 Dry Dryas Dwarf Shrub	3.5	2.1			1	1						
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	3.2	3.0	0.2	0.2	19	19	2.6	2.6	0.2	0.2	9	9
Riverine Moist Low Willow-Sedge Meadow	2.7	2.6	0.2	0.2	20	21	2.8	2.8	0.1	0.1	18	18
Riverine Moist Tall Willow Shrub	2.2	1.9			1	1						
Riverine Wet Sedge Meadow	3.3	3.2	0.1	0.1	42	42	3.0	3.0	0.0	0.0	107	106
Riverine Wet Sedge-Willow Meadow	3.3	3.2	0.1	0.1	65	63	3.0	3.0	0.1	0.1	44	44
Upland Dry Dryas Dwarf Shrub	4.8	4.8	0.2	0.2	2	2						
Upland Moist Low Willow Shrub	4.2	4.2	0.7	0.7	4	4	3.8	3.8	0.3	0.3	7	7
Riverine Moist Sedge-Shrub Meadow							3.1	3.0	0.2	0.2	5	5
Upland Moist Tussock Meadow							3.0	2.9	0.2	0.2	6	6

Table 3.25 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 2019.

	Reference						Test					
	Mean		SE		n		Mean		SE		n	
Ecotype	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Coastal Barrens	102.9	65.1	2.7	7.6	12	10	99.5	75.8	3.1	2.6	10	10
Coastal Dry Elymus Meadow	146.0	59.0		19.6	1	3	108.0	104.0			1	1
Coastal Moist Willow Dwarf Shrub	65.0	48.7	4.0	13.6	3	3	90.0	66.0	7.1	1.0	3	3
Human Modified Low Shrub	63.0	48.0			1	1						
Human Modified Wet Meadow	51.0	35.0	1.0	3.0	2	4		27.0				1
Lowland Deep-polygon Complex	46.5	32.9	1.3	1.1	22	22	44.3	31.7	1.2	0.8	19	19
Lowland Moist Sedge-Shrub Meadow	30.0	22.0			1	1						
Lowland Wet Sedge Meadow	48.2	34.7	1.2	1.0	17	18	43.5	34.5	1.1	1.1	11	11
Lowland Wet Sedge-Willow Meadow	37.0	28.0			1	1	42.7	41.0	2.2	0.6	3	3
Riverine Deep-polygon Complex	42.8	31.2	2.3	1.6	9	9	46.3	31.5	1.2	1.8	12	12
Riverine Dry Dryas Dwarf Shrub	60.0	50.0			1	1						
Riverine Moist Herb Meadow	103.3	83.3	0.9	6.2	3	3	85.5	76.0	5.5	3.0	2	2
Riverine Moist Low Willow Shrub	64.7	48.5	4.7	4.0	19	19	68.2	48.4	6.0	5.2	9	9
Riverine Moist Low Willow-Sedge Meadow	51.6	40.3	3.0	1.8	20	21	53.0	37.5	3.1	2.7	18	18
Riverine Moist Tall Willow Shrub	133.0	119.0			1	1						
Riverine Wet Sedge Meadow	49.5	35.0	1.8	0.8	42	42	47.4	34.2	0.6	0.6	107	106
Riverine Wet Sedge-Willow Meadow	45.8	34.4	1.0	1.1	65	63	49.9	36.4	1.2	1.0	44	44
Upland Dry Dryas Dwarf Shrub	76.0	45.0	26.0	15.0	2	2						
Upland Moist Low Willow Shrub	64.0	47.2	19.9	16.1	4	4	98.9	80.9	7.4	7.5	7	7
Riverine Moist Sedge-Shrub Meadow							42.8	32.8	3.5	6.5	5	5
Upland Moist Tussock Meadow							43.0	25.5	3.2	2.2	6	6

terrestrial ecotype. 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 2019, the ecotype in the Test Area with the highest average elevation above sea level was Upland Moist Low Willow Shrub (Figure 3.35, Table 3.24). In the Reference Area, the average elevation of Upland Moist Willow Shrub was exceeded by Upland Dry Dryas Dwarf Shrub in both 2013 and 2019 (Table 3.24). These ecotypes are typical of active and inactive sand dunes and feature some of 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 2019 included Upland Moist Tussock Meadow, Human Modified Wet Meadow, and Riverine and Lowland Deep-polygon Complex (Figure 3.36, Table 3.25). Map ecotypes in the Reference Area with shallow thaw depths included Lowland Moist Sedge-Shrub Meadow, Lowland Wet Sedge-Willow Meadow, and Riverine and Lowland Deep-polygon Complex (Figure 3.36, Table 3.25).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 2019, ecotypes with the deepest thaw depths were Coastal Dry Elymus Meadow, Upland Moist Low Willow Shrub and Riverine Moist Herb Meadow. In the Reference Area in 2019, ecotypes with the deepest thaw depths included Riverine Moist Tall Willow Shrub, 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, per the Monitoring Plan (ABR and Baker 2013). In general, elevations remained approximately the same between 2013 and 2019 across all ecotypes in both Reference and Test Areas. Thaw depth generally decreased (i.e., thinner active layer) in 2019 across all ecotypes in both Reference and Test Areas. This is related to the timing of the RTK Surveys in 2013 as compared to 2019. In 2013, the RTK surveys were conducted in the first and second weeks of August, while in 2019 the RTK surveys were conducted approximately 3 weeks earlier, during the second and third weeks of July.

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 buries existing surface organics. Surface organic thickness provides a metric by which to assess changes in sedimentation 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 3.37 and Table 3.26. 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 the surface terrain unit Delta Abandoned Overbank Deposit in the Test Area, average surface organic thickness overlapped with 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 this surface geomorphic unit are not significant between years and Areas. However, the average surface organic thickness in both Areas in 2019 was below the lower 95% CI of each respective Area in 2013. This indicates that average surface organic thickness in both Areas in 2019 was significantly thinner than in 2013. Additionally, the variability of surface organic thickness increased in 2019 in both Areas as indicated by the larger standard deviations and 95% CIs in 2019 than in 2013.

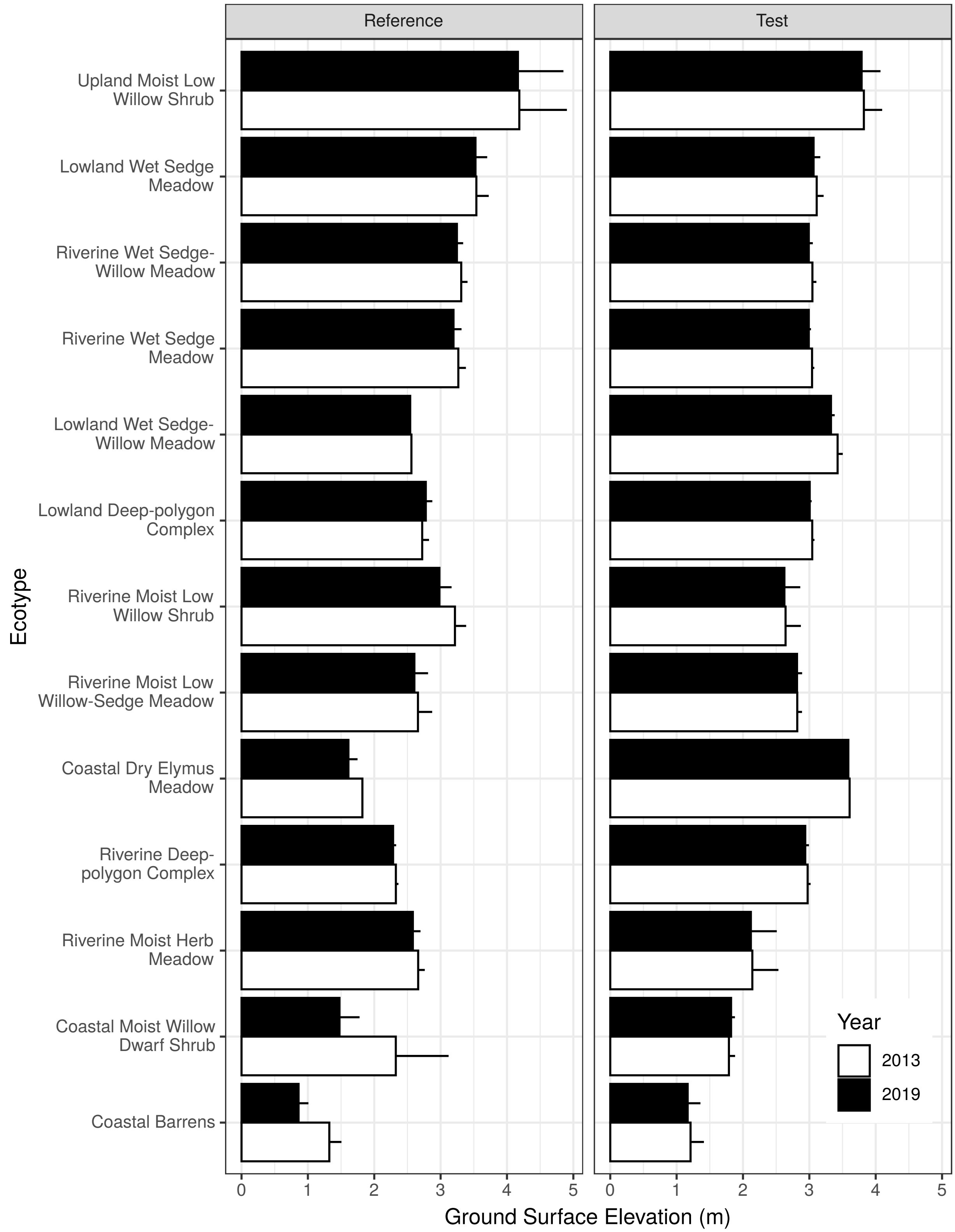

Figure 3.35 Barchart illustrating average elevation above British Petroleum mean sea level, and standard error, for map ecotype classes in the CD5 Habitat Monitoring, northern Alaska, 2013 and 2019.

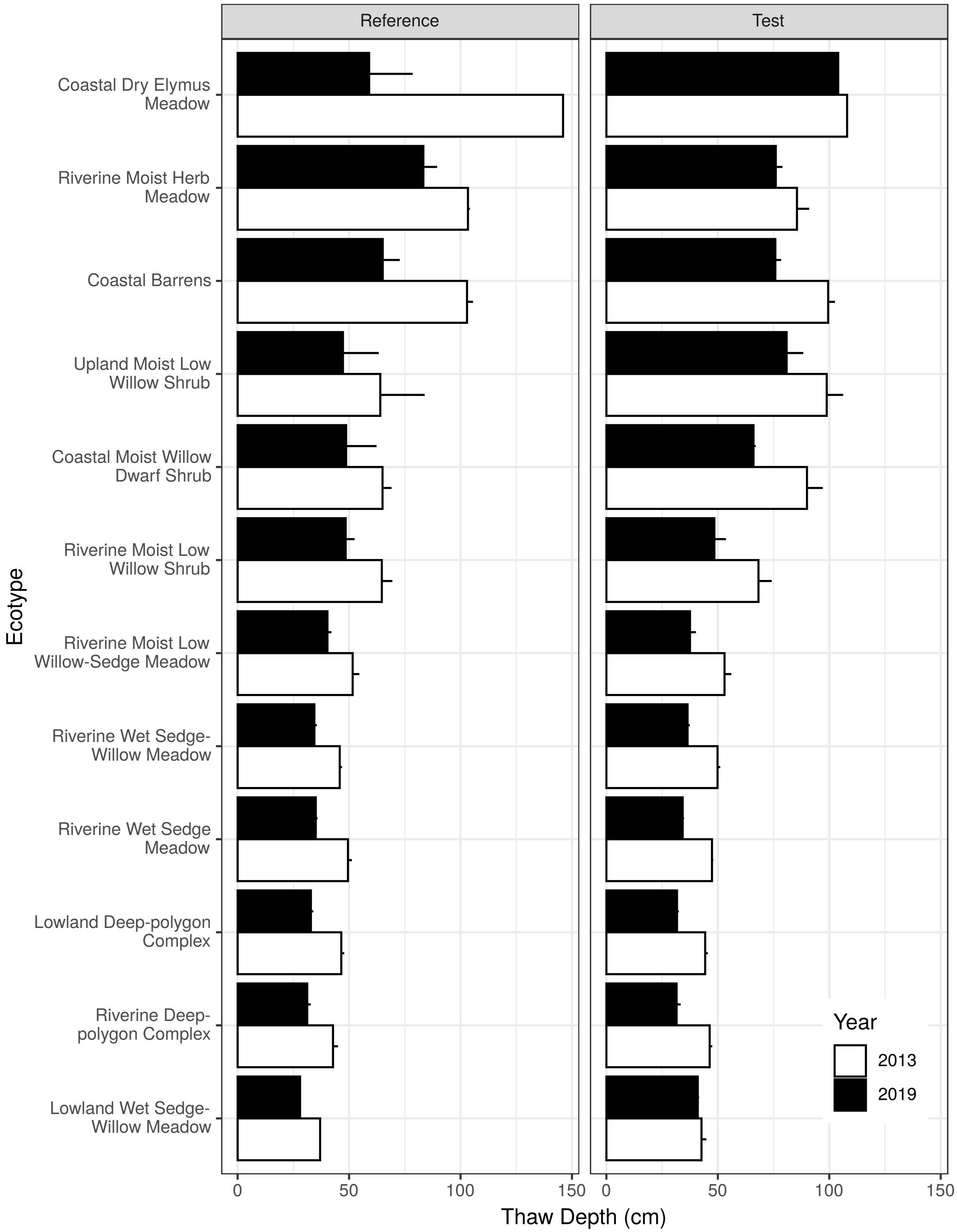

Figure 3.36 Barchart illustrating average thaw depth and standard error for map ecotype classes in the CD5 Habitat Monitoring, northern Alaska, 2013 and 2019.

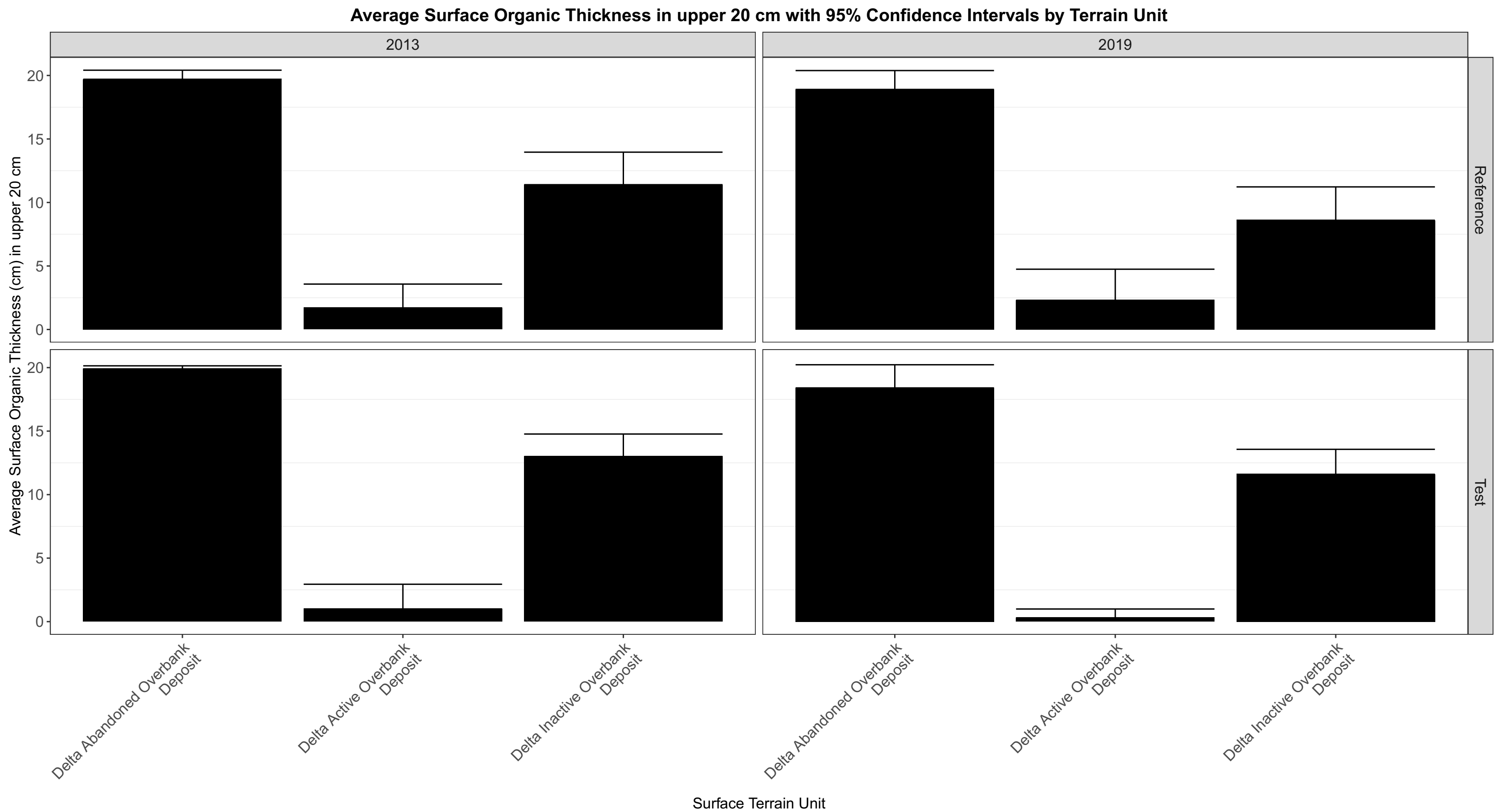

Figure 3.37 Surface organic thickness bar charts with 95% confidence intervals by surface terrain unit, area, and year for common surface terrain unit classes, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Table 3.26 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 2019.

Surface Terrain Unit	Study Area	Sample Year	Average Surface Organic Thickness (cm)	Standard Deviation	n	Standard Error	95% CI	Lower 95% CI	Upper 95% CI
Delta Abandoned Overbank Deposit									
	Reference	2013	19.7	1.3	15	0.3	0.7	19.0	20.4
	Reference	2019	18.9	2.7	15	0.7	1.5	17.4	20.4
	Test	2013	19.9	0.5	19	0.1	0.2	19.7	20.1
	Test	2019	18.4	3.8	19	0.9	1.8	16.6	20.2
Delta Active Overbank Deposit									
	Reference	2013	1.7	2.3	8	0.8	1.9	-0.2	3.6
	Reference	2019	2.3	3	8	1.1	2.4	-0.1	4.7
	Test	2013	1	1.4	4	0.7	1.9	-0.9	2.9
	Test	2019	0.3	0.5	4	0.3	0.7	-0.4	1.0
Delta Inactive Overbank Deposit									
	Reference	2013	11.4	7.8	38	1.3	2.6	8.8	14.0
	Reference	2019	8.6	8	38	1.3	2.6	6.0	11.2
	Test	2013	13	7.2	66	0.9	1.8	11.2	14.8
	Test	2019	11.6	8	66	1.0	2.0	9.6	13.6

In 2013, the average surface organic thickness in Delta Active Overbank Deposit in the Test Area overlapped with the 95% confidence intervals of the corresponding surface terrain unit in the Reference Area. This indicates that the observed differences in surface organic thickness for this surface geomorphic units were not significant between Areas that year. In 2019, the average surface organic thickness in this geomorphic unit in the Test Area decreased relative to 2013, but remained with the 95% CI of the Reference Area. The average surface organic thickness in the Reference Area in 2019 increased relative to 2013 and was greater than the upper 95% CI of the Test Area. This indicates a significant difference in average surface organic thickness between the Reference and Test Area in 2019. However, within each Area the changes in average surface organic thickness beween years were not significant as indicated by the 2019 average overlapping with the 2013 95% CIs (and vice versa). Additionally, surface organic thickness in this geomorphic unit in the Reference Area is more variable in 2019 than in 2013, while in the Test Area the variability decreased in 2019. This suggests that between 2013 and 2019 sedimentation in this geomorphic unit has increased in the Reference Area, and decreased in the Test Area, and the resulting changes in surface organic thickness between years were not significant within each Area.

In 2013, the average surface organic thickness in Delta Inactive Overbank Deposits in the Test Area overlapped with the 95% confidence intervals of the corresponding surface terrain unit in the Reference Area. This indicates that the observed differences in surface organic thickness for this surface geomorphic units were not significant between Areas that year. In 2019, the average surface organic thickness in this geomorphic unit in the Test Area was greater than the upper 95% CI of the Reference Area. This indicates a significant difference in average surface organic thickness between the Reference and Test Area. Average surface organic thickness decreased in both Areas in 2019. However, the decrease in the Test Area in 2019 was not significantly different from the average thickness in 2013 as indicated by the 2019 average overlapping with the 2013 95% CIs (and vice versa). Whereas the decrease in the Reference Areas in 2019 was significantly different based on an 2019 average thickness less than the 2013 lower 95% CI. This suggests that between 2013 and 2019 sedimentation increased in this geomorphic unit in both Areas, and the resulting changes in surface organic thickness between years were significant in the Reference Area, but not in the Test Area.

An assessment of ground cover classes in Reference and Test Areas by year (Figure 3.38) showed that mosses, mineral soil, and water were the predominant ground cover classes in all years and Areas. The average mineral soil cover was higher in 2013 (36% in the Reference Area and 44% in the Test Area, Appendix L) than in 2019 (33% in the Reference Area and 30% in the Test Area) in both Areas; however these changes were within the range of variability as measured by the standard deviation. The number of plots where mineral soil hits were recorded approximately the same in 2019 in the Test Area (n = 26 and 29 in 2013 and 2019, respectively), while in the Reference Area the number of plots where mineral soil hits were recorded decreased by 12 plots relative to 2013 (n = 34 and 22 in 2013 and 2019, respectively). Thus the decrease in average mineral soil cover in 2019 in the Reference Areas reflects a lower number of plots with low mineral soil cover. This indicates that in the Reference Area mineral soil as a ground cover was more widespread in 2013, and at Vegetation Plots where mineral soils were present, its cover was on average higher. In contrast, mineral soil in 2019 in the Reference Area was less widespread, and at Vegetation Plots where mineral soil was present, its cover was on average slightly lower. In the Test Area mineral soil was similarly widespread in both years (slightly higher in 2019), but average mineral soil cover was overall lower in 2019. This can be explained by the lower magnitude spring breakup floods that occurred in 2017, 2018, and 2019 (Baker 2017, 2018, 2019), which were characterized by limited overbank flooding, resulting in less widespread sedimentation.

Average moss cover was approximately the same in the Reference (avg. 49% and 54% in 2013/2019, respectively) and Test Areas (avg. 48% and 52% in 2013/2019, respectively) in both years. Moss cover increased slightly in 2019 in both the Reference (+5%) and Test (+4%) Areas. The number of plots at which moss was recorded also increased slightly in both the Reference (+4 plots)

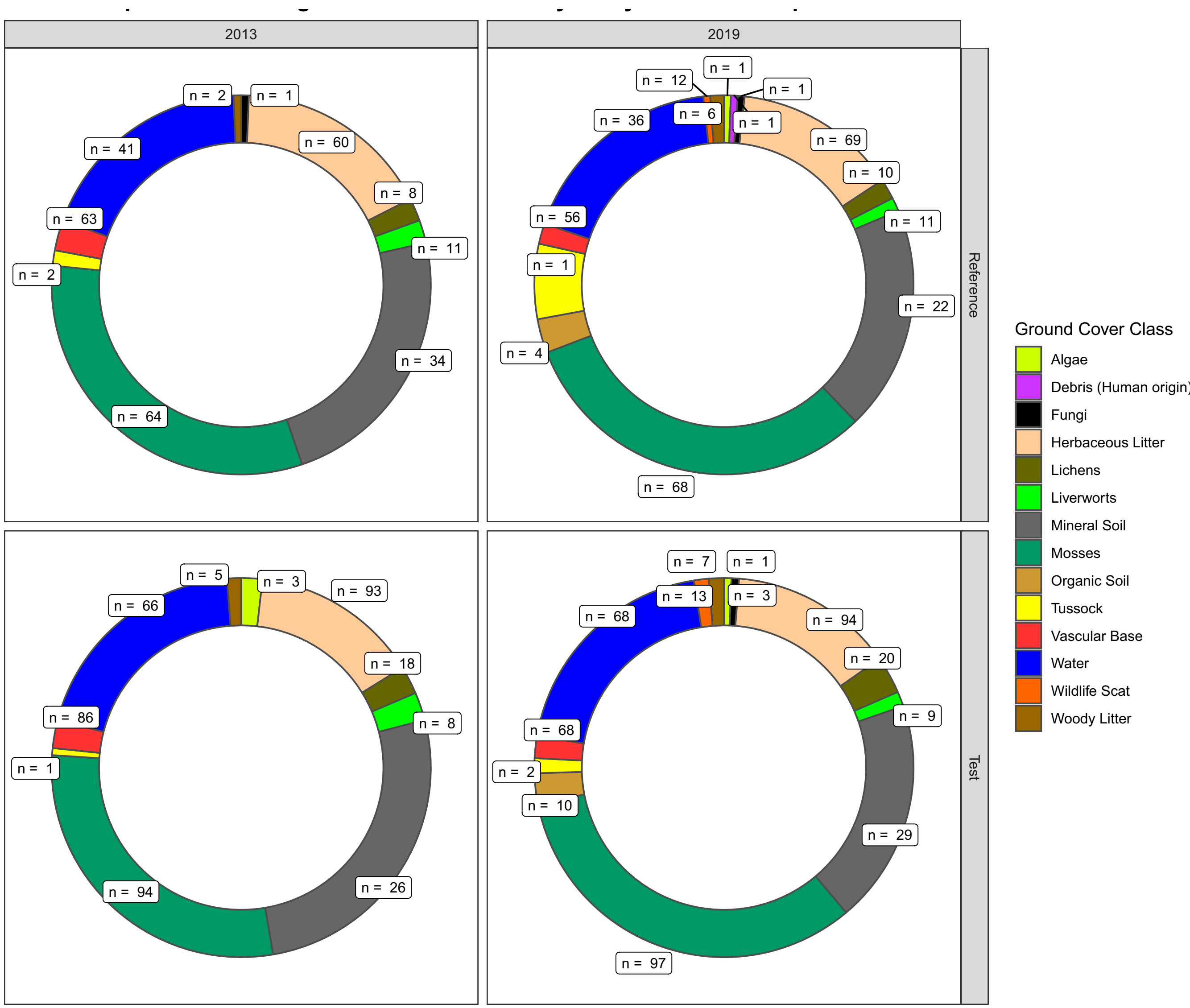

Figure 3.38 Ring chart displaying the proportion of average total ground cover for all ecotypes by sample year and study area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

and Test Area (+3 plots). This indicates consistency between the 2 Areas in moss cover with an overall slight increase between 2013 and 2019. The slight decrease in mineral soil cover in both Areas in 2019 discussed above is likely related, at least in part, to the slight increase in moss cover in both Areas 2019. As moss covered increases bare mineral soil is overtopped by the moss resulting in a decrease in mineral soil cover.

Average water cover was approximately the same in the Reference (avg. 29% and 31% in 2013/2019, respectively) and Test Areas (avg. 29% and 30% in 2013/2019, respectively) in both years. Water cover increased slightly in 2019 in both the Reference Area (+2%), and decreased slightly in the Test Areas (-2%), but these changes were well within the range of variability based on the standard deviation. The number of plots at which water was recorded decreased slightly in the Reference Area (-5 plots), and increased slightly in the Test Area (+2 plots). The relatively small changes in water cover indicate consistency between the 2 Areas in water cover.

The 2013, 2016, and 2019 Geomorphology Monitoring Photo Points photos for Photo Point 1 and 2 are presented in Figures 3.6 and 3.7. Photo Point 1 at 110° (Panels 1a, 1b, 1c. 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. These photos also show the bank erosion that occurred at this site between 2013 and 2016, and which appears to have stabilized by 2019. Photo Point 1 at 190° (Panels 2a, 2b, and 2c in Figure 3.6) also shows the bank erosion that occurred at this site between 2013 and 2016. The 2019 shows the bank has further eroded since 2016; however the erosion rate appears to have slowed relative to the earlier period given the shorter distance of bank that has eroded since 2016. Photo Point 2 (Panels 1a, 1b, and 1c in Figure 3.7) slightly higher water than in 2013 covering the riverbar in foreground, little to no bank erosion, deposition of driftwood at the edge of the bank, and early vegetation succession on the scourmark in the center photo that was first seen in 2016. Figure 3.8 displays the photographs from Photo Point 3, the Geomorphology Monitoring Photo Point that was established in 2016 on the Niġliq Channel Bridge. Photo Point 3 at 329° (Panels 1a, 1b. in Figure 3.8) shows little to no bank erosion directly downstream of the bridge and some driftwood on the riverbank in 2019 that was not there in 2016. Photo Point 3 at 149° (Panels 2a, 2b. in Figure 3.8) shows little to no bank erosion directly upstream of the 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 3.39). Drift lines and driftwood were observed across the CD5 Study Area in 2019. In some cases drift lines that were observed in 2013 were no longer present in 2016 and 2019 (Panels 1a, 1b, and 1c in Figure 3.39) indicating that flood waters had moved the drift materials. In other cases, drift lines and driftwood were found in 2016 and 2019 at sites where drift lines were absent in 2013 (Panels 2a, 2b, and 2c in Figure 3.39). In this example, the drift lines were unchanged from 2016 to 2019, indicating that overbank flooding has not occurred at this location since at least 2016.

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 (several thousand photographs taken to date) that can be used to qualitatively monitor landscape change through time and provide context for changes identified during the ITU map update effort. Figure 3.5 displays an example of repeat photographs taken along Habitat Line 1 at plot t2sc-0000-hab. This Habitat Line is located on a Delta Inactive Channel Deposit; such sites experience infrequent riverine flooding and support a diverse assemblage of shrubs, forbs, and graminoids. Large feltleaf willow (*Salix alaxensis*) shrubs are evident in the background of both photo pairs, and many of them appear to have increased in size over the 7-year interval. Although tall shrubs such as feltleaf willow are limited in extent within the CD5 Study Area, they are attractive targets for qualitative monitoring using repeat photography because they are readily identified in the photography, are fast-growing and long-lived, and occupy early

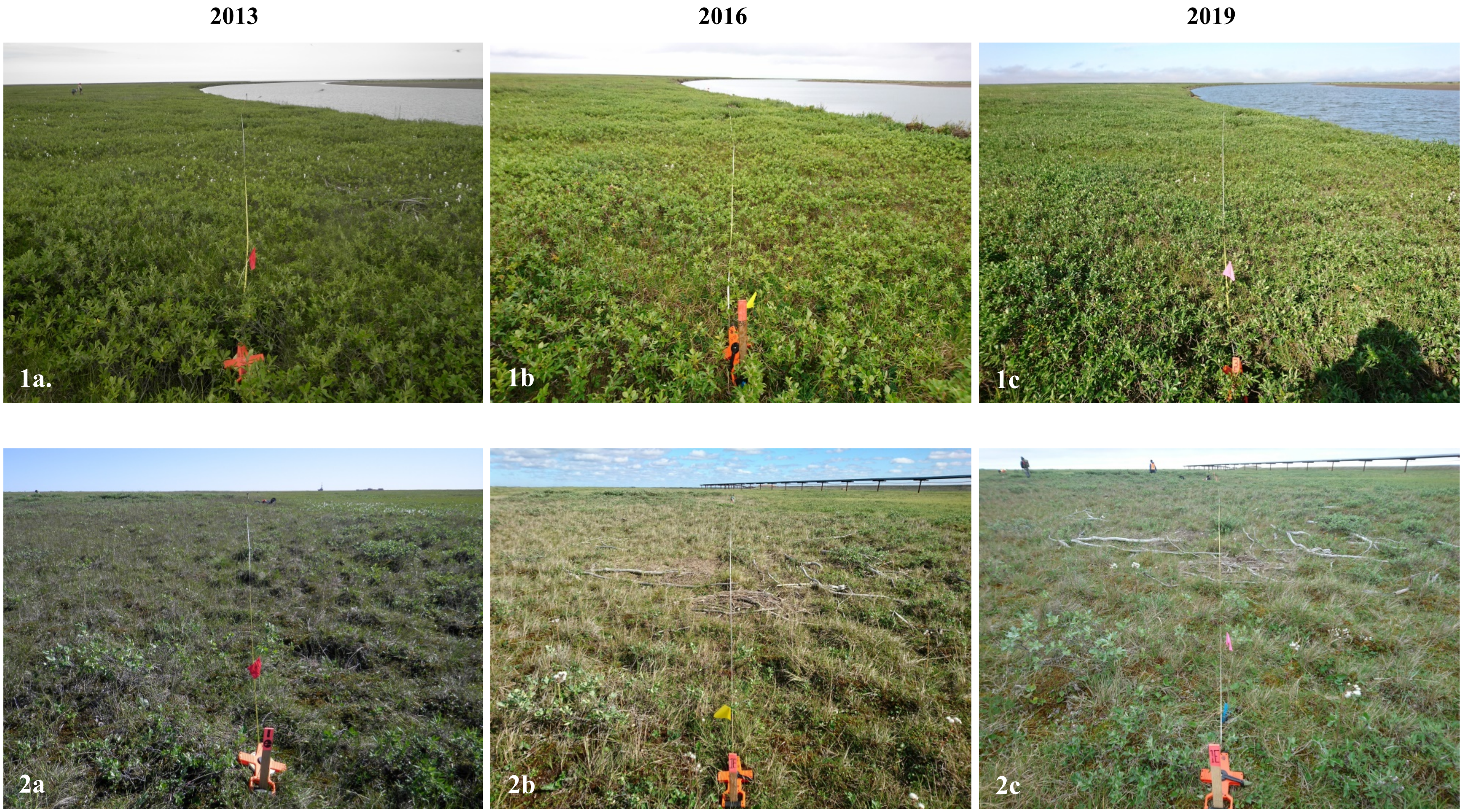

Figure 3.39 Upper Panels (1a,1b, and 1c), examples of drift lines observed in 2013 but not in 2016 and 2019. Lower Panels (2a, 2b, and 2c), drift lines observed in 2016 and 2019 but not in 2013.

successional environments (i.e., near the Niġliq Channel) that are often subject to flooding, sedimentation, and other forms of disturbance. The foreground of both photo pairs is occupied by Arctic seashore willow (*Salix ovalifolia*), a dwarf shrub, as well as diverse forbs such as Tilesius' wormwood (*Artemisia tilesii*) and Lake Huron tansy (*Chrysanthemum bipinnatum*). The extent of Arctic seashore willow appears similar in 2013 and 2019. Changes in forb species-composition abundance are somewhat difficult to interpret; many of the differences appear to be due to phenological differences at the time of photography. Bare sediment evident in the foreground of both 2013 photos was probably deposited during the large spring flood that occurred earlier that year. Bare ground is less extensive in the 2019 photographs; the combination of increased shrub extent and decreased bare ground extent indicates vegetation succession and a lack of disturbance at this plot since 2013. The photos presented here provide an example 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 2019 HABITAT MONITORING

The 2019 Habitat Monitoring effort was focused on collecting the second 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.

The habitat assessment showed changes in cover for *Salix* in Patterned Wet Meadow habitat; *Salix* cover increased in the Reference Area, but declined in the Test Area. The pattern for 2019 included cover increases in the Test Area, but not to the extent that *Salix* is increasing in the Reference Area. *Salix* cover changes were also significant between years, thus *Salix* is changing in this habitat both independently of Area, but also when Area is included. This result was noted by Wells et al. (2017) from the 2016 CD5 Habitat Monitoring effort, and this is a pattern that bears increased scrutiny in future monitoring assessments.

Total live vascular cover remained the same or increased across nearly all Plot Ecotypes and several wildlife habitats. The increases in TLVC were most commonly related to increases in sedge (*Carex* sp. and *Eriophorum* sp.) and low shrub cover (predominantly *Salix*). Significant changes in TLVC were observed in the following wildlife habitats: Deep Polygon Complex (increased in Test Area, slight decreased in Reference Area), Dry Halophytic Meadow (increased in Reference Area, no change in Test Area), and Moist Halophytic Dwarf Shrub, Nonpatterned Wet Meadow, and Patterned Wet Meadow; each of which showed large increases in TLVC between 2013 and 2019 in all Areas.

The results of the assessment of detailed ground cover classes at Vegetation Plots showed that in general surface water and mineral soil cover decreased, and moss and litter cover increased in a number of Plot Ecotypes in both the Reference and Test Areas. The changes observed in both the Reference and Test Areas indicate that the observed differences in these ground cover attributes between 2013 and 2019 are not related to the CD5 Road. Instead these differences are most likely related to differences in the magnitude and extent of spring breakup flooding in 2013 versus 2019 and natural variability through time (Baker 2013, 2019). In 2013 breakup floodwaters inundated nearly the entire CD5 Study Area for several days; whereas the 2019 breakup flood was of much lower magnitude, and only lower floodplain surfaces (i.e. active channel and active overbank deposits) were inundated.

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 in the Abandoned Overbank Deposits geomorphic unit. There were significant differences in surface organic thickness between years and Areas in Inactive and Active Overbank Deposits. However, the changes between years within each Area and geomorphic unit were not significant, and the standard errors overlapped substantially, suggesting that the observed changes were within the natural range of variability. The one exception was the significant decrease in surface organic thickness in Inactive Overbank Deposits in the Reference Area between years. Given the location of this observed change in the Reference Area we cannot attribute it to the CD5 Road, but rather assume that this is related to natural variability in riverine flooding and sedimentation through time.

The vegetation assessment found that 80% of Vegetation Plots (144 plots) had not changed in plant species composition between 2013 and 2019, 6% (10 plots) showed a change, and 14% (25 plots) were flagged as potentially changing species composition between 2013 and 2019. Of the 10 plots that showed changes in species composition, 3 were Upland Sandy Alkaline Moist Low Willow Shrub, which is characterized by low willow vegetation on inactive sand dunes. Environmental variables related to riverine processes of flooding, sedimentation, and deeper thaw depths, suggest that these plots are expressing a higher degree of riverine activity (i.e. more flooding) in 2019. These changes occurred in both the Test and Reference areas north and south of the CD5 Road, indicating that the observed changes are unrelated to the CD5 Road. The remaining 7 plots that changed are all wet tundra (4 Wet Sedge Meadow Tundra and 3 Wet Sedge-Willow Tundra), and all but 1 plot was located in Test Areas. Of the 6 plots located in the Test Area, five of which were located on first or second transect north or south of the CD5 Road. The changes at the Wet Sedge Meadow Tundra plots were attributable to increases in the cover of sedges (*Carex* sp. and *Eriophorum* sp.), and 3 of the Wet Sedge Meadow Tundra plots showed minor subsidence since 2013. The changes at 2 of the Wet Sedge-Willow Tundra plots correspond to predicted increases in elevation and less frequent flooding, with increases in *Salix reticulata* and *Equisetum* spp. The 1 remaining Wet Sedge-Willow Tundra plot was flagged as disturbed by avian grazing, and while species richness increased, total vascular cover declined by 9.2% in 2019. Given the close proximity of the first and second transect north and south of the CD5 Road, the changes observed in the 5 plots located along these transects are most likely the result of impacts from the CD5 Road. However, the number of plots is very low, suggesting these results reflect localized changes in plant species composition associated with the CD5 Road. Additionally, evidence of goose grazing was observed at one plot in the Test Area in 2019, indicating that natural disturbances may in some cases play a role in the observed changes.

Changes in species richness between ecotypes, years, and Areas were relatively small and within the range of variability, based on the standard deviation. In most cases species richness remained approximately the same, or increased slightly. The relationship between species richness, total live cover, and search time was significant ($p<0.001$) and proportion of the variance explained was moderately high (0.51). This suggests that some of the differences observed in species richness between years may be related to search time, but that other factors are also involved, for instance, Plot Ecotype.

The landscape change analysis showed that, in addition to the expected landscape changes related to the direct placement of the CD5 development infrastructure, the second ecosystem map update effort revealed a large increase in the thermokarst in both the Test and Reference Areas. The occurrence of thermokarst in both the Test and Reference Areas in the 2018 mapping, and at approximately the same percent increase in area, suggests that the onset of thermokarst since 2012 is not entirely attributable to the CD5 road. An important contributing factor is likely to include the finding that annual mean Arctic air temperatures have exceeded all previous records for the past 6 years (2014–2019) (Overland et al. 2019). Additionally, a long-term, regional trend in ice-wedge degradation has been detected across the Alaskan Arctic (Frost et al. 2018), thus the thermokarst detected in the CD5 study area is also likely part of this broader trend. The remaining changes where relatively small, localized landscape changes consistent 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 2019 across all ecotypes in both Reference and Test Areas. Thaw depth generally decreased (i.e., thinner active layer) in 2019 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 2019 (mid-July).

In summary, the results of the 2019 Habitat Monitoring showed very little ecosystem change between 2013 and 2019. Broad-scale changes that were observed between years, including the decrease of standing water and mineral soil cover, and increase in moss cover were observed in both Reference and Test Areas, and hence not attributable to the CD5 Road. Rather, differences in break-up flooding between 2013 and 2019 is the primary causal factor lending to the differences observed. The changes in *Salix* cover in Patterned Wet Meadow habitat, namely *Salix* cover increasing in both Areas but more rapidly in the reference area, warrant increased scrutiny in future monitoring efforts. The CD5 Habitat Monitoring Study effort is scheduled to be conducted again in 2024.

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Appendix A. Species list for all years, indicating the years each species was encountered, number of occurrences, which have voucher specimens, and rare and invasiveness rankings; CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Deciduous Shrubs	*Alnus fruticosa* Rupr.	alnfru	2013, 2016, 2019	3	FALSE	NULL	NULL	-999
	Arctous alpina (L.) Nied	arcalp1	2013, 2016, 2019	42	FALSE	NULL	NULL	509023
	Arctous rubra (Rehder & E.H. Wilson) Nakai	arcrub1	2013, 2016, 2019	181	TRUE	NULL	NULL	509025
	Betula nana L.	betnan	2016, 2019	2	FALSE	NULL	NULL	19479
	Salix alaxensis (Andersson) Coville	salala	2013, 2016, 2019	66	FALSE	NULL	NULL	22497
	Salix arbusculoides Andersson	salarb	2013, 2016, 2019	7	TRUE	NULL	NULL	504953
	Salix arctica Pall.	salarc	2013, 2016, 2019	17	TRUE	NULL	NULL	565479
	Salix arctophila Cockerell ex A. Heller	salarc1	2016	1	TRUE	NULL	NULL	22481
	Salix fuscescens Andersson	salfus	2013, 2016	5	FALSE	NULL	NULL	22536
	Salix glauca L.	salgla	2013, 2016, 2019	174	TRUE	NULL	NULL	22482
	Salix hastata L.	salhas	2019	1	TRUE	NULL	NULL	22542
	Salix niphoclada Rydb.	salnip1	2013	1	TRUE	NULL	NULL	520860
	Salix ovalifolia Trautv.	salova	2013, 2016, 2019	238	TRUE	NULL	NULL	22485
	Salix phlebophylla Andersson	salphl	2013	1	FALSE	NULL	NULL	22486
	Salix polaris Wahlenb.	salpol1	2019	1	FALSE	NULL	NULL	22487
	Salix pulchra Cham.	salpul1	2013, 2016, 2019	520	TRUE	NULL	NULL	22488
	Salix reticulata L.	salret	2013, 2016, 2019	616	FALSE	NULL	NULL	22489
	Salix richardsonii Hook.	salric1	2013, 2016, 2019	889	TRUE	NULL	NULL	22576
	Salix rotundifolia Trautv.	salrot	2013, 2016, 2019	5	FALSE	NULL	NULL	565484
	Vaccinium uliginosum L.	vaculi	2013, 2016, 2019	48	FALSE	NULL	NULL	23574
Evergreen Shrubs	*Andromeda polifolia* L.	andpol	2013, 2016, 2019	164	FALSE	NULL	NULL	23465
	Cassiope tetragona (L.) D. Don	castet	2013, 2016, 2019	146	FALSE	NULL	NULL	23535
	Dryas integrifolia M. Vahl	dryint	2013, 2016, 2019	606	FALSE	NULL	NULL	24614
	Empetrum nigrum L.	empnig	2013, 2016, 2019	12	FALSE	NULL	NULL	23743
	Ledum decumbens (Aiton) Lodd. ex Steud.	leddec	2013, 2016, 2019	15	FALSE	NULL	NULL	23541
	Vaccinium vitis-idaea L.	vacvit	2013, 2016, 2019	46	FALSE	NULL	NULL	505637
Ferns and allies	*Equisetum arvense* L.	equarv	2013, 2016, 2019	210	TRUE	NULL	NULL	17152
	Equisetum fluviatile L. ampl. Ehrh.	equflu	2013, 2016	2	FALSE	NULL	NULL	17150
	Equisetum scirpoides Michx.	equsci	2013, 2016, 2019	440	TRUE	NULL	NULL	17151
	Equisetum variegatum Schleich.	equvar	2013, 2016, 2019	669	TRUE	NULL	NULL	17149

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Ferns and allies	*Equisetum variegatum* ssp. *variegatum* Schleich. ex F. Weber & D. Mohr	equvar1	2016, 2019	2	FALSE	NULL	NULL	897848
Forbs	*Androsace chamaejasme* Host ssp. *lehmannia* (Spreng.) Hult.	andcha	2013, 2019	3	TRUE	NULL	NULL	184552
	Androsace chamaejasme Wulfen ex Host	andcha1	2016, 2019	2	FALSE	NULL	NULL	23931
	Anemone parviflora Michx.	anepar	2013, 2016, 2019	9	FALSE	NULL	NULL	18433
	Anemone richardsonii Hook.	aneric	2013, 2016, 2019	3	FALSE	NULL	NULL	18434
	Arabis lyrata L. ssp. *kamchatica* (Fisch.) Hult.	aralyr	2013	1	TRUE	NULL	NULL	184311
	Arnica alpina (L.) Olin	arnalp1	2016	1	FALSE	NULL	NULL	36556
	Arnica frigida C.A. Mey.	arnfri	2019	1	FALSE	NULL	NULL	184943
	Arnica lessingii Greene	arnles	2013, 2016, 2019	5	FALSE	NULL	NULL	36567
	Artemisia arctica Less.	artarc2	2016, 2019	3	FALSE	NULL	NULL	35432
	Artemisia arctica Less. ssp. *arctica*	artarc1	2013	1	FALSE	NULL	NULL	35433
	Artemisia tilesii Ledeb.	arttil	2013, 2016, 2019	35	TRUE	NULL	NULL	35440
	Aster sibiricus L.	astsib	2013, 2016, 2019	36	FALSE	NULL	NULL	35513
	Astragalus alpinus L.	astalp1	2013, 2016, 2019	231	TRUE	NULL	NULL	25393
	Astragalus alpinus L. *ssp. arcticus* (Bunge) Hultén	astarc	2019	1	FALSE	NULL	NULL	192323
	Astragalus eucosmus B.L. Rob.	asteuc1	2016, 2019	83	FALSE	NULL	NULL	25509
	Astragalus eucosmus Hornem. ssp. *sealei* (LePage) Hult.	astsea	2013, 2016, 2019	12	TRUE	NULL	NULL	25511
	Astragalus eucosmus Robins. ssp. *eucosmus*	asteuc	2013, 2016, 2019	43	FALSE	NULL	NULL	-999
	Astragalus umbellatus Bunge	astumb	2013, 2016, 2019	182	TRUE	NULL	NULL	25394
	Calla palustris L.	calpal2	2019	2	FALSE	NULL	NULL	42546
	Caltha palustris L.	calpal1	2013, 2016, 2019	34	FALSE	NULL	NULL	18454
	Cardamine hyperborea O.E. Schulz	carhyp	2013, 2016, 2019	44	FALSE	NULL	NULL	22770
	Cardamine pratensis L.	carpra3	2016, 2019	37	TRUE	NULL	NULL	22773
	Cardamine pratensis L. ssp. *angustifolia* (Hook.) O.E. Schultz	carpra1	2013, 2016, 2019	28	TRUE	NULL	NULL	525385
	Castilleja caudata (Pennell) Rebr.	cascau	2013, 2016, 2019	8	TRUE	NULL	NULL	33050
	Cerastium beeringianum Cham. & Schlecht.	cerbee1	2016	1	FALSE	NULL	NULL	19944
	Cerastium jenisejense Hult.	cerjen	2019	1	FALSE	NULL	NULL	19956
	Chenopodium album L.	chealb	2016	1	TRUE	NULL	37	20592
	Chrysanthemum bipinnatum L.	chrbip	2013, 2016, 2019	58	TRUE	NULL	NULL	35793
	Cnidium cnidiifolium (Turcz.) Schischk.	cnicni	2019	1	FALSE	NULL	NULL	29464
	Epilobium latifolium L.	epilat	2013, 2016	4	FALSE	NULL	NULL	27281
	Gentiana propinqua Richardson	genpro	2016, 2019	15	FALSE	NULL	NULL	30066

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Forbs	*Gentiana propinqua* Richards. ssp. *propinqua*	genpro1	2013, 2016	14	TRUE	NULL	NULL	-999
	Hedysarum alpinum L.	hedalp	2013, 2016, 2019	27	TRUE	NULL	NULL	26723
	Hedysarum alpinum ssp. *americanum* (Michx. ex Pursh) B. Fedtsch.	hedame	2019	2	TRUE	NULL	NULL	525927
	Hedysarum mackenzii Richards.	hedmac	2013, 2016, 2019	10	TRUE	NULL	NULL	-999
	Hippuris vulgaris L.	hipvul	2013, 2016, 2019	12	FALSE	NULL	NULL	27069
	Lupinus arcticus S. Wats.	luparc	2013, 2016, 2019	230	FALSE	NULL	NULL	25917
	Melandrium affine J. Vahl	melaff	2016	1	FALSE	NULL	NULL	19976
	Melandrium apetalum (L.) Fenzl.	melape	2013, 2016, 2019	8	FALSE	NULL	NULL	19977
	Melandrium apetalum (L.) Fenzl ssp. *arcticum* (E. Fries) Hultén	melarc	2016	1	FALSE	NULL	NULL	526144
	Menyanthes trifoliata L.	mentri	2019	2	FALSE	NULL	NULL	30102
	Myriophyllum spicatum ssp. *exalbescens* (Fern.) Hult.	myrsib	2013	1	FALSE	NULL	NULL	526193
	Oxytropis borealis DC.	oxybor	2013, 2016, 2019	21	TRUE	NULL	NULL	26165
	Oxytropis campestris (L.) DC.	oxycam	2013, 2016, 2019	3	FALSE	NULL	NULL	26166
	Oxytropis deflexa (Pall.) DC.	oxydef	2013, 2016, 2019	16	TRUE	NULL	NULL	26167
	Oxytropis maydelliana Trautv.	oxymay	2013	1	FALSE	NULL	NULL	504086
	Oxytropis viscida Nutt.	oxyvis	2013	1	FALSE	NULL	NULL	26183
	Papaver macounii Greene	papmac	2013, 2016	3	TRUE	NULL	NULL	18885
	Papaver macounii ssp. discolor (Hultén) Rändel ex D.F. Murray	papdis	2019	2	TRUE	NULL	NULL	526306
	Parnassia kotzebuei Cham. & Schlecht.	parkot	2013, 2016, 2019	42	TRUE	NULL	NULL	24205
	Parnassia palustris L.	parpal	2013, 2016, 2019	6	TRUE	NULL	NULL	24206
	Parrya nudicaulis (L.) Regel	parnud	2013, 2016, 2019	5	TRUE	NULL	NULL	22987
	Pedicularis capitata Adams.	pedcap	2013, 2016, 2019	115	FALSE	NULL	NULL	33353
	Pedicularis kanei Durand	pedkan1	2019	2	FALSE	NULL	NULL	33354
	Pedicularis langsdorffii Fisch.	pedlan3	2013, 2016, 2019	75	TRUE	NULL	NULL	834152
	Pedicularis langsdorffii Fisch. ssp.*arctica* (R. Br.) Pennell	pedlan1	2013, 2016, 2019	3	TRUE	NULL	NULL	834229
	Pedicularis langsdorffii Fisch. ssp.*langsdorffii*	pedlan2	2013	2	FALSE	NULL	NULL	834230
	Pedicularis sudetica Willd.	pedsud	2013, 2016, 2019	439	TRUE	NULL	NULL	33357
	Pedicularis sudetica Willd. ssp. *albolabiata* Hultén	pedalb	2013	3	TRUE	NULL	NULL	524423
	Pedicularis verticillata L.	pedver	2013, 2016, 2019	68	TRUE	NULL	NULL	33358
	Petasites frigidus (L.) Franchet	petfri	2013, 2016, 2019	309	FALSE	NULL	NULL	36054
	Platanthera hyperborea (L.) Lindl.	plahyp	2013, 2019	3	FALSE	NULL	NULL	43427
	Platanthera obtusata (Pursh) Lindl.	plaobt	2013, 2016, 2019	5	TRUE	NULL	NULL	43411

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Forbs	*Polemonium boreale* Adams	polbor	2013	1	FALSE	NULL	NULL	31000
	Polygonum bistorta L. ssp. *plumosum* (Small) Hult.	polbis	2013, 2016, 2019	41	FALSE	NULL	NULL	526455
	Polygonum viviparum L.	polviv	2013, 2016, 2019	508	FALSE	NULL	NULL	20864
	Potamogeton pectinatus L.	potpec	2016	1	FALSE	NULL	NULL	39010
	Potamogeton vaginatus Turcz.	potvag	2016	1	TRUE	NULL	NULL	39053
	Potentilla palustris (L.) Scop.	potpal	2013, 2016, 2019	215	FALSE	NULL	NULL	24676
	Primula egaliksensis Wormsk.	priega	2016, 2019	3	TRUE	NULL	NULL	24022
	Pyrola grandiflora Radius	pyrgra	2013, 2016, 2019	142	FALSE	NULL	NULL	23754
	Pyrola secunda L.	pyrsec1	2013, 2016, 2019	50	FALSE	NULL	NULL	23755
	Pyrola secunda L. ssp. *obtusata* (Turcz.) Hult.	pyrobt	2019	1	FALSE	NULL	NULL	526524
	Pyrola secunda L. ssp. *secunda*	pyrsec2	2013	1	FALSE	NULL	NULL	-999
	Ranunculus gmelini DC.	rangme1	2016	3	TRUE	NULL	NULL	504726
	Ranunculus gmelini DC. ssp. gmelini	rangme	2013	1	FALSE	NULL	NULL	-999
	Ranunculus hyperboreus Rottb.	ranhyp	2013, 2016, 2019	8	TRUE	NULL	NULL	18571
	Ranunculus lapponicus L.	ranlap	2013, 2016, 2019	23	TRUE	NULL	NULL	18620
	Ranunculus pallasii Schlect.	ranpal	2013, 2016, 2019	6	FALSE	NULL	NULL	18572
	Ranunculus reptans L.	ranrep	2016	1	TRUE	NULL	NULL	195002
	Rubus arcticus L.	rubarc1	2016, 2019	4	FALSE	NULL	NULL	24849
	Rubus chamaemorus L.	rubcha	2013, 2016, 2019	28	FALSE	NULL	NULL	24850
	Rumex arcticus Trautv.	rumarc	2013, 2016, 2019	3	TRUE	NULL	NULL	20935
	Sagina intermedia Fenzl	sagint	2016	1	TRUE	NULL	NULL	20020
	Saussurea angustifolia (Willd.) DC.	sauang	2013, 2016, 2019	23	TRUE	NULL	NULL	36075
	Saussurea viscida Hultén	sauvis1	2016	1	FALSE	NULL	NULL	36082
	Saxifraga cernua L.	saxcer	2013, 2016, 2019	30	FALSE	NULL	NULL	24223
	Saxifraga foliolosa R. Br.	saxfol	2013, 2016, 2019	8	TRUE	NULL	NULL	24226
	Saxifraga hieracifolia Waldst. & Kit.	saxhie	2013, 2016, 2019	14	TRUE	NULL	NULL	505021
	Saxifraga hirculus L.	saxhir	2013, 2016, 2019	484	FALSE	NULL	NULL	24228
	Saxifraga punctata L.	saxpun	2013, 2016, 2019	63	FALSE	NULL	NULL	24238
	Saxifraga punctata L. ssp. *nelsoniana* (D. Don) Hult.	saxnel	2016, 2019	8	FALSE	NULL	NULL	24242
	Saxifraga tricuspidata Rottb.	saxtri	2013	1	FALSE	NULL	NULL	24246
	Sedum rosea (L.) Scop. ssp. *integrifolium* (Raf.) Hult.	sedros	2013, 2016, 2019	3	FALSE	NULL	NULL	526670
	Senecio atropurpureus (Ledeb.) Fedtsch.	senatr	2013, 2016, 2019	47	FALSE	NULL	NULL	36085

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Forbs	*Sibbaldia procumbens* L.	sibpro	2013	2	FALSE	NULL	NULL	25308
	Silene acaulis L.	silaca	2013, 2016, 2019	6	FALSE	NULL	NULL	20041
	Stellaria crassifolia Ehrh.	stecra	2016, 2019	3	FALSE	NULL	NULL	20164
	Stellaria humifusa Rottb.	stehum	2013, 2016, 2019	4	TRUE	NULL	NULL	20166
	Stellaria laeta Richards.	stelae	2016	5	FALSE	NULL	NULL	20167
	Stellaria longipes Goldie	stelon1	2013, 2016, 2019	140	TRUE	NULL	NULL	20168
	Taraxacum ceratophorum (Ledeb.) DC.	tarcer	2019	2	TRUE	NULL	NULL	36200
	Tofieldia pusilla (Michx.) Pers.	tofpus	2013, 2016, 2019	12	TRUE	NULL	NULL	43052
	Utricularia intermedia Hayne	utrint	2013, 2016, 2019	24	TRUE	NULL	NULL	34454
	Utricularia minor L.	utrmin	2013, 2016, 2019	8	FALSE	NULL	NULL	34457
	Utricularia vulgaris L. ssp. *macrorhiza* (LeConte) Clauson	utrvul	2013, 2016, 2019	18	TRUE	NULL	NULL	526799
	Valeriana capitata Pall.	valcap	2013, 2016, 2019	127	FALSE	NULL	NULL	35351
	Wilhelmsia physodes (Fisch.) McNeill	wilphy	2013, 2016, 2019	40	TRUE	NULL	NULL	20374
Grasses	*Alopecurus magellanicus* Lam.	alomag	2013, 2016, 2019	68	FALSE	NULL	NULL	782160
	Alopecurus pratensis L.	alopra	2013	1	FALSE	NULL	52	40438
	Anthoxanthum arcticum Veldkamp	antarc	2013, 2016, 2019	106	TRUE	NULL	NULL	565876
	Anthoxanthum hirtum (Schrank) Y. Schouten & Veldkamp	anthir	2013, 2016, 2019	5	TRUE	NULL	NULL	508921
	Anthoxanthum monticola ssp. *alpinum* (Sw. ex Willd.) Soreng	antalp1	2019	1	FALSE	NULL	NULL	797298
	Arctagrostis latifolia (R. Br.) Griseb.	arclat	2013, 2016, 2019	210	FALSE	NULL	NULL	40472
	Arctagrostis latifolia (R. Br.) Griseb. ssp. *latifolia*	arclat1	2016, 2019	9	TRUE	NULL	NULL	524886
	Arctophila fulva (Trin.) Anderss.	arcful	2013, 2016, 2019	17	FALSE	NULL	NULL	500961
	Bromus pumpellianus Scribn.	bropum3	2013, 2016, 2019	18	TRUE	NULL	NULL	40480
	Bromus pumpellianus Scribn. var.*pumpellianus*	bropum1	2019	1	FALSE	NULL	NULL	798288
	Bromus pumpellianus ssp. *pumpellianus* Scribn.	bropum5	2016, 2019	2	TRUE	NULL	NULL	797312
	Calamagrostis canadensis (Michx.) P. Beauv.	calcan	2013	2	FALSE	NULL	NULL	40544
	Calamagrostis deschampsioides Trin.	caldes	2016	1	TRUE	NULL	NULL	40531
	Calamagrostis stricta ssp. *inexpansa* (A. Gray) C.W. Greene	caline1	2013, 2016	2	TRUE	NULL	NULL	523717
	Calamagrostis stricta (Timm) Koeler ssp. *stricta*	calstr1	2019	1	TRUE	NULL	NULL	523718
	Cinna latifolia (Trev. ex Goepp.) Griseb.	cinlat2	2019	2	FALSE	NULL	NULL	40584
	Deschampsia cespitosa (L.) P. Beauv.	desces	2013, 2016, 2019	49	TRUE	NULL	NULL	502001
	Deschampsia cespitosa (L.) P. Beauv. ssp. *cespitosa*	desces1	2019	2	TRUE	NULL	NULL	523960
	Deschampsia sukatschewii (Popl.) Roshev.	dessuk	2019	1	TRUE	NULL	NULL	512189

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Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Grasses	*Dupontia fisheri* R. Br.	dupfis1	2013, 2016, 2019	149	TRUE	NULL	NULL	502186
	Elymus macrourus (Turcz. ex Steud.) Tzvelev	elymac	2013, 2016, 2019	16	TRUE	NULL	NULL	502269
	Elymus violaceus (Hornem.) Feilberg	elyvio1	2013	1	FALSE	NULL	NULL	783180
	Festuca baffinensis Polunin	fesbaf	2013, 2016, 2019	5	TRUE	NULL	NULL	40793
	Festuca brachyphylla Schult. & Schult. f.	fesbra	2013, 2016, 2019	23	TRUE	NULL	NULL	40794
	Festuca rubra L.	fesrub	2013, 2016, 2019	115	TRUE	NULL	NULL	40796
	Festuca rubra ssp. *arctica* (Hack.) Govor.	fesarc	2013, 2016, 2019	12	TRUE	NULL	NULL	524072
	Festuca rubra ssp. *pruinosa* (Hack.) Piper	fesrub3	2016	1	TRUE	NULL	NULL	524076
	Koeleria asiatica Domin	koeasi	2019	1	TRUE	NULL	NULL	41804
	Leymus mollis (Trin.) Pilg.	leymol1	2016, 2019	9	FALSE	NULL	NULL	503437
	Leymus mollis (Trin.) Pilg. ssp. *mollis* (Trin.) Hulten	leymol	2013, 2016, 2019	22	FALSE	NULL	NULL	524229
	Phippsia algida (Soland.) R. Br.	phialg	2019	2	TRUE	NULL	NULL	41059
	Poa alpina L.	poaalp1	2013, 2019	4	FALSE	NULL	NULL	41076
	Poa arctica R. Br.	poaarc	2013, 2016, 2019	242	TRUE	NULL	NULL	41077
	Poa arctica ssp. *arctica* R. Br.	poaarc1	2016, 2019	23	TRUE	NULL	NULL	41078
	Poa arctica ssp. *lanata* (Scribn. & Merr.) Soreng	poalan1	2013, 2019	2	TRUE	NULL	NULL	524985
	Poa glauca M. Vahl.	poagla	2013, 2016, 2019	6	TRUE	NULL	NULL	41084
	Poa glauca ssp. *glauca* Vahl	poagla1	2016	1	TRUE	NULL	NULL	524542
	Poa pratensis L.	poapra	2016	2	TRUE	NULL	NULL	41088
	Poa pratensis ssp. *alpigena* (Lindm.) Hiitonen	poaalp3	2016, 2019	9	TRUE	NULL	NULL	797439
	Poa sublanata Reverd.	poasub	2019	1	TRUE	NULL	NULL	784741
	Puccinellia nuttalliana (Schult.) Hitchc.	pucnut1	2019	1	TRUE	NULL	NULL	41200
	Puccinellia phryganodes (Trin.) Scribner & Marr.	pucphr	2016, 2019	3	TRUE	NULL	NULL	41192
	Puccinellia vaginata (Lange) Fern. & Weath.	pucvag	2013, 2016, 2019	4	TRUE	NULL	NULL	41195
	Trisetum spicatum (L.) K. Richt.	trispi1	2013, 2016, 2019	29	TRUE	NULL	NULL	41294
Lichens	*Alectoria ochroleuca* (Hoffm.) A. Massal.	aleoch	2019	2	TRUE	NULL	NULL	-999
	Bryocaulon divergens (Ach.) Kärnefelt	brydiv	2019	1	TRUE	NULL	NULL	190567
	Cetraria islandica (L.) Ach.	cetisl	2013, 2016, 2019	35	TRUE	NULL	NULL	190618
	Cetraria islandica (L.) Ach. ssp. *islandica*	cetisl2	2013	2	FALSE	NULL	NULL	-999
	Cladina mitis (Sandst.) Hustich	clamit	2019	1	FALSE	NULL	NULL	-999
	Cladonia cariosa (Ach.) Spreng.	clacar1	2013	1	TRUE	NULL	NULL	189863
	Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel	clachl	2019	1	TRUE	NULL	NULL	189870

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Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Lichens	*Cladonia cornuta* (L.) Hoffm.	clacor	2013	1	FALSE	NULL	NULL	189873
	Cladonia ecmocyna Leighton	claecm	2013	1	FALSE	NULL	NULL	189893
	Cladonia fimbriata (L.) Fr.	clafim	2016	1	TRUE	NULL	NULL	189897
	Cladonia furcata (Hudson) Schrader	clafur	2013	1	TRUE	NULL	NULL	189900
	Cladonia pyxidata (L.) Hoffm.	clapyx	2013, 2016	5	TRUE	NULL	NULL	189956
	Cladonia squamosa Hoffm.	clasqu	2013, 2019	3	FALSE	NULL	NULL	189968
	Cladonia subfurcata (Nyl.) Arnold	clasub	2016	1	TRUE	NULL	NULL	189976
	Dactylina arctica (Richardson) Nyl.	dacarc	2013, 2016, 2019	22	FALSE	NULL	NULL	190651
	*Flavocetraria cucullata (*Bellardi) Kärnefelt & Thell	flacuc	2013, 2016, 2019	43	FALSE	NULL	NULL	-999
	Flavocetraria nivalis (L.) Kärnefelt & Thell	flaniv	2013	2	FALSE	NULL	NULL	-999
	Lobaria linita (Ach.) Rabenh.	loblin	2013, 2016, 2019	13	TRUE	NULL	NULL	191259
	Masonhalea richardsonii (Hook.)	masric	2013, 2019	2	FALSE	NULL	NULL	190698
	Nephroma arcticum (L.) Torss.	neparc	2013, 2016, 2019	4	FALSE	NULL	NULL	191286
	Nephroma expallidum (Nyl.) Nyl.	nepexp	2013, 2016, 2019	12	TRUE	NULL	NULL	191288
	Ochrolechia frigida (Sw.) Lynge	ochfri	2019	2	FALSE	NULL	NULL	14019
	Parmelia saxatilis (L.) Ach.	parsax	2013, 2019	3	TRUE	NULL	NULL	14010
	Peltigera aphthosa (L.) Willd.	pelaph	2013, 2016, 2019	164	TRUE	NULL	NULL	191224
	Peltigera canina (L.) Willd.	pelcan	2013, 2016, 2019	14	TRUE	NULL	NULL	191226
	Peltigera didactyla (With.) J. R. Laundon	peldid	2013	4	TRUE	NULL	NULL	191229
	Peltigera leucophlebia (Nyl.) Gyelnik	pelleu	2013, 2016, 2019	13	TRUE	NULL	NULL	191237
	Peltigera rufescens (Weiss) Humb.	pelruf	2013, 2019	6	TRUE	NULL	NULL	191246
	Psoroma hypnorum (Vahl) Gray	psohyp	2019	2	FALSE	NULL	NULL	191463
	Sphaerophorus fragilis (L.) Pers.	sphfra	2019	1	TRUE	NULL	NULL	-999
	Stereocaulon alpinum Laurer ex Funck	stealp	2013	2	TRUE	NULL	NULL	-999
	Thamnolia subuliformis (Ehrh.) Culb.	thasub	2016	1	FALSE	NULL	NULL	192029
	Thamnolia vermicularis (Sw.) Ach. ex Schaerer	thaver	2013, 2016, 2019	17	FALSE	NULL	NULL	192030
Liverworts	*Aneura pinguis* (L.) Dumort.	anepin	2016, 2019	126	TRUE	NULL	NULL	15461
	Blepharostoma trichophyllum (L.) Dum.	bletri	2013, 2016, 2019	7	TRUE	NULL	NULL	14254
	Marchantia polymorpha L	marpol	2013, 2016, 2019	21	TRUE	NULL	NULL	15587
	Mesoptychia sahlbergii (Lindb. & Arnell) A. Evans	messah	2019	4	TRUE	NULL	NULL	14686
	Moerckia hibernica (Hook.) Gott.	moehib	2019	2	TRUE	NULL	NULL	15446
	Pseudolepicolea fryei (Perss.) Grolle & Ando	psefry	2019	1	TRUE	NULL	NULL	14247

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Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Liverworts	*Ptilidium ciliare* (L.) Hampe	pticil	2016, 2019	2	FALSE	NULL	NULL	14281
	Scapania paludicola Loeske & Müll. Frib.	scapal	2016	1	FALSE	NULL	NULL	15108
	Tritomaria quinquedentata (Huds.) H. Buch	triqui	2019	2	TRUE	NULL	NULL	14838
Mosses	*Abietinella abietina* (Hedw.) Fleisch.	abiabi	2013, 2016, 2019	51	TRUE	NULL	NULL	547520
	Arnellia fennica (Gott.) Lindb.	arnfen	2016	1	TRUE	NULL	NULL	14667
	Aulacomnium acuminatum (Lindb. & Arnell) Kindb.	aulacu	2013, 2016, 2019	6	FALSE	NULL	NULL	547552
	Aulacomnium palustre (Hedw.) Schwaegr.	aulpal	2013, 2016, 2019	289	TRUE	NULL	NULL	547555
	Aulacomnium turgidum (Wahlenb.) Schwaegr.	aultur	2013, 2016, 2019	319	TRUE	NULL	NULL	547556
	Brachythecium albicans (Hedw.) B.S.G.	braalb	2016	4	TRUE	NULL	NULL	16248
	Brachythecium mildeanum (Schimp.) Schimp. ex Milde	bramil	2013, 2016, 2019	17	TRUE	NULL	NULL	547586
	Brachythecium salebrosum (Web. et Mohr) B.S.G.	brasal	2016, 2019	6	TRUE	NULL	NULL	16249
	Brachythecium turgidum (Hartm.) Kindb.	bratur	2013, 2016, 2019	19	TRUE	NULL	NULL	16250
	Bryoerythrophyllum ferruginascens (Stirt.) Giac.	bryfer	2019	1	TRUE	NULL	NULL	547601
	Bryoerythrophyllum recurvirostrum (Hedw.) Chen	bryrec1	2013, 2019	2	TRUE	NULL	NULL	16706
	Bryum cyclophyllum (Schwägr.) Bruch & Schimp.	brycyc	2019	1	TRUE	NULL	NULL	15969
	Bryum pseudotriquetrum (Hedw.) Gaertn. et al.	brypse	2013, 2016, 2019	82	TRUE	NULL	NULL	15975
	Bryum rutilans Brid.	bryrut	2013	1	TRUE	NULL	NULL	547639
	Calliergon cordifolium (Hedw.) Kindb.	calcor	2019	3	TRUE	NULL	NULL	16185
	Calliergon giganteum (Schimp.) Kindb.	calgig	2013, 2016, 2019	110	TRUE	NULL	NULL	16188
	Calliergon richardsonii (Mitt.) Kindb. in Warnst.	calric	2016, 2019	173	TRUE	NULL	NULL	16186
	Calliergon stramineum (Brid.) Kindb.	calstr	2013, 2019	2	FALSE	NULL	NULL	16189
	Campylium polygamum (B.S.G.) C.Jens.	campol	2013	3	TRUE	NULL	NULL	16215
	Campylium stellatum (Hedw.) C.E.O. Jensen var. *arcticum* (R.S. Williams) Sav.-Ljub.	camarc1	2013, 2016, 2019	117	TRUE	NULL	NULL	549351
	Campylium stellatum (Hedw.) C.Jens.	camste1	2013, 2016, 2019	447	TRUE	NULL	NULL	16212
	Catoscopium nigritum (Hedw.) Brid.	catnig	2013, 2016, 2019	16	TRUE	NULL	NULL	16119
	Ceratodon purpureus (Hedw.) Brid.	cerpur	2013, 2016, 2019	12	TRUE	NULL	NULL	16864
	Cinclidium arcticum B.S.G.	cinarc	2016	12	FALSE	NULL	NULL	16052
	Cinclidium latifolium Lindb.	cinlat1	2013, 2016, 2019	289	TRUE	NULL	NULL	547669
	Cinclidium stygium Sw. in Schrad.	cinsty	2016, 2019	19	TRUE	NULL	NULL	16051
	Cinclidium subrotundum Lindb.	cinsub	2013, 2019	2	TRUE	NULL	NULL	547670
	Cirriphyllum cirrosum (Schwaegr.) Grout	circir	2013, 2016, 2019	13	TRUE	NULL	NULL	547672
	Climacium dendroides (Hedw.) Web. et Mohr.	cliden	2013, 2016, 2019	14	TRUE	NULL	NULL	16451

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Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Mosses	*Cratoneuron filicinum* (Hedw.) Spruce	crafil	2016	1	TRUE	NULL	NULL	16168
	Cyrtomnium hymenophyllum (B.S.G.) Holmen	cyrhym	2016	1	TRUE	NULL	NULL	547700
	Desmatodon heimii (Hedw.) Mitt.	deshei1	2019	2	TRUE	NULL	NULL	16672
	Desmatodon heimii (Hedw.) Mitt. var. *arctica* (Lindb.) H.A. Crum	desarc	2013, 2019	2	TRUE	NULL	NULL	549358
	Desmatodon heimii (Hedw.) Mitt. var. heimii	deshei	2016	1	TRUE	NULL	NULL	549357
	Dicranella subulata (Hedw.) Schimp.	dicsub	2019	1	TRUE	NULL	NULL	16819
	Dicranum angustum Lindb.	dicang	2013	1	TRUE	NULL	NULL	547718
	Dicranum brevifolium (Lindb.) Lindb.	dicbre	2016	2	TRUE	NULL	NULL	547720
	Dicranum elongatum Schleich. ex Schwaegr.	dicelo	2013, 2019	9	TRUE	NULL	NULL	16772
	Dicranum groenlandicum Brid.	dicgro	2016, 2019	17	TRUE	NULL	NULL	547721
	Dicranum majus Sm.	dicmaj	2013	2	TRUE	NULL	NULL	16764
	Dicranum scoparium Hedw.	dicsco	2019	2	TRUE	NULL	NULL	16763
	Dicranum spadiceum Zett.	dicspa	2013, 2016	3	TRUE	NULL	NULL	547727
	Distichium capillaceum (Hedw.) B.S.G.	discap	2013, 2016, 2019	243	TRUE	NULL	NULL	16867
	Distichium inclinatum (Hedw.) B.S.G.	disinc	2013	1	TRUE	NULL	NULL	16868
	Ditrichum flexicaule (Schwaegr.) Hampe	ditfle	2013, 2016, 2019	13	TRUE	NULL	NULL	16857
	Drepanocladus aduncus (Hedw.) Warnst. s.l.	dreadu	2013, 2016, 2019	10	TRUE	NULL	NULL	16171
	Drepanocladus brevifolius (Lindb.) Warnst.	drebre	2013, 2016, 2019	75	TRUE	NULL	NULL	547743
	Drepanocladus sendtneri (Schimp. ex C.Muell.) Warnst.	dresen	2013	4	TRUE	NULL	NULL	547747
	Drepanocladus sordidus (Müller Hal.) Hedenas	dresor	2016, 2019	3	TRUE	NULL	NULL	-999
	Encalypta affinis R. Hedwig	encaff	2016	1	TRUE	NULL	NULL	548237
	Encalypta alpina Sm.	encalp	2013, 2016	2	TRUE	NULL	NULL	547750
	Encalypta rhaptocarpa Schwägr.	encrha	2013, 2016	3	TRUE	NULL	NULL	547759
	Entodon concinnus (De Not.) Par.	entcon	2013, 2016	3	TRUE	NULL	NULL	16394
	Eurhynchium pulchellum (Hedw.) Jenn.	eurpul	2013, 2016, 2019	5	TRUE	NULL	NULL	16261
	Fissidens adianthoides Hedwig	fisadi1	2013	1	TRUE	NULL	NULL	16910
	Fissidens osmundioides Hedw.	fisosm	2016, 2019	5	TRUE	NULL	NULL	16903
	Funaria hygrometrica Hedw.	funhyg	2019	1	FALSE	NULL	NULL	15818
	Hamatocaulis lapponicus (Norrl.) Hedenäs	hamlap	2019	2	TRUE	NULL	NULL	547834
	Hamatocaulis vernicosus (Mitt.) Hedenaes	hamver	2013, 2016, 2019	103	TRUE	NULL	NULL	547835
	Hylocomium splendens (Hedw.) B.S.G.	hylspl	2013, 2016, 2019	235	TRUE	NULL	NULL	16375
	Hypnum bambergeri Schimp.	hypbam	2013, 2019	12	TRUE	NULL	NULL	16311

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Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Mosses	*Hypnum lindbergii* Mitt.	hyplin	2013, 2016, 2019	15	TRUE	NULL	NULL	16314
	Leptobryum pyriforme (Hedw.) Wils.	leppyr1	2016, 2019	19	TRUE	NULL	NULL	16018
	Limprichtia cossonii (Schimp.) Anderson et al.	limcos	2016, 2019	9	TRUE	NULL	NULL	547893
	Limprichtia revolvens (Sw.) Loeske	limrev	2013, 2016, 2019	409	TRUE	NULL	NULL	547894
	Loeskypnum badium (Hartm.) Paul	loebad	2016, 2019	2	TRUE	NULL	NULL	547897
	Meesia longiseta Hedw.	meelon	2013, 2016, 2019	10	TRUE	NULL	NULL	16115
	Meesia triquetra (Richter) Aongstr.	meetri	2013, 2016, 2019	467	TRUE	NULL	NULL	16116
	Meesia uliginosa Hedw.	meeuli	2013, 2016, 2019	22	TRUE	NULL	NULL	16114
	Mnium blyttii B. S.G.	mnibly	2019	1	TRUE	NULL	NULL	547906
	Myurella julacea (Schwaegr.) B.S.G.	myujul	2013, 2016, 2019	5	TRUE	NULL	NULL	16154
	Myurella tenerrima (Brid.) Lindb.	myuten	2016	1	TRUE	NULL	NULL	547911
	Oncophorus virens (Hedw.) Brid.	oncvir	2013, 2016	5	TRUE	NULL	NULL	16796
	Oncophorus wahlenbergii Brid.	oncwah	2013, 2016, 2019	253	TRUE	NULL	NULL	16798
	Orthothecium chryseum (Schwägr.) Schimp.	ortchr1	2013, 2016, 2019	67	TRUE	NULL	NULL	548243
	Paludella squarrosa (Hedw.) Brid.	palsqu	2013, 2016	5	TRUE	NULL	NULL	16110
	Philonotis fontana (Hedw.) Brid.	phifon	2016, 2019	14	TRUE	NULL	NULL	16076
	Philonotis fontana (Hedw.) Brid. var. *pumila* (Turner) Brid.	phipum	2013	2	TRUE	NULL	NULL	16079
	Plagiomnium ellipticum (Brid.) T.Kop.	plaell	2013, 2016, 2019	46	TRUE	NULL	NULL	547964
	Plagiomnium medium (Bruch & Schimp.) T. Kop.	plamed	2016	1	TRUE	NULL	NULL	548245
	Pleurozium schreberi (Brid.) Mitt.	plesch	2019	9	TRUE	NULL	NULL	16373
	Pohlia crudoides (Sull. & Lesq.) Broth.	pohcru1	2019	1	TRUE	NULL	NULL	547987
	Pohlia nutans (Hedw.) Lindb.	pohnut	2016, 2019	14	TRUE	NULL	NULL	16006
	Polytrichastrum alpinum (Hedw.) G.L.Sm.	polalp	2016	5	TRUE	NULL	NULL	548247
	Polytrichum commune Hedw.	polcom	2013, 2019	2	FALSE	NULL	NULL	15759
	Polytrichum commune Hedw. var. jensenii (I. Hagen) Mönk.	poljen1	2013, 2016, 2019	40	TRUE	NULL	NULL	549431
	Polytrichum hyperboreum R.Br.	polhyp	2019	3	TRUE	NULL	NULL	547999
	Polytrichum juniperinum Hedw.	poljun	2013, 2016, 2019	31	TRUE	NULL	NULL	15762
	Polytrichum strictum Brid.	polstr	2013, 2019	2	TRUE	NULL	NULL	548005
	Polytrichum swartzii Hartm.	polswa	2016, 2019	2	TRUE	NULL	NULL	548006
	Pseudocalliergon turgescens (T.Jens.) Loeske	psetur	2013, 2016, 2019	6	TRUE	NULL	NULL	548018
	Psilopilum cavifolium (Wilson) I. Hagen	psicav	2019	2	TRUE	NULL	NULL	548035
	Racomitrium canescens (Hedw.) Brid.	raccan	2016	1	FALSE	NULL	NULL	548239

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Mosses	*Racomitrium lanuginosum* (Hedw.) Brid.	raclan	2019	1	TRUE	NULL	NULL	548055
	Rhizomnium andrewsianum (Steere) T. Kop.	rhiand	2013	2	FALSE	NULL	NULL	548073
	Rhizomnium magnifolium (Horik.) T. Kop.	rhimag	2013	5	FALSE	NULL	NULL	548077
	Rhytidium rugosum (Hedw.) Kindb.	rhyrug	2013, 2016, 2019	17	TRUE	NULL	NULL	16388
	Sanionia uncinata (Hedw.) Loeske	sanunc	2013, 2016, 2019	68	TRUE	NULL	NULL	548225
	Sarmenthypnum sarmentosum (Wahlenb.) Tuom. & T. Kop.	sarsar1	2013, 2016, 2019	6	TRUE	NULL	NULL	548087
	Scorpidium scorpioides (Hedw.) Limpr.	scosco	2013, 2016, 2019	296	TRUE	NULL	NULL	16196
	Sphagnum angustifolium (Russ. ex Russ.) C. Jens	sphang	2016	1	TRUE	NULL	NULL	548193
	Sphagnum fimbriatum Wils.	sphfim	2016, 2019	8	TRUE	NULL	NULL	15742
	Sphagnum orientale Sav.-Ljub.	sphori	2016, 2019	3	TRUE	NULL	NULL	548209
	Sphagnum rubellum Wils.	sphrub	2019	1	TRUE	NULL	NULL	548213
	Sphagnum squarrosum Crome	sphsqu	2013, 2019	2	TRUE	NULL	NULL	15698
	Sphagnum subsecundum Nees ex Sturm	sphsub	2013, 2019	6	TRUE	NULL	NULL	15722
	Sphagnum warnstorfii Russ.	sphwar	2019	2	TRUE	NULL	NULL	15740
	Tetraplodon mnioides (Hedw.) Bruch & Schimp. in B.S.G.	tetmni	2019	1	TRUE	NULL	NULL	15867
	Thuidium recognitum (Hedw.) Lindb.	thurec	2016	1	FALSE	NULL	NULL	16130
	Timmia austriaca Hedw.	timaus	2013, 2016, 2019	33	TRUE	NULL	NULL	16071
	Timmia megapolitana Hedw.	timmeg	2016	5	TRUE	NULL	NULL	16072
	Timmia norvegica Zett.	timnor1	2019	4	TRUE	NULL	NULL	16070
	Tomentypnum nitens (Hedw.) Loeske	tomnit	2013, 2016, 2019	666	TRUE	NULL	NULL	548133
	Tortella tortuosa (Hedw.) Limpr.	tortor	2013, 2019	7	TRUE	NULL	NULL	16662
	Tortula ruralis (Hedw.) Gaertn., Meyer, & Scherb.	torrur	2013, 2016, 2019	4	TRUE	NULL	NULL	16632
Rushes	*Juncus arcticus* Willd.	junarc	2013, 2016, 2019	20	FALSE	NULL	NULL	39222
	Juncus arcticus Willd. ssp. *alaskanus* Hult.	junala	2019	2	TRUE	NULL	NULL	524195
	Juncus biglumis L.	junbig	2013, 2016, 2019	55	TRUE	NULL	NULL	39225
	Juncus castaneus Sm.	juncas1	2016, 2019	2	FALSE	NULL	NULL	39229
	Juncus triglumis L.	juntri	2013, 2016, 2019	108	TRUE	NULL	NULL	39239
	Luzula arctica Blytt.	luzarc1	2013, 2016, 2019	14	TRUE	NULL	NULL	39331
	Luzula arcuata (Wahlenb.) Sw.	luzarc2	2016, 2019	5	FALSE	NULL	NULL	39337
	Luzula arcuata (Wahlenb.) Sw. ssp. *Unalaschcensis* (Buchenau) Hult.	luzuna	2013	1	TRUE	NULL	NULL	524283
	Luzula confusa Lindeb.	luzcon	2016	1	TRUE	NULL	NULL	39332
	Luzula multiflora (Retz.) Lej.	luzmul	2013, 2016, 2019	22	TRUE	NULL	NULL	39333

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Rushes	*Luzula multiflora* (Retz.) Lej. ssp. *multiflora* var. *kjellmaniana* (Miyabe & Kudo) Sam.	luzkje	2013	3	TRUE	NULL	NULL	-999
	Luzula multiflora ssp. *frigida* (Buchenau) V.I. Krecz.	luzfri	2016	3	TRUE	NULL	NULL	524284
	Luzula spicata (L.) DC.	luzspi	2013, 2016	2	FALSE	NULL	NULL	39350
	Luzula tundricola Gorodk.	luztun	2013, 2016, 2019	130	TRUE	NULL	NULL	39334
Sedges	*Carex amblyorhyncha* Krecz.	caramb	2013, 2016, 2019	153	TRUE	NULL	NULL	39490
	Carex aquatilis Wahlenb.	caraqu1	2019	311	FALSE	NULL	NULL	39374
	Carex aquatilis Wahlenb. ssp. *aquatilis*	caraqu	2013, 2016	623	FALSE	NULL	NULL	-999
	Carex atrata L.	caratr5	2019	1	FALSE	NULL	NULL	808384
	Carex atrofusca Schkuhr	caratr1	2013, 2016, 2019	61	TRUE	NULL	NULL	39511
	Carex aurea Nutt.	caraur	2013	2	FALSE	NULL	NULL	39445
	Carex bicolor All.	carbic	2013, 2016, 2019	7	TRUE	NULL	NULL	39377
	Carex bigelowii Torr.	carbig	2013, 2016, 2019	206	TRUE	NULL	NULL	39378
	Carex capillaris L.	carcap1	2013, 2016, 2019	26	TRUE	NULL	NULL	39540
	Carex chordorrhiza Ehrh.	carcho	2013, 2016, 2019	379	TRUE	NULL	NULL	39547
	Carex krausei Boeck.	carkra	2013, 2016, 2019	137	TRUE	NULL	NULL	39407
	Carex magellanica Lam. ssp. *irrigua* (Wahlenb.) Hult.	carmag	2019	1	FALSE	NULL	NULL	523770
	Carex maritima Gunn.	carmar	2013, 2016, 2019	17	TRUE	NULL	NULL	39419
	Carex membranacea Hook.	carmem	2013, 2016, 2019	17	FALSE	NULL	NULL	39420
	Carex misandra R. Br.	carmis	2013, 2016, 2019	19	TRUE	NULL	NULL	39422
	Carex praegracilis W. Boott	carpra	2016	1	FALSE	NULL	NULL	39767
	Carex rariflora (Wahlenb.) Smith	carrar	2013, 2016, 2019	330	TRUE	NULL	NULL	39427
	Carex rotundata Wahlenb.	carrot	2013, 2016, 2019	46	TRUE	NULL	NULL	39430
	Carex saxatilis L. ssp. *laxa* (Trautv.) Kalela	carsax	2013, 2016, 2019	202	FALSE	NULL	NULL	525417
	Carex scirpoidea Michx.	carsci	2016	1	FALSE	NULL	NULL	39799
	Carex subspathacea Wormsk.	carsub	2013	1	TRUE	NULL	NULL	39436
	Carex ursina Dew.	carurs	2019	1	TRUE	NULL	NULL	39440
	Carex vaginata Tausch	carvag	2013, 2016, 2019	15	FALSE	NULL	NULL	39859
	Carex williamsii Britt.	carwil	2013, 2016, 2019	86	TRUE	NULL	NULL	39872
	Eriophorum angustifolium Honck.	eriang1	2016, 2019	311	FALSE	NULL	NULL	40080
	Eriophorum angustifolium Honck. ssp. *subarcticum* (V. Vassiljev) Hult.	eriang	2013, 2016, 2019	569	FALSE	NULL	NULL	40083
	Eriophorum russeolum E. Fries var *albidum* Nyl.	erialb	2019	7	TRUE	NULL	NULL	808548
	Eriophorum russeolum Fries	erirus	2013, 2016, 2019	456	TRUE	NULL	NULL	40085

Appendix A. Continued.

Lifeform	Scientific Name	ABR Species Code	Sample Years	Number of Occurrences	Voucher Specimen	AK/Global/Federal Listing	AKEPIC Invasiveness Rank	ITIS TSN
Sedges	*Eriophorum russeolum* Fries ssp. *rufescens* (Andersson) Hyl.	eriruf	2016	3	TRUE	NULL	NULL	40087
	Eriophorum scheuchzeri Hoppe	erisch	2013, 2016	19	FALSE	NULL	NULL	40088
	Eriophorum vaginatum L.	erivag	2013, 2016, 2019	118	FALSE	NULL	NULL	40104
	Kobresia myosuroides (Vill.) Fiori & Paol.	kobmyo	2013, 2016	2	TRUE	NULL	NULL	40140

Appendix B. Integrated Taxonomic Information System (ITIS) database synonymy table for ABR taxa that are either not accepted or not recognized for plants found in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2019.

Lifeform	Scientific Name	ABR Species Code	ABR Taxon TSN	ITIS Accepted Name	Accepted TSN	ABR Taxon Status
Deciduous Shrubs	*Alnus fruticosa* Rupr.	alnfru	-999	*Alnus viridis* ssp. *fruticosa* (Rupr.) Nyman	525225	not recognized
Evergreen Shrubs	*Ledum decumbens* (Aiton) Lodd. ex Steud.	leddec	23541	*Rhododendron tomentosum* Harmaja	894434	not accepted
Forbs	*Arabis lyrata* L. ssp. *kamchatica* (Fisch.) Hult.	aralyr	184311	*Arabidopsis lyrata* ssp. *kamchatica* (Fisch. ex DC.) O'Kane & Al-Shehbaz	823326	not accepted
	Arnica frigida C.A. Mey.	arnfri	184943	*Arnica griscomii* ssp. *frigida* (C.A. Mey. ex Iljin) S.J. Wolf	525279	not accepted
	Artemisia arctica Less.	artarc2	35432	*Artemisia norvegica* ssp. *saxatilis* (Besser) H.M. Hall & Clem.	525294	not accepted
	Artemisia arctica Less. ssp. *arctica*	artarc1	35433	*Artemisia norvegica* ssp. *saxatilis* (Besser) H.M. Hall & Clem.	525294	not accepted
	Aster sibiricus L.	astsib	35513	*Eurybia sibirica* (L.) G.L. Nesom	513459	not accepted
	Astragalus alpinus L. ssp. *arcticus* (Bunge) Hultén	astarc	192323	*Astragalus alpinus* var. *alpinus* L.	192322	not accepted
	Astragalus eucosmus Hornem. ssp. *sealei* (LePage) Hult.	astsea	25511	*Astragalus eucosmus* B.L. Rob.	25509	not accepted
	Astragalus eucosmus Robins. ssp. *eucosmus*	asteuc	-999	NULL	NULL	not recognized
	Cardamine hyperborea O.E. Schulz	carhyp	22770	*Cardamine digit*ata Richardson	22791	not accepted
	Cardamine pratensis L. ssp. *angustifolia* (Hook.) O.E. Schultz	carpra1	525385	*Cardamine nymanii* Gand.	510096	not accepted
	Cerastium jenisejense Hult.	cerjen	19956	*Cerastium regeli*i Ostenf.	19960	not accepted
	Chrysanthemum bipinnatum L.	chrbip	35793	*Tanacetum bipinnatum* (L.) Sch. Bip.	36324	not accepted
	Epilobium latifolium L.	epilat	27281	*Chamerion latifolium* (L.) Holub	510758	not accepted
	Gentiana propinqua Richardson	genpro	30066	*Gentianella propinqua* ssp. *propinqua* (Richardson) J.M. Gillett	30067	not accepted
	Gentiana propinqua Richards. ssp. *propinqua*	genpro1	-999	NULL	NULL	not recognized
	Hedysarum alpinum ssp. *americanum* (Michx. ex Pursh) B. Fedtsch.	hedame	525927	*Hedysarum alpinum* L.	26723	not accepted
	Hedysarum mackenzii Richards.	hedmac	-999	*Hedysarum boreale* ssp. *mackenziei* (Richardson) S.L. Welsh	524125	not recognized
	Melandrium affine J. Vahl	melaff	19976	*Silene involucrata* ssp. *involucrata* (Cham. & Schltdl.) Bocquet	524704	not accepted
	Melandrium apetalum (L.) Fenzl.	melape	19977	*Silene uralensis* ssp. *uralensis* (Rupr.) Bocquet	20134	not accepted
	Melandrium apetalum (L.) Fenzl ssp. *arcticum* (E. Fries) Hultén	melarc	526144	*Silene uralensis* ssp. *uralensis* (Rupr.) Bocquet	20134	not accepted
	Myriophyllum spicatum ssp. *exalbescens* (Fern.) Hult.	myrsib	526193	*Myriophyllum sibiricum* Kom.	503906	not accepted
	Oxytropis viscida Nutt.	oxyvis	26183	*Oxytropis borealis* var. *viscida* (Nutt.) S.L. Welsh	531355	not accepted
	Pedicularis kanei Durand	pedkan1	*33354*	*Pedicularis lanata Cham. & Schltdl.*	33364	not accepted
	Polygonum bistorta L. ssp. *plumosum* (Small) Hult.	polbis	526455	*Bistorta plumosa* (Small) Greene	823771	not accepted
	Polygonum viviparum L.	polviv	20864	*Bistorta vivipara* (L.) Delarbre	823849	not accepted
	Potamogeton pectinatus L.	potpec	39010	*Stuckenia pectinata* (L.) Börner	757504	not accepted
	Potamogeton vaginatus Turcz.	potvag	39053	*Stuckenia vaginata* (Turcz.) Holub	757506	not accepted
	Potentilla palustris (L.) Scop.	potpal	24676	*Comarum palustre* L.	501615	not accepted
	Pyrola secunda L.	pyrsec1	23755	*Orthilia secunda* (L.) House	504066	not accepted
	Pyrola secunda L. ssp. *obtusata* (Turcz.) Hult.	pyrobt	526524	*Orthilia secunda* (L.) House	504066	not accepted
	Pyrola secunda L. ssp. *secunda*	pyrsec2	-999	NULL	NULL	not recognized
	Ranunculus gmelini DC. ssp. *gmelini*	rangme	-999	NULL	NULL	not recognized
	Ranunculus reptans L.	ranrep	195002	*Ranunculus flammula* var. *reptans* (L.) E. Mey.	539475	not accepted
	Sagina intermedia Fenzl	sagint	20020	*Sagina nivalis* (Lindblom) Fr.	20030	not accepted

Appendix B. Continued.

Lifeform	Scientific Name	ABR Species Code	ABR Taxon TSN	ITIS Accepted Name	Accepted TSN	ABR Taxon Status
Forbs	*Saussurea viscida* Hultén	sauvis1	36082	*Saussurea angustifolia* var. *viscida* (Hultén) S.L. Welsh	531233	not accepted
	Saxifraga foliolosa R. Br.	saxfol	24226	*Micranthes foliolosa* (R. Br.) Gornall	895005	not accepted
	Saxifraga hieracifolia Waldst. & Kit.	saxhie	505021	*Micranthes hieraciifolia* (Waldst. & Kit. ex Willd.) Haw.	895027	not accepted
	Saxifraga punctata L.	saxpun	24238	*Micranthes nelsoniana* var. *nelsoniana* (D. Don) Small	895081	not accepted
	Saxifraga punctata L. ssp. *nelsoniana* (D. Don) Hult.	saxnel	24242	*Micranthes nelsoniana* var. *nelsoniana* (D. Don) Small	895081	not accepted
	Sedum rosea (L.) Scop. ssp. *integrifolium* (Raf.) Hult.	sedros	526670	*Rhodiola integrifolia* ssp. *integrifolia* Raf.	566078	not accepted
	Senecio atropurpureus (Ledeb.) Fedtsch.	senatr	36085	*Tephroseris integrifolia* ssp. *atropurpurea* (Ledeb.) B. Nord.	526760	not accepted
	Stellaria laeta Richards.	stelae	20167	*Stellaria longipes* ssp. *longipes* Goldie	525013	not accepted
Lichens	*Alectoria ochroleuca* (Hoffm.) A. Massal.	aleoch	-999	NULL	NULL	not recognized
	Cetraria islandica (L.) Ach. ssp. *islandica*	cetisl2	-999	NULL	NULL	not recognized
	Cladina mitis (Sandst.) Hustich	clamit	-999	NULL	NULL	not recognized
	Flavocetraria cucullata (Bellardi) Kärnefelt & Thell	flacuc	-999	NULL	NULL	not recognized
	Flavocetraria nivalis (L.) Kärnefelt & Thell	flaniv	-999	NULL	NULL	not recognized
	Sphaerophorus fragilis (L.) Pers.	sphfra	-999	NULL	NULL	not recognized
	Stereocaulon alpinum Laurer ex Funck	stealp	-999	NULL	NULL	not recognized
Mosses	*Drepanocladus sordidus* (Müller Hal.) Hedenas	dresor	-999	NULL	NULL	not recognized
Rushes	*Juncus arcticus* Willd. ssp. *alaskanus* Hult.	junala	524195	*Juncus arcticus* var. *alaskanus* (Hultén) S.L. Wels*h*	536406	not accepted
	Luzula arctica Blytt.	luzarc1	39331	*Luzula nivalis* (Laest.) Spreng.	817939	not accepted
	Luzula arcuata (Wahlenb.) Sw. ssp. *Unalaschcensis* (Buchenau) Hult.	luzuna	524283	*Luzula arcuata ssp. unalaschkensis* (Buchenau) Hultén	817953	not accepted
	Luzula multiflora (Retz.) Lej. ssp. *multiflora* var. *kjellmaniana* (Miyabe & Kudo) Sam.	luzkje	-999	NULL	NULL	not recognized
	Luzula tundricola Gorodk.	luztun	39334	*Luzula kjellmaniana* Miyabe & Ku*dô*	817943	not accepted
Sedges	*Carex amblyorhyncha* Krecz.	caramb	39490	*Carex marina* Dewey	501244	not accepted
	Carex aquatilis Wahlenb. ssp. *aquatilis*	caraqu	-999	*Carex aquatilis* Wahlenb.	39374	not recognized
	Carex misandra R. Br.	carmis	39422	*Carex fuliginosa* Schkuhr	808391	not accepted
	Carex saxatilis L. ssp. *laxa* (Trautv.) Kalela	carsax	525417	*Carex saxatilis* L.	39431	not accepted
	Eriophorum angustifolium Honck. ssp. *subarcticum* (V. Vassiljev) Hult.	eriang	40083	*Eriophorum angustifolium* ssp. *angustifolium* Honck.	40081	not accepted
	Eriophorum russeolum Fries ssp. *rufescens* (Andersson) Hyl.	eriruf	40087	*Eriophorum chamissonis* C.A. Mey.	40093	not accepted

Appendix C. 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 2019.

Plot Ecotype	Study Area	Vascularity	2013 Species Richness	2013 St. Dev.	2013 Sample Size	2019 Species Richness	2019 St. Dev.	2019 Sample Size	Species Richness Diff.
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	Non-Vascular	3	NULL	1	2	1	2	-1
	Reference	Vascular	11	4	2	12	0	2	1
	Test	Vascular	16	NULL	1	14	NULL	1	-2
Coastal Sandy Moist Brackish Barrens	Reference	Vascular	5	5	5	3	2	5	-2
	Test	Vascular	2	1	3	3	2	4	1
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	Non-Vascular	4	3	13	8	4	13	4
	Reference	Vascular	13	3	13	13	5	13	0
	Test	Non-Vascular	6	2	13	7	4	13	1
	Test	Vascular	12	3	13	14	3	13	2
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Non-Vascular	7	NULL	1	7	NULL	1	0
	Reference	Vascular	16	NULL	1	14	NULL	1	-2
	Test	Non-Vascular	8	2	3	16	5	3	8
	Test	Vascular	15	2	3	15	4	3	0
Riverine Loamy Alkaline Moist Low Willow Shrub	Reference	Non-Vascular	5	3	8	5	2	6	0
	Reference	Vascular	17	2	8	17	2	6	0
	Test	Non-Vascular	3	1	7	10	5	7	7
	Test	Vascular	23	5	7	23	4	7	0
Riverine Loamy Alkaline Moist Mixed Herb	Reference	Vascular	21	NULL	1	22	NULL	1	1
	Test	Vascular	19	2	2	22	1	2	3
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	Non-Vascular	1	0	2	3	1	2	2
	Reference	Vascular	26	1	2	28	4	2	2
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	Non-Vascular	5	3	8	7	5	9	2
	Reference	Vascular	17	4	8	13	4	10	-4
	Test	Non-Vascular	8	4	8	9	5	8	1
	Test	Vascular	19	6	8	18	5	8	-1
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	Non-Vascular	16	9	2	11	4	2	-5
	Reference	Vascular	24	5	2	21	3	2	-3
	Test	Non-Vascular	8	3	5	20	8	5	12
	Test	Vascular	25	4	5	26	3	5	1
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Reference	Non-Vascular	8	2	8	8	3	7	0
	Reference	Vascular	17	5	8	19	4	7	2

Appendix C. Continued.

Plot Ecotype	Study Area	Vascularity	2013 Species Richness	2013 St. Dev.	2013 Sample Size	2019 Species Richness	2019 St. Dev.	2019 Sample Size	Species Richness Diff.
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Test	Non-Vascular	6	3	29	9	4	26	3
	Test	Vascular	15	4	29	15	5	27	0
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	Non-Vascular	9	3	16	10	4	17	1
	Reference	Vascular	21	4	16	21	6	17	0
	Test	Non-Vascular	8	3	19	10	6	21	2
	Test	Vascular	19	3	19	19	5	21	0
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	Non-Vascular	5	NULL	1	23	NULL	1	18
	Reference	Vascular	33	NULL	1	33	NULL	1	0
	Test	Non-Vascular	11	1	2	17	16	2	6
	Test	Vascular	26	5	2	26	4	2	0
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	Non-Vascular	5	NULL	1	7	NULL	1	2
	Reference	Vascular	13	NULL	1	18	NULL	1	5
	Test	Non-Vascular	2	2	3	7	4	2	5
	Test	Vascular	20	6	3	19	5	3	-1

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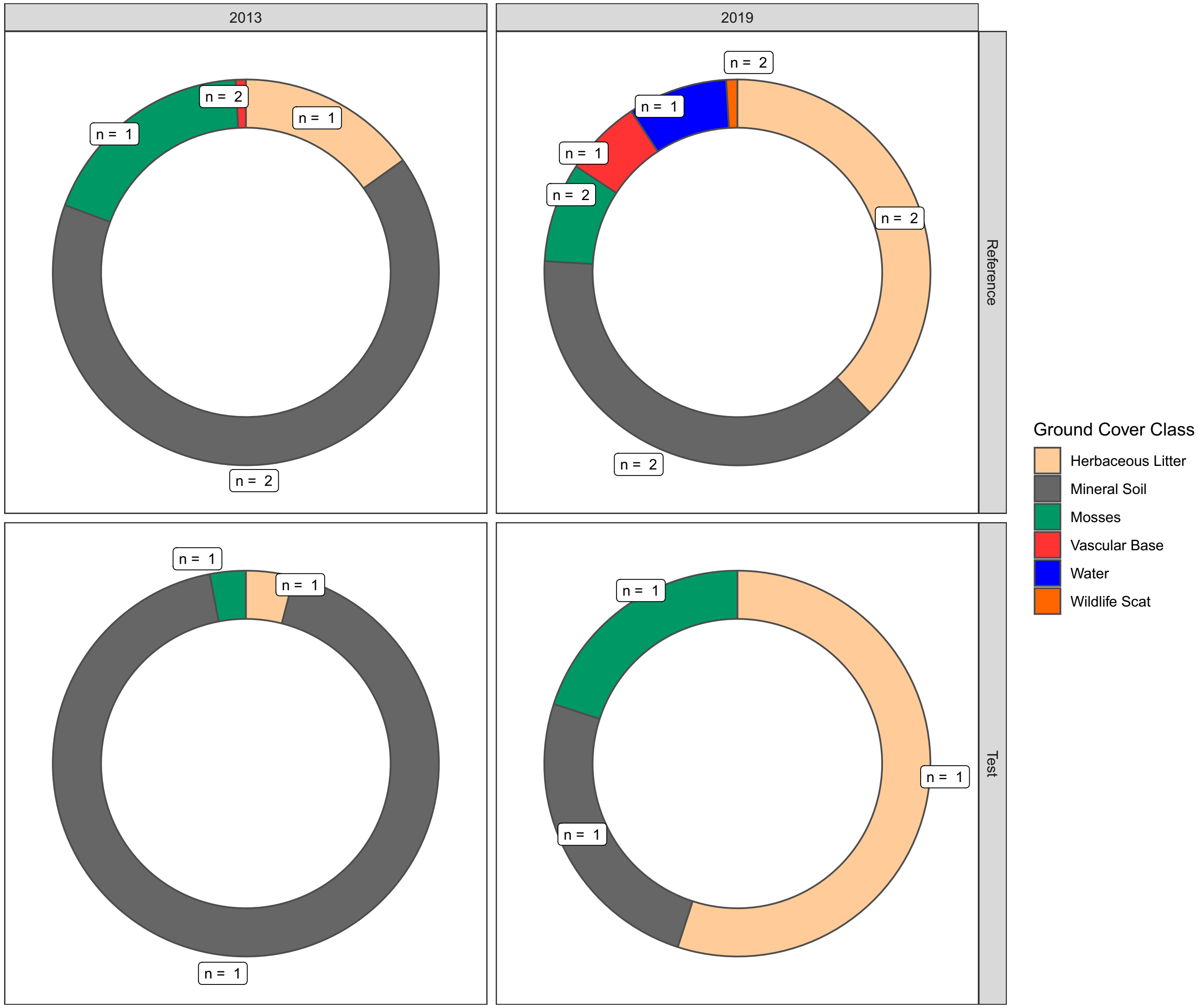
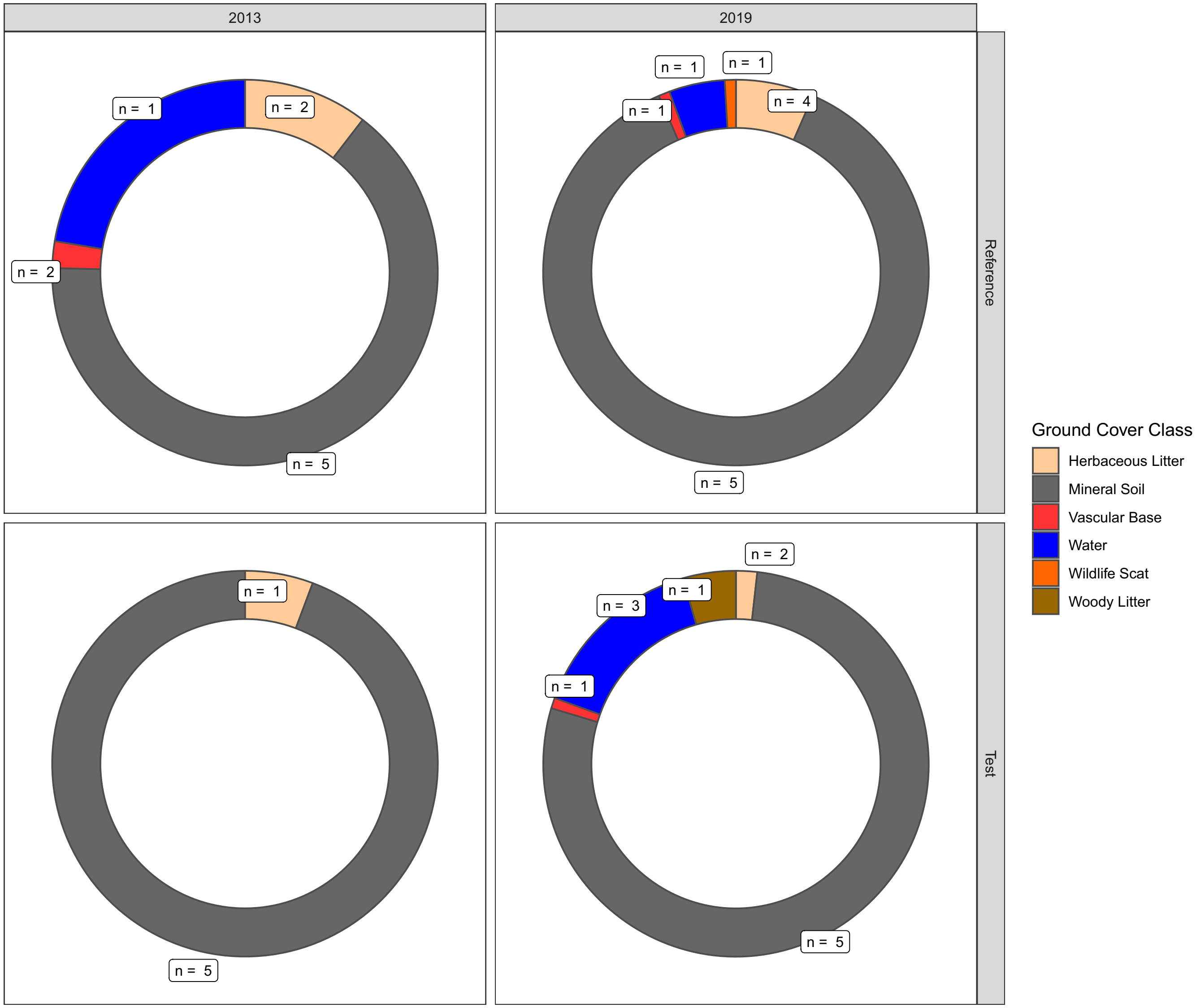
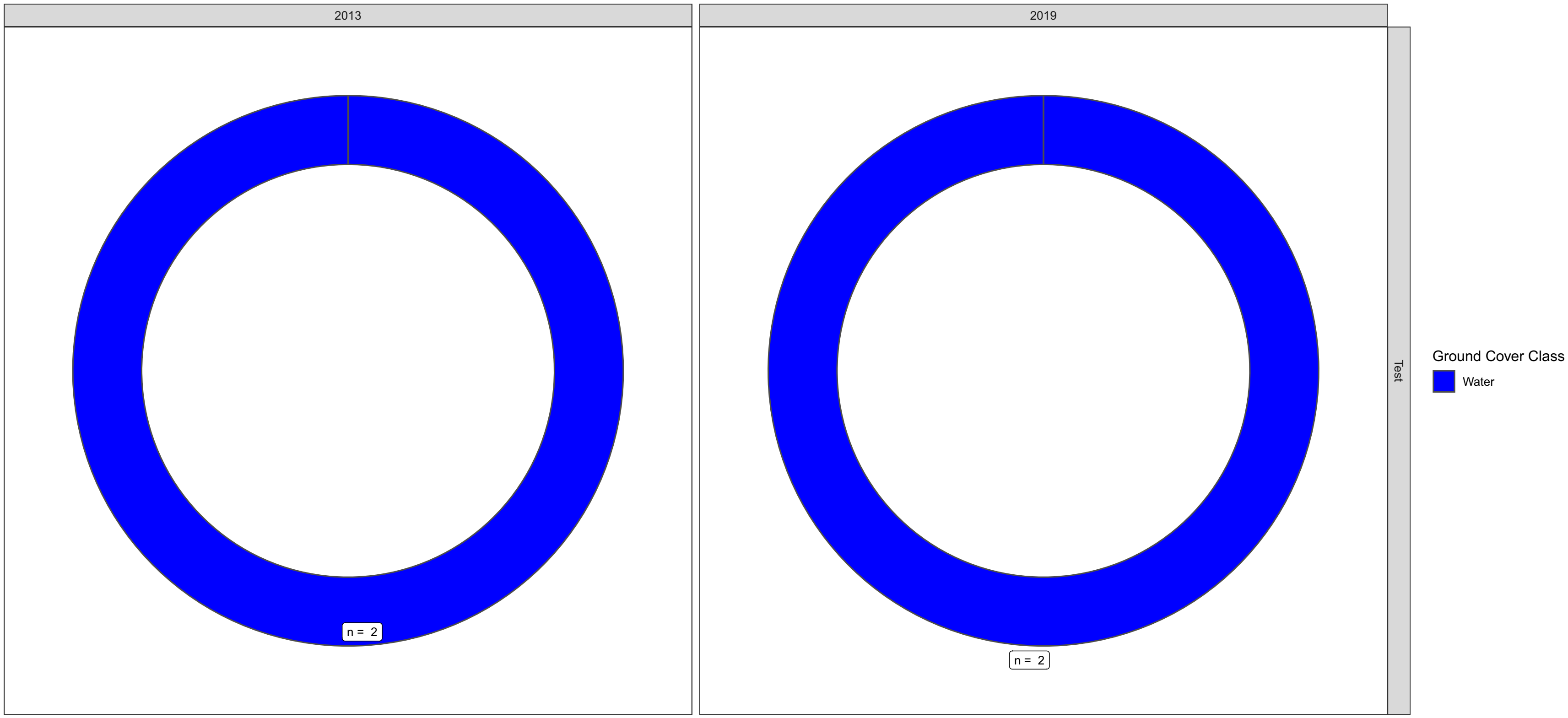


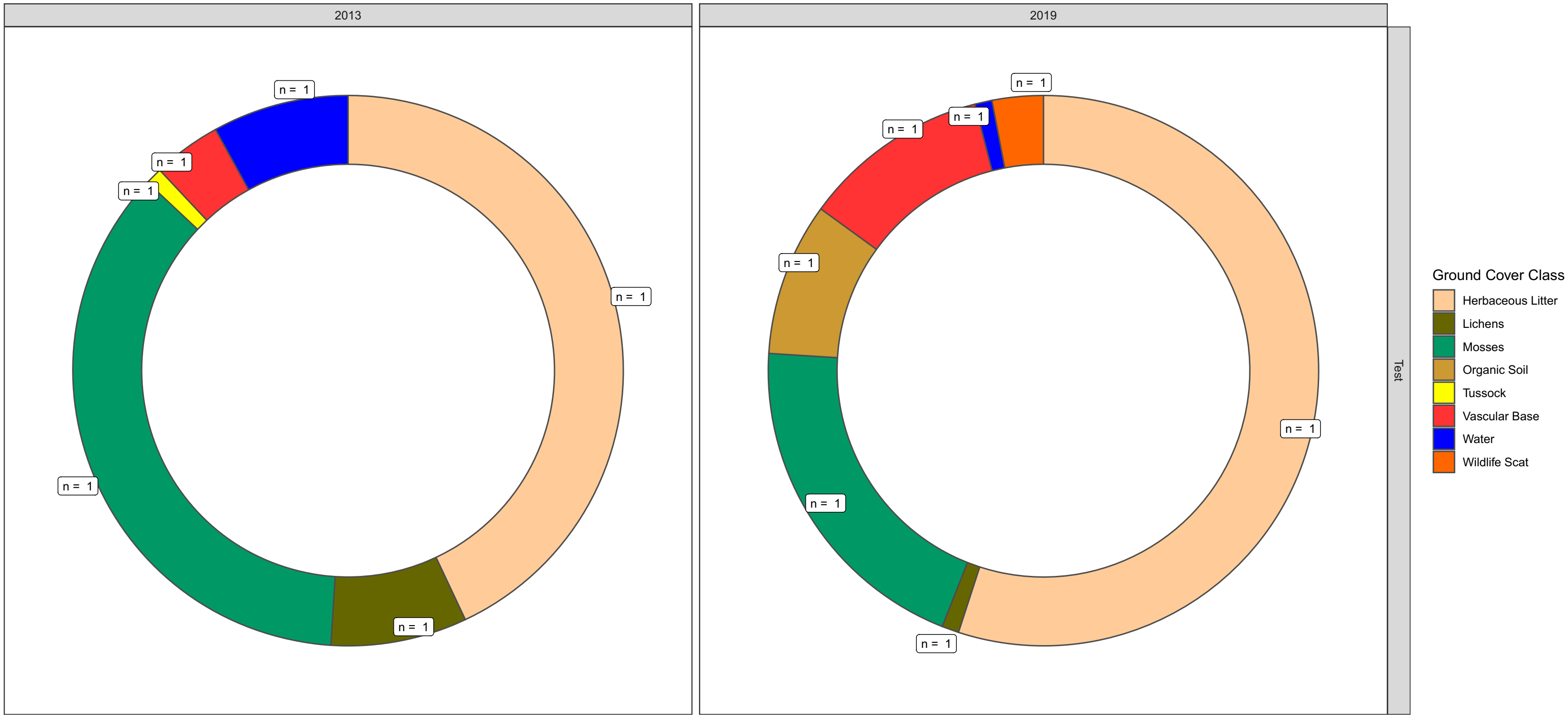
Appendix D1. Ring charts displaying the proportion of average total ground cover for the plot ecotype Coastal Loamy Brackish Moist Willow Dwarf Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



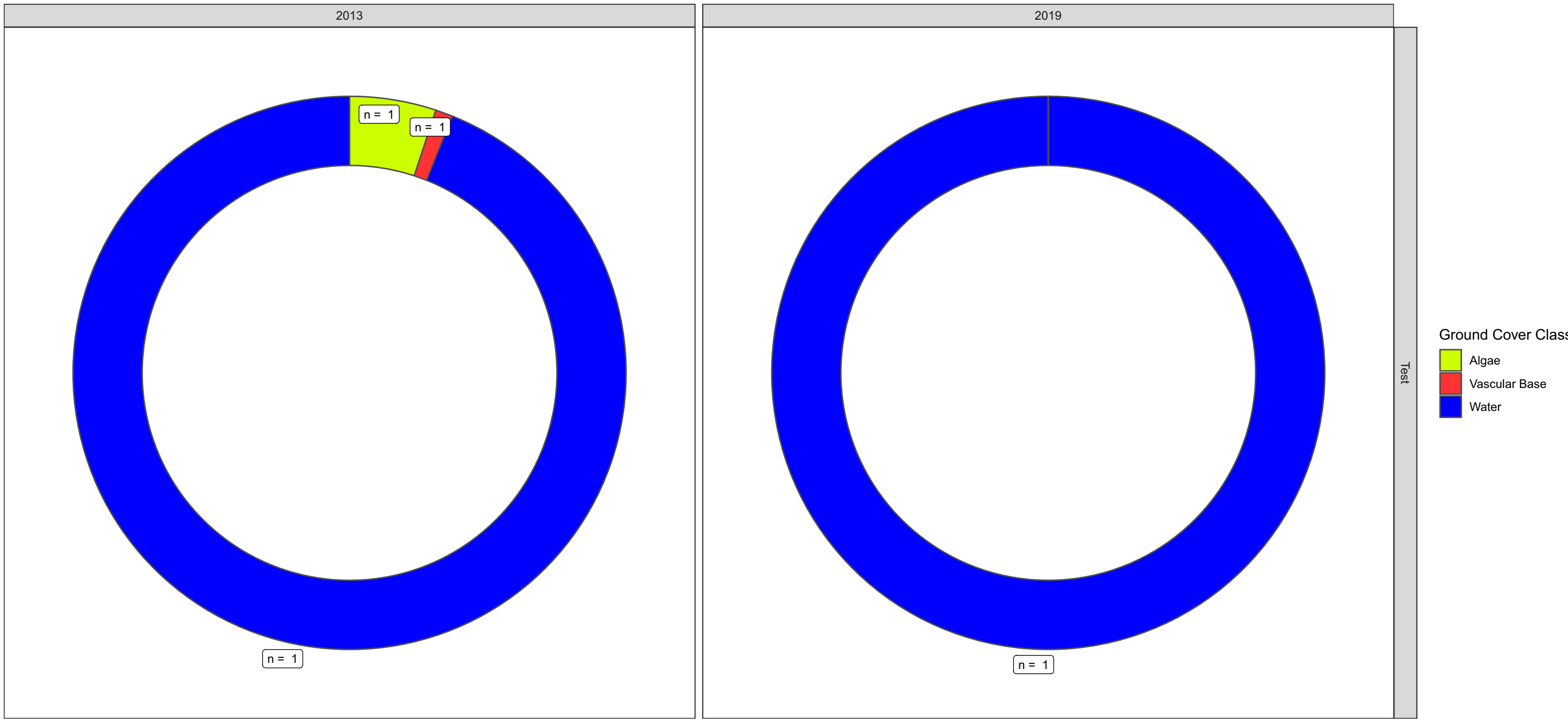
Appendix D2. Ring charts displaying the proportion of average total ground cover for the plot ecotype Coastal Sandy Moist Brackish Barrens by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



Appendix D3. 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 2019.



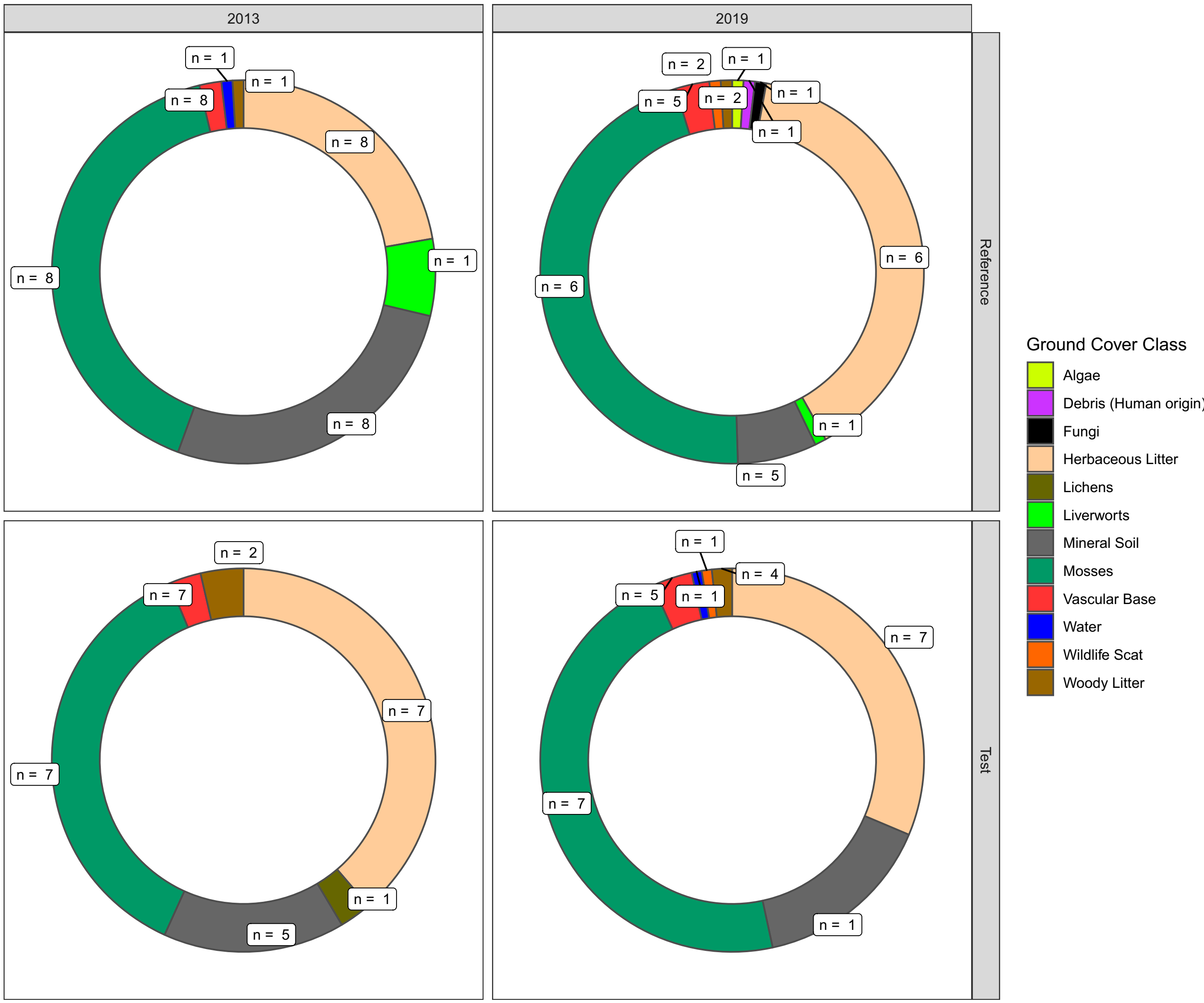
Appendix D4. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



Appendix D5. 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 2019.

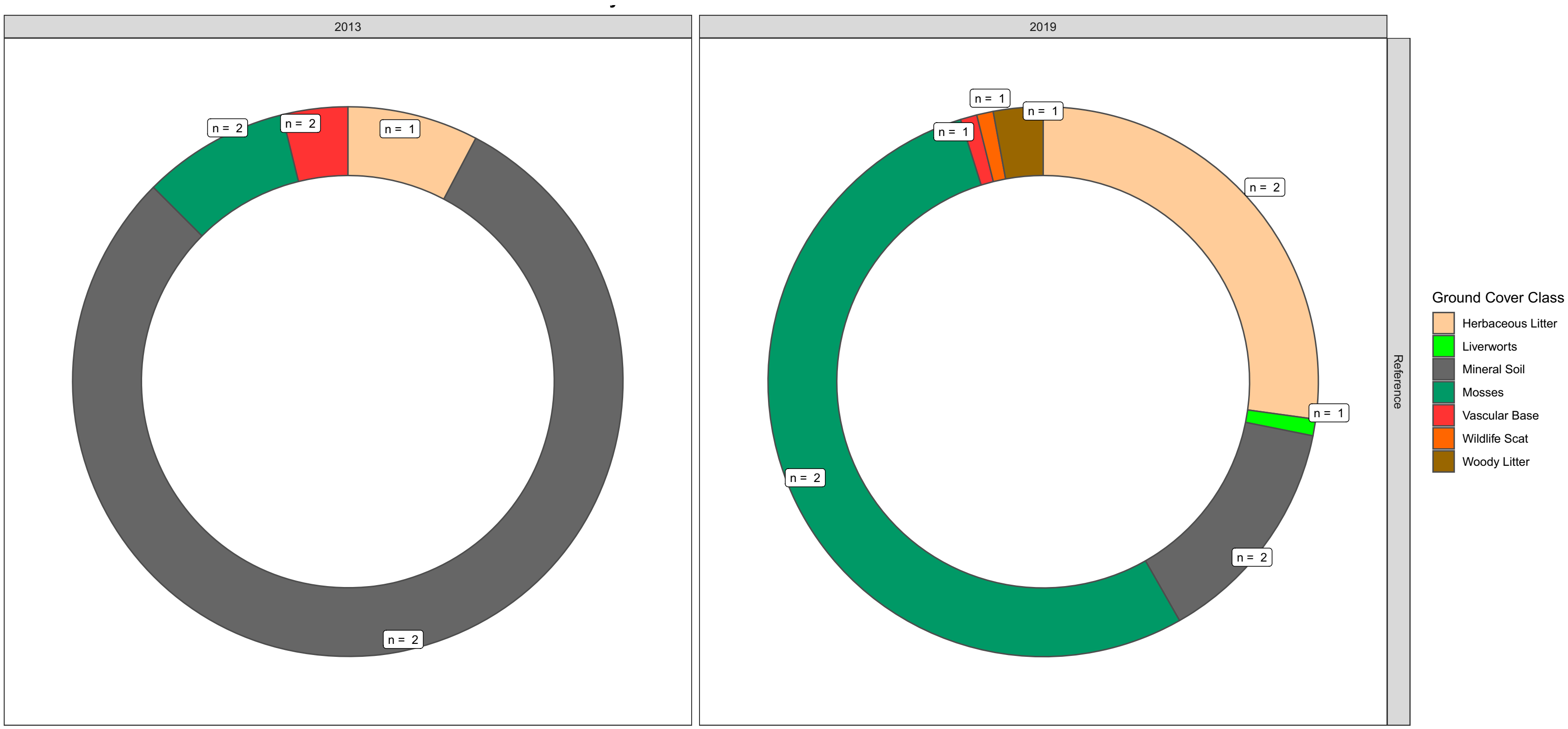
Appendix D6. Ring charts displaying the proportion of average total ground cover for the plot ecotype Lowland Organic-rich Circumneutral Wet Sedge Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Appendix D7. 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 2019.

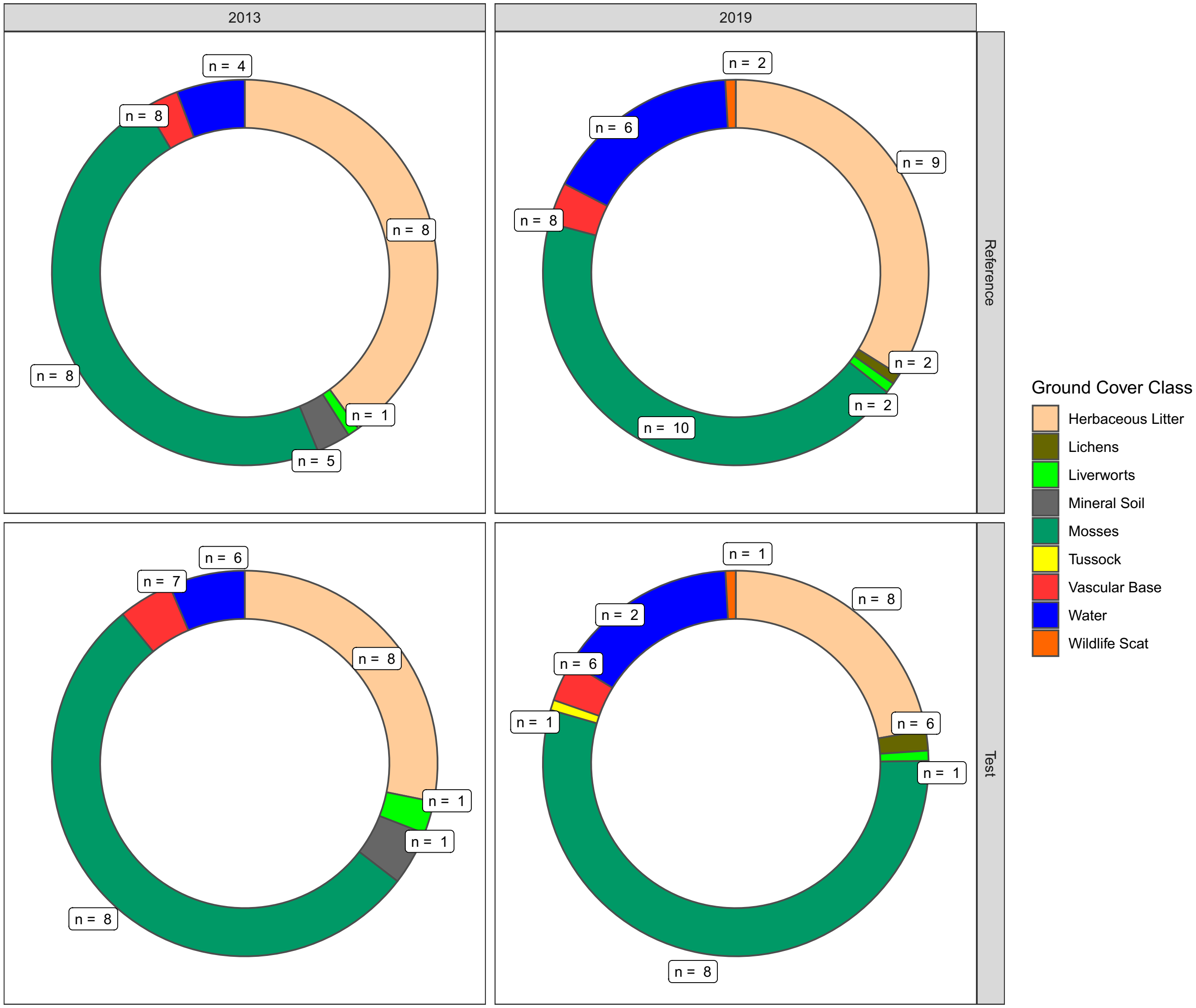


Appendix D8. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Low Willow Shrub by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

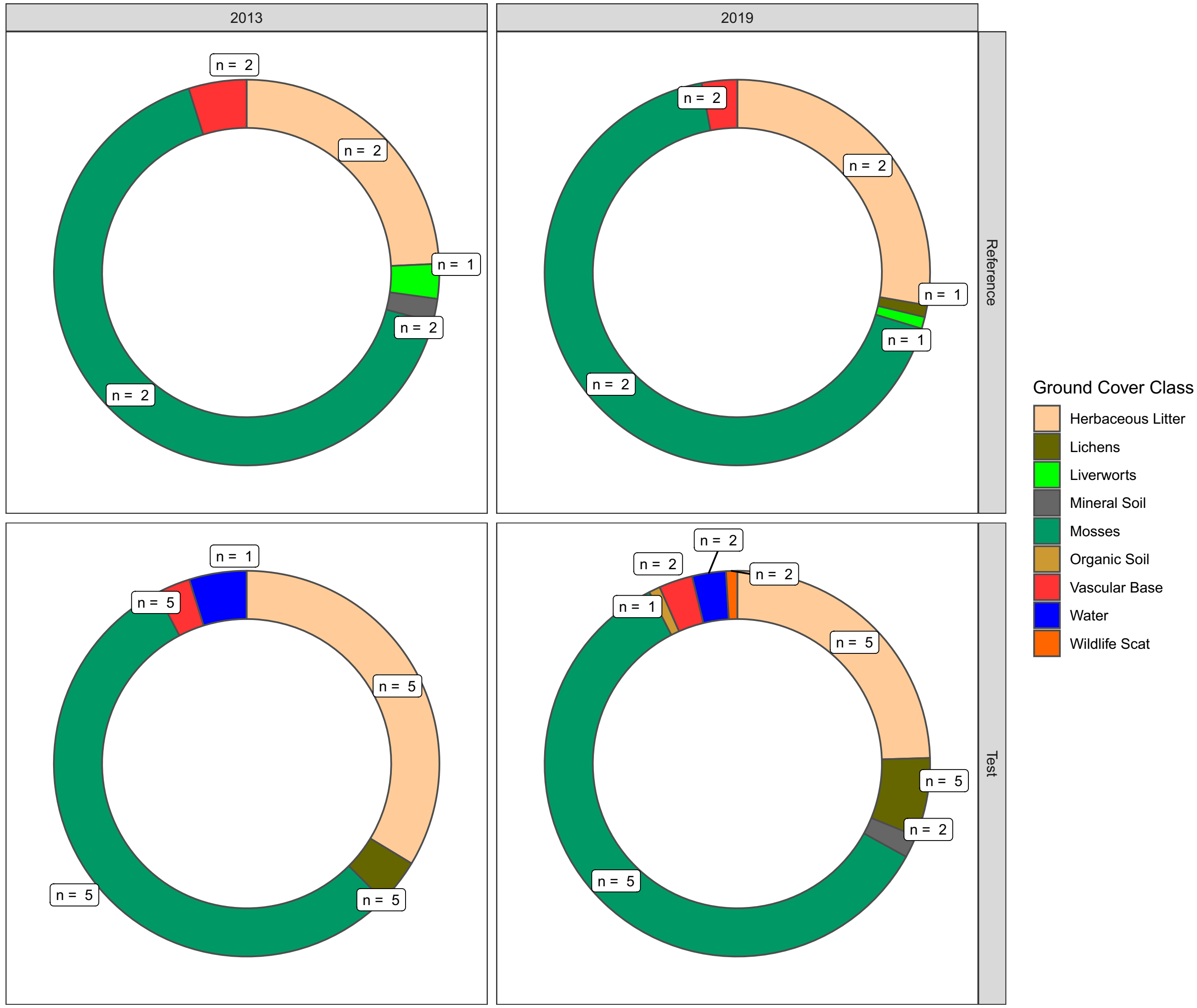
Appendix D9. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Mixed Herb by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



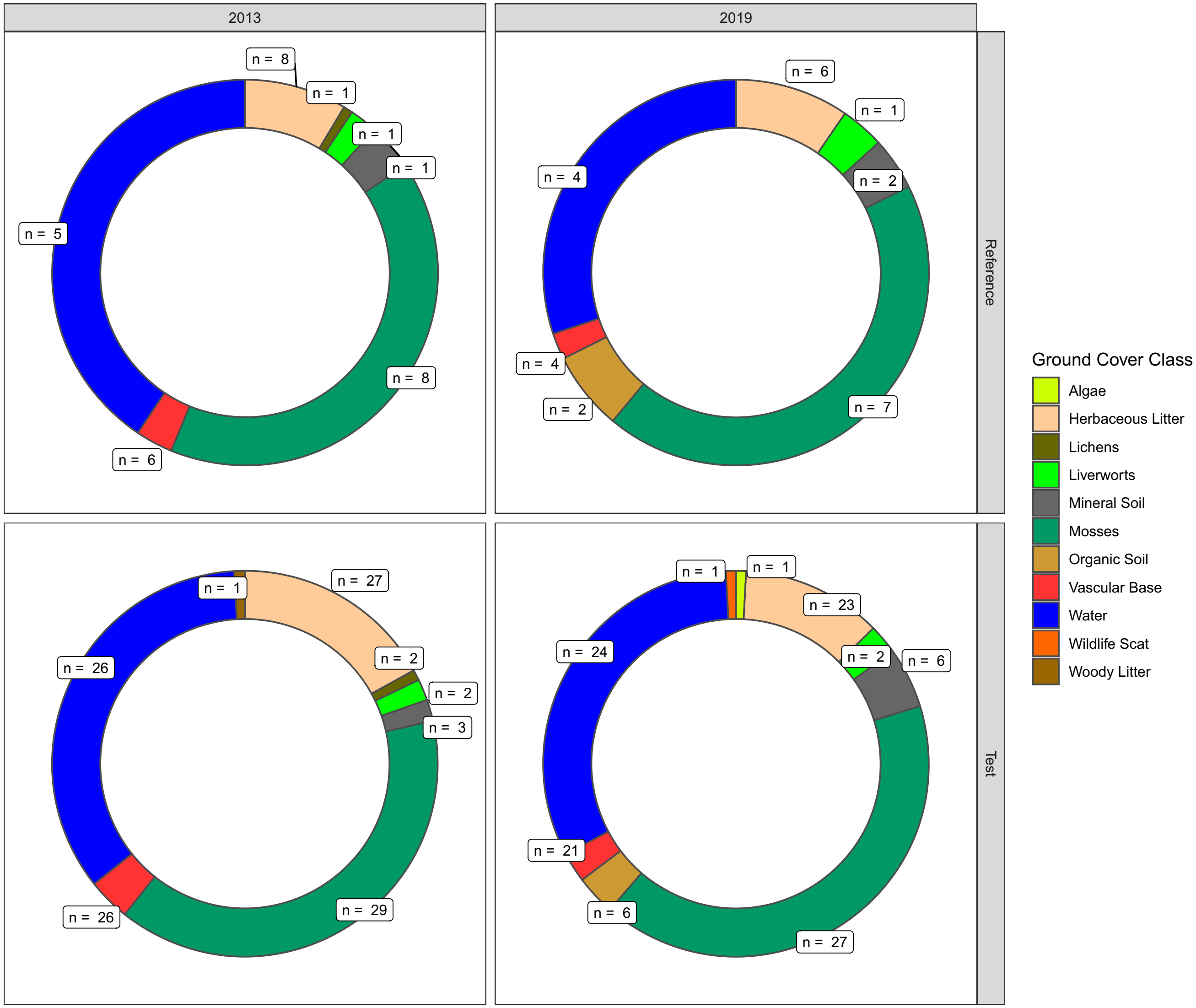
Appendix D10. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy Alkaline Moist Tall Willow Shrub by sample year, Alaska, 2013 and 2019.



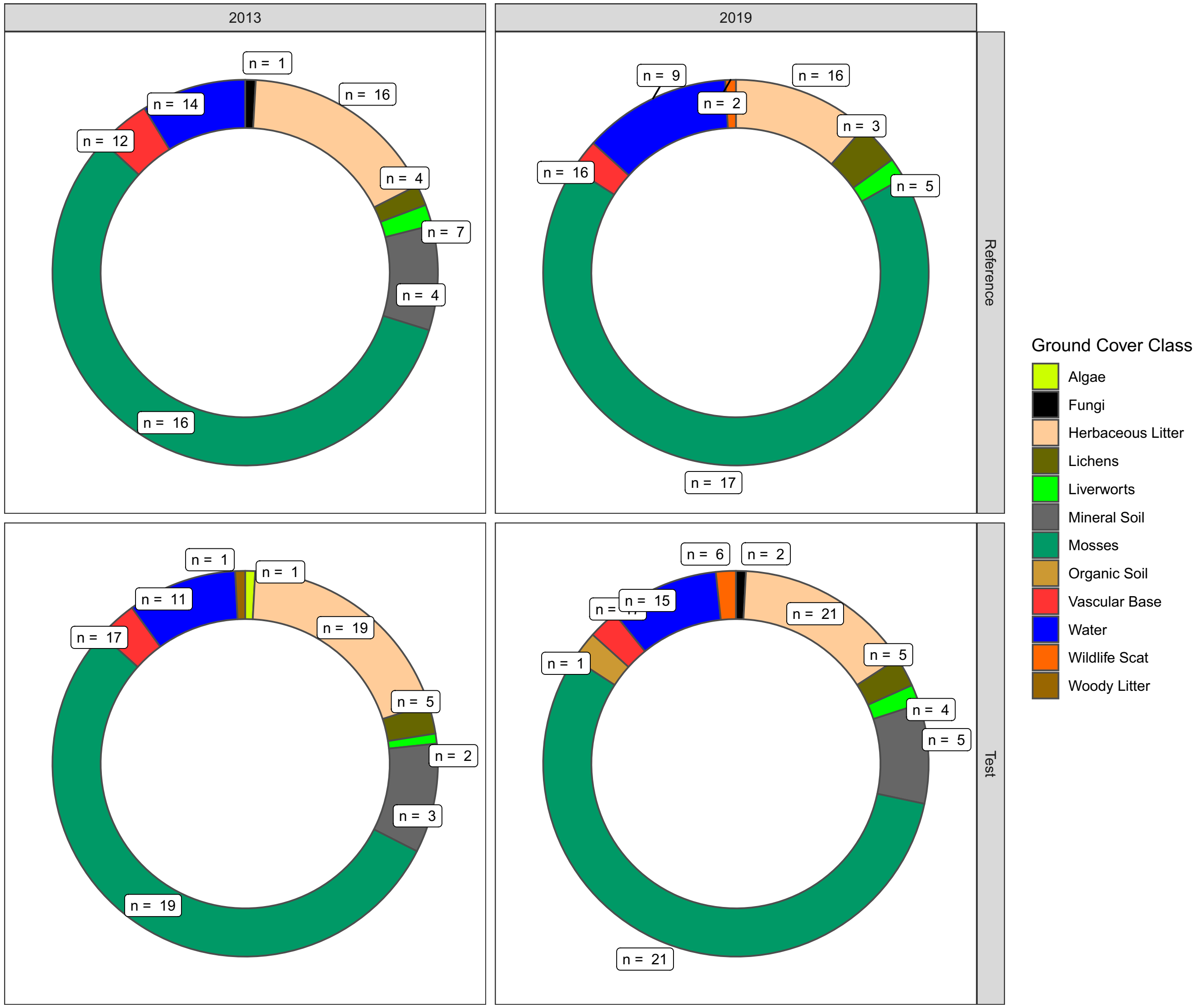
Appendix D11. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



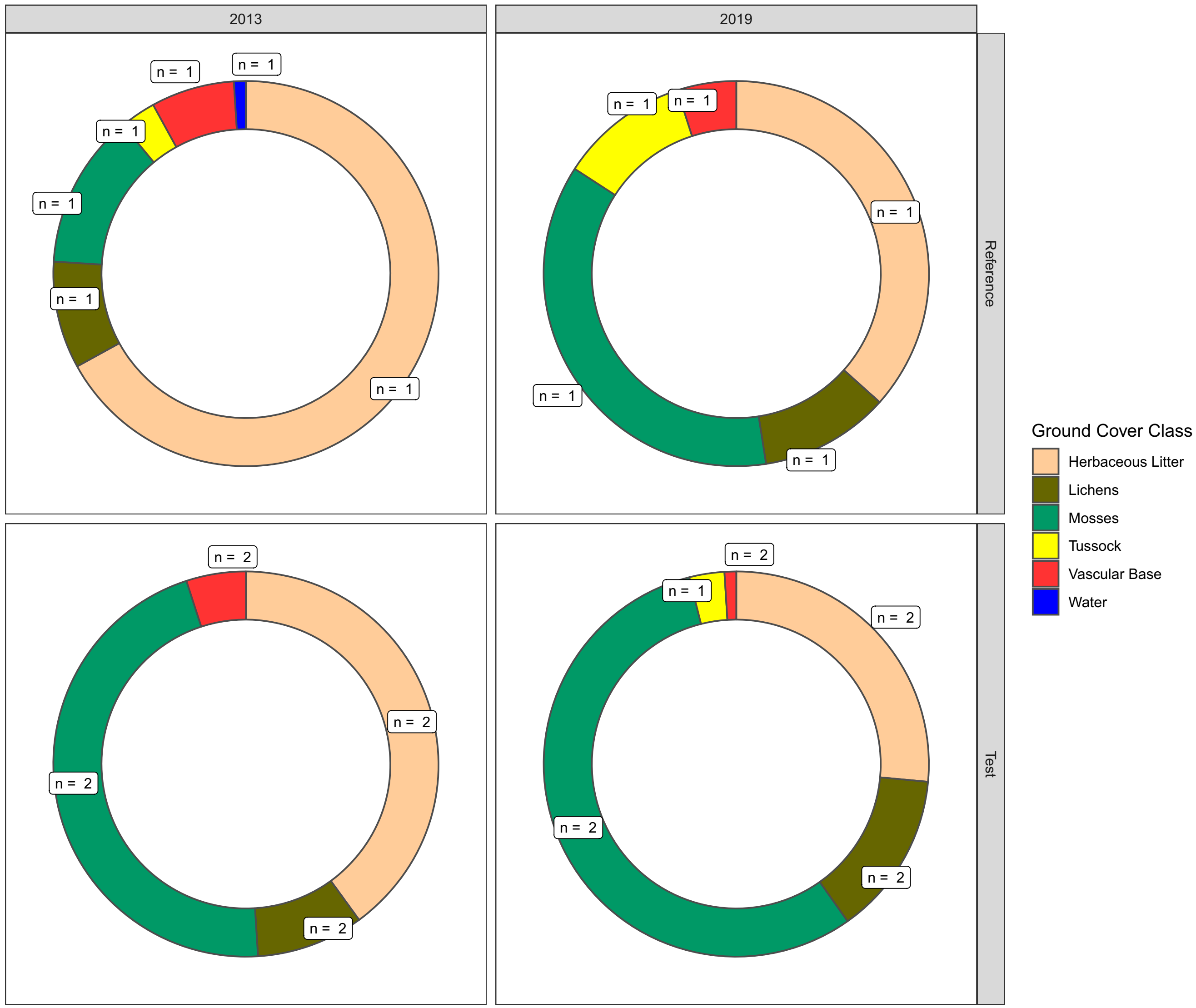
Appendix D12. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



Appendix D13. 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 2019.

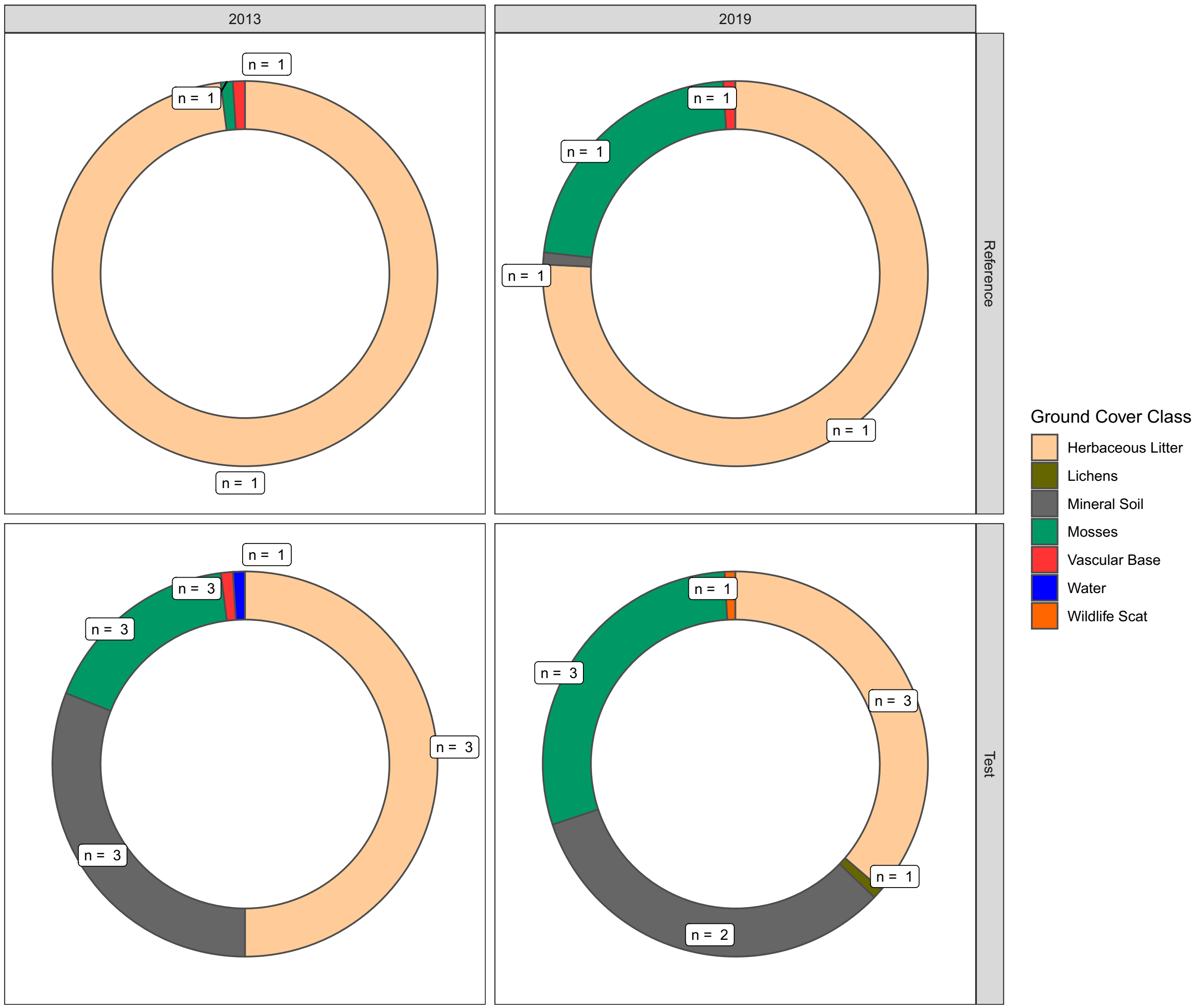


Appendix D14. Ring charts displaying the proportion of average total ground cover for the plot ecotype Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



Appendix D15. 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 2019.

Appendix D16. 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 2019.



Appendix D17. 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 2019.

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Appendix E. 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 2019.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Coastal Loamy Brackish Moist Willow Dwarf Shrub	2013	Reference	Herbaceous Litter	18.4	18.4	18	NULL	1
	2013	Reference	Mineral Soil	57.9	98.7	78	28.8	2
	2013	Reference	Mosses	22.4	22.4	22	NULL	1
	2013	Reference	Vascular Base	1.3	1.3	1	0	2
	2019	Reference	Herbaceous Litter	14.5	67.1	41	37.2	2
	2019	Reference	Mineral Soil	4	77.6	41	52.1	2
	2019	Reference	Mosses	6.6	11.8	9	3.7	2
	2019	Reference	Vascular Base	6.6	6.6	7	NULL	1
	2019	Reference	Water	9.2	9.2	9	NULL	1
	2019	Reference	Wildlife Scat	1.3	1.3	1	0	2
	2013	Test	Herbaceous Litter	4	4	4	NULL	1
	2013	Test	Mineral Soil	93.4	93.4	93	NULL	1
	2013	Test	Mosses	2.6	2.6	3	NULL	1
	2019	Test	Herbaceous Litter	55.3	55.3	55	NULL	1
	2019	Test	Mineral Soil	25	25	25	NULL	1
	2019	Test	Mosses	19.7	19.7	20	NULL	1
Coastal Sandy Moist Brackish Barrens	2013	Reference	Herbaceous Litter	6.6	21.3	14	10.4	2
	2013	Reference	Mineral Soil	68.4	100	87	13.7	5
	2013	Reference	Vascular Base	1.3	5.3	3	2.8	2
	2013	Reference	Water	30.3	30.3	30	NULL	1
	2019	Reference	Herbaceous Litter	1.3	13.2	7	6.5	4
	2019	Reference	Mineral Soil	85.5	100	93	6.6	5
	2019	Reference	Vascular Base	1.3	1.3	1	NULL	1
	2019	Reference	Water	5.3	5.3	5	NULL	1
	2019	Reference	Wildlife Scat	1.3	1.3	1	NULL	1
	2013	Test	Herbaceous Litter	6.3	6.3	6	NULL	1
	2013	Test	Mineral Soil	93.8	100	99	2.8	5
	2019	Test	Herbaceous Litter	1.3	2.6	2	0.9	2
	2019	Test	Mineral Soil	68.4	100	88	13.1	5
	2019	Test	Vascular Base	1.3	1.3	1	NULL	1
	2019	Test	Water	1.3	31.6	17	15.2	3

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Coastal Sandy Moist Brackish Barrens	2019	Test	Woody Litter	5.3	5.3	5	NULL	1
Lowland Lake	2013	Test	Water	100	100	100	0	2
	2019	Test	Water	100	100	100	0	2
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	2013	Test	Herbaceous Litter	43.4	43.4	43	NULL	1
	2013	Test	Lichens	7.9	7.9	8	NULL	1
	2013	Test	Mosses	35.5	35.5	36	NULL	1
	2013	Test	Tussock	1.3	1.3	1	NULL	1
	2013	Test	Vascular Base	4	4	4	NULL	1
	2013	Test	Water	7.9	7.9	8	NULL	1
	2019	Test	Herbaceous Litter	55.3	55.3	55	NULL	1
	2019	Test	Lichens	1.3	1.3	1	NULL	1
	2019	Test	Mosses	19.7	19.7	20	NULL	1
	2019	Test	Organic Soil	9.2	9.2	9	NULL	1
	2019	Test	Vascular Base	10.5	10.5	11	NULL	1
	2019	Test	Water	1.3	1.3	1	NULL	1
	2019	Test	Wildlife Scat	2.6	2.6	3	NULL	1
Lowland Organic-rich Circumneutral Sedge Marsh	2013	Test	Algae	5.3	5.3	5	NULL	1
	2013	Test	Vascular Base	1.3	1.3	1	NULL	1
	2013	Test	Water	93.3	93.3	93	NULL	1
	2019	Test	Water	100	100	100	NULL	1
Lowland Organic-rich Circumneutral Wet Sedge Meadow	2013	Reference	Herbaceous Litter	13.3	23.7	17	4.1	5
	2013	Reference	Lichens	1.3	1.3	1	NULL	1
	2013	Reference	Mosses	1.3	71.1	44	25.9	10
	2013	Reference	Vascular Base	1.3	9.2	4	2.6	11
	2013	Reference	Water	13.2	100	57	36.4	13
	2019	Reference	Herbaceous Litter	1.3	27.6	8	7.7	12
	2019	Reference	Lichens	1.3	1.3	1	NULL	1
	2019	Reference	Mosses	1.3	86.8	40	35.3	12
	2019	Reference	Organic Soil	1.3	2.6	2	0.9	2
	2019	Reference	Vascular Base	1.3	4	3	1.1	10
	2019	Reference	Water	4	98.6	53	37.7	13
	2019	Reference	Woody Litter	1.3	1.3	1	NULL	1

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Lowland Organic-rich Circumneutral Wet Sedge Meadow	2013	Test	Algae	1.3	1.3	1	NULL	1
	2013	Test	Herbaceous Litter	2.6	40.8	18	12.6	10
	2013	Test	Lichens	1.3	1.3	1	NULL	1
	2013	Test	Liverworts	1.3	21.1	11	14	2
	2013	Test	Mosses	10.5	67.1	36	15.9	13
	2013	Test	Vascular Base	1.3	13.3	5	3.6	11
	2013	Test	Water	2.6	71.1	45	25.1	13
	2019	Test	Herbaceous Litter	6.6	29	18	6.9	12
	2019	Test	Liverworts	1.3	1.3	1	NULL	1
	2019	Test	Mineral Soil	2.6	2.6	3	0	3
	2019	Test	Mosses	2.6	81.6	37	23.8	13
	2019	Test	Vascular Base	1.3	6.6	4	2.1	8
	2019	Test	Water	2.6	90.8	43	24.9	13
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	2013	Reference	Herbaceous Litter	4	4	4	NULL	1
	2013	Reference	Mosses	68.4	68.4	68	NULL	1
	2013	Reference	Tussock	1.3	1.3	1	NULL	1
	2013	Reference	Vascular Base	5.3	5.3	5	NULL	1
	2013	Reference	Water	21.1	21.1	21	NULL	1
	2019	Reference	Herbaceous Litter	30.3	30.3	30	NULL	1
	2019	Reference	Mosses	60.5	60.5	61	NULL	1
	2019	Reference	Vascular Base	7.9	7.9	8	NULL	1
	2019	Reference	Water	1.3	1.3	1	NULL	1
	2013	Test	Herbaceous Litter	6.6	30.3	19	11.9	3
	2013	Test	Liverworts	1.3	1.3	1	NULL	1
	2013	Test	Mosses	54	72.4	64	9.2	3
	2013	Test	Vascular Base	1.3	4	3	1.9	2
	2013	Test	Water	11.8	19.7	15	4	3
	2019	Test	Herbaceous Litter	9.2	25	16	8.2	3
	2019	Test	Liverworts	1.3	1.3	1	NULL	1
	2019	Test	Mosses	50	69.7	61	10.1	3
	2019	Test	Organic Soil	1.3	1.3	1	NULL	1
	2019	Test	Vascular Base	1.3	5.3	4	2.3	3

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	2019	Test	Water	9.2	23.7	18	8	3
Outlier	2013	Reference	Herbaceous Litter	7.9	84.2	47	29.6	6
	2013	Reference	Lichens	2.6	2.6	3	NULL	1
	2013	Reference	Mineral Soil	1.3	77.6	21	37.7	4
	2013	Reference	Mosses	6.6	75	34	26.8	6
	2013	Reference	Vascular Base	1.3	6.6	4	2.1	6
	2013	Reference	Water	2.6	2.6	3	NULL	1
	2013	Reference	Woody Litter	1.3	1.3	1	NULL	1
	2019	Reference	Herbaceous Litter	11.8	79	45	27.7	6
	2019	Reference	Lichens	1.3	2.6	2	0.9	2
	2019	Reference	Mineral Soil	1.3	14.5	8	5.4	4
	2019	Reference	Mosses	11.8	88.2	45	30.1	6
	2019	Reference	Vascular Base	4	5.3	5	0.8	4
	2019	Reference	Water	1.3	1.3	1	NULL	1
	2019	Reference	Wildlife Scat	1.3	1.3	1	0	2
	2019	Reference	Woody Litter	1.3	1.3	1	0	2
	2013	Test	Herbaceous Litter	12	29	18	9.2	3
	2013	Test	Lichens	7.9	7.9	8	NULL	1
	2013	Test	Mineral Soil	22.7	71.1	47	34.2	2
	2013	Test	Mosses	4	77.6	41	52.1	2
	2013	Test	Vascular Base	4	4	4	NULL	1
	2013	Test	Water	57.3	57.3	57	NULL	1
	2019	Test	Fungi	1.3	1.3	1	NULL	1
	2019	Test	Herbaceous Litter	19.7	47.4	36	14.2	3
	2019	Test	Mineral Soil	23.7	23.7	24	NULL	1
	2019	Test	Mosses	19.7	56.6	43	20.2	3
	2019	Test	Vascular Base	1.3	4	3	1.9	2
	2019	Test	Water	32.9	32.9	33	NULL	1
	2019	Test	Woody Litter	1.3	1.3	1	NULL	1
Riverine Loamy Alkaline Moist Low Willow Shrub	2013	Reference	Herbaceous Litter	6.6	36.8	24	11.9	8
	2013	Reference	Liverworts	6.6	6.6	7	NULL	1
	2013	Reference	Mineral Soil	1.3	84.2	29	27.5	8

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Loamy Alkaline Moist Low Willow Shrub	2013	Reference	Mosses	5.3	77.6	44	24.3	8
	2013	Reference	Vascular Base	1.3	5.3	2	1.5	8
	2013	Reference	Water	1.3	1.3	1	NULL	1
	2013	Reference	Woody Litter	1.3	1.3	1	NULL	1
	2019	Reference	Algae	1.3	1.3	1	NULL	1
	2019	Reference	Debris (Human origin)	1.3	1.3	1	NULL	1
	2019	Reference	Fungi	1.3	1.3	1	NULL	1
	2019	Reference	Herbaceous Litter	14.5	72.4	41	23.3	6
	2019	Reference	Liverworts	1.3	1.3	1	NULL	1
	2019	Reference	Mineral Soil	1.3	14.5	7	6.1	5
	2019	Reference	Mosses	14.5	79	48	26.1	6
	2019	Reference	Vascular Base	1.3	4	3	1.3	5
	2019	Reference	Wildlife Scat	1.3	1.3	1	0	2
	2019	Reference	Woody Litter	1.3	1.3	1	0	2
	2013	Test	Herbaceous Litter	9.2	80.3	43	25.5	7
	2013	Test	Lichens	2.6	2.6	3	NULL	1
	2013	Test	Mineral Soil	1.3	71.1	17	30.5	5
	2013	Test	Mosses	13.2	75	41	24.3	7
	2013	Test	Vascular Base	1.3	5.3	3	1.6	7
	2013	Test	Woody Litter	2.6	5.3	4	1.9	2
	2019	Test	Herbaceous Litter	7.9	65.8	37	18.8	7
	2019	Test	Mineral Soil	18.4	18.4	18	NULL	1
	2019	Test	Mosses	31.6	88.2	55	18.4	7
	2019	Test	Vascular Base	1.3	9.2	4	3	5
	2019	Test	Water	1.3	1.3	1	NULL	1
	2019	Test	Wildlife Scat	1.3	1.3	1	NULL	1
	2019	Test	Woody Litter	1.3	2.6	2	0.8	4
Riverine Loamy Alkaline Moist Mixed Herb	2013	Reference	Mineral Soil	93.4	93.4	93	NULL	1
	2013	Reference	Vascular Base	6.6	6.6	7	NULL	1
	2019	Reference	Herbaceous Litter	18.4	18.4	18	NULL	1
	2019	Reference	Mineral Soil	69.7	69.7	70	NULL	1
	2019	Reference	Mosses	9.2	9.2	9	NULL	1

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Loamy Alkaline Moist Mixed Herb	2019	Reference	Vascular Base	2.6	2.6	3	NULL	1
	2013	Test	Herbaceous Litter	6.6	22.4	14	11.2	2
	2013	Test	Mineral Soil	71.1	89.5	80	13	2
	2013	Test	Mosses	1.3	1.3	1	NULL	1
	2013	Test	Vascular Base	4	4	4	0	2
	2013	Test	Woody Litter	1.3	1.3	1	NULL	1
	2019	Test	Herbaceous Litter	4	59.2	32	39.1	2
	2019	Test	Mineral Soil	34.2	88.2	61	38.1	2
	2019	Test	Mosses	6.6	6.6	7	0	2
	2019	Test	Woody Litter	1.3	1.3	1	NULL	1
Riverine Loamy Alkaline Moist Tall Willow Shrub	2013	Reference	Herbaceous Litter	7.9	7.9	8	NULL	1
	2013	Reference	Mineral Soil	72.4	93.3	83	14.8	2
	2013	Reference	Mosses	5.3	13.2	9	5.5	2
	2013	Reference	Vascular Base	1.3	6.6	4	3.7	2
	2019	Reference	Herbaceous Litter	18.4	36.8	28	13	2
	2019	Reference	Liverworts	1.3	1.3	1	NULL	1
	2019	Reference	Mineral Soil	9.2	18.4	14	6.5	2
	2019	Reference	Mosses	54	56.6	55	1.9	2
	2019	Reference	Vascular Base	1.3	1.3	1	NULL	1
	2019	Reference	Wildlife Scat	1.3	1.3	1	NULL	1
	2019	Reference	Woody Litter	2.6	2.6	3	NULL	1
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	2013	Reference	Herbaceous Litter	13.2	84.2	42	25.1	8
	2013	Reference	Liverworts	1.3	1.3	1	NULL	1
	2013	Reference	Mineral Soil	1	5.3	3	1.7	5
	2013	Reference	Mosses	10.5	75	50	23.7	8
	2013	Reference	Vascular Base	1.3	5.3	3	1.3	8
	2013	Reference	Water	1.3	18.4	6	8.6	4
	2019	Reference	Herbaceous Litter	11.8	79	39	24.2	9
	2019	Reference	Lichens	1.3	1.3	1	0	2
	2019	Reference	Liverworts	1.3	1.3	1	0	2
	2019	Reference	Mosses	11.8	73.7	50	24.5	10
	2019	Reference	Vascular Base	1.3	7.9	4	2.4	8

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	2019	Reference	Water	1.3	86.8	19	33.6	6
	2019	Reference	Wildlife Scat	1.3	1.3	1	0	2
	2013	Test	Herbaceous Litter	9.2	65.8	31	17.9	8
	2013	Test	Liverworts	2.6	2.6	3	NULL	1
	2013	Test	Mineral Soil	5.3	5.3	5	NULL	1
	2013	Test	Mosses	25	74.7	59	16	8
	2013	Test	Vascular Base	1.3	8	5	2.7	7
	2013	Test	Water	1.3	22.4	7	7.9	6
	2019	Test	Herbaceous Litter	5.3	56.6	26	16.3	8
	2019	Test	Lichens	1.3	5.3	2	1.6	6
	2019	Test	Liverworts	1.3	1.3	1	NULL	1
	2019	Test	Mosses	38.2	88.2	64	17.8	8
	2019	Test	Tussock	1.3	1.3	1	NULL	1
	2019	Test	Vascular Base	1.3	7.9	4	2.7	6
	2019	Test	Water	6.6	30.3	18	16.7	2
	2019	Test	Wildlife Scat	1.3	1.3	1	NULL	1
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	2013	Reference	Herbaceous Litter	22.4	26.7	25	3	2
	2013	Reference	Liverworts	2.6	2.6	3	NULL	1
	2013	Reference	Mineral Soil	1.3	2.7	2	1	2
	2013	Reference	Mosses	65.3	69.7	68	3.1	2
	2013	Reference	Vascular Base	4	5.3	5	1	2
	2019	Reference	Herbaceous Litter	11.8	43.4	28	22.3	2
	2019	Reference	Lichens	1.3	1.3	1	NULL	1
	2019	Reference	Liverworts	1.3	1.3	1	NULL	1
	2019	Reference	Mosses	51.3	85.5	68	24.2	2
	2019	Reference	Vascular Base	1.3	4	3	1.9	2
	2013	Test	Herbaceous Litter	23	50	35	11.7	5
	2013	Test	Lichens	1.3	8.1	4	2.5	5
	2013	Test	Mosses	42.1	67.6	57	10.4	5
	2013	Test	Vascular Base	1.3	6.6	3	2.2	5
	2013	Test	Water	5.3	5.3	5	NULL	1
	2019	Test	Herbaceous Litter	7.9	36.8	26	11.1	5

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	2019	Test	Lichens	5.3	10.5	7	2.2	5
	2019	Test	Mineral Soil	1.3	2.6	2	0.9	2
	2019	Test	Mosses	48.7	80.3	63	11.9	5
	2019	Test	Organic Soil	1.3	1.3	1	NULL	1
	2019	Test	Vascular Base	1.3	4	3	1.9	2
	2019	Test	Water	1.3	5.3	3	2.8	2
	2019	Test	Wildlife Scat	1.3	1.3	1	0	2
Riverine Organic-rich Circumneutral Wet Sedge Meadow	2013	Reference	Herbaceous Litter	2.6	34.3	11	10.3	8
	2013	Reference	Lichens	1.3	1.3	1	NULL	1
	2013	Reference	Liverworts	2.7	2.7	3	NULL	1
	2013	Reference	Mineral Soil	5.3	5.3	5	NULL	1
	2013	Reference	Mosses	5.3	93.4	52	35	8
	2013	Reference	Vascular Base	1.3	10.5	4	3.6	6
	2013	Reference	Water	1.4	89.3	52	34.7	5
	2019	Reference	Herbaceous Litter	1.3	21.1	13	8	6
	2019	Reference	Liverworts	5.3	5.3	5	NULL	1
	2019	Reference	Mineral Soil	1.3	10.5	6	6.5	2
	2019	Reference	Mosses	9.2	100	59	34.7	7
	2019	Reference	Organic Soil	4	13.2	9	6.5	2
	2019	Reference	Vascular Base	1.3	4	3	1.1	4
	2019	Reference	Water	5.3	82.9	41	32	4
	2013	Test	Herbaceous Litter	1.3	46.1	19	13.4	27
	2013	Test	Lichens	1.3	1.3	1	0	2
	2013	Test	Liverworts	1.3	2.6	2	0.9	2
	2013	Test	Mineral Soil	1.3	2.6	2	0.8	3
	2013	Test	Mosses	1.3	89.3	44	27	29
	2013	Test	Vascular Base	1.3	14.5	4	2.9	26
	2013	Test	Water	1.3	80	39	27.4	26
	2013	Test	Woody Litter	1.3	1.3	1	NULL	1
	2019	Test	Algae	1.3	1.3	1	NULL	1
	2019	Test	Herbaceous Litter	1.3	46.1	14	12.3	23
	2019	Test	Liverworts	1.3	4	3	1.9	2

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Organic-rich Circumneutral Wet Sedge Meadow	2019	Test	Mineral Soil	1.3	10.7	6	3.4	6
	2019	Test	Mosses	2.6	97.4	49	28.7	27
	2019	Test	Organic Soil	1.3	6.6	4	2.5	6
	2019	Test	Vascular Base	1.3	8	3	1.9	21
	2019	Test	Water	1.3	97.4	38	30.8	24
	2019	Test	Wildlife Scat	1.3	1.3	1	NULL	1
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	2013	Reference	Fungi	1.3	1.3	1	NULL	1
	2013	Reference	Herbaceous Litter	5.3	52	19	11.1	16
	2013	Reference	Lichens	1.3	4	2	1.3	4
	2013	Reference	Liverworts	1.3	4	2	1.2	7
	2013	Reference	Mineral Soil	1.3	27.6	10	12.4	4
	2013	Reference	Mosses	30.3	82.9	65	15.7	16
	2013	Reference	Vascular Base	1.3	14.5	5	3.8	12
	2013	Reference	Water	1.3	36.8	10	11.5	14
	2019	Reference	Herbaceous Litter	1.3	38.2	13	10.1	16
	2019	Reference	Lichens	1.3	6.6	4	2.7	3
	2019	Reference	Liverworts	1.3	2.6	2	0.7	5
	2019	Reference	Mosses	40.8	96.1	76	15.6	17
	2019	Reference	Vascular Base	1.3	5.3	3	1.4	16
	2019	Reference	Water	2.6	30.3	14	10.4	9
	2019	Reference	Wildlife Scat	1.3	1.3	1	0	2
	2013	Test	Algae	1.3	1.3	1	NULL	1
	2013	Test	Herbaceous Litter	4	43.4	23	10.4	19
	2013	Test	Lichens	1.3	5.3	3	1.9	5
	2013	Test	Liverworts	1.3	1.3	1	0	2
	2013	Test	Mineral Soil	1.3	27.6	11	14.8	3
	2013	Test	Mosses	36.8	92.1	65	15.2	19
	2013	Test	Vascular Base	1.3	5.3	4	1.2	17
	2013	Test	Water	1.3	18.4	11	5.3	11
	2013	Test	Woody Litter	1.3	1.3	1	NULL	1
	2019	Test	Fungi	1.3	1.3	1	0	2
	2019	Test	Herbaceous Litter	2.6	36.8	18	8.7	21

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	2019	Test	Lichens	1.3	6.6	3	2.2	5
	2019	Test	Liverworts	1.3	4	2	1.3	4
	2019	Test	Mineral Soil	1.3	25	10	9.9	5
	2019	Test	Mosses	39.5	93.4	67	14.7	21
	2019	Test	Organic Soil	2.6	2.6	3	NULL	1
	2019	Test	Vascular Base	1.3	6.6	3	1.8	17
	2019	Test	Water	1.3	30.3	11	10.2	15
	2019	Test	Wildlife Scat	1.3	6.6	2	2.1	6
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	2013	Reference	Herbaceous Litter	67.1	67.1	67	NULL	1
	2013	Reference	Lichens	9.2	9.2	9	NULL	1
	2013	Reference	Mosses	13.2	13.2	13	NULL	1
	2013	Reference	Tussock	2.6	2.6	3	NULL	1
	2013	Reference	Vascular Base	6.6	6.6	7	NULL	1
	2013	Reference	Water	1.3	1.3	1	NULL	1
	2019	Reference	Herbaceous Litter	36.8	36.8	37	NULL	1
	2019	Reference	Lichens	10.5	10.5	11	NULL	1
	2019	Reference	Mosses	36.8	36.8	37	NULL	1
	2019	Reference	Tussock	10.5	10.5	11	NULL	1
	2019	Reference	Vascular Base	5.3	5.3	5	NULL	1
	2013	Test	Herbaceous Litter	38.2	42.1	40	2.8	2
	2013	Test	Lichens	4	14.5	9	7.4	2
	2013	Test	Mosses	44.7	47.4	46	1.9	2
	2013	Test	Vascular Base	2.6	6.6	5	2.8	2
	2019	Test	Herbaceous Litter	26.3	27.6	27	0.9	2
	2019	Test	Lichens	2.6	25	14	15.8	2
	2019	Test	Mosses	44.7	68.4	57	16.7	2
	2019	Test	Tussock	2.6	2.6	3	NULL	1
	2019	Test	Vascular Base	1.3	1.3	1	0	2
Upland Sandy Alkaline Dry Barrens	2013	Test	Herbaceous Litter	2.6	2.6	3	NULL	1
	2013	Test	Mineral Soil	96.1	96.1	96	NULL	1
	2013	Test	Vascular Base	1.3	1.3	1	NULL	1
	2019	Test	Herbaceous Litter	27.6	27.6	28	NULL	1

Appendix E. Continued.

Plot Ecotype	Sample Year	Study Area	Ground Cover Class	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	n
Upland Sandy Alkaline Dry Barrens	2019	Test	Mineral Soil	68.4	68.4	68	NULL	1
	2019	Test	Mosses	4	4	4	NULL	1
Upland Sandy Alkaline Moist Low Willow Shrub	2013	Reference	Herbaceous Litter	97.4	97.4	97	NULL	1
	2013	Reference	Mosses	1.3	1.3	1	NULL	1
	2013	Reference	Vascular Base	1.3	1.3	1	NULL	1
	2019	Reference	Herbaceous Litter	75	75	75	NULL	1
	2019	Reference	Mineral Soil	1.3	1.3	1	NULL	1
	2019	Reference	Mosses	22.4	22.4	22	NULL	1
	2019	Reference	Vascular Base	1.3	1.3	1	NULL	1
	2013	Test	Herbaceous Litter	17.3	68.4	50	28.4	3
	2013	Test	Mineral Soil	1.3	76	31	39.4	3
	2013	Test	Mosses	5.3	27.6	17	11.2	3
	2013	Test	Vascular Base	1.3	1.3	1	0	3
	2013	Test	Water	1.3	1.3	1	NULL	1
	2019	Test	Herbaceous Litter	18.4	59.2	41	20.8	3
	2019	Test	Lichens	1.3	1.3	1	NULL	1
	2019	Test	Mineral Soil	5.3	68.4	37	44.7	2
	2019	Test	Mosses	11.8	48.7	33	19.2	3
	2019	Test	Wildlife Scat	1.3	1.3	1	NULL	1

Appendix F. Mean elevation, thaw depth, water table depth, surface organic thickness, pH, and electrical conductivity for all plot ecotypes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Coastal Loamy Brackish Moist Willow Dwarf Shrub	Reference	2013	Elevation (cm)	190	165	73	306	2
	Reference	2019	Elevation (cm)	129	57	88	169	2
	Test	2013	Elevation (cm)	187	NULL	187	187	1
	Test	2019	Elevation (cm)	187	NULL	187	187	1
	Reference	2013	Thaw Depth (cm)	64	9	57	70	2
	Reference	2019	Thaw Depth (cm)	45	32	22	67	2
	Test	2013	Thaw Depth (cm)	81	NULL	81	81	1
	Test	2019	Thaw Depth (cm)	65	NULL	65	65	1
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Test	2013	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Test	2019	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Reference	2013	Water Table Depth (cm)	-34	14	-44	-24	2
	Reference	2019	Water Table Depth (cm)	-17	23	-33	-1	2
	Test	2013	Water Table Depth (cm)	-68	NULL	-68	-68	1
	Test	2019	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Reference	2013	Electrical Conductivity (um)	1770	184	1640	1900	2
	Reference	2019	Electrical Conductivity (um)	1615	262	1430	1800	2
	Test	2013	Electrical Conductivity (um)	500	NULL	500	500	1
	Test	2019	Electrical Conductivity (um)	420	NULL	420	420	1
	Reference	2013	pH	7.6	0.7	7.1	8.1	2
	Reference	2019	pH	7.5	0.1	7.4	7.5	2
	Test	2013	pH	7.3	NULL	7.3	7.3	1
	Test	2019	pH	7.6	NULL	7.6	7.6	1
Coastal Sandy Moist Brackish Barrens	Reference	2013	Elevation (cm)	102	44	56	151	5
	Reference	2019	Elevation (cm)	87	68	0	159	5
	Test	2013	Elevation (cm)	107	55	46	193	5
	Test	2019	Elevation (cm)	106	58	52	193	5
	Reference	2013	Thaw Depth (cm)	102	4	96	107	5
	Reference	2019	Thaw Depth (cm)	59	33	0	76	5
	Test	2013	Thaw Depth (cm)	103	9	93	114	5

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Coastal Sandy Moist Brackish Barrens	Test	2019	Thaw Depth (cm)	75	7	65	83	5
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	5
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	5
	Test	2013	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	5
	Test	2019	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	5
	Reference	2013	Water Table Depth (cm)	-46	41	-90	-9	3
	Reference	2019	Water Table Depth (cm)	-4	4	-7	0	3
	Test	2013	Water Table Depth (cm)	-30	22	-60	-8	4
	Test	2019	Water Table Depth (cm)	-13	4	-17	-10	3
	Reference	2013	Electrical Conductivity (um)	2196	2677	500	6900	5
	Reference	2019	Electrical Conductivity (um)	1582	2602	140	6200	5
	Test	2013	Electrical Conductivity (um)	4644	7814	450	18600	5
	Test	2019	Electrical Conductivity (um)	5580	9185	890	22000	5
	Reference	2013	pH	7.9	0.3	7.6	8.4	5
	Reference	2019	pH	7.5	0.7	6.8	8.3	5
	Test	2013	pH	7.3	0.4	6.6	7.6	5
	Test	2019	pH	7.3	0.3	7.1	7.8	5
Lowland Lake	Test	2013	Elevation (cm)	299	2	297	300	2
	Test	2019	Elevation (cm)	301	NULL	301	301	1
	Test	2013	Thaw Depth (cm)	42	6	38	46	2
	Test	2019	Thaw Depth (cm)	32	NULL	32	32	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	20	0	20	20	2
	Test	2019	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Test	2013	Water Table Depth (cm)	23	3	21	25	2
	Test	2019	Water Table Depth (cm)	20	NULL	20	20	1
	Test	2013	Electrical Conductivity (um)	275	7	270	280	2
	Test	2019	Electrical Conductivity (um)	250	NULL	250	250	1
	Test	2013	pH	7.9	0.2	7.7	8	2
	Test	2019	pH	8	NULL	8	8	1
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	Test	2013	Elevation (cm)	347	NULL	347	347	1
	Test	2019	Elevation (cm)	318	NULL	318	318	1
	Test	2013	Thaw Depth (cm)	40	NULL	40	40	1

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Lowland Organic-rich Circumneutral Moist Sedge-Shrub Meadow	Test	2019	Thaw Depth (cm)	35	NULL	35	35	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Test	2019	Surface Organic Thick. in upper 20 (cm)	14	NULL	14	14	1
	Test	2013	Water Table Depth (cm)	-16	NULL	-16	-16	1
	Test	2019	Water Table Depth (cm)	-16	NULL	-16	-16	1
	Test	2013	Electrical Conductivity (um)	410	NULL	410	410	1
	Test	2019	Electrical Conductivity (um)	560	NULL	560	560	1
	Test	2013	pH	6.2	NULL	6.2	6.2	1
	Test	2019	pH	6.7	NULL	6.7	6.7	1
Lowland Organic-rich Circumneutral Sedge Marsh	Test	2013	Elevation (cm)	297	NULL	297	297	1
	Test	2019	Elevation (cm)	291	NULL	291	291	1
	Test	2013	Thaw Depth (cm)	47	NULL	47	47	1
	Test	2019	Thaw Depth (cm)	32	NULL	32	32	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Test	2019	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Test	2013	Water Table Depth (cm)	15	NULL	15	15	1
	Test	2019	Water Table Depth (cm)	21	NULL	21	21	1
	Test	2013	Electrical Conductivity (um)	310	NULL	310	310	1
	Test	2019	Electrical Conductivity (um)	350	NULL	350	350	1
	Test	2013	pH	7	NULL	7	7	1
	Test	2019	pH	6.7	NULL	6.7	6.7	1
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Reference	2013	Elevation (cm)	327	81	216	430	13
	Reference	2019	Elevation (cm)	328	73	231	422	13
	Test	2013	Elevation (cm)	292	25	252	340	13
	Test	2019	Elevation (cm)	286	25	249	330	13
	Reference	2013	Thaw Depth (cm)	46	3	40	51	13
	Reference	2019	Thaw Depth (cm)	37	3	31	41	13
	Test	2013	Thaw Depth (cm)	46	5	35	52	13
	Test	2019	Thaw Depth (cm)	36	4	29	41	13
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	20	0	20	20	13
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	18.8	2.9	10	20	13
	Test	2013	Surface Organic Thick. in upper 20 (cm)	20	0	20	20	13

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Lowland Organic-rich Circumneutral Wet Sedge Meadow	Test	2019	Surface Organic Thick. in upper 20 (cm)	19.4	2.2	12	20	13
	Reference	2013	Water Table Depth (cm)	1	4	-4	11	13
	Reference	2019	Water Table Depth (cm)	2	6	-7	15	13
	Test	2013	Water Table Depth (cm)	-1	4	-9	5	13
	Test	2019	Water Table Depth (cm)	0	3	-3	6	13
	Reference	2013	Electrical Conductivity (um)	442	121	210	680	13
	Reference	2019	Electrical Conductivity (um)	324	104	210	510	13
	Test	2013	Electrical Conductivity (um)	357	82	250	530	13
	Test	2019	Electrical Conductivity (um)	358	175	150	850	11
	Reference	2013	pH	6.8	0.4	6.1	7.4	13
	Reference	2019	pH	6.6	0.3	6.2	7.4	13
	Test	2013	pH	6.5	0.3	6	7.1	13
	Test	2019	pH	6.5	0.2	6	6.9	11
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Elevation (cm)	357	NULL	357	357	1
	Reference	2019	Elevation (cm)	357	NULL	357	357	1
	Test	2013	Elevation (cm)	270	15	258	287	3
	Test	2019	Elevation (cm)	263	18	246	281	3
	Reference	2013	Thaw Depth (cm)	41	NULL	41	41	1
	Reference	2019	Thaw Depth (cm)	23	NULL	23	23	1
	Test	2013	Thaw Depth (cm)	45	2	44	47	3
	Test	2019	Thaw Depth (cm)	36	5	30	39	3
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	20	NULL	20	20	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	20	0	20	20	3
	Test	2019	Surface Organic Thick. in upper 20 (cm)	19	1.7	17	20	3
	Reference	2013	Water Table Depth (cm)	0	NULL	0	0	1
	Reference	2019	Water Table Depth (cm)	0	NULL	0	0	1
	Test	2013	Water Table Depth (cm)	-4	4	-8	-1	3
	Test	2019	Water Table Depth (cm)	2	5	-3	5	3
	Reference	2013	Electrical Conductivity (um)	400	NULL	400	400	1
	Reference	2019	Electrical Conductivity (um)	240	NULL	240	240	1
	Test	2013	Electrical Conductivity (um)	293	98	180	350	3

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Lowland Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	2019	Electrical Conductivity (um)	227	74	170	310	3
	Reference	2013	pH	6.9	NULL	6.9	6.9	1
	Reference	2019	pH	6.3	NULL	6.3	6.3	1
	Test	2013	pH	6.5	0.3	6.3	6.8	3
	Test	2019	pH	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
	Reference	2019	Elevation (cm)	279	94	127	416	6
	Test	2013	Elevation (cm)	260	43	204	347	7
	Test	2019	Elevation (cm)	255	46	204	352	7
	Reference	2013	Thaw Depth (cm)	59	18	40	92	8
	Reference	2019	Thaw Depth (cm)	51	14	32	70	6
	Test	2013	Thaw Depth (cm)	61	17	34	78	7
	Test	2019	Thaw Depth (cm)	44	15	23	63	7
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	4.2	7.7	0	19	8
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	1.2	2.4	0	6	6
	Test	2013	Surface Organic Thick. in upper 20 (cm)	3.8	3.8	0	10	7
	Test	2019	Surface Organic Thick. in upper 20 (cm)	2	2.6	0	7	7
	Reference	2013	Water Table Depth (cm)	-29	18	-65	-13	6
	Reference	2019	Water Table Depth (cm)	-20	10	-34	-9	5
	Test	2013	Water Table Depth (cm)	-36	17	-60	-22	4
	Test	2019	Water Table Depth (cm)	-21	2	-23	-19	3
	Reference	2013	Electrical Conductivity (um)	544	322	260	1250	8
	Reference	2019	Electrical Conductivity (um)	3152	5962	210	15300	6
	Test	2013	Electrical Conductivity (um)	439	244	220	860	7
	Test	2019	Electrical Conductivity (um)	678	463	250	1500	6
	Reference	2013	pH	7.2	0.7	6	8	8
	Reference	2019	pH	7.2	0.5	6.6	8	6
	Test	2013	pH	7.3	1	5.6	8.1	7
	Test	2019	pH	7.1	0.3	6.7	7.6	6
Riverine Loamy Alkaline Moist Mixed Herb	Reference	2013	Elevation (cm)	258	NULL	258	258	1
	Reference	2019	Elevation (cm)	247	NULL	247	247	1
	Test	2013	Elevation (cm)	214	55	175	253	2

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Riverine Loamy Alkaline Moist Mixed Herb	Test	2019	Elevation (cm)	212	55	173	251	2
	Reference	2013	Thaw Depth (cm)	105	NULL	105	105	1
	Reference	2019	Thaw Depth (cm)	90	NULL	90	90	1
	Test	2013	Thaw Depth (cm)	86	8	80	91	2
	Test	2019	Thaw Depth (cm)	76	4	73	79	2
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Test	2019	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Reference	2013	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Reference	2019	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Test	2013	Water Table Depth (cm)	-999	0	-999	-999	2
	Test	2019	Water Table Depth (cm)	-999	0	-999	-999	2
	Reference	2013	Electrical Conductivity (um)	580	NULL	580	580	1
	Reference	2019	Electrical Conductivity (um)	530	NULL	530	530	1
	Test	2013	Electrical Conductivity (um)	490	0	490	490	2
	Test	2019	Electrical Conductivity (um)	555	64	510	600	2
	Reference	2013	pH	8.1	NULL	8.1	8.1	1
	Reference	2019	pH	7.7	NULL	7.7	7.7	1
	Test	2013	pH	8.1	0.1	8	8.1	2
	Test	2019	pH	7.7	0.6	7.3	8.1	2
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	2013	Elevation (cm)	252	49	217	286	2
	Reference	2019	Elevation (cm)	238	62	194	281	2
	Reference	2013	Thaw Depth (cm)	118	21	103	133	2
	Reference	2019	Thaw Depth (cm)	95	34	71	119	2
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	0	0	0	0	2
	Reference	2013	Water Table Depth (cm)	-999	0	-999	-999	2
	Reference	2019	Water Table Depth (cm)	-25	NULL	-25	-25	1
	Reference	2013	Electrical Conductivity (um)	430	226	270	590	2
	Reference	2019	Electrical Conductivity (um)	1130	481	790	1470	2
	Reference	2013	pH	8.2	0	8.2	8.2	2

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Riverine Loamy Alkaline Moist Tall Willow Shrub	Reference	2019	pH	7.2	0.4	6.9	7.4	2
Riverine Loamy-Organic Circumneutral Moist Low Willow-Sedge Meadow	Reference	2013	Elevation (cm)	229	79	113	385	8
	Reference	2019	Elevation (cm)	245	83	110	382	10
	Test	2013	Elevation (cm)	296	46	239	381	8
	Test	2019	Elevation (cm)	294	47	240	382	8
	Reference	2013	Thaw Depth (cm)	50	19	5	67	8
	Reference	2019	Thaw Depth (cm)	42	8	30	58	10
	Test	2013	Thaw Depth (cm)	52	9	44	70	8
	Test	2019	Thaw Depth (cm)	39	9	30	54	8
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	7	8	0	20	8
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	3.5	2.8	0	7	10
	Test	2013	Surface Organic Thick. in upper 20 (cm)	9.9	7.1	0	20	8
	Test	2019	Surface Organic Thick. in upper 20 (cm)	12.4	6.9	1	20	8
	Reference	2013	Water Table Depth (cm)	-12	14	-38	-2	8
	Reference	2019	Water Table Depth (cm)	-8	12	-35	4	10
	Test	2013	Water Table Depth (cm)	-10	7	-20	-3	8
	Test	2019	Water Table Depth (cm)	-6	3	-10	-1	8
	Reference	2013	Electrical Conductivity (um)	916	497	390	1840	8
	Reference	2019	Electrical Conductivity (um)	697	399	230	1330	10
	Test	2013	Electrical Conductivity (um)	519	597	180	1980	8
	Test	2019	Electrical Conductivity (um)	513	571	120	1880	8
	Reference	2013	pH	7	0.5	6.4	7.8	8
	Reference	2019	pH	6.6	0.2	6.2	6.9	10
	Test	2013	pH	6.6	0.5	5.9	7.3	8
	Test	2019	pH	6.7	0.5	6.1	7.7	8
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Reference	2013	Elevation (cm)	263	48	229	297	2
	Reference	2019	Elevation (cm)	266	61	223	309	2
	Test	2013	Elevation (cm)	305	44	277	383	5
	Test	2019	Elevation (cm)	299	40	270	369	5
	Reference	2013	Thaw Depth (cm)	48	15	37	58	2
	Reference	2019	Thaw Depth (cm)	41	16	30	52	2
	Test	2013	Thaw Depth (cm)	46	8	37	56	5

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Riverine Loamy-Organic Circumneutral Moist Sedge-Shrub Meadow	Test	2019	Thaw Depth (cm)	33	11	19	49	5
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	11	12.7	2	20	2
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	12.5	10.6	5	20	2
	Test	2013	Surface Organic Thick. in upper 20 (cm)	12.6	5.9	4	18	5
	Test	2019	Surface Organic Thick. in upper 20 (cm)	13.4	5.4	5	20	5
	Reference	2013	Water Table Depth (cm)	-29	0	-29	-29	2
	Reference	2019	Water Table Depth (cm)	-17	17	-29	-5	2
	Test	2013	Water Table Depth (cm)	-27	7	-33	-16	5
	Test	2019	Water Table Depth (cm)	-19	7	-25	-10	4
	Reference	2013	Electrical Conductivity (um)	600	71	550	650	2
	Reference	2019	Electrical Conductivity (um)	535	92	470	600	2
	Test	2013	Electrical Conductivity (um)	360	172	179	610	5
	Test	2019	Electrical Conductivity (um)	532	371	190	1030	5
	Reference	2013	pH	7	0.4	6.7	7.3	2
	Reference	2019	pH	6.5	0.1	6.4	6.6	2
	Test	2013	pH	6.6	0.6	5.7	7.2	5
	Test	2019	pH	6.7	0.5	6	7.3	5
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Reference	2013	Elevation (cm)	338	75	206	395	8
	Reference	2019	Elevation (cm)	325	76	204	381	7
	Test	2013	Elevation (cm)	305	33	238	383	29
	Test	2019	Elevation (cm)	297	34	230	386	27
	Reference	2013	Thaw Depth (cm)	45	6	38	53	8
	Reference	2019	Thaw Depth (cm)	34	2	30	37	7
	Test	2013	Thaw Depth (cm)	48	4	38	56	29
	Test	2019	Thaw Depth (cm)	38	4	30	48	27
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	11.9	7.5	0	20	8
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	11	9.2	0	20	7
	Test	2013	Surface Organic Thick. in upper 20 (cm)	16.2	6	3	20	29
	Test	2019	Surface Organic Thick. in upper 20 (cm)	13.8	8.2	0	20	27
	Reference	2013	Water Table Depth (cm)	-5	9	-24	5	8
	Reference	2019	Water Table Depth (cm)	-5	6	-14	3	7
	Test	2013	Water Table Depth (cm)	-3	4	-10	5	29

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Riverine Organic-rich Circumneutral Wet Sedge Meadow	Test	2019	Water Table Depth (cm)	-2	7	-20	12	27
	Reference	2013	Electrical Conductivity (um)	453	233	170	770	8
	Reference	2019	Electrical Conductivity (um)	516	347	180	1130	7
	Test	2013	Electrical Conductivity (um)	474	172	230	830	29
	Test	2019	Electrical Conductivity (um)	376	160	130	690	26
	Reference	2013	pH	6.7	0.3	6.2	7.2	8
	Reference	2019	pH	6.6	0.3	6.3	7.2	7
	Test	2013	pH	6.5	0.2	6.1	7.2	29
	Test	2019	pH	6.5	0.2	5.9	7	27
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Reference	2013	Elevation (cm)	331	70	231	425	16
	Reference	2019	Elevation (cm)	316	81	181	423	17
	Test	2013	Elevation (cm)	295	25	246	338	19
	Test	2019	Elevation (cm)	292	26	240	336	21
	Reference	2013	Thaw Depth (cm)	47	7	37	62	16
	Reference	2019	Thaw Depth (cm)	34	6	27	46	17
	Test	2013	Thaw Depth (cm)	47	5	31	55	19
	Test	2019	Thaw Depth (cm)	34	7	23	51	21
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	14.3	6.5	0	20	16
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	11.6	7.8	0	20	17
	Test	2013	Surface Organic Thick. in upper 20 (cm)	11.7	7.8	0.3	20	19
	Test	2019	Surface Organic Thick. in upper 20 (cm)	10	8.2	0	20	21
	Reference	2013	Water Table Depth (cm)	-6	4	-11	2	16
	Reference	2019	Water Table Depth (cm)	-4	6	-23	7	17
	Test	2013	Water Table Depth (cm)	-7	6	-25	8	19
	Test	2019	Water Table Depth (cm)	-7	6	-24	-1	21
	Reference	2013	Electrical Conductivity (um)	517	280	190	1250	16
	Reference	2019	Electrical Conductivity (um)	462	246	210	1100	17
	Test	2013	Electrical Conductivity (um)	455	280	200	1470	19
	Test	2019	Electrical Conductivity (um)	457	196	230	920	21
	Reference	2013	pH	6.8	0.3	6.3	7.4	16
	Reference	2019	pH	6.6	0.3	6.2	6.9	17
	Test	2013	pH	6.5	0.3	6	7.3	19

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Riverine Organic-rich Circumneutral Wet Sedge-Willow Meadow	Test	2019	pH	6.4	0.3	6	6.8	21
Upland Loamy-Organic Circumneutral Moist Tussock Meadow	Reference	2013	Elevation (cm)	273	NULL	273	273	1
	Reference	2019	Elevation (cm)	270	NULL	270	270	1
	Test	2013	Elevation (cm)	341	23	325	357	2
	Test	2019	Elevation (cm)	333	22	317	348	2
	Reference	2013	Thaw Depth (cm)	40	NULL	40	40	1
	Reference	2019	Thaw Depth (cm)	36	NULL	36	36	1
	Test	2013	Thaw Depth (cm)	39	13	29	48	2
	Test	2019	Thaw Depth (cm)	20	4	17	22	2
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	15	NULL	15	15	1
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	19	NULL	19	19	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	13	7.1	8	18	2
	Test	2019	Surface Organic Thick. in upper 20 (cm)	7	1.4	6	8	2
	Reference	2013	Water Table Depth (cm)	-11	NULL	-11	-11	1
	Reference	2019	Water Table Depth (cm)	-10	NULL	-10	-10	1
	Test	2013	Water Table Depth (cm)	-26	8	-32	-20	2
	Test	2019	Water Table Depth (cm)	-17	NULL	-17	-17	1
	Reference	2013	Electrical Conductivity (um)	590	NULL	590	590	1
	Reference	2019	Electrical Conductivity (um)	460	NULL	460	460	1
	Test	2013	Electrical Conductivity (um)	170	71	120	220	2
	Test	2019	Electrical Conductivity (um)	175	163	60	290	2
	Reference	2013	pH	6.8	NULL	6.8	6.8	1
	Reference	2019	pH	6.2	NULL	6.2	6.2	1
	Test	2013	pH	6.2	0	6.2	6.2	2
	Test	2019	pH	6.2	0.4	5.9	6.5	2
Upland Sandy Alkaline Dry Barrens	Test	2013	Elevation (cm)	364	NULL	364	364	1
	Test	2019	Elevation (cm)	361	NULL	361	361	1
	Test	2013	Thaw Depth (cm)	82	NULL	82	82	1
	Test	2019	Thaw Depth (cm)	100	NULL	100	100	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Test	2019	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Test	2013	Water Table Depth (cm)	-999	NULL	-999	-999	1

Appendix F. Continued.

Plot Ecotype	Study Area	Sample Year	Data Attribute	Average	Standard Deviation	Min.	Max.	Sample Size
Upland Sandy Alkaline Dry Barrens	Test	2019	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Test	2013	Electrical Conductivity (um)	30	NULL	30	30	1
	Test	2019	Electrical Conductivity (um)	30	NULL	30	30	1
	Test	2013	pH	8.6	NULL	8.6	8.6	1
	Test	2019	pH	8.6	NULL	8.6	8.6	1
Upland Sandy Alkaline Moist Low Willow Shrub	Reference	2013	Elevation (cm)	538	NULL	538	538	1
	Reference	2019	Elevation (cm)	536	NULL	536	536	1
	Test	2013	Elevation (cm)	419	86	340	510	3
	Test	2019	Elevation (cm)	417	83	342	506	3
	Reference	2013	Thaw Depth (cm)	120	NULL	120	120	1
	Reference	2019	Thaw Depth (cm)	90	NULL	90	90	1
	Test	2013	Thaw Depth (cm)	105	13	90	114	3
	Test	2019	Thaw Depth (cm)	68	17	56	87	3
	Reference	2013	Surface Organic Thick. in upper 20 (cm)	0.5	NULL	0.5	0.5	1
	Reference	2019	Surface Organic Thick. in upper 20 (cm)	0	NULL	0	0	1
	Test	2013	Surface Organic Thick. in upper 20 (cm)	0.3	0.6	0	1	3
	Test	2019	Surface Organic Thick. in upper 20 (cm)	0.2	0.3	0	0.5	3
	Reference	2013	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Reference	2019	Water Table Depth (cm)	-999	NULL	-999	-999	1
	Test	2013	Water Table Depth (cm)	-999	0	-999	-999	3
	Test	2019	Water Table Depth (cm)	-999	0	-999	-999	3
	Reference	2013	Electrical Conductivity (um)	450	NULL	450	450	1
	Reference	2019	Electrical Conductivity (um)	100	NULL	100	100	1
	Test	2013	Electrical Conductivity (um)	167	168	60	360	3
	Test	2019	Electrical Conductivity (um)	123	61	70	190	3
	Reference	2013	pH	8.2	NULL	8.2	8.2	1
	Reference	2019	pH	8.1	NULL	8.1	8.1	1
	Test	2013	pH	8.1	0.3	7.9	8.4	3
	Test	2019	pH	8	0.3	7.7	8.2	3

Appendix G. Mean cover by vegetation structure class and herbaceous and woody plant height for common wildlife habitat classes in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

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	40.00	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	0.00			100	11.13	4.31
2019	Test	Barrens	18.21	65.81	6.71	2.24	0.00	3.51	3.51	0.32	1.60	0.64	11.54	2.67	0.67	100	5.12	1.29
2019	Reference	Barrens	6.04	82.64	10.57	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.00			100	4.88	1.29
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	97.50	28.95	1.08	100	31.60	0.85
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	94.54	31.66	1.27	100	27.34	0.79
2019	Reference	Moist Low Shrub	2.87	3.94	28.10	44.23	0.36	21.58	3.44	24.52	12.11	26.60	91.21	25.88	1.12	100	23.56	1.21
2019	Test	Moist Low Shrub	1.64	7.05	29.89	48.84	1.23	23.19	3.97	18.19	11.70	25.24	89.53	29.63	1.32	100	21.08	0.67
2019	Test	Dry Dwarf Shrub	0.00	1.33	29.33	33.33	5.33	12.00	9.33	21.33	21.33	22.67	93.33	12.29	2.35	100	19.87	1.71
2019	Reference	Dry Dwarf Shrub	2.00	0.00	26.00	37.00	4.00	11.00	4.00	30.00	32.00	14.00	94.12	10.94	1.92	100	15.71	1.53
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	93.33	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	100.00	15.82	2.12	100	26.06	2.70
2019	Test	Moist Herb Meadow	0.00	29.10	14.18	10.45	0.00	33.58	18.66	2.24	16.42	2.24	57.69	6.60	2.63	100	19.15	2.59
2019	Reference	Moist Herb Meadow	0.00	29.31	20.69	12.07	0.00	25.86	0.86	0.86	0.00	28.44	59.09	57.54	18.63	100	16.64	2.07
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	82.35	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	87.50	51.71	14.79	100	29.25	3.24
2019	Test	Moist Sedge-Shrub Meadow	0.00	0.73	27.74	68.61	1.46	16.06	2.19	27.74	29.93	10.95	96.43	10.59	1.56	100	18.39	1.61
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	100.00	13.86	1.31	100	26.93	1.96
2019	Test	Moist Tussock Tundra	8.04	0.00	27.68	33.93	0.00	16.07	7.14	44.64	8.93	18.75	73.91	16.53	2.07	100	27.13	2.13
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	86.96	19.60	2.79	100	39.48	2.76
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	78.28	19.67	0.70	100	33.80	0.74
2013	Test	Patterned Wet Meadow	5.61	0.03	44.29	53.18	2.53	8.61	0.99	25.88	6.78	9.19	70.03	18.01	0.47	100	30.96	0.36
2019	Reference	Patterned Wet Meadow	7.63	0.42	35.88	56.83	1.34	16.26	0.08	28.83	8.30	12.49	65.96	16.09	0.89	100	26.52	0.66
2019	Test	Patterned Wet Meadow	5.67	0.23	42.72	60.13	1.66	9.65	0.38	29.66	7.62	9.65	62.17	15.00	0.49	100	26.42	0.58
2019	Test	Nonpatterned Wet Meadow	4.08	0.10	38.87	61.86	0.73	10.66	1.88	33.54	5.33	11.80	71.66	18.81	0.99	100	26.94	0.73

Appendix G. Continued.

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)
2019	Reference	Nonpatterned Wet Meadow	5.43	0.31	36.88	68.01	0.54	15.76	1.63	27.48	6.44	11.03	67.18	18.90	1.43	100	25.75	0.66
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	79.49	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	76.72	21.54	1.08	100	33.90	0.77
2019	Reference	Moist Halophytic Dwarf Shrub	4.00	6.40	24.00	26.40	0.00	12.00	15.20	22.40	40.80	0.80	100.00	5.04	0.75	100	14.04	1.86
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	100.00	5.46	1.00	100	18.58	1.72
2019	Test	Dry Halophytic Meadow	0.00	51.67	25.00	0.83	0.00	14.17	5.83	0.00	0.00	5.83	4.35	60.00		100	13.17	2.31
2019	Reference	Dry Halophytic Meadow	0.00	53.33	22.67	1.33	0.00	17.33	13.33	0.00	0.00	0.00	0.00			100	14.00	3.81
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	4.17	23.00		100	34.54	4.71
2019	Test	Deep Polygon Complex	19.80	0.56	38.25	45.44	1.24	8.89	0.56	29.47	6.97	8.10	48.80	11.33	1.07	100	26.11	0.90
2019	Reference	Deep Polygon Complex	22.02	0.30	41.93	45.85	0.90	10.11	0.15	21.87	4.98	6.64	56.67	11.76	0.82	100	30.02	1.09
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	55.95	12.61	0.71	100	32.29	0.84
2013	Reference	Deep Polygon Complex	23.08	0.00	38.91	38.01	1.36	6.64	0.00	24.28	5.28	9.80	62.60	15.68	0.96	100	35.80	1.14
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	50.00	21.00		100	5.00	3.00

Appendix H. 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 2019.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Barrens	reference	Bare ground	98.36–98.56	98.21–98.71	98.46	82.13–83.21	81.35–83.99	82.67
		Forbs	2.69–3.47	2.14–4.02	3.08	0.53–0.69	0.41–0.81	0.61
		Grasses	0.27–0.35	0.20–0.42	0.31	0.31–0.41	0.24–0.48	0.36
		Litter	2.31–2.61	2.10–2.82	2.46	11.07–11.97	10.42–12.62	11.52
		Salix	0.27–0.35	0.20–0.42	0.31	0.00–0.00	0.00–0.00	0
		Soil	98.36–98.56	98.21–98.71	98.46	82.13–83.21	81.35–83.99	82.67
		Tall shrub	0.27–0.35	0.20–0.42	0.31	0.00–0.00	0.00–0.00	0
		Total live vascular	3.49–4.51	2.74–5.26	4	0.88–1.06	0.74–1.20	0.97
		Water	0.00–0.00	0.00–0.00	0	5.46–6.18	4.95–6.69	5.82
	test	Bare ground	69.16–71.56	67.43–73.29	70.36	68.64–70.52	67.29–71.87	69.58
		Dryas	0.69–0.89	0.55–1.03	0.79	0.00–0.00	0.00–0.00	0
		Dwarf shrub	0.97–1.19	0.82–1.34	1.08	4.21–5.19	3.51–5.89	4.7
		Forbs	6.65–7.89	5.75–8.79	7.27	7.43–8.67	6.54–9.56	8.05
		Grasses	0.54–0.64	0.46–0.72	0.59	4.24–4.94	3.73–5.45	4.59
		Litter	10.65–12.31	9.46–13.50	11.48	16.04–17.60	14.92–18.72	16.82
		Low shrub	7.79–9.47	6.58–10.68	8.63	2.48–3.40	1.81–4.07	2.94
		Mosses	2.59–3.37	2.03–3.93	2.98	5.00–5.96	4.32–6.64	5.48
		Salix	8.28–9.96	7.07–11.17	9.12	7.00–8.28	6.08–9.20	7.64
		Sedges	2.68–3.18	2.32–3.54	2.93	0.33–0.45	0.24–0.54	0.39
		Soil	69.16–71.56	67.43–73.29	70.36	68.64–70.52	67.29–71.87	69.58
		Tall shrub	0.16–0.22	0.12–0.26	0.19	0.00–0.00	0.00–0.00	0
		Total live vascular	20.86–23.54	18.92–25.48	22.2	19.41–21.95	17.59–23.77	20.68
		Water	15.12–17.00	13.77–18.35	16.06	14.15–15.53	13.15–16.53	14.84

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Deep Open Water with Islands or Polygonized Margins	reference	Litter	0.00–0.00	0.00–0.00	0	40.65–59.35	27.19–72.81	50
		Sedges	0.00–0.00	0.00–0.00	0	40.65–59.35	27.19–72.81	50
		Total live vascular	0.00–0.00	0.00–0.00	0	40.65–59.35	27.19–72.81	50
		Water	100.00–100.00	100.00–100.00	100	40.65–59.35	27.19–72.81	50
	test	Litter	4.34–6.18	3.02–7.50	5.26	0.00–0.00	0.00–0.00	0
		Mosses	4.34–6.18	3.02–7.50	5.26	2.17–3.09	1.51–3.75	2.63
		Sedges	2.17–3.09	1.51–3.75	2.63	2.17–3.09	1.51–3.75	2.63
		Total live vascular	2.17–3.09	1.51–3.75	2.63	2.17–3.09	1.51–3.75	2.63
		Water	93.81–95.65	92.49–96.97	94.73	96.91–97.83	96.25–98.49	97.37
Deep Open Water without Islands		Forbs	2.14–2.86	1.63–3.37	2.5	0.00–0.00	0.00–0.00	0
		Litter	0.00–0.00	0.00–0.00	0	2.14–2.86	1.63–3.37	2.5
		Sedges	2.14–2.86	1.63–3.37	2.5	2.14–2.86	1.63–3.37	2.5
		Total live vascular	4.29–5.71	3.27–6.73	5	2.14–2.86	1.63–3.37	2.5
		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
		Bare ground	0.26–0.34	0.20–0.40	0.3	0.82–0.90	0.75–0.97	0.86
		Dryas	3.09–3.31	2.93–3.47	3.2	2.01–2.13	1.92–2.22	2.07
		Dwarf shrub	4.98–5.26	4.77–5.47	5.12	4.73–5.11	4.45–5.39	4.92
		Forbs	6.41–6.83	6.12–7.12	6.62	10.00–10.42	9.69–10.73	10.21
		Grasses	0.00–0.00	0.00–0.00	0	0.12–0.16	0.09–0.19	0.14
		Lichens	1.27–1.41	1.18–1.50	1.34	0.82–0.90	0.75–0.97	0.86
		Litter	60.75–61.85	59.96–62.64	61.3	61.03–61.99	60.33–62.69	61.51
		Liver	0.67–0.77	0.60–0.84	0.72	0.52–0.62	0.46–0.68	0.57

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Deep Polygon Complex	reference	Low shrub	10.09–10.61	9.73–10.97	10.35	6.76–7.08	6.53–7.31	6.92
		Mosses	38.08–39.30	37.19–40.19	38.69	45.67–46.81	44.85–47.63	46.24
		Salix	9.97–10.47	9.62–10.82	10.22	7.20–7.50	6.98–7.72	7.35
		Sedges	23.82–24.38	23.41–24.79	24.1	21.93–22.37	21.63–22.67	22.15
		Soil	0.26–0.34	0.20–0.40	0.3	0.12–0.16	0.09–0.19	0.14
		Total live vascular	48.49–49.61	47.68–50.42	49.05	46.53–47.63	45.73–48.43	47.08
		Water	41.03–42.39	40.05–43.37	41.71	36.88–38.10	35.99–38.99	37.49
	test	Algae	0.31–0.43	0.24–0.50	0.37	0.08–0.10	0.06–0.12	0.09
		Bare ground	0.59–0.69	0.52–0.76	0.64	1.23–1.41	1.10–1.54	1.32
		Dryas	4.17–4.47	3.95–4.69	4.32	3.73–4.03	3.52–4.24	3.88
		Dwarf shrub	6.11–6.43	5.88–6.66	6.27	6.66–7.02	6.40–7.28	6.84
		Forbs	5.40–5.72	5.16–5.96	5.56	8.44–8.90	8.12–9.22	8.67
		Grasses	0.26–0.32	0.21–0.37	0.29	0.44–0.52	0.39–0.57	0.48
		Lichens	2.43–2.61	2.29–2.75	2.52	1.01–1.11	0.94–1.18	1.06
		Litter	58.91–59.99	58.15–60.75	59.45	64.66–65.50	64.06–66.10	65.08
		Liver	0.17–0.21	0.14–0.24	0.19	0.21–0.25	0.17–0.29	0.23
		Low shrub	5.85–6.13	5.65–6.33	5.99	7.73–8.07	7.48–8.32	7.9
		Mosses	40.35–41.33	39.65–42.03	40.84	45.02–46.02	44.31–46.73	45.52
		Salix	5.30–5.56	5.11–5.75	5.43	7.60–7.92	7.37–8.15	7.76
		Sedges	20.42–21.06	19.96–21.52	20.74	27.83–28.47	27.37–28.93	28.15
		Soil	0.59–0.69	0.52–0.76	0.64	0.18–0.22	0.15–0.25	0.2
		Total live vascular	40.92–41.98	40.17–42.73	41.45	55.28–56.54	54.36–57.46	55.91
		Water	36.18–37.36	35.33–38.21	36.77	32.17–33.39	31.29–34.27	32.78
Dry Dwarf Shrub	reference	Bare ground	1.40–2.02	0.96–2.46	1.71	0.62–0.88	0.42–1.08	0.75
		Dryas	13.85–14.75	13.21–15.39	14.3	12.00–13.34	11.03–14.31	12.67

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Dry Dwarf Shrub	reference	Dwarf shrub	32.25–35.19	30.13–37.31	33.72	33.07–36.55	30.58–39.04	34.81
		Forbs	21.78–25.52	19.10–28.20	23.65	11.13–12.59	10.07–13.65	11.86
		Grasses	5.58–6.38	5.00–6.96	5.98	5.37–6.81	4.34–7.84	6.09
		Lichens	2.15–2.79	1.69–3.25	2.47	5.10–6.98	3.74–8.34	6.04
		Litter	70.70–72.72	69.25–74.17	71.71	70.59–73.61	68.42–75.78	72.1
		Low shrub	13.47–14.85	12.47–15.85	14.16	15.04–18.18	12.77–20.45	16.61
		Mosses	38.13–41.75	35.51–44.37	39.94	31.38–34.88	28.85–37.41	33.13
		Salix	17.71–19.21	16.63–20.29	18.46	19.66–22.56	17.57–24.65	21.11
		Sedges	8.50–10.66	6.95–12.21	9.58	22.32–26.62	19.23–29.71	24.47
		Soil	1.40–2.02	0.96–2.46	1.71	0.00–0.00	0.00–0.00	0
		Total live vascular	86.34–90.64	83.23–93.75	88.49	95.21–98.55	92.81–100.95	96.88
		Water	0.00–0.00	0.00–0.00	0	4.14–5.94	2.85–7.23	5.04
	test	Bare ground	0.00–0.00	0.00–0.00	0	1.15–1.51	0.89–1.77	1.33
		Dryas	18.88–21.12	17.26–22.74	20	16.38–18.28	15.01–19.65	17.33
		Dwarf shrub	22.88–25.12	21.26–26.74	24	20.15–22.51	18.45–24.21	21.33
		Forbs	4.85–5.81	4.17–6.49	5.33	11.69–12.31	11.24–12.76	12
		Grasses	2.49–2.85	2.23–3.11	2.67	8.85–9.81	8.17–10.49	9.33
		Lichens	11.69–12.31	11.24–12.76	12	4.85–5.81	4.17–6.49	5.33
		Litter	84.68–85.98	83.75–86.91	85.33	79.69–80.31	79.24–80.76	80
		Low shrub	16.68–17.98	15.75–18.91	17.33	21.67–23.67	20.23–25.11	22.67
		Mosses	23.93–26.73	21.90–28.76	25.33	31.56–35.10	29.01–37.65	33.33
		Salix	16.97–17.69	16.45–18.21	17.33	22.88–25.12	21.26–26.74	24
		Sedges	16.61–18.05	15.58–19.08	17.33	20.03–22.63	18.17–24.49	21.33
		Soil	0.00–0.00	0.00–0.00	0	1.15–1.51	0.89–1.77	1.33
		Total live vascular	65.27–68.07	63.24–70.10	66.67	88.07–90.59	86.26–92.40	89.33

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Dry Halophytic Meadow	reference	Bare ground	92.90–93.30	92.61–93.59	93.1	80.43–82.23	79.14–83.52	81.33
		Forbs	1.15–1.51	0.89–1.77	1.33	16.68–17.98	15.75–18.91	17.33
		Grasses	3.89–4.57	3.39–5.07	4.23	13.15–13.51	12.89–13.77	13.33
		Litter	6.61–6.95	6.37–7.19	6.78	34.19–35.15	33.51–35.83	34.67
		Mosses	0.00–0.00	0.00–0.00	0	1.15–1.51	0.89–1.77	1.33
		Soil	92.90–93.30	92.61–93.59	93.1	80.43–82.23	79.14–83.52	81.33
		Total live vascular	5.19–5.95	4.64–6.50	5.57	31.46–32.54	30.68–33.32	32
	test	Bare ground	71.71–74.29	69.86–76.14	73	80.94–82.62	79.74–83.82	81.78
		Dwarf shrub	0.57–0.77	0.42–0.92	0.67	0.00–0.00	0.00–0.00	0
		Forbs	5.60–6.40	5.01–6.99	6	11.47–12.23	10.92–12.78	11.85
		Grasses	7.63–8.59	6.95–9.27	8.11	11.43–13.75	9.75–15.43	12.59
		Litter	40.56–41.88	39.62–42.82	41.22	26.48–28.34	25.13–29.69	27.41
		Low shrub	0.00–0.00	0.00–0.00	0	0.57–0.77	0.42–0.92	0.67
		Mosses	0.00–0.00	0.00–0.00	0	0.57–0.77	0.42–0.92	0.67
		Salix	0.57–0.77	0.42–0.92	0.67	4.08–5.26	3.23–6.11	4.67
		Soil	71.71–74.29	69.86–76.14	73	80.94–82.62	79.74–83.82	81.78
		Tall shrub	0.00–0.00	0.00–0.00	0	3.40–4.60	2.53–5.47	4
		Total live vascular	14.32–15.24	13.66–15.90	14.78	28.32–29.90	27.20–31.02	29.11
Grass Marsh	reference	Forbs	17.32–19.50	15.75–21.07	18.41	0.00–0.00	0.00–0.00	0
		Grasses	26.47–30.85	23.31–34.01	28.66	2.95–4.19	2.07–5.07	3.57
		Mosses	1.08–1.54	0.76–1.86	1.31	0.00–0.00	0.00–0.00	0
		Sedges	0.00–0.00	0.00–0.00	0	5.91–8.37	4.13–10.15	7.14
		Total live vascular	43.92–50.22	39.38–54.76	47.07	8.86–12.56	6.20–15.22	10.71
		Water	68.50–76.88	62.47–82.91	72.69	100.00–100.00	100.00–100.00	100
Human Modified		Bare ground	0.00–0.00	0.00–0.00	0	7.89–10.77	5.82–12.84	9.33

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Human Modified	reference	Dwarf shrub	0.00–0.00	0.00–0.00	0	5.13–7.37	3.53–8.97	6.25
		Forbs	0.00–0.00	0.00–0.00	0	2.66–3.34	2.17–3.83	3
		Litter	89.96–93.36	87.53–95.79	91.66	54.74–59.42	51.38–62.78	57.08
		Liver	0.00–0.00	0.00–0.00	0	0.82–1.18	0.56–1.44	1
		Low shrub	0.00–0.00	0.00–0.00	0	1.64–2.36	1.13–2.87	2
		Mosses	28.31–30.01	27.09–31.23	29.16	40.83–46.51	36.73–50.61	43.67
		Salix	0.00–0.00	0.00–0.00	0	7.20–9.30	5.68–10.82	8.25
		Sedges	23.26–32.30	16.76–38.80	27.78	35.18–42.82	29.69–48.31	39
		Total live vascular	33.22–47.34	23.06–57.50	40.28	50.69–62.31	42.33–70.67	56.5
		Water	0.00–0.00	0.00–0.00	0	16.54–20.46	13.71–23.29	18.5
Moist Halophytic Dwarf Shrub		Bare ground	58.53–63.33	55.08–66.78	60.93	25.19–28.11	23.09–30.21	26.65
		Dwarf shrub	38.26–40.26	36.82–41.70	39.26	39.12–40.30	38.27–41.15	39.71
		Forbs	13.24–15.20	11.83–16.61	14.22	14.09–15.69	12.95–16.83	14.89
		Grasses	5.95–6.59	5.49–7.05	6.27	17.36–19.74	15.65–21.45	18.55
		Litter	32.60–34.26	31.40–35.46	33.43	51.82–53.56	50.57–54.81	52.69
		Liver	0.57–0.77	0.43–0.91	0.67	0.00–0.00	0.00–0.00	0
		Low shrub	0.00–0.00	0.00–0.00	0	0.57–0.77	0.43–0.91	0.67
		Mosses	20.73–24.61	17.94–27.40	22.67	21.32–23.22	19.95–24.59	22.27
		Salix	38.26–40.26	36.82–41.70	39.26	39.83–40.91	39.06–41.68	40.37
		Sedges	7.92–9.42	6.83–10.51	8.67	17.35–19.99	15.45–21.89	18.67
		Soil	58.53–63.33	55.08–66.78	60.93	25.19–28.11	23.09–30.21	26.65
		Total live vascular	68.45–71.07	66.56–72.96	69.76	94.62–97.02	92.88–98.76	95.82
		Water	1.70–2.30	1.28–2.72	2	8.62–10.04	7.60–11.06	9.33
	test	Bare ground	95.75–96.61	95.13–97.23	96.18	52.44–57.62	48.71–61.35	55.03
		Dwarf shrub	27.35–30.09	25.38–32.06	28.72	26.61–29.13	24.81–30.93	27.87

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Moist Halophytic Dwarf Shrub	test	Forbs	17.18–17.78	16.74–18.22	17.48	23.37–25.15	22.09–26.43	24.26
		Grasses	1.82–2.62	1.24–3.20	2.22	25.78–28.28	23.98–30.08	27.03
		Litter	24.43–24.95	24.06–25.32	24.69	55.90–60.28	52.76–63.42	58.09
		Mosses	0.66–0.94	0.45–1.15	0.8	14.96–18.46	12.43–20.99	16.71
		Salix	27.35–30.09	25.38–32.06	28.72	26.61–29.13	24.81–30.93	27.87
		Soil	95.75–96.61	95.13–97.23	96.18	52.44–57.62	48.71–61.35	55.03
		Total live vascular	48.14–50.92	46.15–52.91	49.53	80.04–82.72	78.12–84.64	81.38
Moist Herb Meadow	reference	Bare ground	86.04–88.68	84.13–90.59	87.36	52.39–55.65	50.05–57.99	54.02
		Forbs	30.39–32.97	28.55–34.81	31.68	27.18–29.68	25.39–31.47	28.43
		Grasses	9.75–10.95	8.88–11.82	10.35	0.57–0.77	0.42–0.92	0.67
		Litter	18.66–20.60	17.27–21.99	19.63	48.72–52.68	45.86–55.54	50.7
		Low shrub	19.27–20.09	18.67–20.69	19.68	20.71–23.03	19.03–24.71	21.87
		Mosses	8.61–10.41	7.31–11.71	9.51	10.52–11.68	9.68–12.52	11.1
		Salix	25.63–26.09	25.30–26.42	25.86	25.42–27.90	23.64–29.68	26.66
		Sedges	3.77–4.65	3.13–5.29	4.21	1.76–2.40	1.30–2.86	2.08
		Soil	86.04–88.68	84.13–90.59	87.36	52.39–55.65	50.05–57.99	54.02
		Tall shrub	7.70–8.82	6.89–9.63	8.26	4.37–5.19	3.79–5.77	4.78
		Total live vascular	77.83–78.87	77.07–79.63	78.35	61.74–66.34	58.44–69.64	64.04
	test	Bare ground	92.58–93.54	91.90–94.22	93.06	62.23–65.33	60.00–67.56	63.78
		Dwarf shrub	18.91–21.27	17.22–22.96	20.09	14.96–16.98	13.51–18.43	15.97
		Forbs	41.67–43.11	40.63–44.15	42.39	30.98–33.02	29.51–34.49	32
		Fungi	1.97–2.79	1.38–3.38	2.38	0.00–0.00	0.00–0.00	0
		Grasses	13.30–14.78	12.24–15.84	14.04	21.23–23.31	19.73–24.81	22.27
		Litter	17.09–19.13	15.62–20.60	18.11	40.88–44.08	38.58–46.38	42.48
		Low shrub	1.72–2.44	1.21–2.95	2.08	1.80–2.32	1.43–2.69	2.06

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Moist Herb Meadow	test	Mosses	0.56–0.78	0.39–0.95	0.67	11.01–12.25	10.11–13.15	11.63
		Salix	21.17–23.19	19.71–24.65	22.18	17.48–19.58	15.97–21.09	18.53
		Sedges	0.00–0.00	0.00–0.00	0	1.25–1.75	0.90–2.10	1.5
		Soil	92.58–93.54	91.90–94.22	93.06	62.23–65.33	60.00–67.56	63.78
		Tall shrub	0.00–0.00	0.00–0.00	0	0.42–0.58	0.30–0.70	0.5
		Total live vascular	83.76–86.96	81.45–89.27	85.36	78.39–82.67	75.31–85.75	80.53
Moist Low Shrub	reference	Algae	0.05–0.07	0.04–0.08	0.06	0.00–0.00	0.00–0.00	0
		Bare ground	21.39–22.49	20.61–23.27	21.94	7.19–7.73	6.79–8.13	7.46
		Dryas	4.66–4.94	4.46–5.14	4.8	3.77–4.03	3.58–4.22	3.9
		Dwarf shrub	10.85–11.35	10.48–11.72	11.1	10.99–11.51	10.63–11.87	11.25
		Forbs	21.29–21.91	20.85–22.35	21.6	21.06–21.72	20.58–22.20	21.39
		Fungi	0.00–0.00	0.00–0.00	0	0.05–0.07	0.04–0.08	0.06
		Grasses	3.63–3.83	3.48–3.98	3.73	3.48–3.70	3.32–3.86	3.59
		Lichens	0.30–0.34	0.26–0.38	0.32	0.27–0.31	0.24–0.34	0.29
		Litter	63.44–64.38	62.76–65.06	63.91	67.08–67.98	66.43–68.63	67.53
		Liver	0.34–0.38	0.30–0.42	0.36	0.29–0.33	0.26–0.36	0.31
		Low shrub	22.51–23.21	22.02–23.70	22.86	24.51–25.13	24.05–25.59	24.82
		Mosses	37.28–38.24	36.59–38.93	37.76	45.03–45.95	44.37–46.61	45.49
		Salix	27.14–27.80	26.68–28.26	27.47	29.02–29.64	28.59–30.07	29.33
		Sedges	17.97–18.65	17.49–19.13	18.31	23.36–24.22	22.74–24.84	23.79
		Soil	21.39–22.49	20.61–23.27	21.94	6.85–7.39	6.46–7.78	7.12
		Tall shrub	1.06–1.26	0.92–1.40	1.16	1.36–1.64	1.15–1.85	1.5
		Total live vascular	83.35–84.67	82.40–85.62	84.01	91.44–92.76	90.49–93.71	92.1
		Water	3.77–4.27	3.40–4.64	4.02	5.34–5.90	4.95–6.29	5.62
	test	Algae	0.09–0.13	0.07–0.15	0.11	0.00–0.00	0.00–0.00	0

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Moist Low Shrub	test	Bare ground	20.11–21.15	19.37–21.89	20.63	9.46–10.16	8.96–10.66	9.81
		Dryas	5.77–6.15	5.50–6.42	5.96	5.03–5.41	4.76–5.68	5.22
		Dwarf shrub	11.98–12.46	11.63–12.81	12.22	13.72–14.36	13.27–14.81	14.04
		Forbs	22.85–23.51	22.37–23.99	23.18	24.41–25.07	23.94–25.54	24.74
		Fungi	0.00–0.00	0.00–0.00	0	0.14–0.18	0.10–0.22	0.16
		Grasses	2.54–2.72	2.41–2.85	2.63	3.89–4.17	3.70–4.36	4.03
		Lichens	1.56–1.74	1.44–1.86	1.65	0.96–1.06	0.89–1.13	1.01
		Litter	63.50–64.28	62.93–64.85	63.89	67.50–68.18	67.01–68.67	67.84
		Liver	0.10–0.12	0.08–0.14	0.11	0.00–0.00	0.00–0.00	0
		Low shrub	24.01–24.67	23.53–25.15	24.34	24.79–25.49	24.28–26.00	25.14
		Mosses	38.72–39.64	38.06–40.30	39.18	46.45–47.45	45.74–48.16	46.95
		Salix	29.40–30.06	28.93–30.53	29.73	30.69–31.39	30.18–31.90	31.04
		Sedges	12.70–13.20	12.35–13.55	12.95	17.91–18.63	17.40–19.14	18.27
		Soil	20.11–21.15	19.37–21.89	20.63	9.46–10.16	8.96–10.66	9.81
		Tall shrub	1.50–1.82	1.27–2.05	1.66	0.59–0.67	0.52–0.74	0.63
		Total live vascular	80.04–81.30	79.13–82.21	80.67	91.11–92.55	90.08–93.58	91.83
		Water	2.78–3.10	2.56–3.32	2.94	3.72–4.08	3.47–4.33	3.9
Moist Sedge-Shrub Meadow		Bare ground	5.71–7.93	4.11–9.53	6.82	0.42–0.58	0.30–0.70	0.5
		Dryas	8.89–9.51	8.45–9.95	9.2	12.72–13.90	11.87–14.75	13.31
		Dwarf shrub	22.10–23.46	21.13–24.43	22.78	24.94–26.34	23.93–27.35	25.64
		Forbs	5.35–6.19	4.75–6.79	5.77	24.48–28.18	21.82–30.84	26.33
		Grasses	1.45–1.83	1.17–2.11	1.64	2.00–2.58	1.58–3.00	2.29
		Lichens	0.42–0.58	0.30–0.70	0.5	1.23–1.55	1.01–1.77	1.39
		Litter	67.45–71.01	64.90–73.56	69.23	70.79–72.65	69.44–74.00	71.72
		Low shrub	7.01–8.07	6.24–8.84	7.54	12.12–13.66	11.01–14.77	12.89

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Moist Sedge-Shrub Meadow	test	Mosses	53.71–56.93	51.39–59.25	55.32	69.63–72.29	67.71–74.21	70.96
		Salix	12.02–13.12	11.24–13.90	12.57	17.05–18.79	15.80–20.04	17.92
		Sedges	17.83–19.89	16.34–21.38	18.86	21.98–23.96	20.55–25.39	22.97
		Soil	5.71–7.93	4.11–9.53	6.82	0.42–0.58	0.30–0.70	0.5
		Total live vascular	57.25–61.21	54.41–64.05	59.23	91.84–94.68	89.80–96.72	93.26
		Water	1.90–2.64	1.37–3.17	2.27	0.95–1.33	0.69–1.59	1.14
Moist Tall Shrub	reference	Bare ground	87.15–89.31	85.60–90.86	88.23	24.78–27.70	22.69–29.79	26.24
		Forbs	16.53–19.47	14.42–21.58	18	7.78–9.22	6.75–10.25	8.5
		Grasses	8.80–11.14	7.11–12.83	9.97	6.56–8.32	5.30–9.58	7.44
		Litter	26.30–27.56	25.39–28.47	26.93	64.03–68.39	60.88–71.54	66.21
		Low shrub	3.04–3.96	2.38–4.62	3.5	10.31–13.03	8.36–14.98	11.67
		Mosses	2.85–3.75	2.19–4.41	3.3	24.21–27.37	21.93–29.65	25.79
		Salix	27.36–29.30	25.97–30.69	28.33	45.20–51.14	40.93–55.41	48.17
		Sedges	0.00–0.00	0.00–0.00	0	3.26–4.34	2.47–5.13	3.8
		Soil	87.15–89.31	85.60–90.86	88.23	24.78–27.70	22.69–29.79	26.24
		Tall shrub	26.19–28.47	24.56–30.10	27.33	37.09–40.91	34.35–43.65	39
		Total live vascular	56.85–60.75	54.04–63.56	58.8	70.44–73.98	67.89–76.53	72.21
		Water	0.00–0.00	0.00–0.00	0	1.80–2.64	1.21–3.23	2.22
Moist Tussock Tundra	test	Dryas	4.58–5.66	3.79–6.45	5.12	3.06–4.18	2.26–4.98	3.62
		Dwarf shrub	9.65–10.87	8.78–11.74	10.26	6.93–8.31	5.94–9.30	7.62
		Forbs	11.47–12.49	10.73–13.23	11.98	13.06–14.42	12.09–15.39	13.74
		Grasses	0.64–0.92	0.44–1.12	0.78	5.99–7.25	5.10–8.14	6.62
		Lichens	2.32–2.96	1.87–3.41	2.64	0.00–0.00	0.00–0.00	0
		Litter	69.01–71.71	67.07–73.65	70.36	59.25–63.63	56.09–66.79	61.44
		Low shrub	14.43–16.03	13.27–17.19	15.23	17.21–18.39	16.37–19.23	17.8

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Moist Tussock Tundra	test	Mosses	23.87–26.79	21.77–28.89	25.33	34.39–38.21	31.65–40.95	36.3
		Salix	17.37–19.37	15.94–20.80	18.37	13.52–14.84	12.57–15.79	14.18
		Sedges	40.95–44.47	38.41–47.01	42.71	30.66–34.06	28.21–36.51	32.36
		Total live vascular	94.11–99.83	90.01–103.93	96.97	78.29–83.59	74.48–87.40	80.94
		Water	24.79–29.33	21.54–32.58	27.06	19.57–23.99	16.38–27.18	21.78
Nonpatterned Wet Meadow	reference	Algae	0.11–0.13	0.09–0.15	0.12	0.00–0.00	0.00–0.00	0
		Bare ground	3.64–4.18	3.25–4.57	3.91	0.70–0.82	0.62–0.90	0.76
		Dryas	3.20–3.44	3.04–3.60	3.32	2.34–2.56	2.18–2.72	2.45
		Dwarf shrub	7.26–7.74	6.90–8.10	7.5	6.16–6.54	5.89–6.81	6.35
		Forbs	14.21–14.85	13.74–15.32	14.53	14.67–15.13	14.33–15.47	14.9
		Grasses	2.48–2.68	2.33–2.83	2.58	1.45–1.59	1.34–1.70	1.52
		Lichens	1.06–1.20	0.96–1.30	1.13	0.39–0.45	0.35–0.49	0.42
		Litter	67.61–68.41	67.03–68.99	68.01	63.97–64.83	63.35–65.45	64.4
		Liver	1.00–1.14	0.90–1.24	1.07	0.05–0.07	0.04–0.08	0.06
		Low shrub	10.80–11.38	10.39–11.79	11.09	12.33–12.93	11.90–13.36	12.63
		Mosses	53.19–54.21	52.45–54.95	53.7	63.32–64.36	62.58–65.10	63.84
		Salix	13.89–14.49	13.45–14.93	14.19	14.30–14.90	13.87–15.33	14.6
		Sedges	22.23–22.77	21.85–23.15	22.5	28.06–28.80	27.52–29.34	28.43
		Soil	3.64–4.18	3.25–4.57	3.91	0.70–0.82	0.62–0.90	0.76
		Tall shrub	0.57–0.71	0.46–0.82	0.64	0.22–0.28	0.18–0.32	0.25
		Total live vascular	60.68–61.70	59.94–62.44	61.19	67.93–69.15	67.05–70.03	68.54
		Water	14.91–15.77	14.28–16.40	15.34	13.90–14.80	13.24–15.46	14.35
	test	Bare ground	3.02–3.58	2.61–3.99	3.3	0.64–0.74	0.56–0.82	0.69
		Dryas	1.52–1.68	1.40–1.80	1.6	2.29–2.53	2.12–2.70	2.41
		Dwarf shrub	3.84–4.12	3.64–4.32	3.98	4.91–5.29	4.65–5.55	5.1

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Nonpatterned Wet Meadow	test	Forbs	9.10–9.54	8.79–9.85	9.32	10.84–11.38	10.45–11.77	11.11
		Fungi	0.00–0.00	0.00–0.00	0	0.23–0.31	0.16–0.38	0.27
		Grasses	0.62–0.78	0.52–0.88	0.7	1.68–1.90	1.53–2.05	1.79
		Lichens	1.70–1.84	1.59–1.95	1.77	0.77–0.89	0.69–0.97	0.83
		Litter	69.51–70.29	68.96–70.84	69.9	70.69–71.51	70.11–72.09	71.1
		Liver	1.03–1.17	0.94–1.26	1.1	0.20–0.26	0.16–0.30	0.23
		Low shrub	14.52–15.18	14.04–15.66	14.85	14.05–14.67	13.59–15.13	14.36
		Mosses	50.84–51.94	50.05–52.73	51.39	62.32–63.38	61.57–64.13	62.85
		Salix	15.63–16.31	15.14–16.80	15.97	15.87–16.49	15.42–16.94	16.18
		Sedges	25.46–26.34	24.84–26.96	25.9	34.78–35.84	34.02–36.60	35.31
		Soil	3.02–3.58	2.61–3.99	3.3	0.41–0.51	0.34–0.58	0.46
		Tall shrub	0.16–0.22	0.12–0.26	0.19	0.07–0.09	0.05–0.11	0.08
		Total live vascular	57.09–58.37	56.17–59.29	57.73	72.16–73.56	71.14–74.58	72.86
		Water	16.09–17.05	15.40–17.74	16.57	13.63–14.53	12.98–15.18	14.08
Patterned Wet Meadow	reference	Algae	0.00–0.00	0.00–0.00	0	0.06–0.08	0.04–0.10	0.07
		Bare ground	2.57–3.05	2.22–3.40	2.81	1.30–1.52	1.13–1.69	1.41
		Dryas	4.30–4.50	4.14–4.66	4.4	3.85–4.09	3.68–4.26	3.97
		Dwarf shrub	7.64–7.96	7.40–8.20	7.8	8.62–9.00	8.36–9.26	8.81
		Forbs	13.00–13.44	12.68–13.76	13.22	16.60–17.26	16.14–17.72	16.93
		Fungi	0.00–0.00	0.00–0.00	0	0.13–0.17	0.10–0.20	0.15
		Grasses	0.53–0.59	0.49–0.63	0.56	0.06–0.08	0.04–0.10	0.07
		Lichens	1.39–1.49	1.31–1.57	1.44	1.11–1.21	1.04–1.28	1.16
		Litter	67.09–67.61	66.70–68.00	67.35	64.13–64.83	63.63–65.33	64.48
		Liver	0.66–0.74	0.61–0.79	0.7	0.20–0.24	0.18–0.26	0.22
		Low shrub	8.75–9.03	8.54–9.24	8.89	13.33–13.77	13.01–14.09	13.55

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
Patterned Wet Meadow	reference	Mosses	52.16–53.10	51.49–53.77	52.63	56.28–57.30	55.54–58.04	56.79
		Salix	10.52–10.82	10.30–11.04	10.67	16.59–17.01	16.29–17.31	16.8
		Sedges	23.16–23.60	22.84–23.92	23.38	28.83–29.39	28.43–29.79	29.11
		Soil	2.57–3.05	2.22–3.40	2.81	1.01–1.23	0.84–1.40	1.12
		Total live vascular	56.32–57.32	55.59–58.05	56.82	73.15–74.23	72.38–75.00	73.69
		Water	20.19–20.95	19.66–21.48	20.57	17.46–18.16	16.96–18.66	17.81
	test	Algae	0.03–0.03	0.02–0.04	0.03	0.12–0.14	0.11–0.15	0.13
		Bare ground	0.31–0.33	0.29–0.35	0.32	1.02–1.12	0.95–1.19	1.07
		Dryas	3.75–3.89	3.64–4.00	3.82	4.23–4.37	4.13–4.47	4.3
		Dwarf shrub	6.64–6.82	6.51–6.95	6.73	7.51–7.71	7.36–7.86	7.61
		Forbs	8.72–8.92	8.58–9.06	8.82	9.84–10.06	9.67–10.23	9.95
		Fungi	0.03–0.03	0.02–0.04	0.03	0.03–0.03	0.02–0.04	0.03
		Grasses	1.07–1.13	1.03–1.17	1.1	0.41–0.45	0.39–0.47	0.43
		Lichens	2.41–2.51	2.33–2.59	2.46	1.61–1.69	1.56–1.74	1.65
		Litter	70.66–71.00	70.41–71.25	70.83	71.00–71.36	70.75–71.61	71.18
		Liver	0.41–0.45	0.39–0.47	0.43	0.20–0.22	0.18–0.24	0.21
		Low shrub	9.47–9.69	9.32–9.84	9.58	10.04–10.26	9.87–10.43	10.15
		Mosses	53.02–53.46	52.71–53.77	53.24	59.69–60.13	59.37–60.45	59.91
		Salix	11.49–11.71	11.33–11.87	11.6	11.99–12.23	11.82–12.40	12.11
		Sedges	26.44–26.78	26.19–27.03	26.61	29.91–30.25	29.67–30.49	30.08
		Soil	0.31–0.33	0.29–0.35	0.32	0.94–1.04	0.88–1.10	0.99
		Tall shrub	0.04–0.06	0.03–0.07	0.05	0.00–0.00	0.00–0.00	0
		Total live vascular	55.59–56.17	55.18–56.58	55.88	61.52–62.06	61.13–62.45	61.79
		Water	17.78–18.26	17.45–18.59	18.02	15.76–16.18	15.45–16.49	15.97
River or Stream	reference	Bare ground	0.00–0.00	0.00–0.00	0	3.09–4.19	2.30–4.98	3.64

Appendix H. Continued.

Wildlife Habitat	Area	Structure Class	2013 75% CI	2013 95% CI	2013 Mean Cover	2019 75% CI	2019 95% CI	2019 Mean Cover
River or Stream	reference	Forbs	3.36–4.64	2.43–5.57	4	0.00–0.00	0.00–0.00	0
		Soil	0.00–0.00	0.00–0.00	0	3.09–4.19	2.30–4.98	3.64
		Total live vascular	3.36–4.64	2.43–5.57	4	0.00–0.00	0.00–0.00	0
		Water	96.56–97.22	96.09–97.69	96.89	95.81–96.91	95.02–97.70	96.36
	test	Algae	0.00–0.00	0.00–0.00	0	2.70–3.96	1.79–4.87	3.33
		Bare ground	0.00–0.00	0.00–0.00	0	18.01–26.43	11.95–32.49	22.22
		Litter	0.00–0.00	0.00–0.00	0	6.01–8.81	3.99–10.83	7.41
		Soil	0.00–0.00	0.00–0.00	0	18.01–26.43	11.95–32.49	22.22
		Water	100.00–100.00	100.00–100.00	100	61.71–72.37	54.05–80.03	67.04
Shallow Open Water with Islands or Polygonized Margins		Litter	0.00–0.00	0.00–0.00	0	4.42–4.50	4.36–4.56	4.46
		Sedges	0.00–0.00	0.00–0.00	0	1.78–2.38	1.36–2.80	2.08
		Total live vascular	0.00–0.00	0.00–0.00	0	1.78–2.38	1.36–2.80	2.08
		Water	100.00–100.00	100.00–100.00	100	100.00–100.00	100.00–100.00	100

Appendix I1. Datafile listing and summary statistics for ground surface elevation measured at Thaw Elevation Monitoring Locations in Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

				Minimum		Maximum		Mean		SE		n	
Area	Direction	Point Type	Ecotype	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Reference	North	Thaw Elev Point	Coastal Barrens	1.2	1	2.7	1.2	2.1	1.1	0.5	0.1	3	2
			Coastal Dry Elymus Meadow	1.8	1.4	1.8	1.9	1.8	1.6		0.2	1	2
			Coastal Moist Willow Dwarf Shrub	3.2	1.9	3.2	1.9	3.2	1.9			1	1
			Human Modified Low Shrub	2	2	2	2	2	2			1	1
			Human Modified Wet Meadow		2		2		2				1
			Lowland Deep-polygon Complex	2.3	2.2	3.2	3.4	2.6	2.7	0.1	0.1	14	14
			Lowland Wet Sedge Meadow	2.3	2.2	3	3	2.5	2.5	0.1	0.1	5	5
			Lowland Wet Sedge-Willow Meadow	2.6	2.5	2.6	2.5	2.6	2.5			1	1
			Riverine Deep-polygon Complex	2.1	2	2.5	2.5	2.3	2.3	0.1	0.1	7	7
			Riverine Moist Low Willow Shrub	3	2	3.8	3.1	3.3	2.4	0.2	0.3	4	4
			Riverine Moist Low Willow-Sedge Meadow	1.9	1.9	3.2	2.5	2.3	2.2	0.2	0.1	7	8
			Riverine Wet Sedge Meadow	2.1	1.7	3.1	3	2.6	2.5	0.1	0.1	10	10
			Riverine Wet Sedge-Willow Meadow	1.8	2.1	3.6	2.9	2.5	2.4	0.1	0	23	22
		Veg Start Point	Coastal Barrens	0.6	0.5	1.5	0.7	1	0.6	0.3	0.1	3	2
			Coastal Dry Elymus Meadow		1.6		1.6		1.6				1
			Coastal Moist Willow Dwarf Shrub	0.7	0.9	3.1	1.7	1.9	1.3	1.2	0.4	2	2
			Lowland Deep-polygon Complex	2.2	2.4	2.8	2.8	2.5	2.5	0.1	0.1	5	5
			Lowland Wet Sedge Meadow	2.5	2.6	2.5	2.6	2.5	2.6			1	1
			Riverine Deep-polygon Complex	2.3	2.2	2.3	2.3	2.3	2.2	0	0	2	2
			Riverine Dry Dryas Dwarf Shrub	3.5	2.1	3.5	2.1	3.5	2.1			1	1
			Riverine Moist Low Willow Shrub	1.2	1.3	2.3	2.2	1.9	1.9	0.3	0.3	3	3
			Riverine Moist Low Willow-Sedge Meadow	1.1	1.1	2.8	2.7	2	2	0.3	0.2	7	7
			Riverine Wet Sedge Meadow	2.1	1.8	3.1	3.1	2.6	2.4	0.2	0.2	6	6
			Riverine Wet Sedge-Willow Meadow	2.3	2.2	3.5	2.5	2.6	2.4	0.2	0.1	5	5
			Upland Moist Low Willow Shrub	2.1	2.2	2.1	2.2	2.1	2.2			1	1
	South	Thaw Elev Point	Coastal Barrens	1	0.5	1.5	1.4	1.2	0.9	0.1	0.2	4	4
			Human Modified Wet Meadow	3.6	3.5	3.6	4.1	3.6	3.8		0.3	1	2
			Lowland Deep-polygon Complex	3.7	3.7	3.7	3.7	3.7	3.7			1	1
			Lowland Moist Sedge-Shrub Meadow	4.1	4.1	4.1	4.1	4.1	4.1			1	1
			Lowland Wet Sedge Meadow	3.8	3.8	4.2	4.2	4.1	4	0.1	0	8	8
			Riverine Moist Herb Meadow	2.5	2.5	2.5	2.5	2.5	2.5			1	1
			Riverine Moist Low Willow Shrub	2.9	2.9	3.9	3.8	3.5	3.4	0.1	0.1	7	7
			Riverine Moist Low Willow-Sedge Meadow	4	4	4	4.2	4	4.1	0	0.1	2	2
			Riverine Wet Sedge Meadow	1.9	1.9	4.3	4.4	3.7	3.6	0.1	0.2	20	20
			Riverine Wet Sedge-Willow Meadow	3.3	3.3	4.3	4.3	3.9	3.9	0	0.1	27	26
			Upland Dry Dryas Dwarf Shrub	4.6	4.6	5	4.9	4.8	4.8	0.2	0.2	2	2

Appendix I1. Continued.

Area	Direction	Point Type	Ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Reference	South	Thaw Elev Point	Upland Moist Low Willow Shrub	4.6	4.5	4.7	4.6	4.6	4.6	0.1	0.1	2	2
			Coastal Barrens	0.7	0	1.5	1.5	1.1	0.8	0.4	0.8	2	2
			Human Modified Wet Meadow	3.9	3.8	3.9	3.8	3.9	3.8			1	1
			Lowland Deep-polygon Complex	3.6	3.6	3.7	3.7	3.7	3.6	0	0	2	2
			Lowland Wet Sedge Meadow	3.9	3.8	4.3	4.2	4	4	0.1	0.1	4	4
			Riverine Moist Herb Meadow	2.6	2.5	2.9	2.8	2.7	2.6	0.1	0.2	2	2
			Riverine Moist Low Willow Shrub	2.6	2.5	4.2	4.1	3.5	3.5	0.3	0.3	5	5
			Riverine Moist Low Willow-Sedge Meadow	3	2.8	4.2	4.2	3.8	3.7	0.3	0.3	4	4
			Riverine Moist Tall Willow Shrub	2.2	1.9	2.2	1.9	2.2	1.9			1	1
			Riverine Wet Sedge Meadow	3.5	3.4	4.3	4.2	3.8	3.8	0.1	0.1	6	6
			Riverine Wet Sedge-Willow Meadow	3.3	3.3	4.2	4.1	3.9	3.8	0.1	0.1	10	10
			Upland Moist Low Willow Shrub	5.4	5.4	5.4	5.4	5.4	5.4			1	1
Test	North	Thaw Elev Point	Coastal Barrens	0.4	0.5	2	2	1.4	1.3	0.3	0.3	5	5
			Coastal Dry Elymus Meadow	3.6	3.6	3.6	3.6	3.6	3.6			1	1
			Lowland Deep-polygon Complex	2.9	2.8	2.9	2.9	2.9	2.9	0	0	2	2
			Lowland Wet Sedge Meadow	3.1	3.1	3.1	3.1	3.1	3.1			1	1
			Riverine Deep-polygon Complex	2.8	2.6	3.3	3.2	3	2.9	0.1	0.1	7	7
			Riverine Moist Low Willow Shrub	1.8	1.6	2.6	2.6	2.2	2.1	0.4	0.5	2	2
			Riverine Moist Low Willow-Sedge Meadow	2.6	2.6	3.4	3.4	3.1	3.1	0.2	0.2	4	4
			Riverine Wet Sedge Meadow	2.7	2.6	4.1	4	3.1	3.1	0.1	0.1	30	30
			Riverine Wet Sedge-Willow Meadow	2.3	2.3	3.9	4	3.1	3.1	0.1	0.1	16	16
			Upland Moist Low Willow Shrub	3.4	3.4	4.5	4.5	3.9	3.9	0.6	0.5	2	2
			Upland Moist Tussock Meadow	2.8	2.6	2.8	2.6	2.8	2.6			1	1
		Veg Start Point	Coastal Barrens	1	0.8	1.9	1.9	1.5	1.4	0.4	0.6	2	2
			Human Modified Wet Meadow		2.4		2.4		2.4				1
			Lowland Deep-polygon Complex	2.8	2.8	2.8	2.8	2.8	2.8			1	1
			Lowland Wet Sedge Meadow	2.7	2.6	3.1	3	2.9	2.8	0.2	0.2	2	2
			Riverine Deep-polygon Complex	2.8	2.8	2.9	2.9	2.9	2.8	0	0.1	2	2
			Riverine Moist Low Willow Shrub	4.1	4	4.1	4	4.1	4			1	1
			Riverine Moist Low Willow-Sedge Meadow	2.4	2.3	2.9	2.9	2.6	2.6	0.1	0.1	7	7
			Riverine Wet Sedge Meadow	2.4	2.3	3.6	3.6	2.9	2.8	0.1	0.1	20	19
			Riverine Wet Sedge-Willow Meadow	2.6	2.6	3.8	3.9	3.2	3.1	0.1	0.1	10	10
			Upland Moist Low Willow Shrub	3	2.8	5.1	5.1	3.8	3.7	0.4	0.4	5	5
			Upland Moist Tussock Meadow	3.6	3.5	3.6	3.5	3.6	3.5			1	1
	South	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	1.6	1.7	1.9	1.9	1.7	1.8	0.1	0.1	2	2
			Lowland Deep-polygon Complex	3	3	3.3	3.3	3.1	3.1	0	0	10	10
			Lowland Wet Sedge Meadow	3	2.9	4	3.9	3.3	3.2	0.2	0.2	5	5
			Lowland Wet Sedge-Willow Meadow	3.3	3.2	3.6	3.4	3.4	3.3	0.1	0.1	2	2

Appendix I1. Continued.

Area	Direction	Point Type	Ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Test	South	Thaw Elev Point	Riverine Deep-polygon Complex	3.2	3.2	3.2	3.2	3.2	3.2			1	1
			Riverine Moist Low Willow Shrub	2	2	3.3	3.2	2.7	2.7	0.4	0.4	3	3
			Riverine Moist Low Willow-Sedge Meadow	2.5	2.6	2.8	3	2.6	2.8	0.1	0.1	3	3
			Riverine Moist Sedge-Shrub Meadow	2.7	2.6	3.1	2.9	2.9	2.8	0.1	0.1	4	4
			Riverine Wet Sedge Meadow	2.6	2.5	3.8	3.8	3.1	3.1	0	0	36	36
			Riverine Wet Sedge-Willow Meadow	2.5	2.5	3.4	3.1	2.9	2.8	0.1	0.1	12	12
			Upland Moist Tussock Meadow	2.4	2.3	3.2	3.1	2.9	2.8	0.3	0.3	3	3
		Veg Start Point	Coastal Barrens	0.5	0.5	1.1	1.4	0.8	0.9	0.2	0.3	3	3
			Coastal Moist Willow Dwarf Shrub	1.9	1.9	1.9	1.9	1.9	1.9			1	1
			Lowland Deep-polygon Complex	3	2.9	3.5	3.2	3.1	3	0.1	0	6	6
			Lowland Wet Sedge Meadow	2.9	2.8	3.3	3.2	3	3	0.1	0.1	3	3
			Lowland Wet Sedge-Willow Meadow	3.4	3.3	3.4	3.3	3.4	3.3			1	1
			Riverine Deep-polygon Complex	2.9	2.9	2.9	2.9	2.9	2.9	0	0	2	2
			Riverine Moist Herb Meadow	1.7	1.7	2.5	2.5	2.1	2.1	0.4	0.4	2	2
			Riverine Moist Low Willow Shrub	2	2	2.6	2.5	2.4	2.4	0.2	0.2	3	3
			Riverine Moist Low Willow-Sedge Meadow	2.8	2.8	3.5	3.5	3	3	0.1	0.2	4	4
			Riverine Moist Sedge-Shrub Meadow	3.8	3.7	3.8	3.7	3.8	3.7			1	1
			Riverine Wet Sedge Meadow	1.6	1.6	3.5	3.4	2.9	2.9	0.1	0.1	21	21
			Riverine Wet Sedge-Willow Meadow	2.6	2.5	3.4	3.3	3	2.9	0.1	0.1	6	6
			Upland Moist Tussock Meadow	3.2	3.2	3.2	3.2	3.2	3.2			1	1

Appendix I2. Datafile listing and summary statistics for thaw depth measured at Thaw Elevation Monitoring Locations in Reference and Test Areas, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

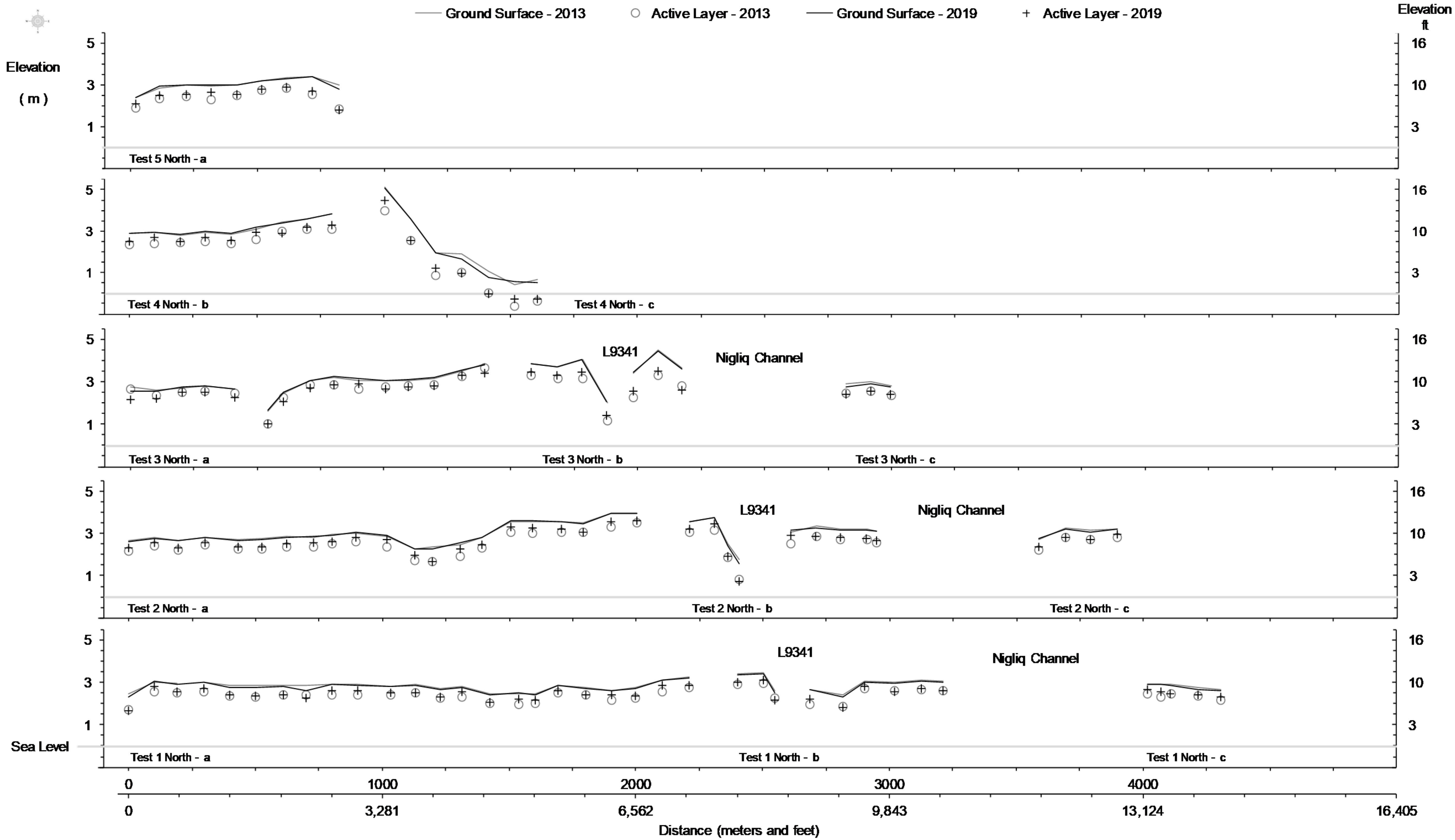
				Minimum		Maximum		Mean		SE		n	
Area	Direction	Point Type	Ecotype	2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Reference	North	Thaw Elev Point	Coastal Barrens	97	64	120	88	110.3	76.0	6.9	12.0	3	2
			Coastal Dry Elymus Meadow	146	20	146	81	146.0	50.5		30.5	1	2
			Coastal Moist Willow Dwarf Shrub	68	57	68	57	68.0	57.0			1	1
			Human Modified Low Shrub	63	48	63	48	63.0	48.0			1	1
			Human Modified Wet Meadow		42		42		42.0				1
			Lowland Deep-polygon Complex	38	20	57	39	47.2	31.9	1.9	1.4	14	14
			Lowland Wet Sedge Meadow	40	26	61	41	49.8	34.6	3.9	2.6	5	5
			Lowland Wet Sedge-Willow Meadow	37	28	37	28	37.0	28.0			1	1
			Riverine Deep-polygon Complex	34	22	58	38	43.0	31.9	2.8	2.1	7	7
			Riverine Moist Low Willow Shrub	40	29	73	58	57.2	42.2	7.7	7.0	4	4
			Riverine Moist Low Willow-Sedge Meadow	47	32	71	58	57.1	43.0	3.1	3.1	7	8
			Riverine Wet Sedge Meadow	36	27	53	42	45.3	34.2	1.8	1.7	10	10
			Riverine Wet Sedge-Willow Meadow	30	22	62	77	46.7	36.0	1.5	2.2	23	22
		Veg Start Point	Coastal Barrens	101	69	106	73	103.0	71.0	1.5	2.0	3	2
			Coastal Dry Elymus Meadow		76		76		76.0				1
			Coastal Moist Willow Dwarf Shrub	57	22	70	67	63.5	44.5	6.5	22.5	2	2
			Lowland Deep-polygon Complex	40	28	51	37	43.8	34.2	2.0	1.7	5	5
			Lowland Wet Sedge Meadow	43	39	43	39	43.0	39.0			1	1
			Riverine Deep-polygon Complex	38	28	46	30	42.0	29.0	4.0	1.0	2	2
			Riverine Dry Dryas Dwarf Shrub	60	50	60	50	60.0	50.0			1	1
			Riverine Moist Low Willow Shrub	50	38	64	70	57.3	53.3	4.1	9.3	3	3
			Riverine Moist Low Willow-Sedge Meadow	5	29	67	50	47.0	40.1	7.6	3.2	7	7
			Riverine Wet Sedge Meadow	37	30	61	46	45.3	36.0	3.4	2.3	6	6
			Riverine Wet Sedge-Willow Meadow	37	35	53	42	44.8	38.8	3.2	1.1	5	5
			Upland Moist Low Willow Shrub	62	54	62	54	62.0	54.0			1	1
	South	Thaw Elev Point	Coastal Barrens	86	59	111	78	98.0	70.2	5.3	4.0	4	4
			Human Modified Wet Meadow	52	28	52	37	52.0	32.5		4.5	1	2
			Lowland Deep-polygon Complex	54	30	54	30	54.0	30.0			1	1
			Lowland Moist Sedge-Shrub Meadow	30	22	30	22	30.0	22.0			1	1
			Lowland Wet Sedge Meadow		28		37		33.4		1.2	8	8
			Riverine Moist Herb Meadow	102	89	102	89	102.0	89.0			1	1
			Riverine Moist Low Willow Shrub	33	21	114	88	71.9	50.9	10.4	8.6	7	7
			Riverine Moist Low Willow-Sedge Meadow	49	35	49	37	49.0	36.0	0.0	1.0	2	2
			Riverine Wet Sedge Meadow	32	25	103	52	52.8	34.8	3.4	1.3	20	20
			Riverine Wet Sedge-Willow Meadow	27	16	59	49	45.0	32.1	1.9	1.7	27	26
			Upland Dry Dryas Dwarf Shrub	50	30	102	60	76.0	45.0	26.0	15.0	2	2
			Upland Moist Low Willow Shrub	28	21	46	24	37.0	22.5	9.0	1.5	2	2

Appendix I2. Continued.

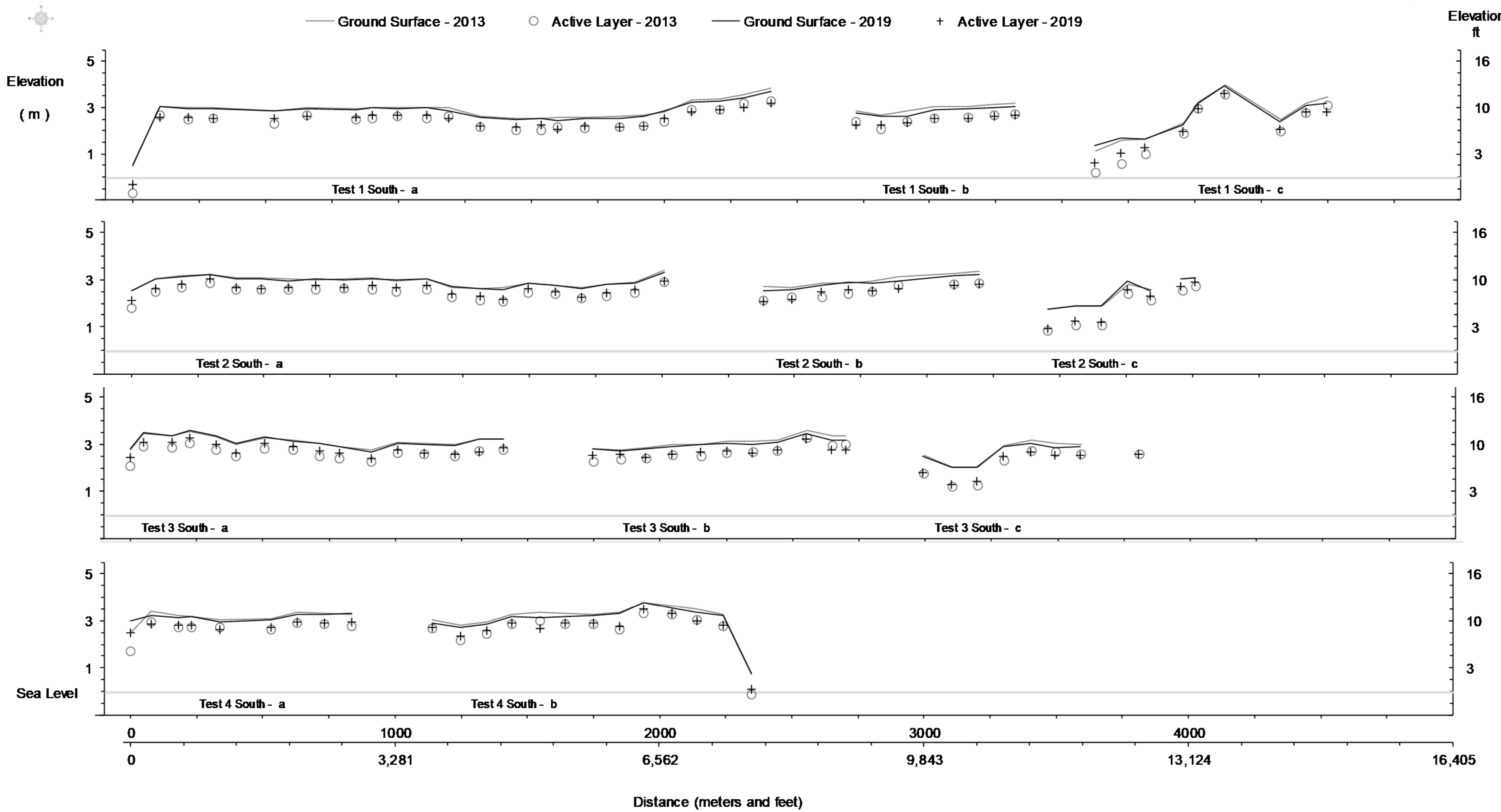
Area	Direction	Point Type	Ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Reference	South	Veg Start Point	Coastal Barrens	96	0	107	76	101.5	38.0	5.5	38.0	2	2
			Human Modified Wet Meadow	50	33	50	33	50.0	33.0			1	1
			Lowland Deep-polygon Complex	43	36	46	40	44.5	38.0	1.5	2.0	2	2
			Lowland Wet Sedge Meadow	47	31	49	41	47.8	36.2	0.5	2.1	4	4
			Riverine Moist Herb Meadow	103	71	105	90	104.0	80.5	1.0	9.5	2	2
			Riverine Moist Low Willow Shrub	37	26	92	59	65.0	47.2	9.0	7.1	5	5
			Riverine Moist Low Willow-Sedge Meadow	40	27	59	48	51.2	37.2	4.0	4.8	4	4
			Riverine Moist Tall Willow Shrub	133	119	133	119	133.0	119.0			1	1
			Riverine Wet Sedge Meadow	44	35	53	38	49.7	36.3	1.3	0.4	6	6
			Riverine Wet Sedge-Willow Meadow	38	23	62	52	46.2	34.9	2.7	2.6	10	10
			Upland Moist Low Willow Shrub	120	90	120	90	120.0	90.0			1	1
Test	North	Thaw Elev Point	Coastal Barrens	85	61	108	85	96.0	76.4	4.5	4.4	5	5
			Coastal Dry Elymus Meadow	108	104	108	104	108.0	104.0			1	1
			Lowland Deep-polygon Complex	42	29	48	31	45.0	30.0	3.0	1.0	2	2
			Lowland Wet Sedge Meadow	43	37	43	37	43.0	37.0			1	1
			Riverine Deep-polygon Complex	40	25	54	39	45.1	31.9	1.6	2.1	7	7
			Riverine Moist Low Willow Shrub	68	43	82	63	75.0	53.0	7.0	10.0	2	2
			Riverine Moist Low Willow-Sedge Meadow	38	22	51	46	44.0	29.0	2.7	5.7	4	4
			Riverine Wet Sedge Meadow	35	20	65	43	47.8	31.8	1.3	1.1	30	30
			Riverine Wet Sedge-Willow Meadow	42	27	70	59	52.1	37.6	1.8	2.0	16	16
			Upland Moist Low Willow Shrub	84	68	117	97	100.5	82.5	16.5	14.5	2	2
			Upland Moist Tussock Meadow	40	26	40	26	40.0	26.0			1	1
		Veg Start Point	Coastal Barrens	105	73	108	83	106.5	78.0	1.5	5.0	2	2
			Human Modified Wet Meadow		27		27		27.0				1
			Lowland Deep-polygon Complex	40	27	40	27	40.0	27.0			1	1
			Lowland Wet Sedge Meadow	44	32	48	41	46.0	36.5	2.0	4.5	2	2
			Riverine Deep-polygon Complex	44	19	50	36	47.0	27.5	3.0	8.5	2	2
			Riverine Moist Low Willow Shrub	90	56	90	56	90.0	56.0			1	1
			Riverine Moist Low Willow-Sedge Meadow	34	28	72	63	52.3	40.1	5.3	4.7	7	7
			Riverine Wet Sedge Meadow	43	25	55	48	47.5	36.3	0.9	1.2	20	19
			Riverine Wet Sedge-Willow Meadow	31	23	55	48	47.8	36.2	2.2	2.1	10	10
			Upland Moist Low Willow Shrub	70	54	115	100	98.2	80.2	9.3	9.8	5	5
			Upland Moist Tussock Meadow	48	17	48	17	48.0	17.0			1	1
	South	Thaw Elev Point	Coastal Moist Willow Dwarf Shrub	85	65	104	68	94.5	66.5	9.5	1.5	2	2
			Lowland Deep-polygon Complex	39	24	56	39	46.8	31.5	1.6	1.4	10	10
			Lowland Wet Sedge Meadow	34	30	46	36	42.2	32.6	2.2	1.0	5	5
			Lowland Wet Sedge-Willow Meadow	40	41	41	42	40.5	41.5	0.5	0.5	2	2
			Riverine Deep-polygon Complex	47	36	47	36	47.0	36.0			1	1

Appendix I2. Continued.

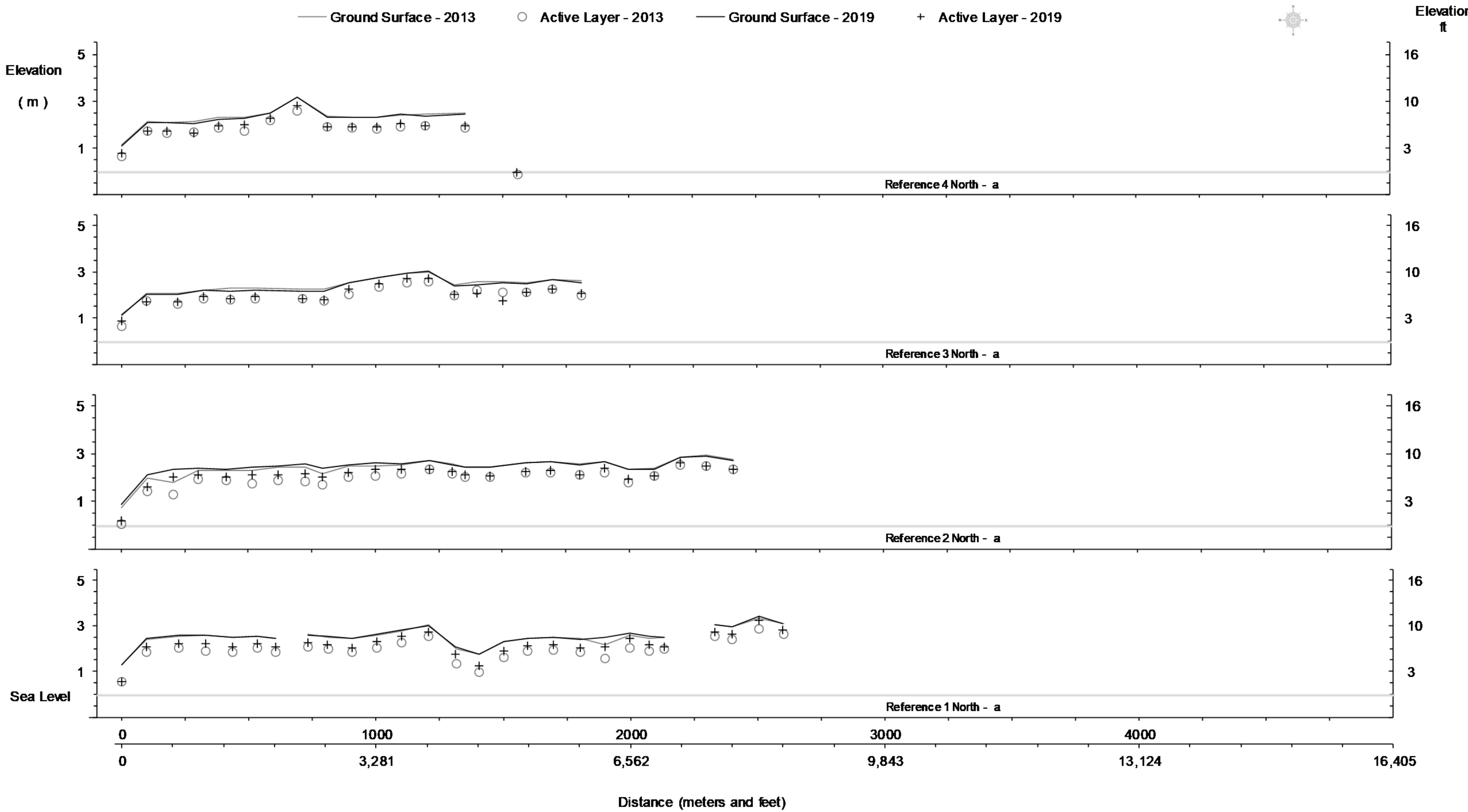
Area	Direction	Point Type	Ecotype	Minimum		Maximum		Mean		SE		n	
				2013	2019	2013	2019	2013	2019	2013	2019	2013	2019
Test	South	Thaw Elev Point	Riverine Moist Low Willow Shrub	43	36	83	73	59.3	50.3	12.1	11.5	3	3
			Riverine Moist Low Willow-Sedge Meadow	60	35	80	52	70.7	41.7	5.8	5.2	3	3
			Riverine Moist Sedge-Shrub Meadow	36	17	42	44	39.5	28.8	1.5	6.5	4	4
			Riverine Wet Sedge Meadow	32	20	72	57	46.1	34.0	1.2	1.4	36	36
			Riverine Wet Sedge-Willow Meadow	31	28	66	42	48.8	34.8	3.2	1.6	12	12
			Upland Moist Tussock Meadow	43	27	49	32	47.0	29.3	2.0	1.5	3	3
		Veg Start Point	Coastal Barrens	93	65	114	82	100.7	73.3	6.7	4.9	3	3
			Coastal Moist Willow Dwarf Shrub	81	65	81	65	81.0	65.0			1	1
			Lowland Deep-polygon Complex	35	31	47	36	40.7	33.3	2.0	0.8	6	6
			Lowland Wet Sedge Meadow	41	31	47	39	44.3	35.3	1.8	2.3	3	3
			Lowland Wet Sedge-Willow Meadow	47	40	47	40	47.0	40.0			1	1
			Riverine Deep-polygon Complex	47	26	52	38	49.5	32.0	2.5	6.0	2	2
			Riverine Moist Herb Meadow	80	73	91	79	85.5	76.0	5.5	3.0	2	2
			Riverine Moist Low Willow Shrub	43	23	78	60	65.3	41.0	11.2	10.7	3	3
			Riverine Moist Low Willow-Sedge Meadow	46	30	58	51	50.0	38.2	2.7	4.9	4	4
			Riverine Moist Sedge-Shrub Meadow	56	49	56	49	56.0	49.0			1	1
			Riverine Wet Sedge Meadow	38	28	61	42	48.9	36.2	1.0	0.8	21	21
			Riverine Wet Sedge-Willow Meadow	44	26	58	48	49.3	36.8	2.2	2.9	6	6
			Upland Moist Tussock Meadow	29	22	29	22	29.0	22.0			1	1



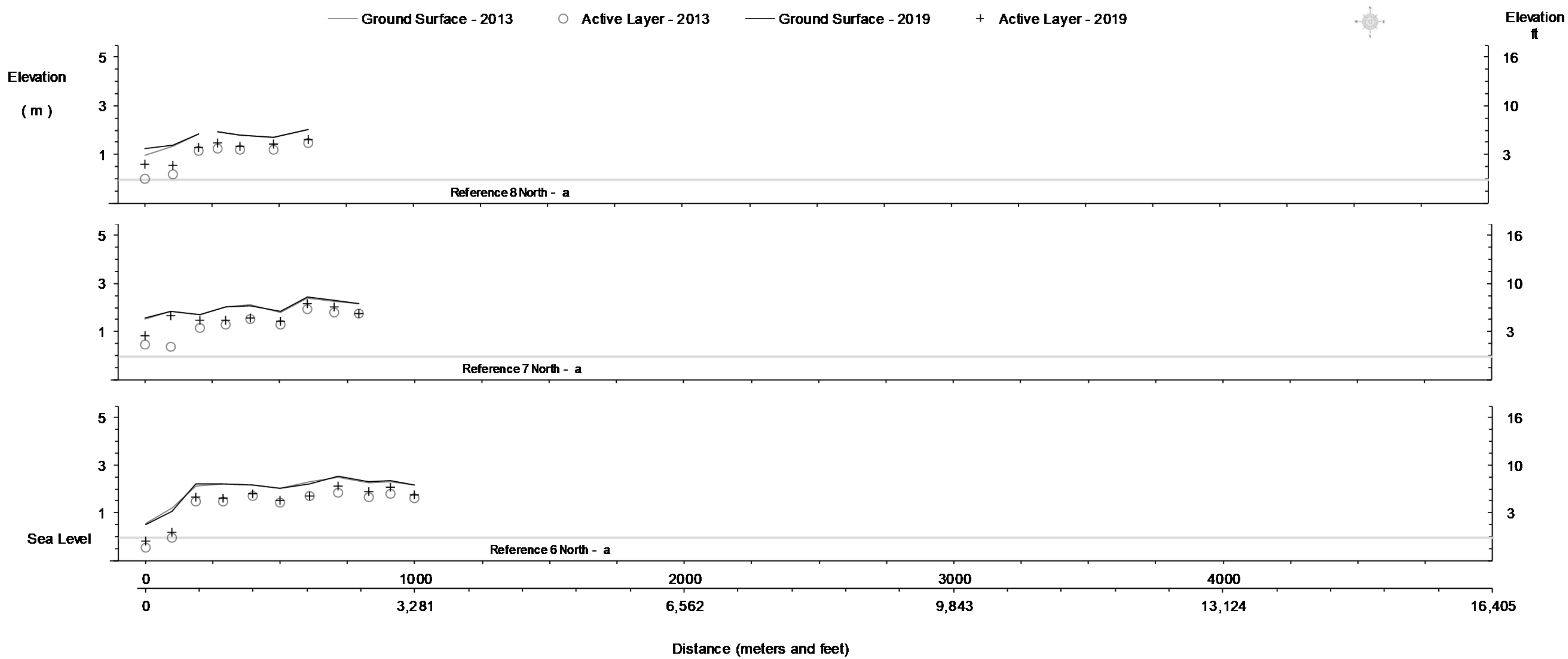
Appendix J1. Cross section of ground surface elevation and thaw depth along transects in the Test North Area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



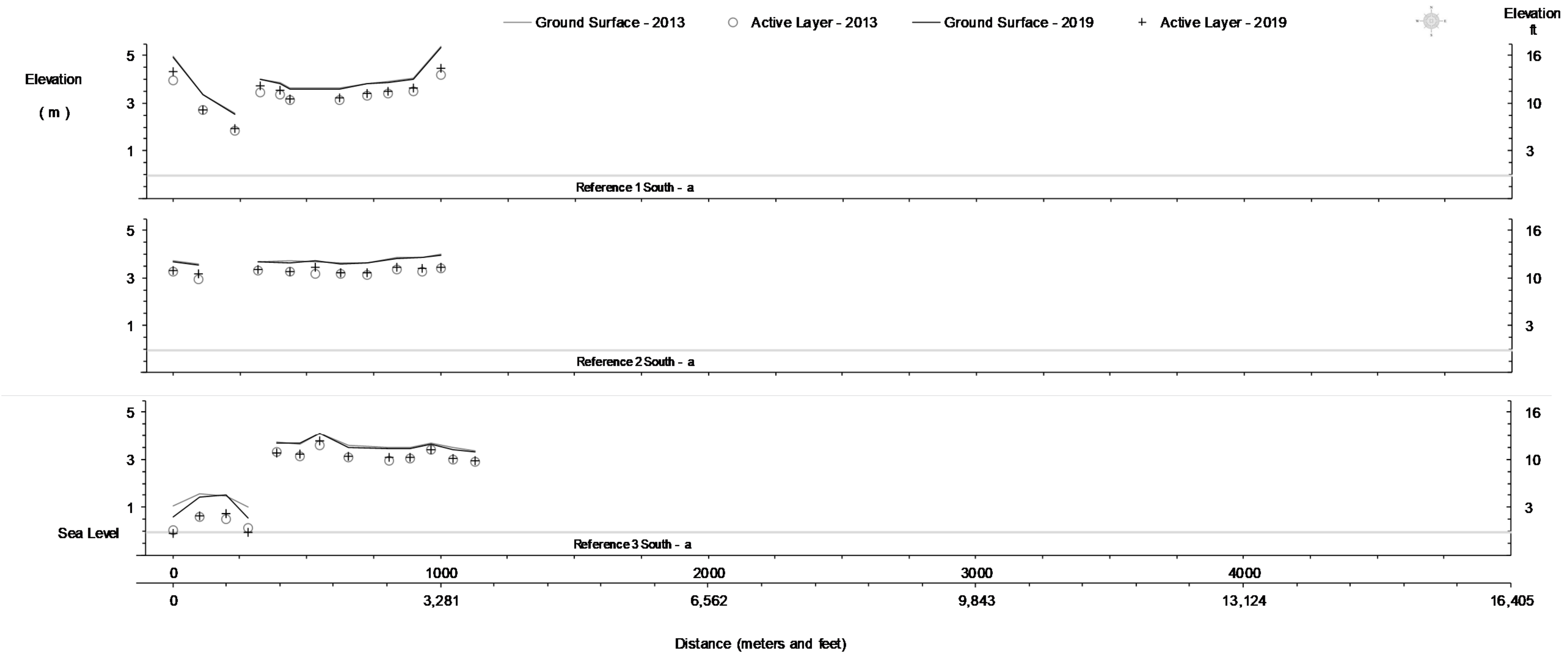
Appendix J2. Cross section of ground surface elevation and thaw depth along transects in the Test South Area, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



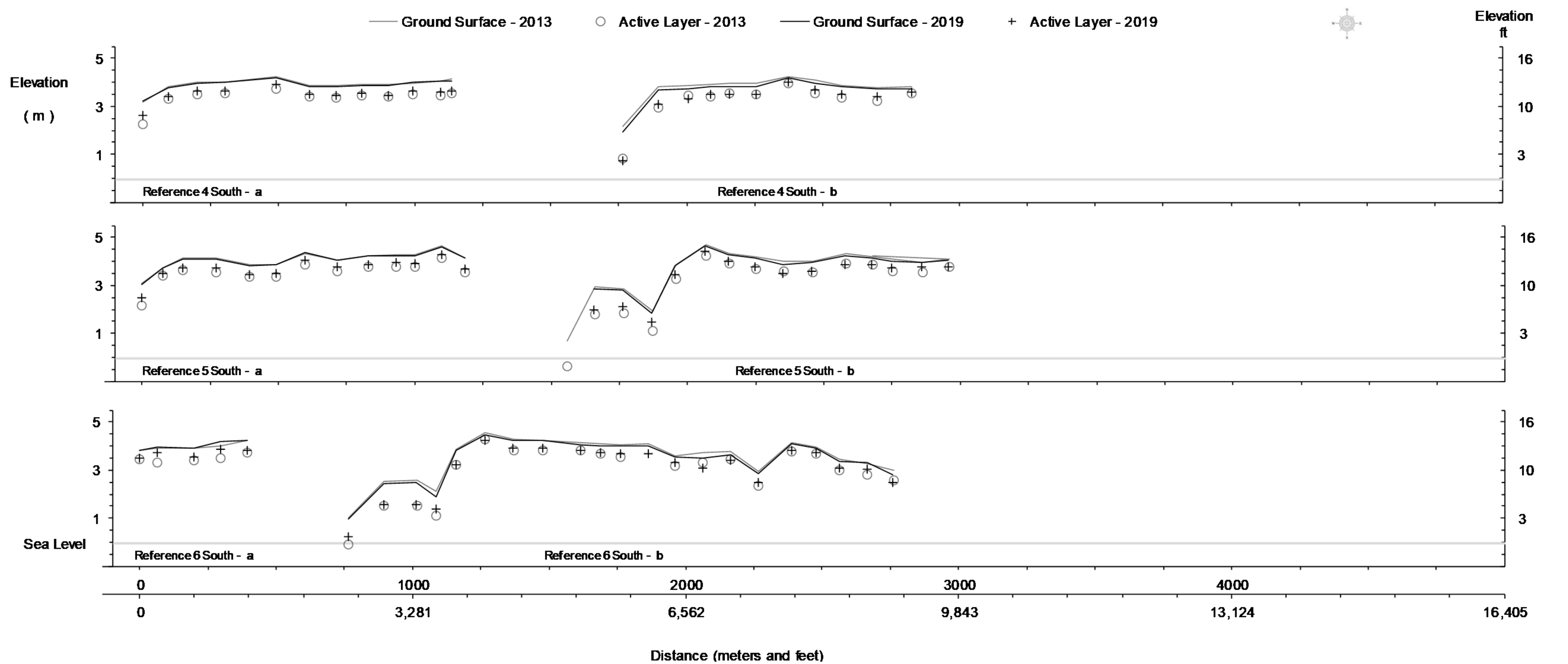
Appendix K1. Cross section of ground surface elevation and thaw depth along transects (1–4) in the Reference North Area Transects, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.



Appendix K2. 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 2019.



Appendix K3. 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 2019.



Appendix K4. 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 2019.

Appendix L. Detailed ground cover summary statistics by sample year, study area, and ground cover class, CD5 Habitat Monitoring Study Area, northern Alaska, 2013 and 2019.

Sample Year	Study Area	Ground Cover	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	Sample Size
2013	Reference	Fungi	1.3	1.3	1	NULL	1
2013	Reference	Herbaceous Litter	2.6	97.4	26	22	60
2013	Reference	Lichens	1.3	9.2	3	3	8
2013	Reference	Liverworts	1.3	6.6	3	2	11
2013	Reference	Mineral Soil	1	100	36	39	34
2013	Reference	Mosses	1.3	93.4	49	27	64
2013	Reference	Tussock	1.3	2.6	2	1	2
2013	Reference	Vascular Base	1.3	14.5	4	3	63
2013	Reference	Water	1.3	100	29	34	41
2013	Reference	Woody Litter	1.3	1.3	1	0	2
2019	Reference	Algae	1.3	1.3	1	NULL	1
2019	Reference	Debris (Human origin)	1.3	1.3	1	NULL	1
2019	Reference	Fungi	1.3	1.3	1	NULL	1
2019	Reference	Herbaceous Litter	1.3	79	24	22	69
2019	Reference	Lichens	1.3	10.5	3	3	10
2019	Reference	Liverworts	1.3	5.3	2	1	11
2019	Reference	Mineral Soil	1.3	100	33	39	22
2019	Reference	Mosses	1.3	100	54	29	68
2019	Reference	Organic Soil	1.3	13.2	5	5	4
2019	Reference	Tussock	10.5	10.5	11	NULL	1
2019	Reference	Vascular Base	1.3	7.9	3	2	56
2019	Reference	Water	1.3	98.6	31	34	36
2019	Reference	Wildlife Scat	1.3	1.3	1	0	12
2019	Reference	Woody Litter	1.3	2.6	2	1	6
2013	Test	Algae	1.3	5.3	3	2	3
2013	Test	Herbaceous Litter	1.3	80.3	24	17	93
2013	Test	Lichens	1.3	14.5	4	4	18
2013	Test	Liverworts	1.3	21.1	4	7	8
2013	Test	Mineral Soil	1.3	100	44	43	26

Appendix L. Continued.

Sample Year	Study Area	Ground Cover	Min. Cover (%)	Max. Cover (%)	Avg. Cover (%)	St. Dev. Cover (%)	Sample Size
2013	Test	Mosses	1.3	92.1	48	24	94
2013	Test	Tussock	1.3	1.3	1	NULL	1
2013	Test	Vascular Base	1.3	14.5	4	2	86
2013	Test	Water	1.3	100	33	29	66
2013	Test	Woody Litter	1.3	5.3	2	2	5
2019	Test	Algae	1.3	1.3	1	NULL	1
2019	Test	Fungi	1.3	1.3	1	0	3
2019	Test	Herbaceous Litter	1.3	65.8	22	15	94
2019	Test	Lichens	1.3	25	5	5	20
2019	Test	Liverworts	1.3	4	2	1	9
2019	Test	Mineral Soil	1.3	100	30	35	29
2019	Test	Mosses	2.6	97.4	52	25	97
2019	Test	Organic Soil	1.3	9.2	4	3	10
2019	Test	Tussock	1.3	2.6	2	1	2
2019	Test	Vascular Base	1.3	10.5	3	2	68
2019	Test	Water	1.3	100	31	30	68
2019	Test	Wildlife Scat	1.3	6.6	2	1	13
2019	Test	Woody Litter	1.3	5.3	2	1	7