

Middle Teklanika River Mini-Grid Vegetation Data Summary and Analysis

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Executive Summary:

- 1) Physical factors related to soil temperature and the distribution of permafrost were the primary drivers of vegetation patterns in this study area. The monitoring sampling design captured strong functional relationships between these physical environmental factors and vegetation response variables including the vegetation structure, plant community composition, and plant species diversity.
- 2) Understanding these primary ecological gradients allow us to make informed hypotheses regarding the potential trajectories of landscape change in this area over time. Specifically, increases in soil temperature that may occur with a warming climate will likely have profound influence in changing the landscape mosaic of this area to a larger-statured woody vegetation mosaic with large patches of conifer forest becoming established in areas that are currently free of trees. Secondly, continued “recovery” from a major flood that occurred in 1967 event will result in more densely vegetated river bars and terraces over time.
- 3) By analyzing these plot data within the context of the soils map unit polygons delineated by the Soils Inventory of Denali, we have a powerful new tool for extrapolating the data acquired at the limited number of sampling points measured according to the randomized systematic grid sampling design to much larger areas of the landscape represented by the polygon soils map. I believe this integration of our quantitative monitoring data collection design and the qualitative mapping effort holds promise for numerous areas of investigation, including wildlife habitat studies, modeling prospective future changes on the landscape and fuels mapping for fire.
- 4) An examination of several pairs of matched historical / recent oblique aerial photographs show that substantial changes in the vegetation mosaic of this study area have occurred in just the past 30 years. These changes include dramatic expansion of spruce forest, and establishment of woody vegetation on gravel bars across the area. The changes that I observed from an examination of photos occur according to a spatial distribution that generally conforms to the expectations generated from quantitative analysis of the plot data – that is the “leading edge” of conifer expansion is occurring in areas of the landscape with thawed terrain and warmer soil temperatures, river corridors and south-exposed slopes. I did not observe rapid conifer expansion in permafrost soils polygons.
- 5) The changes observed in the repeat photographs are clearly significant enough to influence other elements of the biota beyond the vegetation, including:
 - a. Moose browse abundance and quality
 - b. Bird habitat mosaic – nesting and foraging habitat
 - c. Hiding cover’ for prey species – thereby affecting raptors, wolves and their prey
 - d. Snow distribution patterns on the landscape and albedo of surface
 - e. Nutrient cycles and thus functional responses to climate
 - f. Amount and distribution of fuels for wildfire

Introduction

The purpose of this document is to present a summary and analysis of the data collected during the first iteration of vegetation sampling in the Middle Teklanika River mini-grid. The goals of analyzing the first iteration of our long term monitoring data are to identify the major ecological gradients captured by the sampling design and help to shed light on the important characteristics of the landscape mosaic sampled by each mini-grid in the vegetation monitoring program. These data analyses are thus essentially educated data mining - explorations of the data to identify important ecological relationships and patterns. The results of these analyses will allow us to make informed hypotheses regarding the potential trajectories of ecological change in different areas of the landscape.

In contrast to research studies that are designed to test specific hypotheses, (with sample locations allocated to optimize the power to test these hypotheses) this monitoring program is designed to sample the landscape as a whole to detect whether change is occurring in fundamental vegetation attributes, and what the character of any such change is. Thus rigorous “exercising” of the data through repeated analyses is crucial to laying the groundwork for detecting changes in subsequent sample iterations.

In addition to presenting the analyses of the plot data for this mini-grid, I have integrated evidence from two other projects to help inform our understanding of the ecological dynamics of the study area. First, plot data were analyzed in the context of the soils map unit polygons delineated by the Denali Soils Inventory project. The goal of these data analyses were to determine whether these map units hold promise for understanding vegetation dynamics measured in the plots, and to determine the potential for using this map product to extrapolate the monitoring plot data to the broader Park landscape. Secondly, I include an examination of four sets of matched repeat historical/recent photo pairs from the immediate area of this mini-grid to provide a temporal dimension to the consideration of vegetation mosaic of the area. The photos show considerable change over the past 29 years.

Another goal of these initial data analyses is to facilitate integration of these data with other elements of the monitoring program. In order for such integration to occur, there must first be communication of the specific results for each monitoring component to others working in different monitoring program areas. For example, considering the results of the vegetation sampling should allow us to generate hypotheses regarding variation in passerine community data that are collected at the same points, or make informed speculation regarding the dynamics of other wildlife species within the study area. In addition, as mentioned above, with this report I begin the process of integrating the vegetation monitoring plot data with the newly completed Soils Map of Denali. This process will allow us to attribute the interpreted polygon map generated as part of the soil survey using quantitative data collected according to a rigorous, randomized sampling design. This integration of two powerful data sets will likely provide substantial benefits in extrapolating the spatially limited point data to larger areas of the Park landscape using the soils map polygons.

Environment of the study area

General Location and Character

The Middle Teklanika R. mini-grid is located west of the Teklanika River, across the river from the Teklanika campground (see maps in [Fig. 1](#)). This mini-grid encompasses a cross-section of the lower reaches of the Big Creek watershed, including parts of the high ridge that separates the Big Creek and Teklanika R. watersheds. This mini-grid includes plots on the floodplain of both of these streams, as well as the adjacent hills and terraces.

This study area was essentially boreal in character, although the highest elevation plots reached the lower alpine zone on the ridge between Big Cr. and the Teklanika R. permafrost was observed in more than half of the plots, and well-developed forest vegetation types were mostly restricted to the thaw bands along the creeks and on warmer, well-drained slopes with more southerly exposures. Plots on solidly frozen ground supported open dwarf birch-ericaceous-sedge vegetation with deep, more or less continuous cover of feather mosses typical of cold soils in this area, and scattered open black spruce woodland in some sites. Steep and/or active slopes (particularly those with a southerly aspect) and recently disturbed floodplain sites support sparser vegetation on mineral soils, with little or no development of a deep moss mat.

Topography

Mean elevation of the plots in this sample was 835 m, and ranged between 761 at point 21 (the farthest north plot on the floodplain of the Teklanika R.) and 997 m at plot # 2 (located high on the ridge between Big Cr. and Teklanika R.). The majority of plots in this mini-grid (17 of 25) were located below 850 m in elevation (see histogram of plot elevations in [Fig. 2](#)). The plots that occurred at higher than 850 m elevation were all in the southern half of the grid, located on the mountain slopes on either side of Big Creek. Two panoramic photos of the landscape in this study area are shown in [photos 1 and 2](#).

The overall tilt of the landscape in this area is towards the north, and thus the distribution of the aspects of the surfaces in this area were conspicuously skewed in this direction ([Fig. 3](#)). Nineteen of the 25 plots had generally northerly aspect (either north, northeast or northwest) whereas only three of the plots had southerly aspects, and the remaining three were facing either due east (2 plots) or due west (1 plot). As a result of this strong northward bias of landscape aspect, the distribution of values for equivalent latitude (*EQ*; a calculated index of solar radiation) for this set of plots were also skewed towards high values, indicating lower than average solar radiation regimes for this latitude (see [Fig. 4](#)). Mean *EQ* for this mini-grid was 64.453°. The *EQ* for a level surface in the area is about 63.67°. Sites that receive less solar energy than a flat surface will have higher *EQ* values, and sites that receive more solar radiation (all other things being equal) will have lower values of *EQ*.

Slope angles of the plots for the Middle Teklanika River mini-grid averaged 10° ($\pm 1.76^\circ$) and had a somewhat bimodal distribution – with 11 plots having slope angles of between 0° and 5°, and six plots with slopes in excess of 20° ([Fig. 5](#)). Plots with steep slopes were located in the

high-relief southern half of this mini-grid, and points in the northern half of the study area were located in flat to gently sloping terrain.

Soils

The map in [Figure 6](#) shows the detailed soils map units (landtype associations) for the Middle Teklanika River mini-grid Clark and Duffy 2005). The primary factor differentiating these units was variation in the surficial geology of the area. The primary surface types were: 1) floodplain deposits; 2) low angle slopes mantled with glacial till; 3) bedrock units that form the mountain ridges in this area. Another primary determinant of soils conditions related to the permafrost status – cold, north-exposed (or flat areas) sites with thin active layers versus warmer slopes on more southerly exposures with deeper active layers. Plots in river corridors were generally not underlain by permafrost. Plots in this mini-grid occurred on five different soils map units, which are described below (see [Fig. 6](#))

Permafrost Soil Map units in study area:

7TM—Alpine Glaciated Low Mountains with Discontinuous Permafrost – 8 plots. This soil map unit occupied upland areas west of Big Creek in this study area and generally had high accumulation of an organic rich A soil horizon on solidly frozen glacial till. This unit was primarily in low angle, gently rolling slopes that supported typical low, moist-to-wet open birch-ericaceous shrublands with high cover of *Carex bigelowii* and scattered stands of (mostly black) spruce. Cold soil temperatures and low productivity characterized this unit; except for occasional moist thaw gullies with relatively lush *Salix*-meadow vegetation (one example was encountered at sample point #4 in this sample).

7TP—Alpine Till Plains with Discontinuous Permafrost – 5 plots. This soil map unit was represented within the study area by the long, low “snout” of land at the northern end of the ridge separating the floodplains of the Teklanika R. and Big Cr. This unit was uniformly underlain by permafrost, with a similar vegetation and landscape mosaic to that of 7TM above, although with comparatively less variability and less relief within this study area.

Non-permafrost Soil Map units in study area:

7FP1—Boreal Flood Plains and Terraces – 7 plots. This unit bisects the study area, and is located in thaw bands on alluvium of both the Teklanika R. and Big Creek. This unit occurs in flat or gently-sloping areas with relatively, warm, mineral soils. The parent material for these soils is alluvium and they are thus generally higher pH than other soil units in the area as a result of deposition of cations by repeated flooding.

7MS1L — Alpine Mixed Lithology Mountains– 4 plots. This unit is located on the bedrock ridge between Big Cr. and the Teklanika R., occupying the upper elevations and steepest slopes of this landscape unit. Well-drained slopes with relatively warm soils and spanning the vegetation gradient from subalpine forest to dwarf-scrub tundra near the ridge.

7MS2—Boreal Glaciated Lower Mountain Slopes – 1 plot (plot #13). This unit is adjacent to 7MS1L in the study area, occurring on the lower, west-facing slopes of the ridge. This unit supported relatively productive stands of white spruce forest on lower mountain slopes, particularly in the drainage features feeding into Big Cr.

Soils and vegetation data for this mini-grid will be presented organized by the detailed soil map units shown in figure 6 because this landscape delineation provides a useful framework within which to understand these monitoring data, and the ecological change that will occur in the area over time. In some cases, there was considerable variability within these map units, particularly when different successional seres were a significant part of the soil unit (such as on the floodplain). However, even in these instances, this framework provides a useful paradigm for understanding these data. In [figure 7](#), I present the values for elevation, slope angle and equivalent latitude for the 25 plots in this mini-grid organized by these soil units.

Active layer depth

Mean active layer depth in the Middle Teklanika R. mini-grid overall was 40.5 cm, but was variable among soils map units. Specifically, the two discontinuous permafrost units (7TP - Alpine Till Plains with Discontinuous Permafrost and 7TM - Alpine Glaciated Low Mountains with Discontinuous Permafrost) had soils with shallow mean active layer depths (30 cm and 34 cm respectively) as compared to the floodplain and mountain units ([Fig. 8](#)). The active layer values were also much less variable within these two permafrost landscape units, with the range between the minimum and maximum active layer depth observations (27 cm and 11 cm respectively) being less one third of the range observed in the floodplain unit (97 cm).

Surface strata depths

Mean living layer depth (the live moss and lichen mat) was 4.5 cm in the Middle Teklanika R. mini-grid. Depth of the soil organic layer averaged 18.4 cm across this mini-grid. Both of these parameters also varied according to the soils map units ([Fig. 9](#)). The permafrost (7TM and 7TP) units had deeper mean living mats (4.6 and 5.9 cm) and organic layers (19.3 and 28.4 cm) than the floodplain and mountain units (7FP1 and 7MS1L), which had mean living mat depths of 3.3 cm and 3.9 cm respectively and mean organic layer depths of 8.8 and 18.1 cm respectively ([Fig. 10](#)).

Soil temperature

Soil temperatures in the permafrost units were (as expected) lower than in the floodplain and mountain slope units ([Fig. 11](#)). Mean soil temperature in the floodplain seven plots (Unit 7FP1) was 7.6° C. Mean soil temperature was 7.0° C and 5.0° C in the two non-permafrost mountain slope units (7MS1L and 7MS2 respectively). In contrast, soil temperature in the two permafrost units (7TP and 7TM) was much colder, 1.3° C and 2.6° C respectively.

Soil moisture

Patterns in soil moisture among the plots in this mini-grid followed topographic position, and were almost identical to patterns in the depth of the organic layer (compare figures [10](#) and [12](#)). The floodplain and mountain slope soils units were less moist and showed considerably more variation among samples than did the permafrost units. Mean percent moisture for the floodplain plots was less than 4 percent, whereas it was above 8 percent for plots in both of the permafrost units ([Fig. 12](#)). Clearly, the colder, organic rich surface soils in the permafrosted units had a higher water holding capacity that resulted in moister soils conditions.

Soil reaction

Mean soil pH across all samples in the Middle Teklanika R. mini-grid was 5.8 ([Fig. 13](#)). The primary pattern worth noting in variation in soil reaction in this mini-grid is a tendency for floodplain soils to have an elevated pH relative to all of the other soils map units in this mini-grid. In fact, three floodplain plots actually had basic soil reaction (greater than 7.0). Mean soil pH was 6.51 for plots in unit 7FP1, whereas it was close to 5.50 for all other units that had multiple plots. Plot 13, which was the only plot located in unit 7MS2, had a high soil pH of 6.28. This plot was centered over a small drainage feature on the west facing slope above Big Cr. It is likely that the influence of moving water in supplying cations to the floodplain soils is the explanation for these patterns.

Soil carbon and nitrogen status

The mean percent soil carbon for samples in the Middle Teklanika R. mini-grid was 18.5 percent ([Fig. 14](#)). Soil carbon was lowest in the floodplain and mountain slope soil map units and highest in the organic-rich soils of the permafrost soils map units, where decomposition is slow and carbon accumulates in the soil column. Soils in units 7Tm and 7TP had an estimated 27 and 21 percent carbon whereas the floodplain soil had an estimated 7 percent soil carbon. The two mountain slope soils map units (7MS1L and 7MS2) had an estimated 17 percent and 3 percent soil carbon, respectively.

The mean percent soil nitrogen for samples in the Middle Teklanika R. mini-grid was 0.9 percent. Soil nitrogen content was closely linked to soil organic matter (percent carbon) across this study area, with low amounts in the floodplain soils and somewhat higher amounts in the organic-rich permafrost soils ([Fig. 15](#)). Mean soil nitrogen was close to one percent or higher for all units except the floodplain unit (7FP1), which had a mean soil nitrogen content of 0.34 percent. The one plot in soils map unit 7MS2 had relatively high soil nitrogen, like due to the presence of n-fixing symbionts growing in association with the *Alnus* and *Equisetum* that occurred in this plot.

Coarse fraction in soils

The mean fraction of the soil of particle sizes greater than 2mm was low in this mini-grid, averaging an estimated 8.5 percent of the total soil ([Fig. 16](#)). Predictably the soil unit with the highest coarse soil fraction was the alpine unit derived from bedrock, with a mean of 30.3 percent coarse fraction. The highly organic soils in the permafrost soils units both had mean

coarse fractions of less than 5 percent, and the alluvial soils in the floodplain unit had an average of 8.3 percent coarse fragments ([Fig. 16](#)).

Covariation Among Physical Attributes

A correlation matrix showing simple correlation coefficients between pairs of physical parameters is shown in [Table One](#). Plot elevation was positively correlated with slope angle because high elevation plots in this area were on steeper slopes. Elevation was negatively correlated with soil pH because plots with elevated pH were concentrated along the streams where cations from running water are deposited in the soil column.

The strongest correlations among physical variables were directly related to the permafrost distribution in this set of plots. There were very strong positive correlations between living and organic mat depths, carbon and nitrogen content of the soil and moisture holding capacity. These factors were all strongly negatively correlated with soil temperature and coarse fraction content of soil. Cold, wet permafrost soils support slow decomposition of organic matter which tends to form a deep layer of partially-decomposed organic detritus (high in carbon). These conditions are related to the formation of a deep moss mat, which further insulates the soil, causing cold, moist conditions. The coarse fragment of soil is low in sites with deep organic soil layer because there is little mineral content of any kind above the frozen layer. The mineral stratum of these soils is often frozen solid. Soils with high coarse fragment content occur in sites with mineral soils derived from bedrock or coarse alluvium.

Principal components analysis (PCA) of all of the soils-related physical data for the plots in this mini-grid highlights the differences between soils from the permafrost map units versus soils from the non-permafrost units – floodplains and mountain units ([Fig. 17](#)). The permafrost unit soils are distinctly clustered together with little variation, scoring low on both axes whereas soils from the non-permafrost units vary considerable along these axes, but score high on both axes. The first axis was strongly correlated with active layer depth ($r = 0.95$), and soil carbon content ($r = 0.60$) whereas the second PCA axis correlated most strongly with depth of the organic mat ($r = 0.76$) and depth of the living mat (0.81). These two axes explained a cumulative 81.5 percent of the variance in the data set, with 57 % explained by the first PCA axis, and 24% explained by the second PCA axis.

It is worth noting that the “outlier” value for the soil from the 7FP1 soil map unit that clustered with the permafrost units was from plot #8, which was a late-succession open spruce forest on the terrace of Big Creek that had unusually deep, fine-grained soil. This soil may have been from an isolated lacustrine or loess deposit, as it appeared to be an at least a 2 m deep layer of fine-grained silt, with no coarse gravels, as one would expect to find on a floodplain.

Vegetation patterns in the study area

Vegetation Types

The two most abundant vegetation types in the study area were open low scrub, which occupied an estimated 31 percent of the area and open needleleaf forest, which occupied approximately 25

percent of the study area (see [Figs. 18A](#) and [18B](#)). Other major vegetation components in this study area were open tall scrub (15 percent), and closed low scrub (about 13 percent of the area). Low scrub types (including open and closed) accounted for 44 percent cover of the study area, and were the predominant types in the permafrost soils units.

The distribution of vegetation types across this study area was related to the variation in soils map units. For example, of the thirteen plots located in soil map units with permafrost, 7TM and 7TP, 54 percent (7 plots) were open low scrub, 15 percent (2 plots) were closed low scrub, 15 percent (2 plots) were open tall scrub, eight percent was closed tall scrub (1 plot) and eight percent (1 plot) was open needleleaf forest. Thus the vegetation that developed on these surfaces was primarily low-statured birch-ericaceous scrub typical of permafrost areas of the landscape in the northern sections of Denali. Whereas the plots located in the permafrost soils units were dominated by scrub vegetation types, with only a single plot with open forest, 57 percent of the plots (4 of 7) on the floodplain soils unit (7FP1) were either forest or woodland vegetation. Two plots in unit 7FP1 were open tall scrub and one was open low scrub.

In the two non-permafrost soil map units located on the bedrock soil map units (7MS1L and 7MS2) four out of five plots (80 percent) were either forest or woodland and the remaining plot was occupied closed low scrub. The plot data thus confirm an expected pattern – plots located on warmer soils with a deeper active layer (either on floodplain or sloping bedrock soils units), supported, in general, taller-statured vegetation, frequently supporting a forest or woodland in comparison with the permafrost units on low-angle slopes that generally supported low birch-ericaceous scrub vegetation.

Vegetation Structure

Key indicators of vegetation structure varied among the plots in the soils map units. Mean cover of bryophytes was roughly similar for the plots in the non-floodplain soils units, varying from 67 percent and 69 percent in the two mountain soil map units ([Fig. 19](#); 7MS1L and 7M2S) to 73 and 82 percent in the two permafrost units (7TM and 7TP respectively). In contrast mean bryophyte cover in the floodplain soil map unit plots was low at 46 percent. This reduced bryophyte cover in the floodplain soil map unit was related to two factors: 1) relatively, dry open soil conditions on the floodplain sites (thus not optimal habitat for bryophytes); and 2) periodic disturbance of several floodplain plots by running water which removes bryophyte biomass, which is slower to recover than vascular plant biomass. Mean percent lichen cover, on the other hand, was quite similar across all of the soils map units – varying between 11 and 16 percent ([Fig. 20](#)).

Graminoid cover also varied according to soil map units, with slightly higher mean graminoid cover in the two permafrost soil map units (22 percent in 7TM and 14 percent in 7 TP; ([Fig. 21](#)) as compared to the floodplain and mountain soil units (8 percent in both mountain units and 11 percent in the floodplain unit). This was almost entirely due to differences in the abundance of the sedge *Carex bigelowii* among plots in these units. *C. bigelowii* is a dominant element in low scrub vegetation on permafrost soils on the north side of the Park (see variation in mean *C. bigelowii* percent cover among soils map units in [fig. 22](#)). Thus high cover of this sedge in the permafrost soil map units accounted for these differences in graminoid cover.

Average percent cover of forb species was essentially the same across all of the soil units (varying between 10 and 16 percent; see [Fig. 23](#)), except forb cover was very low in the permafrost soil unit 7TP, with mean cover of forb species of less than 2 percent. Highest forb cover was observed in the plots located in the floodplain map unit (7FP1), which had a mean forb cover of 16 percent.

Dwarf shrubs were conspicuously more abundant in the permafrost soil map units 7TM and 7TP, which had mean dwarf shrub cover of 20 and 25 percent ([Fig. 24](#)), as compared to the floodplain and mountain soil units, which all had mean dwarf shrub cover of 9 percent or less. This is due to the increased abundance of the ericaceous dwarf shrubs *Vaccinium vitis-idaea*, *Oxycoccus microcarpus*, and *Empetrum nigrum* in the cool, moist soils and dense feather moss mat of these permafrost sites relative to warmer, drier sites on mineral substrates, where these species occur in lower abundance.

Mean cover of shrub species was the highest of any vascular plant vegetation growth forms, averaging 45 percent across the entire mini-grid. The lowest average shrub cover for any of the soils units was 35 percent observed in the floodplain map unit (7FP1) and the highest mean shrub cover was 61 percent observed in the 7TM soils unit ([Fig. 25](#)).

The taxonomic composition of mean shrub cover varied markedly among these units. [Figure 26](#) shows the percentage of the total shrub cover for each soil unit contributed by each shrub species observed in this study area. The dominant shrub species in the permafrost soils units were *Betula nana*, *Ledum decumbens*, *Salix pulchra* and *Vaccinium uliginosum*. In contrast, the plots located in the floodplain and mountain units had more variable contributions of cover from a larger suite of shrub species, including soapberry (*Shepherdia canadensis*) alder (*Alnus viridis*) and the willows *Salix alaxensis*, *S. richardsonii*, and *S. arbusculoides*.

We observed marked variation in mean tree canopy cover among plots located in the five soils map units ([Fig. 27](#)). Tree canopy cover was negligible in the two permafrost soils units (7TM and 7TP). The floodplain and mountain soil map units, on the other hand all had an average of more than 17 percent cover of trees. Plots in floodplain unit 7FP1 averaged 17 percent tree cover, whereas mean tree cover in unit 7MS1L was 21 percent, and tree cover in the one plot in unit 7MS2 was 39 percent.

Vertical arrangement of plant biomass

There were considerable differences in the vertical pattern of abundance for live plant biomass among the different soil map units. Specifically, the stature of the vegetation in the permafrost units was conspicuously lower as compared to vegetation in non-permafrost soils units, with biomass arranged in strata close to the ground and with little to no plant cover occurring above 2 m from the ground ([Fig 28](#)). This pattern in the vertical arrangement of cover reflects lower productivity and reduced growth in the cold, wet organic soil conditions characteristic of these landscape units.

Tree, sapling and seedling density and basal area

Overall density of trees and saplings was highest in the non-permafrost plots, with 2100 stems per hectare in the floodplain soil map unit, 800 stems/ha in the 7MS2 unit, and 562.5 stems/ha in unit 7MS1L ([Fig. 29](#)). In contrast, the two permafrost soil map units, 7TM and 7TP had very low average tree densities of 181.3 stems/ha and 220 stems/ha respectively.

All of the trees and saplings in the soil units other than the floodplain (7FP1) were white spruce (*Picea glauca*). In the floodplain unit, 7% of these individuals (all in the sapling size class of < 12 cm DBH) were balsam poplar (*Populus balsamifera*).

The floodplain soil unit also had by far the highest density of tree seedlings, with a mean density of 17,946 seedlings per hectare. The two mountain units had similar mean seedling densities, with 2031 stems/ha in 7MS1L and 2500 stems/ha in 7MS2. The plots in the two permafrost soil units, in contrast, had low mean seedling densities of 938 stems/ha in 7TM and 1125 stems/ha in 7TP. It's worth noting that the magnitude of difference in seedling density between permafrost and non-permafrost units is less than for other size classes of trees. This may indicate a "wave" of recent establishment of seedlings in permafrost areas that could potentially change the vegetation of these areas in the coming decades. [Figure 30](#) shows the seedling densities by species observed for the soils units. White spruce seedlings were the most abundant across the entire gradient, with significant numbers of *Populus* seedlings in the floodplain units and (to a lesser degree) in unit 7MS1L. Black spruce (*Picea mariana*) seedlings were only observed in the plots within the permafrost soil unit 7TP.

Mean basal area of trees was highest in the non-permafrost soil units, but with a different pattern of abundance among units than for tree density ([Fig. 31](#)). Due to larger mean tree size in the two non-permafrost mountain units, basal area was highest in these two units, with a mean basal area of 17.4 m²/ha in 7MS2 and 7.8 m²/ha in 7MS1L. In contrast, the floodplain unit, which had the highest *density* of trees and saplings, had mean tree and sapling basal area of 5.1 m²/ha. In contrast mean basal area of trees in the plots in soil units 7TM and 7TP were 0.8 m²/ha and 2.5 m²/ha respectively reflecting a much lower level of tree productivity in these plots.

Dominant Vascular Plant Species

The dominant vascular plant species varied among the plots according to the five soils map units, with considerable turnover among dominant species among these units as well as differences in the abundances of species cover values ([Fig. 32](#) shows the four taxa with highest cover for each of the soils map units). The most abundant species in the non-permafrost soil map units (both on the floodplain and mountain units - 7MS1L, 7MS2, and 7FP1) was white spruce (*Picea glauca*) which was only a minor cover component of the two permafrost soils units (7TM and 7TP). The second most abundant species for each of the three non-permafrost soils units was a willow, but interestingly it was a different willow species in each case. The dominant willow in the floodplain sites was *Salix alaxensis*, in unit 7MS1L it was the common upland species *Salix glauca*. *Salix richardsonii* was the dominant willow species in the one plot in unit 7MS2, which was located in a prominent drainage feature, where *S. richardsonii* frequently occurs in high abundance, especially in the subalpine areas of the park.

Only one species was a dominant member within both permafrost and non-permafrost soils units – the ubiquitous dwarf birch, *Betula nana*. *Betula nana* was one of the four most abundant taxa for all of the soil units except for the single plot located in unit 7MS2. The dominant taxa in the two permafrost soils map units (7TM and 7TP) were very similar – with *Betula nana*, *Ledum decumbens*, and *Carex bigelowii* all in the top four in cover percentage for both of these units. The one difference in composition of the four most abundant vascular plant taxa among the plots in the two permafrost soil units was that *Salix pulchra* was displaced by *Vaccinium vitis-idaea* in 7TP. It should be noted that both *S. pulchra* and *V. vitis-idaea* were among the top seven in mean percent cover for both of these units so it was a quantitative, not qualitative difference. In fact, the species with the top 10 mean cover percentages in these two soils units were identical except for the occurrence of *Spiraea stevenii* in this list for unit 7TM and *Salix richardsonii* was in top 10 in unit 7TP.

Species frequencies of occurrence

The frequency of occurrence values for the 15 species that occurred in 50 percent or more of the 25 plots in this mini-grid are shown in [Figure 33](#). The species with the highest frequency in this study area were *Vaccinium vitis-idaea* (96 % of plots) *Picea glauca* (88 %), *V. uliginosum* (88 %), *Betula nana* (84 %), and *Empetrum nigrum* (84 %). These are all widespread and common boreal plant species that occur across the boreal and subalpine zones in the northern region of the Park.

There were 18 species that were observed in 50% or more of the 8 plots located in the permafrost soil map unit **7TM** ([Fig. 34](#)). Of these 18 species, only *Spiraea stevenii* was unique to the high frequency list for this unit – that is, all of the other species observed in high frequency in 7TM also occurred in high frequency in at least one other soil map unit within the study area. Eight of the high frequency species in map unit 7TM were observed in high frequency in all of the soil map units, three were observed in high frequency in three of the map units and the remaining six species were observed in high frequency in the two permafrost soil map units (7TM and 7TP) but not in the other two units.

Twenty-one species occurred in 50 percent or more of the 5 plots in soil map unit **7TP** ([Fig. 35](#)). Of these, only two species were unique to the high-frequency list for this map unit – *Eriophorum vaginatum* and *Senecio atropurpureus* (two species commonly found in permafrost sites in the interior). Eight species occurred in high frequency in *all* of the soil map units, three of the species occurred in high frequency in three map units and (as mentioned above) , six species were observed in high frequency in the two permafrost soil map units (7TM and 7TP) but not in the other two units. Two of the high frequency species in this unit (*Salix glauca* and *Equisetum scirpoides*) occurred in high frequency in one other non-permafrost soils unit.

Twenty species of vascular plants occurred in 50% or more of the seven plots located in the floodplain soils map unit **7FP1** ([Fig. 36](#)). Five of these species (*Arctostaphylos rubra*, *Aster sibiricus*, *Epilobium latifolium*, *Salix alaxensis*, and *Shepherdia canadensis*) were only observed in high frequency in the **7FP1** soils map unit. Four species (*Epilobium angustifolium*, *Calamagrostis canadensis*, *Potentilla fruticosa* and *Solidago multiradiata*) occurred in high frequency in the two non-permafrost soils map units but not in high frequency in the permafrost

units described above. Three of the twenty high frequency species for this soils unit occurred in high frequency in three of the soil map units (*Arctagrostis latifolia*, *Festuca altaica*, and *Petasites frigidus*)

Thirty-five vascular plant species occurred in 50% or more of the four plots that were located in soil map unit 7MS1L ([Fig. 37](#)). Nineteen of these species were only recorded in high frequency within this soils map unit, a much higher proportion of unique species than was observed for any of the other soil map units. Two of these 35 species occurred in high frequency in three of the soil map units in this study area, and two species occurred in two soil map units including this one and one permafrost unit.

Vascular plant species richness

A total of 147 vascular plant species was observed within this mini-grid. Vascular plant species richness was markedly variable across the plots in this mini-grid, ranging from 14 vascular plant species in two, cold, acidic permafrost sites (plots 18 and 20) to a high of 57 in a lush, diverse site on the floodplain of Big Creek (plot 24). Mean vascular plant species richness per plot was 27.3 species across the sample (± 2.2 species). Mean vascular plant species richness per plot varied according to soil map unit, with highest mean species richness in the non-permafrost soil units (7MS1L, 7MS2, and 7FP1) and low mean species richness in the permafrost units (7TM and 7TP; see [Fig. 38](#)).

To further examine the species richness characteristics of the vegetation that develops in the different soil map units, I calculated cumulative species –area curves for each set of plots in the respective soil map units (shown in [Fig. 39](#)). This represents the accumulation curve of new, unique species as additional plots are sampled, and reflects larger scale patterns in species turnover among plots than simply evaluating mean species richness per plot. [Figure 39](#) shows the *qualitative* differences between the species accumulation rate observed in the plots in the two permafrost units versus that for the non-permafrost units. Each plot is 200 square meters, so these curves show the average number of unique species added to the sample as each additional plot is added. Note that the number of species observed in the one plot in unit 7MS2 (200 m²) contained more unique vascular plant species than the 5 plots (1000 m²) measured in unit 7TP! These data clearly demonstrate the strong constraints that permafrost conditions exert on vascular plant community diversity for this region of the Park.

Community composition

I used detrended correspondence analysis (DCA) to ordinate species cover data in order to investigate patterns in community composition among the 25 plots measured in this mini-grid. Community composition of the plots in this mini-grid varied in relation to the soils map units as we would expect given the results presented above. The gradient identified by the first DCA axis was strongly related to soil temperature, and plots located in cold, heavily permafrosted sites in units 7TM and 7TP scored low on the axis, whereas sites in warm soils in the floodplain and mountain units scored high.

[Figure 40](#) shows a dot-plot of the vegetation scores on DCA axis 1 for plots in the five soil map units. Note that the greatest variability in vegetation scores within an individual soils map unit was for the unit 7FP1, in which there was a minimum DCA-1 score of 13 and a maximum DCA-1 score of 503, for a range in scores of 490 within the plots in this soil unit. In contrast, there was a range of DCA-1 scores of 137 and 145 for plots in units 7Tm and 7TP respectively. To a great degree, this wide range in DCA-1 scores within the floodplain unit reflects differing successional status of the plots found there. Plots scoring high on this axis within this unit were open, relatively recently disturbed plots with little development of a moss mat and warm soils. Plots in this unit that received a low score on this axis, on the other hand, were late-succession spruce forest areas on terraces, where a moss mat had developed and closing of the vegetation resulted in overall cooler soil temperatures and more typical late-succession vegetation with greater similarities to the late-succession permafrost plots.

The relatively low range of scores within the plots on the permafrost units reflects two things: 1) all of these plots were located in late-succession areas with a fully developed moss mat, and cold permafrost soils; and 2) there are very strong constraints on the vegetation that will develop in permafrost sites - there is a limited suite of widespread, dominant taxa that occur in these sites, with little variation other than in the relative contribution of these “usual suspects” to the total vegetative cover of a site.

Rare and endemic species

This boreal mini-grid had relatively low species richness of endemic vascular plants. We observed a total of 4 Alaska-Yukon endemic species and 6 Beringian endemic species in this mini-grid. Mean endemic species richness values were 0.2 species per plot for Alaska-Yukon endemics and 1.2 species per plot for Beringian endemics. For comparison, in the nearby Primrose Ridge alpine mini-grid, we observed an average of 1.8 occurrences of Alaska-Yukon endemic species per plot and (8 taxa for the complete mini-grid) and 7.0 occurrences of Beringian endemic species (21 different Beringian endemic taxa for the entire mini-grid).

There were no species that are tracked as rare on a statewide basis by the Alaska Natural Heritage Program observed in the 25 sample plots in the Middle Teklanika River mini-grid.

Covariation among vegetation variables

A correlation matrix for a set of vegetation variables measured at these plots is shown in [Table 2](#). This table presents the simple correlation coefficient between each pair of variables, and is a useful way to examine how these vegetation metrics covary on the landscape.

The three direct measures of tree species abundance (density, basal area and cover) were all strongly correlated. This was expected because these are different ways of measuring the abundance of tree species in the plot. Density of seedlings and tree density were also positively correlated. The three measures of tree abundance were all strongly negatively correlated with shrub cover in this set of plots, which reflects competition among these woody plants for light and resources – shrub cover is usually reduced under forest canopy relative to open sites. Tree cover was also moderately negatively correlated with dwarf shrub cover and bryophyte cover.

This is due to the fact that moss and dwarf shrub cover was highest in heavily-permafrosted sites which were inimical to the establishment of dense tree cover.

The tree abundance metrics were moderately positively correlated to the measures of species richness within this sample (mean number of species in the 1m, 4 m, and 200 m plot sizes). This correlation of tree cover and species richness is due to the fact that permafrost plots are uniformly species-poor and also support few trees, so in those areas of the landscape free of permafrost, the abundance of both trees and number of species in the plant community both are more free to vary upward than in areas controlled by permafrost.

Forb cover was positively correlated with the measures of species richness; forbs make up the vast majority of taxa in the Park, thus where forbs are more abundant there is often an increase in relative diversity of the plant community. Graminoid cover was negatively correlated with species richness in this data set because the cover of graminoids was primarily contributed by *Carex bigelowii* – a dominant taxon in the uniformly species-poor dwarf birch-ericaceous scrub in permafrost situations. Areas of high *C. bigelowii* cover in this data set were species-poor permafrost sites. Cover of dwarf shrubs and moss were also strongly positively correlated in the data set reflecting relatively high cover of dwarf shrub taxa in the deep and continuous mat of feather mosses found in the open, wet vegetation of permafrost sites.

Relationships Between the Vegetation and Physical Environment

The results presented thus far have shown marked covariation in mean vegetation and soils attributes among the plots located in the five soils map unit polygons for this study area. These patterns in mean response of plots in different soils units have shown the importance of permafrost in controlling various aspects of the vegetation. However there was also variation *within* the soil map units. In order to identify specific causal relationships between vegetation parameters and specific environmental factors I used regression analysis and gradient analysis to identify relationships between vegetation and environment in this sample of plots. The results of these analyses help us to understand primary environmental gradients in the study area and to predict what changes may occur in the study area over time.

Due to the pronounced influence of permafrost in controlling the structure and composition of the vegetation in this study, I have concentrated on soil temperature in examining specific relationships between vegetation and environment in this data set.

Soil temperature and community composition and species richness

The first DCA axis (DCA1) identified a strong gradient in the variation of species abundances correlated with transition from permafrost vegetation to areas with thawed soils. Species that scored high on this axis occurred strictly in non-permafrost sites on mineral soil, including such relatively thermophilic species as *Leymus innovatus*, *Oxytropis borealis*, *Salix alaxensis*, and *Shepherdia canadensis*. These are species associated with warm, gravelly and well-drained soils on the Park landscape. Conversely, species that scored low on this axis were generally those characteristic of cold, moist to wet and highly organic soils in permafrost locations across the

north side of the Park, including *Polygonum bistorta*, *Rubus chamaemorus*, *Ledum decumbens*, *Oxycoccus microcarpus* and *Carex bigelowii* (note that all of these species occurred in high frequency only in the two permafrost soil map units – see [Figs. 34](#) and [35](#)).

A regression of plot scores on DCA1 against plot mean soil temperature for this set of plots yielded a tight and very highly significant relationship between these two variables ($p > 0.00001$, $r^2 = 0.872$; see [Fig. 41](#)). This analysis shows a highly significant linear relationship between the character of the vegetation found in a plot (as captured by DCA1) and soil temperature. This is strong evidence that soil temperature influences the composition of the vegetation for any given surface within this study area.

Soil temperature was significantly positively related to total plot species richness and mean species richness per 4 m² quadrat in the Middle Teklanika river mini-grid. Plots with warmer soils had, on average more vascular plant species than plots with colder soil temperatures (see [Figs. 42](#) and [43](#)). This was true for total plot species richness ($p = 0.015$, $r^2 = 0.232$; [Fig. 42](#)) as well as average species richness in the 4 m² quadrats ($p = 0.039$, $r^2 = 0.174$; [Fig. 43](#)).

Soil temperature and the relative cover of growth form elements

I used gradient analysis to investigate the relationships between soil temperature and percent cover of different growth form elements within the vegetation cover. The relationship between cover variables and soil temperature did not always meet the assumptions for regression analysis, and examination of the gradient responses of cover to the range soil temperatures observed is a useful tool for discerning patterns in these data.

The two strongest mean responses of cover elements to the gradient in soil temperature were observed for trees and graminoids (see [figs 44](#) and [45](#)). Tree cover was strongly positively related to increasing plot soil temperature within this sample ([Fig. 44](#)) whereas graminoid cover showed highest cover in the plots with coldest soil temperatures (0 to 2 degrees mean temperature; [Fig. 45](#)). This dichotomy represents the transition from sedge-dominated (*Carex bigelowii* and *Eriophorum vaginatum*), low productivity vegetation in cold permafrost soils to more productive, larger-statured vegetation supporting tree growth in areas with relatively warmer soil temperatures. Shrub cover was also highest in the set of plots with coldest mean soil temperatures (between 0 and 2 degrees C; see [Fig. 46](#)).

With tree cover, forb cover was the only other element of the vegetative cover that showed an increase in cover in the warmest soil category ([Fig. 47](#)). In contrast, the cover of lichens, mosses, and dwarf shrubs all were *lowest* in the set of plots with warmest mean soil temperatures, and highest in the intermediate soil temperature category (mean soil temperatures between 2 and 4 degrees C).

In addition to variation in the growth form composition of the vegetative cover, there were also differences in the vertical arrangement of biomass in response to soil temperature in this data set. Specifically, along the gradient in soil temperature, the highest mean live plant cover in two highest vertical strata (50 to 200 cm and > 200 cm) was observed in the set of plots with highest

soil temperatures ($> 4^{\circ}\text{C}$) with much reduced cover in these strata for plots in the two cold soil temperature groups ([Fig. 48](#)).

Soil temperature and tree density and basal area

Tree density of all three size classes – seedlings ($\leq 1.37\text{ m}$ tall; [Fig. 49](#)), saplings ($< 12\text{ cm}$ DBH; [Fig. 50](#)) and trees ($> 12\text{ cm}$ DBH; [Fig. 51](#)) all showed strong positive responses to the gradient in soil temperature within the study area (see Figures 49 through 51). Mean density of trees in each size class each showed steep patterns of increase with increasing soil temperature in this sample. This strong pattern indicates the importance of soil temperature in controlling the distribution of trees on the landscape, particularly in a mosaic of discontinuous permafrost. Tree growth was negligible in areas of cold, wet permafrost soil in this area of the Park.

A window on the past – historical/recent photo pairs in the vicinity

30 years of Vegetation Change in the Middle Teklanika River mini-grid area

We were able to acquire a set of matched oblique aerial photo pairs of several locations in the vicinity of the Middle Teklanika River mini-grid. Original photos were taken in 1976 and then repeated in 2005. These photo pairs allow us to examine what visible changes in vegetation structure have occurred in a selected set of locations in this area of the Park over the last 29 years, providing a valuable glimpse into the past for the vegetation monitoring program. The general location and direction of view of these photos is shown in Photo 3. These photo pairs show remarkable changes having occurred in this area in a short span of time (ecologically speaking). Some of the changes visible in these photos reflect expected successional development of vegetation through time, while others suggest directional changes in the vegetation that may result in major shifts in the landscape mosaic of the Park. I will discuss three of these photo-pairs in this section; the areas approximate covered by these photographs are shown in the map in [Figure 52](#).

Photo Pair #1 – looking east along tributary creek of Big Creek at northern end of the Middle Teklanika River mini-grid

Original Photo from 1976	Repeated Photo from 2005
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Click on the links above to view two repeated photo views of this area.

Striking structural changes in the vegetation have occurred in the area encompassed by this photo pair in the past 29 years. The turquoise-blue box shows equivalent locations on the ground in the two images. Note the striking increase in conifer forest cover over the period in the vicinity of this box.

Specifically, the following marked changes are visible between the two images:

- 1) the density of white spruce has increased, particularly in areas of warmer soil temperatures on the bluff on the left side of the frame and along the creek;
- 2) the amount of aspen on the bluff has apparently also increased, and there is less exposed gravelly areas on the slopes of the bluff;
- 3) there has been minor revegetation of a point bar gravel exposure visible in 1976 along the stream course.
- 4) Interestingly, spruce cover is **not** increased appreciably in the open dwarf birch-ericaceous shrub on permafrost soils in low relief areas.

Photo Pair #2 – looking east at Ridge between Big Creek and Teklanika River south of the Middle Teklanika R. mini-grid.

<u>Original photo from 1976</u>	<u>Repeated photo from 2005</u>
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Click on the links above to view two repeated photo views of this area.

There are two primary structural changes in the vegetation cover of this area during the interval that separates these photos that are visible in this photo pair. First, there has been a substantial establishment (or growth) of white spruce across the southern flank of the small E-W trending ridge in the foreground (and scattered other areas of the photo) and secondly there has been substantial revegetation of the gravel bars of Big Creek. Large areas of open gravels are visible in the 1976 photo and equivalent areas in 2005 supported relatively dense stands of willow and alder. This is an expected successional development of the vegetation in the absence of new disturbance (e.g. flooding), but it is worth noting that the vast majority of the repeated photo pairs of gravel bars that we have examined (from across then Park) have shown considerable establishment of shrub vegetation over this time period. There is much less evidence of removal of these vegetation types from areas due to new disturbance or flooding. This likely reflects widespread “recovery” from a very large flood event that occurred in the area in 1967, just 9 years prior to the initial photo set.

Photo Pair #3– area at the confluence of Big Creek and Teklanika R – looking south up drainages (north of the Middle Teklanika R. mini-grid).

<u>Original photo from 1976</u>	<u>Repeated photo from 2005</u>
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Click on the links above to view two repeated photo views of this area.

The primary changes over the 29 year period visible in this photo is the establishment of relatively dense stand of vegetation on the east bank of the river channel, that was primarily open river bar in 1976. In addition, there was continued successional change of the vegetation in the first terrace east of the river, where open scrub in 1976 has undergone succession to a denser canopy cover in 2005. Considerable establishment of spruce also occurred in the lower part of the frame, also on the first terrace east of the river. Secondly, the gravel bar of Big Creek shows considerable successional changes, specifically, establishment and growth of shrub vegetation in the alluvial gravels has been substantial over this period. There is considerable open, gravelly terrain in the 1976 photo that is vegetated with riparian willows in the 2005 photograph.

Photo Pair #4 – looking southwest up the Teklanika River drainage along the Denali Park Road.

<u>Original Photo from 1976</u>	<u>Repeated Photo from 2005</u>
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Click on the links above to view two repeated photo views of this area.

The landscape shown in the original photo is dominated by very open, low shrub-birch-ericaceous vegetation on the open flats east of the Teklanika River. In the areas east of the Park Road, trees are extremely scattered, confined to widely spaced individuals and a few patches of spruce, all confined to the drainages.

General conclusions from examination of these photo pairs:

I observed the following primary changes in the vegetation shown in these photo frames over the past 29 years:

- 1) Spruce invasion into formerly treeless sites, particularly areas on thawed soils along creeks or south-exposed slopes
- 2) Widespread establishment of shrub vegetation on gravel bars of both Teklanika R. and Big Creek.

Spruce expansion

The vegetation of parts of this area has changed in a profound and “directional” way in the past few decades. Areas that have likely been free of trees for (at least) centuries are apparently rapidly experiencing establishment and growth of patches of spruce forest. It appears that spruce forest is expanding most rapidly in areas with warmer, well-drained soil conditions, and is not

occurring appreciably in permafrost areas. Of course, we are limited to observing *visible* tree establishment in these photo pairs. However, quantitative data from the mini-grid indicate very little establishment of trees in the permafrost soil units in this area.

The information yielded from these photos confirms patterns observed in the ecological data measured in the plot network, which indicated a strong control of tree abundance by soil temperature, and a virtual absence of trees from plots located on permafrost. Similarly, these photos show a proliferation of trees in the thaw band along the creeks and in warmer, south-exposed hillsides and bluffs.

Colonization of gravel bars by tall shrubs

A very large flood scoured the gravel bars of interior Alaska rivers in 1967, including those of Denali National Park. The graph shown in [Figure 53](#) shows the daily mean stream flow discharge of the Teklanika River in the Park for the period 1964-1974. The huge flood event occurred in August 1967, during which peak flows of the Teklanika River were roughly ten times the average discharge for this shallow, braided stream. Judging from my examination of numerous historical/recent photograph pairs of floodplains across the Park, this flood event had massive and widespread ecological consequences, including removal of river terrace vegetation, erosion and redeposition of alluvial sediments on massive scale, and changes to stream channel morphology and position across the Park. These significant ecological changes would presumably have large influence throughout the system, particularly since gravel bars are an important component of habitat for many species of wildlife including moose, grizzly bears, and small mammals.

The examination of these photo pairs makes very apparent the fact that Park ecosystems are far from static, and that change, even in the relatively short span of time encompassed by these photos is occurring on a wide scale. Thus the “baseline” vegetation data that we gathered by installing the network of permanent vegetation plots in the Middle Teklanika R. mini-grid is different than the one we would have measured just 30 years earlier, with likely important unmeasured consequences for Park biota.

Discussion and Conclusions

Primary ecological gradients in the plot data

Data from the Middle Teklanika River mini-grid plots revealed strong control over vegetation patterns by permafrost dynamics and variation in soil temperature in this study area. Almost all vegetation attributes, including measures of productivity, species richness, and community composition varied substantially along the gradient in soil temperature and active layer depth spanned by this set of plots. Secondly, the role of fluvial disturbance along the stream corridors was an important factor, causing variation in successional status among plots on the river terraces and gravel bars of Big Creek and the Teklanika River. Furthermore, topography (slope, aspect, and elevation) has the ultimate defining role in causing the variation in soil temperature, permafrost status and disturbance regime, which are the more proximal causes of

the variation in vegetation. Topographic position is primary because it affects solar radiation regime of a surface, site drainage characteristics and susceptibility to fluvial disturbance.

Understanding the importance of the particular physical factors that cause the specific variation in vegetation patterns within this study area allow us to make informed hypotheses regarding potential trajectories of landscape and vegetation change in this area. For example, we would expect that changes in the climate that bring about rising soil temperatures would have potentially profound affects on the vegetation mosaic in this area, due to the tight correlations of vegetation and soil temperature. Specifically, we would expect expansion of woody taxa and trees, and the development of larger-statured vegetation across this area. In fact, the repeat photos apparently confirm that this change is already underway – we have observed an apparent expansion in spruce in this area. Specifically, spruce has spread most visibly in areas of the landscape with warmer soil temperatures – stream corridors and south-exposed slopes.

Combining soils map information with monitoring data as a tool for modeling and research

In analyzing the data for this mini-grid, I have examined the variation in mean responses of measured variables according to the five soils map units that were delineated for this area by the Denali Soils Inventory. These analyses showed that the variation in vegetation and physical parameters for the different soil map units varied in relatively predictable ways. For example, low-statured and relatively species-poor vegetation dominated by ericaceous dwarf shrubs and sedges typical of permafrost situations predominated in the permafrost soils map units and more productive and species-rich vegetation was associated with the three non-permafrost units. This is, of course, not a surprising result, but I believe that the ability to use data collected through a rigorous, standardized probability-based sampling design to assign mean values to the soils map unit polygons represents a potentially powerful tool for extrapolating our results across the landscape for use in modeling, research and other monitoring activities.

One set of potential uses of these joint Inventory and Monitoring data is in the general category of wildlife habitat mapping. Key components of the habitat quality for a wide variety of wildlife species are captured by our measurements, including: the vertical arrangement of plant cover, estimated biomass of different forage species, abundance and species composition of various elements of the vegetation. Songbirds, for example, often have strong habitat preferences that are based on vertical complexity of the vegetation, and to a lesser extent the taxonomic composition of the vegetation structure (particularly on the level of conifer vs. broadleaf). By assigning mean structural characteristics to the vegetation cover of different soils map unit polygons (based on the plot data), we could potentially use make reasonably accurate, interpreted “habitat maps” for selected avian species. Furthermore, because the soils map unit represents a biophysical unit (delineations were based upon the interpretation of a set of biophysical data by the soils scientist) and not a vegetation map, we theoretically should be able to update these polygon-based habitat maps with each new iteration of plot data to extrapolate site-based changes over the broader landscape. These iterative habitat maps could then be “tested” through their predictive power on the changing dynamics of the songbird community.

Another example of habitat mapping that could be undertaken through an integrated use of the plot data and soils map would be “forage” quality maps for ungulate species. For example in the four soil map units represented by multiple plots within this data set, the second most abundant species was a willow for each unit – but a different willow species in each case. If we were to “score” each willow species based upon its forage quality (according to the literature) we could develop a matrix to apply a score to each soils map unit polygon that would rate its level of forage quality. This map could then be tested by looking at patterns in the spatial distribution of moose through time. Perhaps this would contribute a useful tool for looking at moose/habitat relationships through time, adding another dimension to the oft-pondered issue of predator-prey interactions in Denali.

Another potential use of the vegetation plot data in combination with soils map unit polygons would be to create a similar winter caribou forage quality map based upon the lichen abundance data that we have accumulated, and a caribou summer forage quality map using preferred forage species of this animal during summer. There are very large data sets with caribou location data over the years for Denali, and it would seem useful to see if any of these map products could reliably predict the patterns in those data both spatially and seasonally.

Significance of the changes observed in photo pairs

The changes evident in the photo pairs of this area are quite significant in my estimation, and are likely the cause of numerous (unmeasured) changes in the ecosystem. For example, the patches of forest that have become established in the area over this 29-year interval certainly have changed snow distribution patterns in the area and the albedo of the land surface, both which will likely have continuing ripple effects through time. These forest patches are also large enough to foreseeably have resulted in changes in bird communities in this area, with forest birds being favored over those of open landscapes in these newly forested sites. The new patches of forest must also represent “hiding cover” for a variety of prey species, which likely affects the balance of some predator-prey interactions in the local area. In addition, it seems likely increased “woodiness” of the landscape would not favor caribou, an animal primarily of the open tundra. Obviously, with increasing establishment of conifer forest in this area, the likelihood and potential severity of forest fires is increased, and will likely to continue to increase through time.

The establishment of large areas of willow, alder and poplar stands on the formerly open gravels of the two floodplains in the study area must strongly influence the habitat quality of this area for moose and its’ other animal inhabitants. Considerable increases in the amount of available browse and forage must have occurred as a part of this successional process, which presumably has affected moose use of the area, and possibly population dynamics of this species also. Is there some way to examine the moose data we have for the period to determine if this is a signal that supports this hypothesis?