National Vegetation Classification: Boreal and Arctic Alaska Regional Analysis

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Abbreviations: NVC (U.S. National Vegetation Classification), NMS (Non-metric Multidimensional Scaling), CAVM (Circumarctic Vegetation Map), CBVM (Circumboreal Vegetation Map), ACCS (Alaska Center for Conservation Science)

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Abstract

The National Vegetation Classification (NVC) provides a standard through which the continuum of species occurring across a landscape may be organized into discrete, observable, taxonomic classes. As Alaska contains the entire arctic and most of the boreal biomes occurring within the United States, consideration of ecological data from these regions is necessary for the full development of the NVC across the range of North American biomes. The work presented herein classifies Arctic and Boreal vegetation at the intermediate levels (macrogroup and group) of the NVC hierarchy. To test assumptions inherent to these mid-level units, the Alaska Center for Conservation Science (ACCS) performed a quantitative analysis of regional vegetation plot data and based on the results of this analysis, proposed revisions to the structure and group descriptions of the hierarchy. This current and continued verification of vegetation types will promote the adoption and use of the NVC in Alaska and foster a more precise understanding of ecological trends in the circumarctic and circumboreal north.

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Introduction

The ecological classification of vegetation seeks to organize the continuum of species occurring across a landscape into discrete, observable, taxonomic classes. While this process allows a more precise and consistent communication of ecological concepts, it also requires generalization and the implementation of somewhat arbitrary boundaries based on character, indicator, differential, and diagnostic species. The National Vegetation Classification (NVC) provides a standard through which these necessary generalizations and delineations can be made and vegetation resources can be summarized (FGDC 2008).

The NVC is a hierarchical organization of cultural and natural vegetation in which natural vegetation is defined as that where ecological processes primarily determine species and site characteristics (Küchler 1969, Westhoff and van der Maarel 1973). Within the NVC, natural vegetation is further classified across eight levels, defined by diagnostic growth forms at upper levels; by compositional similarity reflecting biogeographic differences, character species, and dominant growth forms at intermediate levels; and by differential and dominant species and compositional similarity at lower, floristic levels. The work presented herein classifies Arctic and Boreal vegetation at the intermediate levels of the NVC hierarchy. Specifically, these levels are the macrogroup, which is defined by the plant species and growth forms reflective of biogeography and site conditions reflective of the region, and the group, which is defined by a comparatively narrow set of diagnostic plant species and growth forms that relate to biogeography (FGDC 2008).

The adoption of the NVC in Alaska has been delayed by the paucity of formally-described and accepted vegetation types at the mid and lower levels of the hierarchy within the region. As Alaska contains the entire arctic and most of the boreal biomes occurring within the United States, consideration of ecological data from these regions is necessary for the full development of the NVC across the range of North American biomes. Intermediate levels have been drafted for Alaska; however, with the exception of some vegetation classes whose ranges extend to the Pacific Northwest, these classes have not been formally reviewed.

To test assumptions inherent to these arctic and boreal mid-level classification units, the Alaska Center for Conservation Science (ACCS) performed a quantitative analysis of regional vegetation plot data and, based on the results of the analysis, proposed revisions to the structure and group descriptions of the hierarchy. This data-driven verification provides a framework for the future validation and revision of the NVC hierarchy and adds consistency and accuracy to the descriptions. Furthermore, the group level is appropriately scaled for landcover mapping; thus, their revision will support the future remapping of vegetation types in Alaska by the LANDFIRE initiative (landfire.gov).

Methods

Scope of Work

The work presented herein addresses the mid-level classification of vegetation in Alaska's arctic and boreal biomes. The scope of this funding opportunity precluded a comprehensive review of all groups in Alaska, therefore 15 arctic and boreal groups that were either undescribed or defined previously without sufficient plot data were targeted for analysis.

Data Selection

Seven datasets containing 792 vegetation plots and representing the diversity of vegetation types of the arctic and boreal biomes were selected for analysis (Table 1). These data were collected by ACCS in support of landcover mapping projects and were previously analyzed for compositional similarity and assigned provisional membership to plant community and alliances. A total of 116 of plots were rejected from analysis for various reasons, including plots representative of a vegetation type transitional between boreal and temperate biomes, plots not representative of homogenous vegetation, or plots whose dominant taxa were not identified to species. For final analyses 676 of 792 plots available were employed to describe 19 groups representing eight macrogroups. Approximately 40 pots were rejected on the basis of poor data quality; the remaining 116 unused plots were excluded from analysis due to membership to a poorly-represented or not-analyzed group. Of the 676 plots used in final analysis, 619 plots with attribution to their proposed groups have been accepted by VegBank (vegbank.org), a permanent, open-access database for the archival of vegetation plot data used in support of the NVC (Peet et al. 2012); 57 plots were not accepted due to lack of geographic coordinates.

Table 1. Summary of the parks or projects from which original datasets were derived, including the years of data collection, number of plots, biomes and associated report citation.

Park/Project	Year(s) of Data Collection	Number of Plots	Biome	Report Citation
Alagnak Wild River (ALAG)	2010	95	Boreal	Boucher, T. and L. Flagstad. 2014. Alagnak Wild River: Landcover classes and plant associations. Natural Resource Technical Report NPS/ALAG/NRTR-2014/927. National Park Service, Fort Collins, CO.
Denali National Park (DENA)	1999	196	Boreal	Boggs, K., A. Garibaldi, J. L. Stephens, J. Grunblatt, and T. Helt. 2001. Denali National Park and Preserve Landcover Mapping Project Volume2: Landcover Classes and Plant Associations. Natural Resource Technical Report NPS/DENA/NRTR—2001/002. National Park Service, Fort Collins, CO.
Colville River Small Mammal Survey (CR)	2015	16	Arctic	Reimer, J., A. Baltensperger, K. Tremble, T. Nawrocki, and L. Flagstad (in preparation) Colville River Small Mammal Surveys, Alaska Natural Heritage Program, University of Alaska Anchorage
Gates of the Arctic National Park and Preserve (GAAR)	1998	110	Arctic & Boreal	Boggs, K., A. Garibaldi, J.L. Stephens, and T. Helt, 1999. Landsat Derived Map and Landcover Descriptions for Gates of the Arctic National Park and Preserve. Natural Resource Technical Report NPS/GAAR/NRTR—1999/001. National Park Service, Fort Collins, CO.
Katmai National Park and Preserve (KATM)	2000, 2002	104	Boreal & Temperate	Boggs K., S. Klein, J. Grunblatt, and B. Koltun. 2003. Landcover classes, ecoregions and plant associations of Katmai National Park and Preserve. Natural Resource Technical Report. NPS/KATM/NRTR—2003/001. US National Park Service, Natural Resource Stewardship and Science
North Slope Science Initiative (NSSI)	2008, 2009, 2011	197	Arctic	Boggs, K. and T. Boucher. 2014. Plant Association Classification for Northern Alaska. Alaska Natural Heritage Program, University of Alaska Anchorage
Yukon-Charley National Park and Preserve (YUCH)	2003	74	Boreal	Boggs, K., and M. Sturdy. 2005. Plant Associations and Post-fire Vegetation Succession in Yukon-Charley Rivers National Preserve. Natural Resource Technical Report NPS/YUCH/NRTR—2005/001. National Park Service, Fort Collins, CO.

Plot Attribution

Plots were assigned a boreal, arctic, arcto-boreal transition, or temperate designation primarily in accordance with location but refined by species composition and/or environmental characteristics (Figure 1). Biome boundaries in Alaska were adopted from the bioclimatic subzones of the Circumarctic Vegetation Map (Raynolds et al. 2006) and from the geographic sectors of the Circumboreal Vegetation Map (Jorgenson and Meidinger 2015).

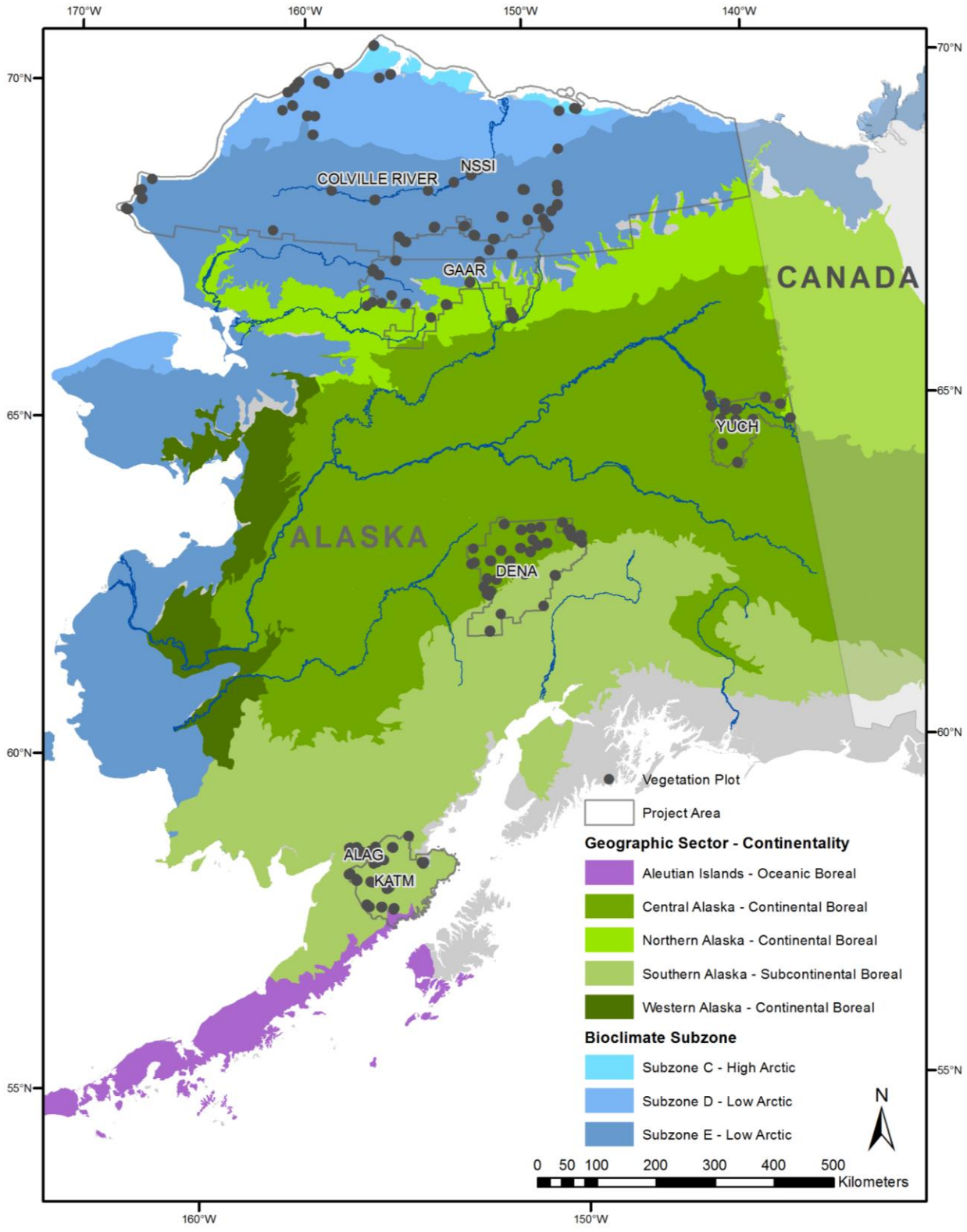

Figure 1. Map showing the location of vegetation plots and project areas included in this analysis. Bioclimatic zones modified from Raynolds et al. (2006) and Jorgenson and Meidinger (2015).

Data Management

Datasets were reconciled to a unified database to facilitate regional analysis and comparison of groupings. The VPro data entry and management system developed for Environment Canada was selected as the system in which to store and manipulate the ecological plot data for this project (MacKenzie and Klassen 2013). VPro is a front-end interface that fills a niche between static data storage systems and community analysis packages. This interface links project-specific or otherwise independent datasets to standardized taxonomy and hierarchy, thereby allowing the organization, analysis and classification of large ecological datasets.

The format and attribution required by the VPro interface required significant revision of the project-specific databases. Sites were assigned unique 7-character identifiers, which served as the primary key for each record, in accordance with their project acronym, year of collection and plot number (Table 2). Categorical variables (e.g. soil moisture regime, Table 3) were standardized; linear measurements (e.g. height, soil profile measurement, elevation) were converted to metric units; geographic coordinates were converted to decimal degrees, referencing the North American Datum of 1983 (NAD83); and site slopes were converted to percent, with flat sites (i.e., those with 0% slope) assigned an aspect of 999 to differentiate them from a 0^{o} (due north) aspect.

Table 2. Original site names, recorded in the "FieldNumber" field, and their respective VPro "PlotNumber" identifiers.

Park Code	Year(s) Surveyed	"FieldNumber" Format	"FieldNumber" (Original Site Name)	"PlotNumber" (VPro ID)
ALAG	2010	[transect#].[plot#]	3.10	AG10025
GAAR	1998		15.06	GA98058
CR	2015	[site#][line#][plot#]	S1L1V01	CR15001
DENA	1999	[3-character alphanumeric transect code][plot#]	01X 002	DN99019
KATM	2000, 2002	[transect name]-[plot#]	Dumpling-4	KT00004
NSSI	2008	NSSI-[plot#] (plots numbered sequentially; identical to VPro ID numbering)	NSSI-011	NS08011
YUCH	2003	[transect#] - [plot#]	21-3	YC03083

Table 3. Soil moisture regime descriptors, their respective codes, and ACCS equivalents based on descriptions in the Field Manual for Describing Terrestrial Ecosystems (BEC 2010).

Soil Moisture Descriptor (VPro)	Code	Soil Moisture Equivalent (ACCS)
Very Xeric	0	-
Xeric	1	Very Dry
Subxeric	2	Dry
Submesic	3	Mesic-Dry
Mesic	4	Mesic
Subhygric	5	Wet-Mesic
Hygric	6	Wet (water table >30cm)
Subhydric	7	Wet (water table ≤30cm)
Hydric	8	Aquatic (water table at surface)

Additional site data and environmental characteristics included survey date, observers, physiognomy (forest, shrub, dwarf-shrub, herbaceous, non-vascular), original regional landcover class and plant association, and summary cover values pertaining to coniferous trees, broadleaf trees, tall shrubs (>1.5m), low shrubs (0.2-1.5m), dwarf shrubs (<0.2m), herbaceous vegetation (including ferns and allies in the Lycopodaceae, Equisetaceae and Selaginaceae families), graminoids (including the Poaceae, Cyperaceae, and Juncaceae families), bryophytes (including liverworts and hornworts), and lichens.

Taxonomic Standardization

The Alaska Center for Conservation Science's local statewide species database served as the reference taxonomy for the analyses presented here. This database was generated from the PLANTS database (USDA 2015), augmented using non-vascular checklists and herbarium records, rare and non-native vascular plant herbarium records, and reviewed by program botanists. The species database largely adheres to PLANTS taxonomy and contains ancillary data for each species, including synonymy, lifeform, wetland indicator and endemic status and invasiveness and conservation ranks. Prior to analysis, taxa were corrected for synonymy and, where intraspecific taxa were assigned, coarsened to the species level. Due to the varying effort given to the record and collection of non-vascular taxa among projects, bryophytes and lichens were collectively analyzed at the life form level (e.g. 2MOSS or 2LICHN).

Data Analysis

Vegetation composition was evaluated using species association tables and formally analyzed using multivariate ordination and indicator species analysis (PC-ORD Version 6; McCune and Mefford 2010). Association tables comparing species composition by plot were constructed to facilitate comparisons among plots and assign preliminary group membership. Using these preliminary groupings, nonmetric multi-dimensional scaling (NMS) was used to visualize the compositional similarity. To reduce heterogeneity within the dataset, plots were stratified by dominant physiognomy (e.g. forest, shrub, herbaceous). The original intention was to analyze boreal and arctic types independently, however compositional similarity between

physiognomicaly similar boreal and arctic groups (e.g. boreal and arctic tussock tundra) encouraged combination of types spanning the arctic and boreal biomes. The combination of woodland, shrubland, and tundra types across biomes allowed evaluation of regional floristics. In order to meet the assumptions required by the statistical methods, variation within each dataset was further reduced by deleting outlier plots (*i.e.*, those ≥2 STD from the grand mean), removing species that occurred only once or twice in the dataset, and equalizing the importance of common and uncommon species by relativizing species covers by their maximum value. The Sørenson (dissimilarity) index was used as the distance measure due to the high percentage of zero-cover values (typically greater than 90%) and the general heterogeneity of the species data. NMS was selected as the analysis tool due to the non-normality of the species response matrix. (For all datasets average skewness and kurtosis of plots failed to approach zero, which indicates normality.) Only significant NMS solutions ($p<0.05$) with stress less than or equal to 20 were accepted for final interpretation.

The collective evaluation of the various groupings suggested by ordination, association tables and literature review informed the final diagnosis of plot data to NVC Group membership. Recommended revisions to the NVC hierarchy were then proposed to and discussed with ecologists responsible for developing the NVC through a series of webinars during which groups were prioritized for revision, analysis results were reviewed, and their implications for the NVC hierarchy were discussed.

Results

Format of Results

Our results are presented in several sections. First is a summary of changes proposed for the NVC as it pertains to Alaska; second are group-level analyses of forest, shrubland and tundra, and dune and salt marsh types in support of these proposed changes; third is an equivalency table summarizing relationships among the proposed NVC and established CBVM and CAVM types (Appendix I); and finally, specific revisions to descriptions of the revised groups are included as Appendix II.

Summary of Proposed Changes to the NVC

The following summarizes changes to the structure of the NVC hierarchy. Changes to group nomenclature are captured in the revisions to hierarchy descriptions (Appendix II).

2B3.M055. North American Boreal Shrubland & Grassland

- Absorption of *Alnus viridis* ssp. *fruticosa* types from G368 North American Arctic & Subarctic Tall Willow Tundra to G357 Western Boreal Mesic Alder – Willow
- Absorption of *Betula glandulosa* types from G369 North American Arctic & Subarctic Low Shrub Tundra to G356 Western Boreal Scrub Birch Shrubland.

4B2.M173. North American Arctic & Subarctic Tundra

- Conceptual expansion of M173 North American Arctic & Subarctic Tundra to include high-elevation and high latitude boreal types, as most dwarf shrub groups (except M404.G613 Boreal Alpine Dwarf Shrub) and the tussock tundra groups show considerable floristic overlap between arctic and boreal ecoregions.
- Renaming of G368 North American Arctic & Subarctic Tall Shrubland to 'North American Arctic & Subarctic Tall Willow Tundra' with *Salix alaxensis* dominance in a floodplain environment as the diagnostic characteristic. Absorption of *Salix alaxensis* types (boreal montane floodplain) from G357 Western Boreal Mesic Alder – Willow into G368
- Division of G369 North American Arctic & Subarctic Low Shrub Tundra to G827. North American Arctic & Subarctic Low Willow Tundra and G828. North American Arctic & Subarctic Scrub Birch Tundra. The latter group is further refined by specifying dominance by *Betula nana* as a diagnostic characteristic.
- Proposition of G(new) North American Arctic & Subarctic Moist Tundra to capture tundra with less than 25% low shrub cover that is not dominated by tussock-forming sedges or Dryas, Willow or Ericaceous dwarf shrubs.

2B2.M172. Northern Vancouverian Lowland-Montane Grassland & Shrubland

- Provisional absorption *Alnus viridis* ssp. *sinuata* types to from G357 Western Boreal Mesic Alder to G354 Vancouverian Alder - Salmonberry - Willow Shrubland

2C4.M780. North American Arctic & Northern Boreal Freshwater Shrubland, Wet Meadow & Marsh

- Proposition of G830. North American Arctic and Subarctic Wet Shrubland to capture the water track type, which is currently not described in any other NVC class.

Group-level Analyses

Forested Boreal Macrogroups and Groups

Analysis of the boreal forest groups supported the existing structure of the NVC Hierarchy. These forested ecosystems have been widely described for Alaska, and many are corroborated by plot data and type descriptions from western Canada. Forested plot data spanned the following Macrogroups and Groups:

M156. Alaskan-Yukon North American Boreal Forest
G349 Alaskan-Yukon Boreal Dry Aspen Forest[1]
G350 Alaskan-Yukon Boreal Mesic-Moist Black Spruce Forest
G579 Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest
G627 Alaskan-Yukon Boreal Moist White Spruce - Hardwood Forest

[1] Limited plot data

M179. North American Boreal Subalpine & Subarctic Woodland
G633 Western Subarctic Woodland
G646 Boreal Subalpine Woodland

M300. North American Boreal Rich Flooded & Swamp Forest
G548 Western Boreal Floodplain Forest

M876. North American Boreal & Sub-Boreal Acidic Bog & Fen
G360 Western North American Boreal Acidic Bog & Fen[1]

Ordination of the entire forest dataset elucidated complex patterning; thus, black spruce forest plots were analyzed separately from the white spruce and deciduous forest plots. This reduced the heterogeneity of each dataset and allowed evaluation of the environmental gradients within the more productive forest types (white spruce, white spruce-deciduous, and deciduous) independently from the less productive forest types (black spruce).

White Sprue and Deciduous Forest Analysis

A three-dimensional NMS solution with final stress of 18.0 was chosen to interpret the white spruce and deciduous boreal forest plots. The total variance explained on three axes was 57.4%, and the greatest proportion of variance was captured by axes 1 (24.9%) and 2 (16.6%). The final ordination segregates plots along axis 1, which is interpreted as a compound nutrient/productivity gradient and axis 2, which is interpreted as a moisture gradient (Figure 2).

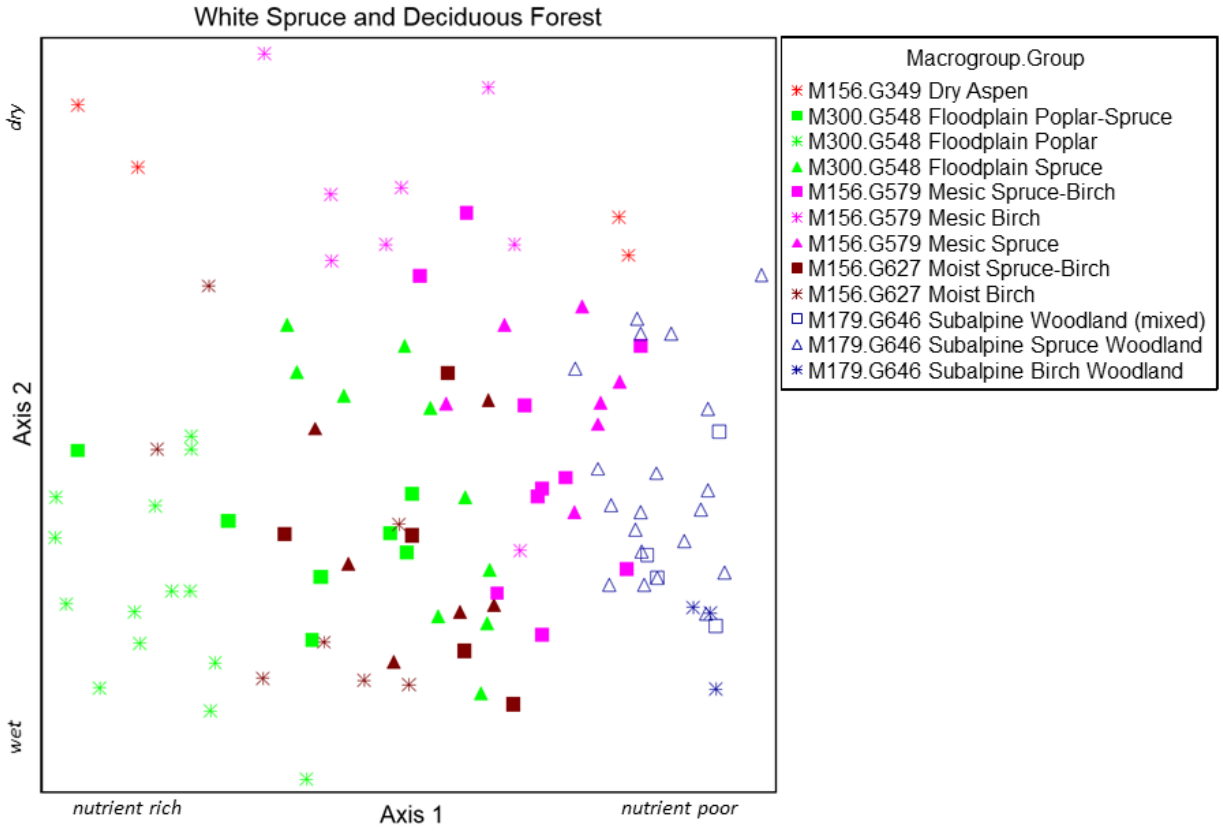

Figure 2. Ordination diagram of boreal forest plots excluding black spruce. Symbol color represents group membership whereas symbols shape represents overstory dominance type (star = deciduous, triangle = coniferous, square = mixed).

On the first axis, floodplain forests (G548; green stars) with a deciduous overstory (*Populus balsamifera*) clustered at the nutrient-rich end of the gradient, whereas subalpine woodlands (G646; blue) with a coniferous overstory (*Picea glauca*) and an ericaceous understory clustered at the nutrient-poor end of the gradient. Intermediate groups were represented by moist spruce-hardwood forest plots (G627; brown) and mesic spruce-hardwood forest plots (G579; pink). Mid- to late-seral floodplain forests with mixed or coniferous overstories (G548; green squares and triangles) occupied the same ordination space as moist spruce-hardwood forests (G627). Along axis 2 wet sites (e.g. floodplain types) occurred in the lower portion of the ordination and dry sites (e.g. G349. Dry Aspen and G579. Mesic Birch) in the upper portion.

Due to missing environmental values in the dataset, it was not possible to evaluate pattern among plots with respect to variables such as pH, moisture, and elevation. However, correlations of individual species to axes support the pattern observed in the ordination (Table 4).

Table 4. Significant correlation coefficients of species to axis 1 and 2 of the white sprue and deciduous forest ordination. For n = 107 plots, r = 0.16 is the critical value for a directional test at α = 0.05.

Productivity Gradient - Axis 1

Correlation with Axis1	Nutrient-rich Site Species	Correlation with Axis1	Nutrient-poor Site Species
-0.47	*Calamagrostis canadensis*	0.55	*Ledum palustre* ssp. *decumbens*
-0.44	*Chamerion angustifolium*	0.47	*Betula nana*
-0.38	*Viburnum edule*	0.43	*Empetrum nigrum*
-0.34	*Trientalis europaea*	0.31	*Vaccinium vitis-idaea*
-0.29	*Rosa acicularis*	0.29	*Vaccinium uliginosum*
-0.28	*Galium boreale*	0.21	*Pedicularis lanata*
-0.28	*Aconitum delphiniifolium*		
-0.26	*Orthilia secunda*		
-0.25	*Equisetum arvense*		
-0.25	*Pyrola asarifolia*		
-0.25	*Cornus sericea* ssp. *sericea*		
-0.25	*Geranium erianthum*		
-0.24	*Streptopus amplexifolius*		
-0.24	*Alnus viridis ssp. sinuata*		
-0.22	*Equisetum arvense*		
-0.22	*Athyrium filix-femina*		

Moisture Gradient - Axis 2

Correlation with Axis 2	Moist-wet Site Species	Correlation with Axis 2	Dry-mesic Site Species
-0.43	*Calamagrostis canadensis*	0.56	*Betula neoalaskana*
-0.35	*Betula papyrifera* var. *kenaica*	0.36	*Populus tremuloides*
-0.29	*Betula nana*	0.34	*Rosa acicularis*
-0.26	*Populus balsamifera*	0.22	*Arctostaphylos uva-ursi*
-0.22	*Sphagnum* spp.	0.22	*Geocaulon lividum*
-0.21	*Ledum palustre* ssp. *decumbens*	0.20	*Alnus viridis* ssp. *fruticosa*
-0.21	*Comarum palustre*		
-0.20	*Alnus incana* ssp. *tenuifolia*		

The analysis focus for this set of groups was to refine the definitions of G627. Alaskan-Yukon Boreal Moist White Spruce - Hardwood Forest, G579. Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest, and G646. Boreal Subalpine Woodland, and to develop a suite of diagnostic indicators for each. The collective evaluation of these groups suggests that in the boreal, moist white spruce-hardwood forests (G627) occur on nutrient-rich sites, while mesic white spruce-hardwood forests (G579) occurs on less productive sites. Differential species for the moist white spruce-hardwood forest group (G627) are consistent with more productive sites; for example, *Calamagrostis canadensis* and *Equisetum arvense* are understory indicators for both floodplain forests and moist spruce-hardwood forests. Differential species for mesic white spruce-hardwood forests (G579) include ericaceous dwarf shrubs indicative of lower site productivity (see individual Group descriptions for a complete list of indicator species, (Table 11). The two Groups also differ in their distributions; moist white spruce-hardwood forest (G627) is more common in the sub-continental, cool boreal region whereas mesic white spruce-hardwood forests (G579) occurs more commonly in the continental, cool boreal region (Figure 1). Along an elevation gradient, subalpine woodlands (G646) occupy sites near the elevational limit of conifers in the continental and sub-continental, cool boreal regions. Northward, this group is largely replaced by subarctic woodlands (G633), which is comprised of stunted woodlands underlain by permafrost (see black spruce analysis). Similar classes for these groups, including mapped distributions, have been defined in the Circumboreal Vegetation Map (Jorgenson and Meidinger 2015). A crosswalk between forested NVC boreal groups and the CBVM classes is provided as Appendix I.

Black Spruce Analysis

In general, black spruce forests tend to occur on relatively cold, low-productivity sites. Analyzing this dataset independently from the rest of the boreal forest allowed closer examination of the environmental gradients in black spruce forests without the influence of the more productive forest types in the ordination. A three-dimensional NMS solution with final stress of 18.5 was chosen to interpret the black spruce boreal forest plots. The total variance explained on three axes was 66.4%, and the greatest proportion of variance was captured by axes 1 (27.3%) and 2 (24.1%). In the black spruce ordination (Figure 3) plots segregated according to moisture status and slope position along axis 1 and site productivity along axis 2. Along axis 1, Boreal Subalpine Woodland (G646) plots occupy the far left of the gradient; these forests typically occurred on well-drained ridge tops or at treeline. Plots representing the Western Subarctic Woodland (G633) group occupy the middle of the gradient; these forests are underlain by permafrost and typically occur on gentle slopes. Western North American Boreal Acidic Bog & Fen (G360) plots occupy the right side of the ordination, but are not tightly clustered as they each represent a different plant association ranging from poor fen to acidic bog. Alaskan-Yukon Boreal Mesic-Moist Black Spruce Forest (G350) plots occupy the upper end of axis 2 and represent the highest productivity black spruce forest type. This group often has a deciduous forest seral stage characterized by an overstory of either *Betula neoalaskana* or *Populus tremuloides*. Contrary to their actual presence, relatively few lowland wetland plots were present

in the black spruce dataset analyzed here. This is likely due to derivation of plot data from National Park lands, which, in Alaska, are often oriented towards mountainous and high elevation terrain.

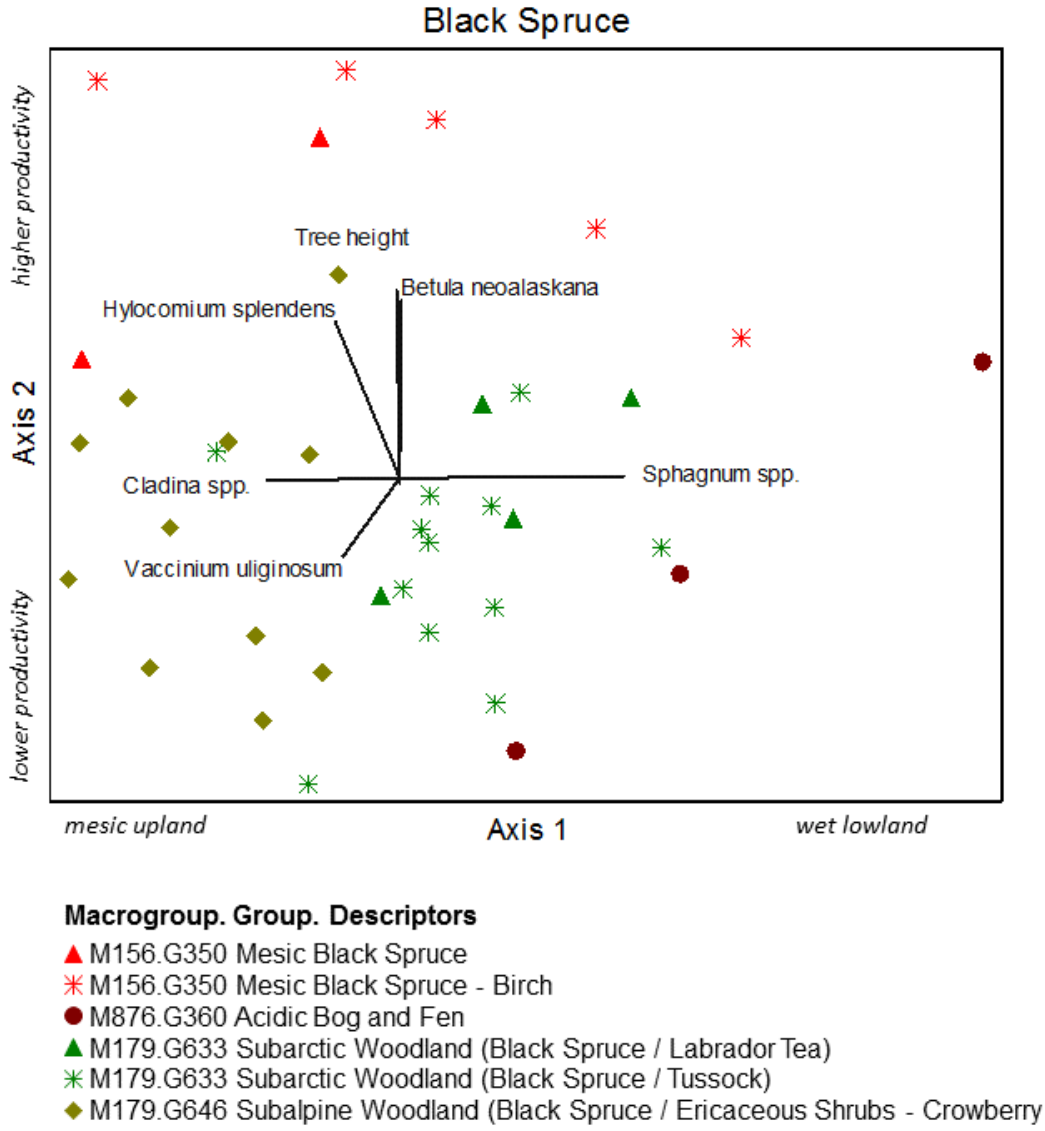

Figure 3. Ordination diagram of black spruce forest plots. Symbol color represents group membership whereas symbols shape represents overstory or understory dominance type (star = presence of deciduous trees or tussock understory, triangle = coniferous and/or *Ledum* understory, circle = wetland, diamond = coniferous with ericaceous understory).

The interpreted gradients are further supported by the type of species most highly correlated to a given axes (Table 5). Along the moisture/topographic position gradient, species characteristic of mesic upland habitats such as members of the *Cladina* lichen genus and the forbs, *Saussurea angustifolia* and *Polygonum bistorta* var. *plumosa*, and the moss *Hylocomium splendens* show high correlation to the left end of axis 1, whereas wetter lowland species such as members of the *Sphagnum* genus as well as the tree *Larix laricina* and the wetland shrub *Chamaedaphne calyculata* are correlated to the opposite end of the axis. Similarly, lower productivity indicators

such as the shrubs *Vaccinium uliginosum* and *Rubus chamaemorus*, and the dwarf shrubs *Andromeda polifolia* and *Loiseleuria procumbens* are highly correlated to the lower end of axis 2, whereas higher productivity indicators such as the shrub *Betula neoalaskana* and *Rosa acicularis* correlate to the upper end of the axis.

Table 5. Significant correlation coefficients of species to axes 1 and 2 of the black spruce ordination. For 41 plots, r = +/- 0.26 is the critical value for directional test at α = 0.05.

Moisture/ Topographic Position Gradient Axis 1			
Correlation with Axis 1	Mesic Upland Species	Correlation with Axis 1	Wet Lowland Species
-0.54	*Cladina* spp.	0.70	*Sphagnum* spp.
-0.51	*Saussurea angustifolia*	0.50	*Larix laricina*
-0.41	*Polygonum bistorta* var. *plumosa*	0.49	*Chamaedaphne calyculata*
-0.37	*Hylocomium splendens*	0.35	*Ledum palustre* ssp. *decumbens*
-0.37	*Picea glauca*	0.32	*Polygonum alpinum*
-0.35	*Vaccinium uliginosum*	0.32	*Rubus chamaemorus*
-0.33	*Dasiphora fruticosa*		
-0.32	*Equisetum scirpoides*		
-0.29	*Geocaulon lividum*		
-0.26	*Mertensia paniculata*		
Productivity Gradient Axis 2			
Correlation with Axis 2	Lower Productivity Indicators	Correlation with Axis 2	Higher Productivity Indicators
-0.41	*Vaccinium uliginosum*	0.62	*Betula neoalaskana*
-0.36	*Rubus chamaemorus*	0.58	*Hylocomium splendens*
-0.34	*Andromeda polifolia*	0.57	*Equisetum sylvaticum*
-0.28	*Carex bigelowii*	0.42	*Rosa acicularis*
-0.26	*Arctostaphylos rubra*	0.41	*Chamerion angustifolium*
		0.40	*Calamagrostis canadensis*
		0.40	*Spiraea stevenii*
		0.40	*Cornus canadensis*
		0.37	*Mertensia paniculata*
		0.30	*Saussurea angustifolia*
		0.27	*Alnus viridis* ssp. *fruticosa*

Shrubland Macrogroups and Groups

To evaluate broad regional vegetation patterns across the arctic and boreal biomes, shrubland data was organized into four broad physiognomic categories, which spanned our entire analysis area: 1. boreal and arctic tall shrub, 2. boreal and arctic low shrub, 3. boreal and arctic dwarf shrub, and 4. boreal and arctic tussock tundra, which has a significant shrub component.

Analysis of the boreal and arctic shrub plots revealed a need for significant revision of several groups. In regions with similar environmental and floristic characteristics, analysis revealed substantial overlap in groups previously described as having exclusively arctic or boreal distributions. Thus, conceptual expansion of several groups is proposed to reflect these findings. Within the shrub classes, changes are proposed within the North American Boreal Shrubland & Grassland (M055) and North American Arctic & Subarctic Tundra (M173) Macrogroups. Shrubland plot data spanned the following Macrogroups and Groups:

M055. North American Boreal Shrubland & Grassland
    G356. Western Boreal Scrub Birch Shrubland
    G357. Western Boreal Mesic Alder - Willow Shrubland
M172. Northern Vancouverian Lowland-Montane Grassland & Shrubland
    G354. Vancouverian Alder - Salmonberry - Willow Shrubland
M173. North American Arctic & Subarctic Tundra
    G827. North American Arctic & Subarctic Low Willow Tundra
    G828. North American Arctic & Subarctic Dwarf Birch Tundra
    G368. North American Arctic & Subarctic Tall Willow Tundra

Tall Shrub

Initial examination of the entire low and tall shrub dataset revealed high overall heterogeneity, which underscored the need to subdivide the data. Plots were subsequently separated according to physiognomic stature and dominant species. Alder and tall willow types were analyzed separately from scrub birch and low willow, and intermediate-height willows (largely *Salix pulchra*) were included in both analyses. Heterogeneity was further reduced within the dataset by removing wetland shrub types (water tracks) and coastal plain moist tundra with low overall shrub cover.

A three-dimensional NMS solution with final stress of 17.9 was selected for the alder-willow ordination. The total variance explained on three axes was 52.3%, and the greatest proportion of variance was captured by axes 1 (18.8%) and 2 (17.7%). Axis 1 is interpreted as a complex moisture and bioclimatic gradient with dry-mesic arctic plots grouping on the left side of the ordination, mesic-moist boreal plots in the center, and moist temperate plots on far right. Axis 2 is interpreted as a productivity gradient with floodplain willow plots occupying the upper end of the gradient and willow tundra plots occupying the lower end (Figure 4). The interpreted gradients are further supported by species correlations to the ordination axes (

Table 6). Along axis 1, species characteristic of mesic to dry arctic or boreal sites such *Salix glauca*, *S. alaxensis*, *S. richardsonii*, *Arctostaphylos* spp. and *Hedysarum alpinum* show strong correlation to the left side of axis 1, while species characteristic of moist temperate sites such as *Calamagrostis canadensis*, *Alnus viridis* ssp. *sinuata*, *Salix pulchra*, *Dryopteris expansa*, and *Veratrum viride* show strong correlation to the right side of the axis. Along axis 2 species characteristic of low productivity sites, such as *Vaccinium vitis-idaea*, *Betula nana*, *Empetrum nigrum*, and *Ledum palustre* ssp. *decumbens* are strongly correlated with the lower portion of the axis, while species characteristic of high productivity sites such as *Salix alaxensis*, *Populus balsamifera*, *Artemisia tilesii*, and *Equisetum arvense* are strongly correlated with the upper portion of the axis.

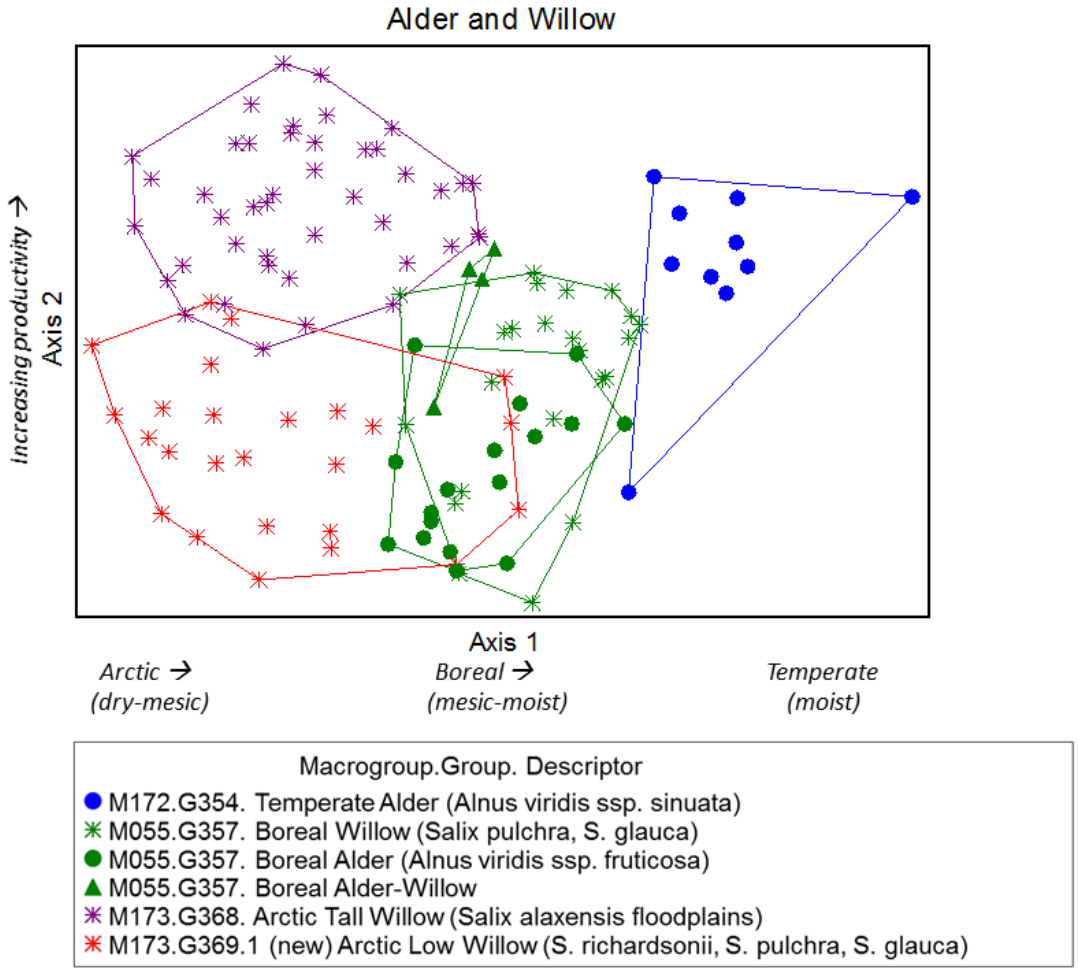

Figure 4. Ordination diagram of arctic and boreal alder and willow. Symbol colors differentiate groups, while symbol shape represent alder (circles) vs. willow (asterisks).

The range of *Alnus viridis* ssp. *sinuata* spans the sub-boreal and temperate biomes while *Alnus viridis* ssp. *fruticosa* occurs in the boreal and sub-arctic biomes (Furlow 1997). The former is provisionally grouped with temperate shrub in Vancouverian Alder - Salmonberry - Willow Shrubland (G354). An analysis of sub-boreal and temperate *Alnus viridis* ssp. *sinuata* plots is

needed to validate this proposal, but is beyond the scope of the current analysis. After removing *Alnus viridis* ssp. *sinuata* plots from the ordination set, the remaining analysis groups (boreal alder, boreal willow, and boreal alder-willow) showed nearly complete overlap in the ordination diagram and were thus combined in the description for the Western Boreal Mesic Alder - Willow Shrubland group (G357).

Table 6. Significant correlations of species to axes 1 and 2 of the alder - willow ordination. For 130 plots, r = +/- 0.16 is the critical value for a directional test at α = 0.05.

Bioclimatic and Moisture Gradient - Axis 1

Correlations with Axis 1	Dry Arctic/Boreal Indicators	Correlations with Axis 1	Moist Temperate Indicators
-0.38	*Salix glauca*	0.66	*Calamagrostis canadensis*
-0.31	*Salix alaxensis*	0.53	*Alnus viridis* ssp. *sinuata*
-0.30	*Salix richardsonii*	0.41	*Salix pulchra*
-0.28	*Salix reticulata*	0.35	*Dryopteris expansa*
-0.27	*Arctostaphylos rubra*	0.30	*Veratrum viride*
-0.27	*Dryas octopetala*	0.27	*Spiraea stevenii*
-0.26	*Hedysarum alpinum*	0.24	*Streptopus amplexifolius*
-0.26	*Arctostaphylos alpina*	0.23	*Rubus arcticus*
-0.25	*Stellaria longipes*	0.22	*Polemonium acutiflorum*
-0.22	*Carex krausei*	0.22	*Athyrium filix-femina*
-0.22	*Festuca rubra*	0.22	*Gymnocarpium dryopteris*
-0.22	*Chamerion latifolium*	0.22	*Comarum palustre*
-0.21	*Bromus inermis* ssp. *pumpellianus*	0.21	*Alnus viridis* ssp. *fruticosa*
-0.20	*Astragalus alpinus*	0.20	*Angelica lucida*

Productivity Gradient - Axis 2

Correlations with Axis 2	Lower Productivity Indicators	Correlations with Axis 2	Higher Productivity Indicators
-0.46	*Vaccinium vitis-idaea*	0.68	*Salix alaxensis*
-0.41	*Betula nana*	0.24	*Populus balsamifera*
-0.40	*Empetrum nigrum*	0.23	*Artemisia tilesii*
-0.37	*Ledum palustre* ssp. *decumbens*	0.20	*Equisetum arvense*
-0.37	*Salix glauca*	0.20	*Chamerion latifolium*
-0.35	*Vaccinium uliginosum*	0.20	*Alnus viridis* ssp. *sinuata*
-0.34	*Sphagnum* spp.		
-0.32	*Carex bigelowii*		
-0.29	*Alnus viridis ssp. fruticosa*		
-0.28	*Rubus chamaemorus*		
-0.24	*Betula glandulosa*		
-0.23	*Cassiope tetragona*		
-0.23	*Calamagrostis purpurascens*		

North American Arctic & Subarctic Tall Shrub Tundra (G368) and Arctic Low Willow Tundra (G827) segregated by species dominance and landscape position with *Salix alaxensis* floodplain plots grouping along the upper, higher-productivity portion of axis 2 and low willow tundra dominated by *Salix glauca*, *S. richardsonii*, and *S. pulchra* grouping on the lower productivity portion of the axis (Figure 5).

With the absorption of *Alnus viridis* ssp. *fruticosa* types into the Western Boreal Mesic Alder - Willow Shrubland (G357) from the North American Arctic & Subarctic Tall Shrub Tundra (G368), this group essentially became a tall willow group with *Salix alaxensis* dominance in a floodplain environment as the diagnostic characteristic.

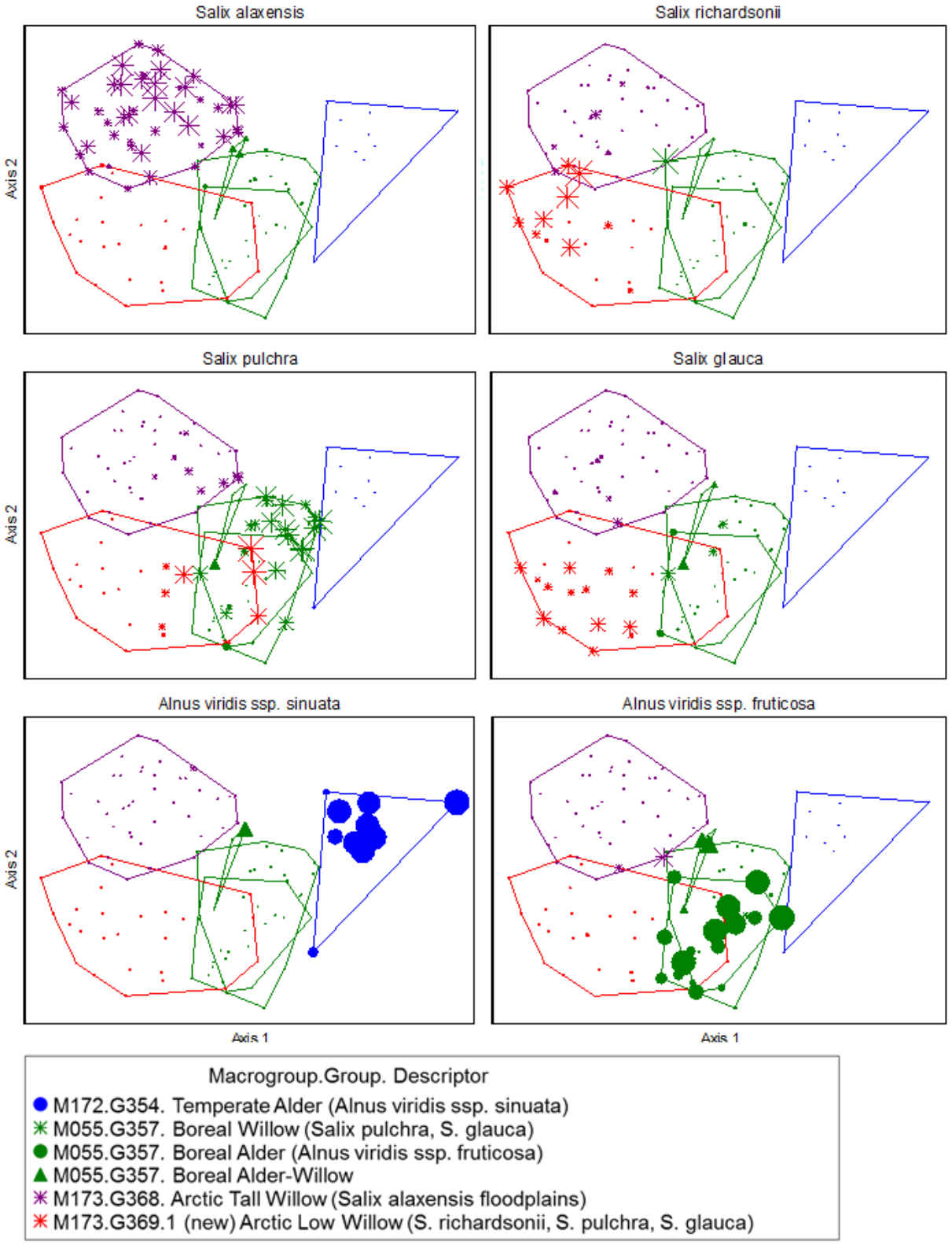

Figure 5. Alder and Willow ordination diagrams with symbols graduated by species abundance within each group.

Low Shrub

A significant, three-dimensional NMS solution with a final stress of 17.9 was selected for the low shrub (scrub birch – willow) ordination. The ordination was rigidly rotated to align the productivity gradient with axis 3. The total variance explained was 50.6%, with the greatest proportion of variance captured by axes 2 (16.3%) and 3 (20.4%). Axis 2 is interpreted as a bioclimatic gradient with arctic plots grouping on the left side of the ordination and temperate plots grouping on right side. Axis 3 is interpreted as a productivity gradient with low productivity plots grouping on the lower end of the gradient and high productivity plots on the upper end of the axis (Figure 6). The interpreted gradients are further supported by species correlations to the ordination axes (Table 7). Species correlations along axis 3 are described as productivity indicators only in the context of this ordination set and are not necessarily consistent indicators for groups not included in this ordination.

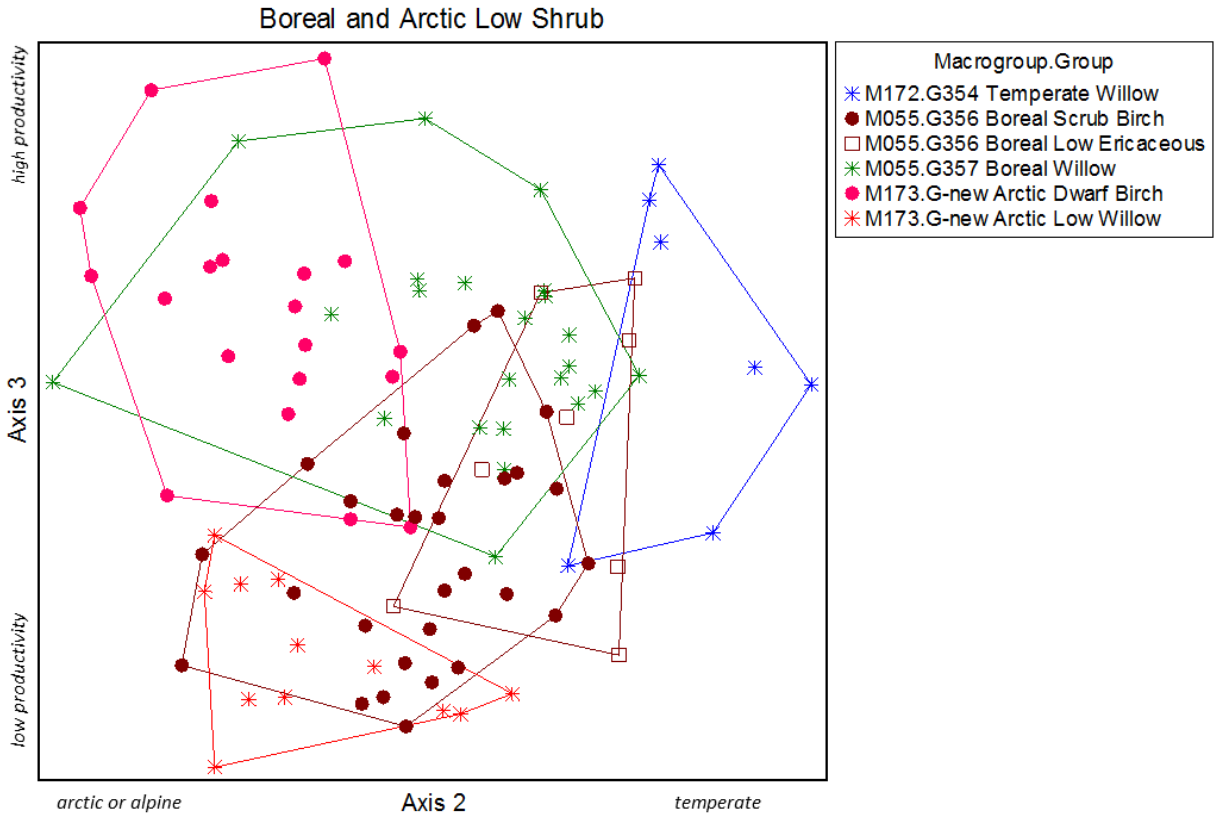

Figure 6. Ordination diagram of arctic and boreal low shrub. Symbol colors differentiate groups while symbol colors represent scrub birch (circles), willow (stars), and ericaceous (squares).

The ordination diagram shows complete separation between the scrub birch and low willow components of North American Arctic & Subarctic Low Shrub Tundra (formerly G369). For this reason, division of this group into two new groups: North American Arctic & Subarctic Low Willow Tundra (G827) and North American Arctic & Subarctic Dwarf Birch Tundra (G828) is proposed. The dwarf birch group is further refined by specifying dominance by *Betula nana* as a

diagnostic characteristic and by extension, all *Betula glandulosa* types are placed in Western Boreal Scrub Birch Shrubland (G356). The ericaceous low shrub component of Western Boreal Scrub Birch Shrubland (G356; hollow squares) is characterized by *Vaccinium uliginosum* and *Ledum palustre* ssp. *decumbens* and, although these plots do not count *Betula glandulosa* or *Betula nana* as a dominant, they occupy much of the same ordination space as the other plots within Western Boreal Scrub Birch Shrubland (G356) and are thus included within that group (Figure 7).

Table 7. Significant correlation coefficients of species to axes 2 and 3 of the low shrub ordination. For 99 plots, r = +/- 0.17 is the critical value for a directional test at α = 0.05.

Bioclimatic Gradient - Axis 2

Correlations with Axis 2	Arctic or Alpine Species	Correlations with Axis 2	Moist Temperate Species
-0.67	*Betula nana*	0.51	*Salix barclayi*
-0.41	*Ledum palustre* ssp. *decumbens*	0.49	*Calamagrostis canadensis*
-0.31	*Anthoxanthum monticola* ssp. *alpinum*	0.35	*Equisetum arvense*
-0.28	*Loiseleuria procumbens*	0.31	*Salix pulchra*
-0.25	*Carex bigelowii*	0.27	*Sanguisorba canadensis*
-0.23	*Dryas octopetala*	0.27	*Geranium erianthum*
-0.22	*Rubus chamaemorus*	0.27	*Chamerion angustifolium*
-0.21	*Luzula confusa*	0.24	*Rhodiola integrifolia* ssp. *integrifolia*
-0.20	*Salix phlebophylla*	0.23	*Dryopteris expansa*
		0.23	*Polemonium acutiflorum*
		0.22	*Comarum palustre*
		0.22	*Gymnocarpium dryopteris*

Productivity Gradient - Axis 3

Correlations with Axis 3	Low Productivity Indicators	Correlations with Axis 3	High Productivity Indicators
-0.47	*Ledum palustre* ssp. *decumbens*	0.62	*Salix richardsonii*
-0.33	*Sphagnum* spp.	0.42	*Salix glauca*
-0.33	*Vaccinium vitis-idaea*	0.37	*Salix alaxensis*
-0.32	*Picea mariana*	0.36	*Salix reticulata*
-0.28	*Spiraea stevenii*	0.35	*Polygonum viviparum*
-0.26	*Equisetum sylvaticum*	0.33	*Dodecatheon frigidum*
-0.25	*Rubus chamaemorus*	0.33	*Lupinus arcticus*
-0.22	*Polygonum alpinum*	0.32	*Arctostaphylos rubra*
-0.20	*Salix fuscescens*	0.29	*Bromus inermis* ssp. *pumpellianus*
-0.20	*Andromeda polifolia*	0.27	*Equisetum varigatum*
-0.20	*Betula nana*	0.26	*Hedysarum alpinum*
		0.25	*Salix arbusculoides*
		0.23	*Anemone richardsonii*
		0.22	*Dryas integrifolia*
		0.22	*Equisetum arvense*

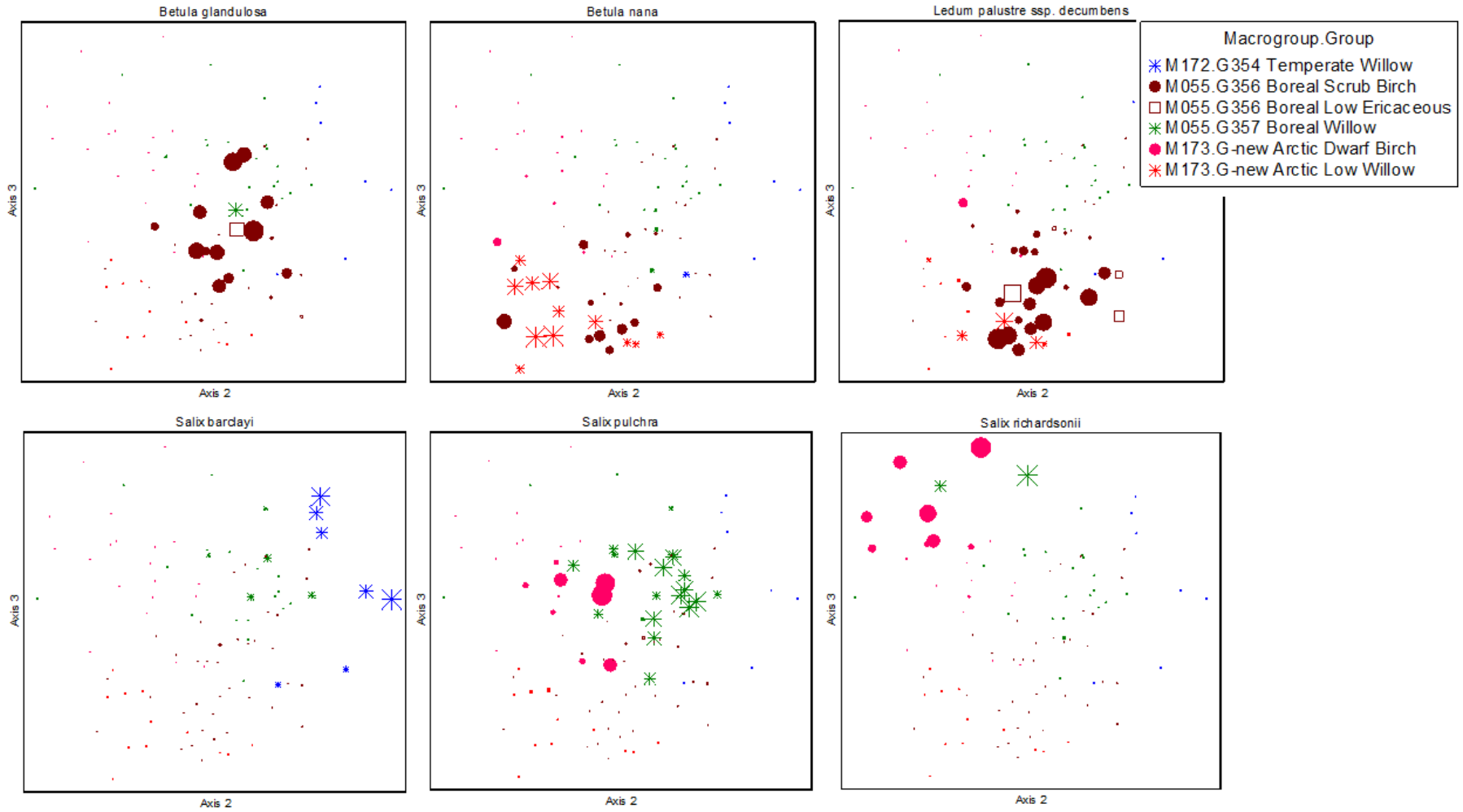

Figure 7. Ordination diagrams of low shrub analysis with symbols graduated by species abundance.

Dwarf Shrub

Despite the considerable dwarf shrub component in tussock tundra, initial examination of ordinations including the entire dwarf shrub and tussock tundra dataset, determined that separate analysis of the dwarf shrub and tussock plots was required to reduce heterogeneity and allow independent evaluation of the environmental gradients. The dwarf shrub and tussock tundra analyses spanned the following macrogroups and groups:

M173. North American Arctic & Subarctic Tundra Macrogroup
- G365. North American Arctic & Subarctic Lichen – Sparse Dwarf Shrub[2]
- G366. North American Arctic & Subarctic Dryas Dwarf Shrub Tundra Group
- G367. North American Arctic & Subarctic Ericaceous Dwarf Shrub Tundra Group
- G614. North American Arctic & Subarctic Willow Dwarf Shrub Tundra Group

M404. Western Boreal Alpine Vegetation Macrogroup
- G613. Western Boreal Alpine Dwarf Shrub Group

M173. North American Arctic & Subarctic Tundra Macrogroup
- G371. North American Arctic & Subarctic Tussock Tundra

While the analysis of plot data supports the current groupings within the North American Arctic & Subarctic Tundra Macrogroup (M173), conceptual expansion of this Macrogroup to include high-elevation and high latitude boreal types is proposed, as both dwarf shrub and tussock tundra show considerable floristic overlap between arctic and boreal ecoregions (Figure 8). Distinctly boreal dwarf shrub plots, located in the lower left corner of the ordination, represent sites dominated by *Empetrum nigrum* (Figure 9). This group is retained as Western Boreal Alpine Dwarf Shrub Tundra (G613) and is discussed below.

[2] Limited plot data

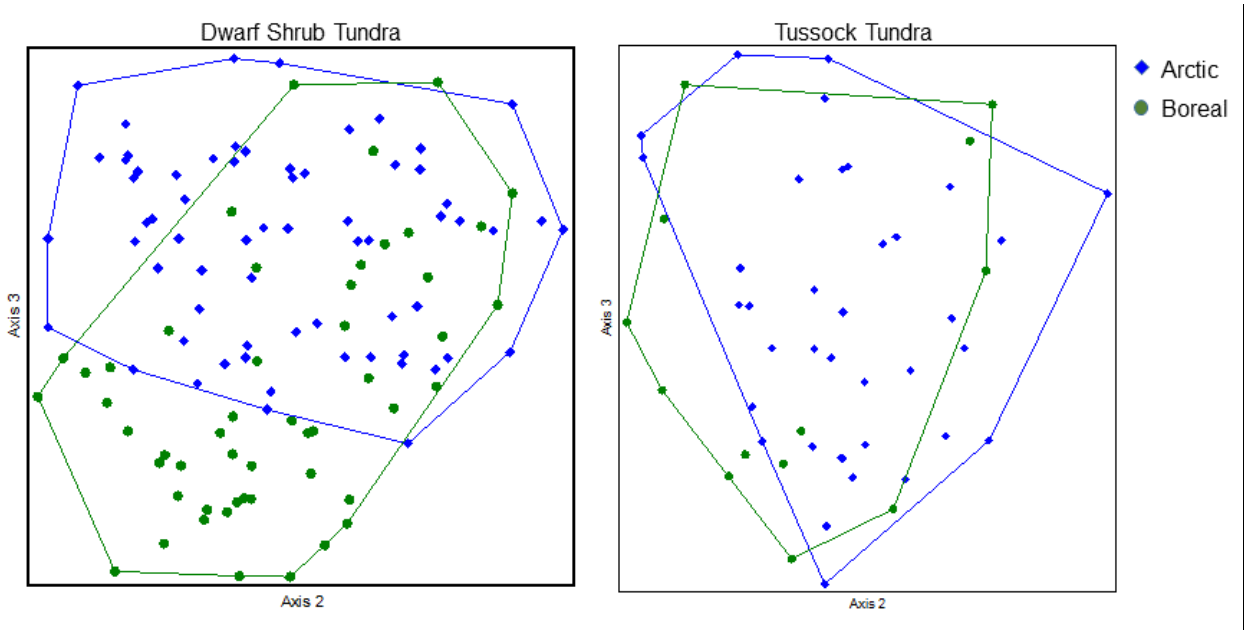

Figure 8. Ordination diagram comparing floristic similarity of Arctic and Boreal Dwarf Shrub and Tussock Tundra plots.

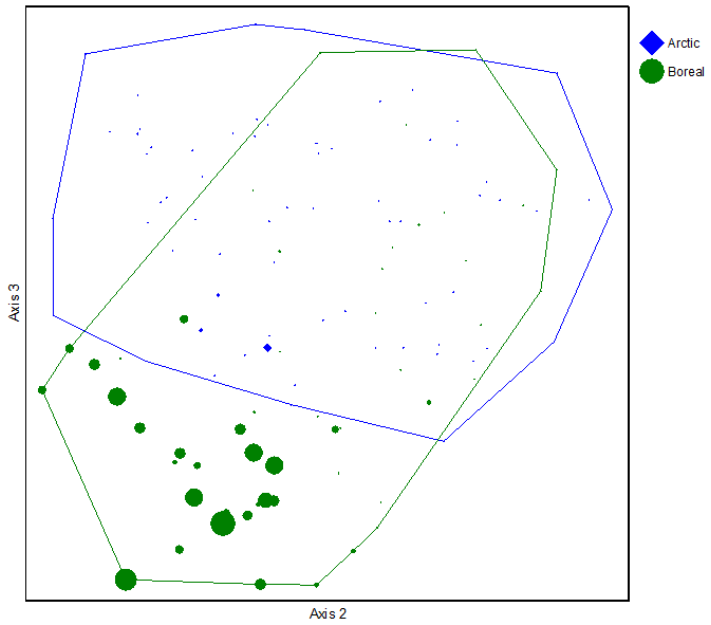

Figure 9. Ordination diagram comparing floristic similarity of Arctic and Boreal Dwarf Shrub and Tussock Tundra plots with symbols graduated by abundance of *Empetrum nigrum*.

A significant, three-dimensional NMS solution with final stress of 20.5 was chosen to interpret the dwarf shrub plots. The greatest proportion of variance was captured by axes 2 and 3 (41.4%). Axis 2 explains 17.7% of the total floristic variation among plots and is most significantly correlated to site moisture (r = -0.412). This axis is interpreted as an elevational gradient with arctic coastal plain and lower elevation boreal plots located on the wetter, left end of the gradient. Axis 3 explains 23.7% of the total floristic variation among plots and is most

significantly correlated to percent cover of lichen (r = -0.559) and low shrub species (r = -0.203). This axis is interpreted as a bioclimatic gradient from Arctic to Boreal. Four of the five dwarf shrub groups are common to both arctic and high-elevation boreal environments and are located in the upper portion of the ordination. The fifth group, Boreal Alpine Dwarf Shrub (G613) is located in the moist, low-elevation boreal area of the ordination and shows separation from the groups that span the arctic and boreal ecoregions (Figure 10).

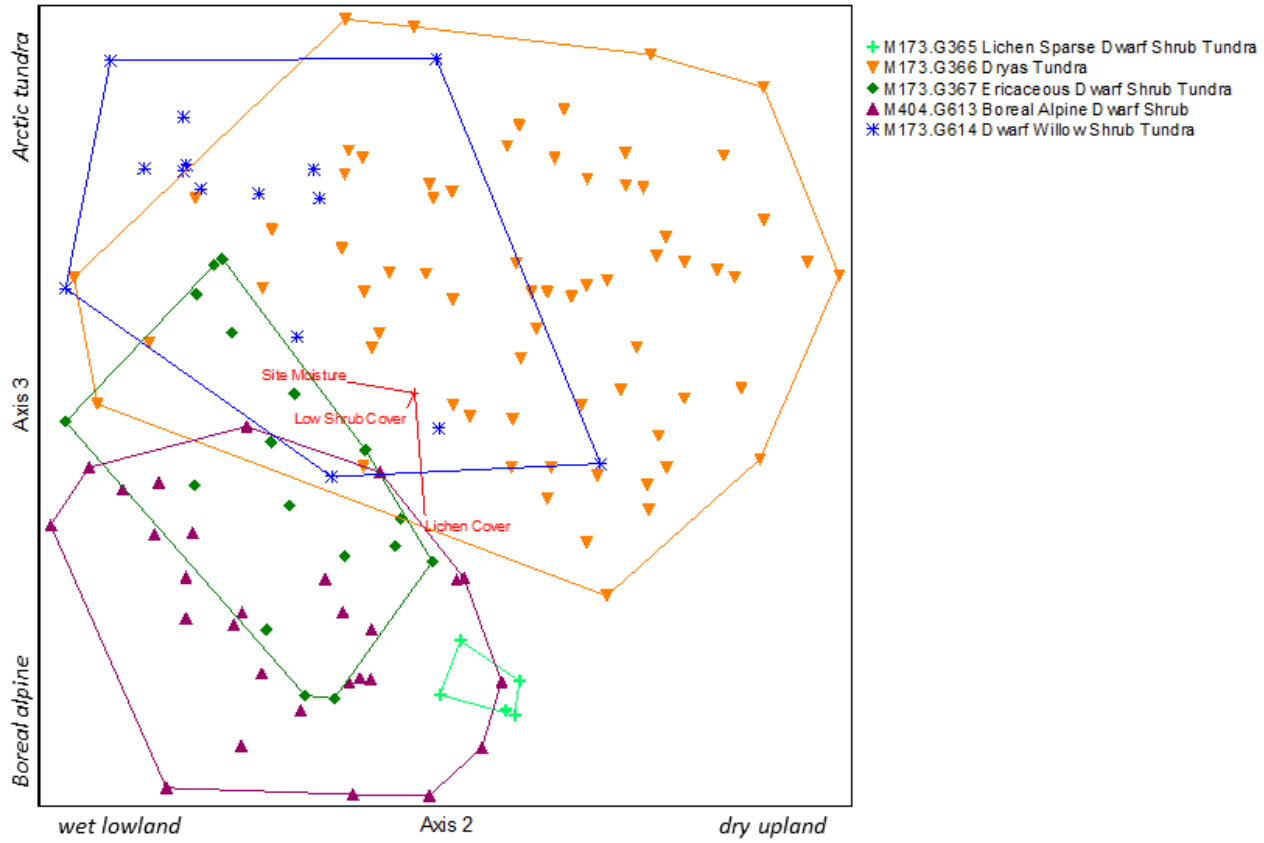

Figure 10. Ordination diagram of dwarf shrub plots symbolized by group and overlain by select environmental variables.

The interpreted gradients are further supported by the type of species most highly correlated to a given axes (Table 8). Along the elevational gradient, species characteristic of lowland or mesic habitats such as the ericaceous shrubs *Vaccinium uliginosum* and *Empetrum nigrum* show high correlation to the left end of axis 2, whereas drier upland species such as the dwarf shrub *Dryas octopetala* and the forbs *Bupleurum americanum, Thalictrum alpinum* and members of the *Saxifraga* genus are correlated to the opposite end of the axis. Similarly, dwarf shrub species with a boreal-centric distribution such as *Empetrum nigrum* and *Loiseleuria procumbens* are highly correlated to the lower end of axis 3, whereas species with a more arctic distribution such as dwarf shrubs *Dryas octopetala* and *Salix reticulata* rise to the upper end of the axis.

Table 8. Significant correlations of species to axes 2 and 3 of the dwarf shrub ordination; 133 plots, r = +/- 0.197 is the critical value for directional test at α = 0.05.

Elevational Gradient - Axis 2			
Correlation with Axis 2	Wet Lowland Species	Correlation with Axis 2	Dry Upland Species
-0.39	Bryophyte Species	0.70	*Dryas octopetala*
-0.37	*Vaccinium uliginosum*	0.25	*Bupleurum americanum*
-0.35	*Empetrum nigrum*	0.22	*Thalictrum alpinum*
-0.27	*Eriophorum vaginatum*	0.22	*Saxifraga tricuspidata*
-0.27	*Salix pulchra*	0.22	*Minuartia macrocarpa*
-0.26	*Equisetum arvense*	0.20	*Arabis lemmonii*
-0.25	*Petasites frigidus*	0.20	*Silene acaulis*
		0.20	*Kobresia myosuroides*
		0.20	*Arenaria capillaris*
		0.19	*Arnica frigida*
		0.19	*Saxifraga oppositifolia*
Bioclimatic Gradient - Axis 3			
Correlation with Axis 3	Boreal Alpine Species	Correlation with Axis 3	Arctic Tundra Species
-0.55	*Empetrum nigrum*	0.47	*Dryas octopetala*
-0.32	*Loiseleuria procumbens*	0.45	*Salix reticulata*
-0.30	*Ledum palustre* ssp. *decumbens*	0.39	*Bryophyte species*
-0.28	*Campanula lasiocarpa*	0.29	*Eriophorum angustifolium*
-0.27	*Carex spectabilis*	0.27	*Carex bigelowii*
-0.24	*Rhodiola integrifolia* ssp. *integrifolia*	0.25	*Polygonum bistorta*
-0.22	*Rhododendron camtschaticum*	0.24	*Equisetum arvense*
		0.24	*Polygonum viviparum*
		0.23	*Pedicularis langsdorffii*
		0.20	*Equisetum scirpoides*

Dryas Dwarf Shrub Tundra

The North American Arctic & Subarctic *Dryas* Dwarf Shrub Tundra Group (G366) is located in the most arctic and upland position within the dwarf shrub ordination (Figure 10). Interestingly, *Dryas* species dominance is well-partitioned within this group (Figure 11), with *Dryas octopetala* occurring on drier sites at high-elevation (average 707 m; n = 48) and lower latitude (69.96°; n = 33) relative to *Dryas integrifolia* dominated plots, which occur on more mesic sites at low-elevation (225.5 m; n = 6) and high latitude (69.22°; n = 10).

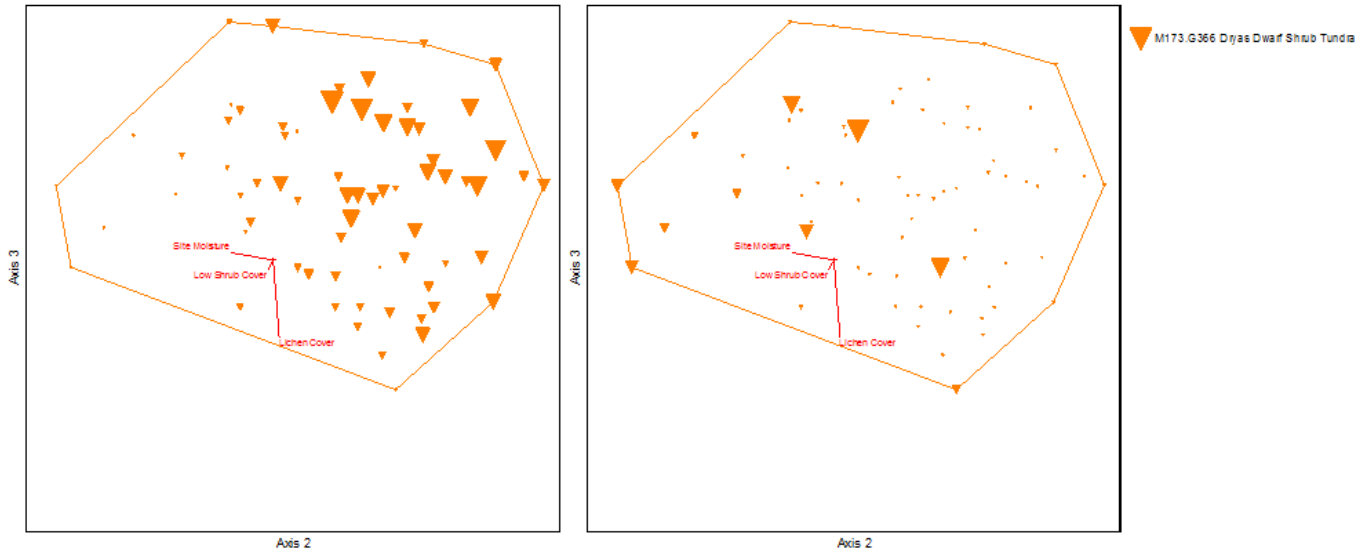

Figure 11. Dryas Dwarf Shrub Tundra plots with symbols graduated in accordance with *Dryas octopetala* (left) and *Dryas integrifolia* (right) abundance.

Dryas Dwarf Shrub tundra is characterized by high constancy and abundance of *Dryas octopetala*; *Dryas integrifolia* occurs less frequently but in high abundance. Also present at high constancy (>40%) are the dwarf shrubs *Salix reticulata* and *Salix arctica* and the ericaceous shrub *Vaccinium uliginosum*. Within the dwarf shrub data set analyzed here, *Dryas octopetala* is the sole significant indicator (p = 0.0002) species, likely due to the greater number of *Dryas octopetala*-dominated plots represented (Appendix II, Table 22).

When split by dominance, the *Dryas octopetala* variant is marginally differentiated by occurrence of the grass *Anthoxanthum monticola* ssp. *alpinum* (p = 0.06) whereas the *Dryas integrifolia* variant is significantly differentiated by *Arctagrostis latifolia* (p = 0.0014), *Papaver* species (p = 0.002) and marginally differentiated by *Polygonum viviparum* (0.0052). Dry types dominated by *Dryas octopetala* are common on slopes and ridges of the Brooks Range Foothills and high-elevation regions of boreal Alaska, whereas types dominated by *Dryas integrifolia* are common on inactive floodplains and drained lake basins of the Arctic Coastal Plain. Where *Dryas* species co-occur, *Dryas octopetala* occupies drier, more exposed microsites with *Dryas integrifolia* restricted to wetter, more protected microsites such as swales or areas of late-lying snow. Segregation of plots by *Dryas* species dominance is suggestive of alliance-level distinctions.

Ericaceous Dwarf Shrub Tundra

The Ericaceous Dwarf Shrub Tundra Group (G367) is located in the higher moisture, lower elevation and boreal area of the Dwarf Shrub ordination (Figure 10). This group is characterized by high constancy (>40%) of the ericaceous shrubs *Ledum palustre* ssp. *decumbens*, *Cassiope tetragona*, *Vaccinium vitis-idaea*; the dwarf willow *Salix phlebophylla*; the low shrubs *Betula nana* and *Salix pulchra*; the dwarf shrub *Diapensia lapponica*; the graminoids *Anthoxanthum*

monticola ssp. *alpinum* and *Luzula confusa*; and the moss *Hylocomium splendens*. The occurrence of the ericaceous shrubs *Vaccinium vitis-idaea* (p = 0.0028), *Ledum palustre* ssp. *decumbens* (p = 0.005) and *Cassiope tetragona* (p = 0.0112) also differentiate the group from other dwarf shrub types analyzed (Appendix II, 23).

A potential alliance level split within the Ericaceous Dwarf Shrub Tundra Group is suggested by coincident species abundances in multivariate space (Figure 12). Within the group, plots supporting high cover of *Ledum palustre* ssp. *decumbens* are also characterized by an abundance of lichen species in the *Cladina* genus (likely *Cladina rangiferina, Cladina mitis, Cladina stellaris,* and *Cladina uncialis*), whereas plots supporting high cover of *Cassiope tetragona* are characterized by an abundance of bryophytes such as *Hylocomium splendens*. It is likely that elevation and ecoregion influence this separation within the group, with *Ledum*-dominated plots associated with low elevation and/or the boreal ecoregion and *Cassiope*-dominated plots associated with moist sites at high elevation and/or the arctic ecoregion.

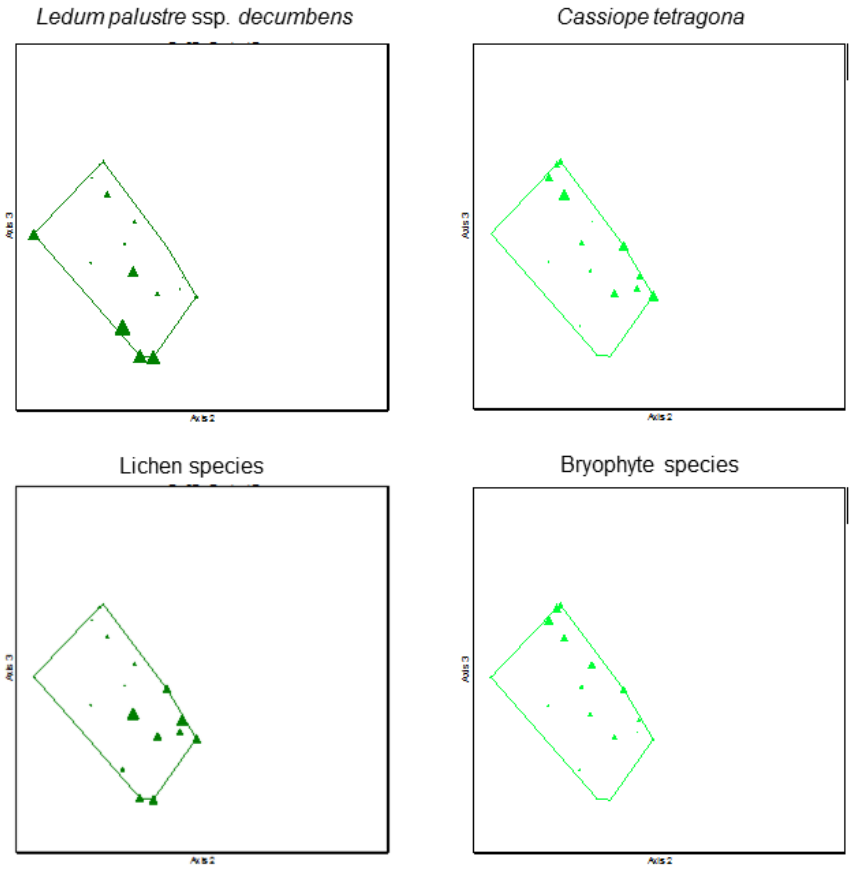

Figure 12. Ordination diagram depicting spatially-coincident species and life form group abundances within the Ericaceous Dwarf Shrub Tundra Group.

Willow Dwarf Shrub Tundra

The Willow Dwarf Shrub Tundra Group (G614) is located in the higher moisture, higher elevation and arctic area in the dwarf shrub ordination (Figure 10). This group is characterized by high constancy (>40%) of the shrubs *Salix pulchra, Salix reticulata, Dryas octopetala, Cassiope tetragona,* and *Salix rotundifolia*, the graminoids *Carex bigelowii* and *Arctagrostis latifolia*, the forb *Petasites frigidus*, and the lichens *Flavocetraria cucullata* and *Thamnolia vermicularis.* While this group occupies small patches and is uncommon on the landscape, it is significantly differentiated (p = <0.05) by numerous species, which speaks to its unique floristics and validity as a discrete group. The occurrence of the dwarf willows, *Salix reticulata* (p = 0.0022), *Salix polaris* (p = 0.0224), and *Salix rotundifolia* (p = 0.0264), the forbs *Petasites frigidus* (p = 0.0074), *Tephroseris atropurpurea* ssp. *frigida* (p = 0.0128), and *Polygonum bistorta* var. *plumosa* (p = 0.0244), the sedges *Carex bigelowii* (p = 0.0266), *Eriophorum angustifolium* (p = 0.0296), and *Eriophorum vaginatum* (p = 0.0366), the horsetail, *Equisetum arvense* (p = 0.0346), *Luzula* species (p = 0.0436) (likely *Luzula confusa* and *Luzula arctica*), and bryophyte species (p = 0.0022) (such as *Tomentypnum nitens, Hylocomium splendens, Aulacomnium* species and *Catoscopium nigritum*) are all significant, differentiating species (Appendix 1, 24).

Western Boreal Alpine Dwarf Shrub Tundra

Despite significant overlap between arctic and boreal dwarf shrub types within the North American Arctic & Subarctic Tundra Macrogroup (M173), a distinctly boreal dwarf shrub type, characterized by *Empetrum nigrum* is evident (Figure 10). While *Empetrum nigrum* occurs throughout Alaska, it rarely dominates communities in the arctic and temperate zones. Thus, while conceptual ranges of *Dryas* (G366), Ericaceous (G367) and Willow (G614) Dwarf Shrub Groups as well as the Tussock Tundra Group (G371) should be expanded to include elevation dwarf shrub types, the Western Boreal Alpine Dwarf Shrub Group (G613) should be preserved within the Western Boreal Alpine Vegetation Macrogroup (M404) This revision will restrict the Western Boreal Alpine Dwarf Shrub Group (G613) to vegetation dominated by *Empetrum nigrum* and eliminate the Dryas, Dwarf Shrub, Dwarf Shrub-Lichen and Ericaceous variants formerly included within the group.

The Boreal Alpine Dwarf Shrub Group is characterized by high constancy (>40%) of the shrubs *Vaccinium uliginosum* and *Ledum palustre* ssp. *decumbens* and the dwarf shrubs *Empetrum nigrum, Loiseleuria procumbens,* and *Salix arctica* and is significantly differentiated by the presence of the dwarf shrubs *Empetrum nigrum* (p = 0.0002), *Rhododendron camtschaticum* (p = 0.0122), and *Loiseleuria procumbens* (p = 0.0164), and the forbs *Rhodiola integrifolia* ssp. *integrifolia* (p = 0.0146) and *Campanula lasiocarpa* (p = 0.038) (Appendix 1, 21).

Tussock Tundra Analysis

The tussock tundra plots were analyzed separately from other groups in the North American Arctic & Subarctic Tundra Macrogroup (M173) due to the widespread recognition of tussock tundra as a distinct type as well as the variation these plots introduced to the ordination when

combined with the dwarf shrub plots. For the tussock tundra plots a significant, three-dimensional NMS solution with final stress of 19.2 was selected for interpretation. The greatest proportion of variance was captured by axes 2 and 3 (56.4%). Axis 2 explains 16.4% of the total floristic variation among plots and is most significantly positively correlated to percent cover of bryophytes (r = 0.344) and negatively correlated to percent cover of low shrubs (r = -0.372). This axis is interpreted as the effects of local topographic variables such as slope and microtopography on site moisture, where higher shrub cover is indicative of improved drainage and higher bryophyte cover is indicative of retarded drainage, likely due to the presence of shallow and continuous permafrost. Axis 3 explains 40.0% of the total floristic variation and is most significantly negatively correlated to the total cover of Sphagnum species (r = -0.338) and tree cover (r = -0.302), which based on the acidifying capacity of the *Sphagnum* genus, is interpreted as a pH gradient (Figure 13).

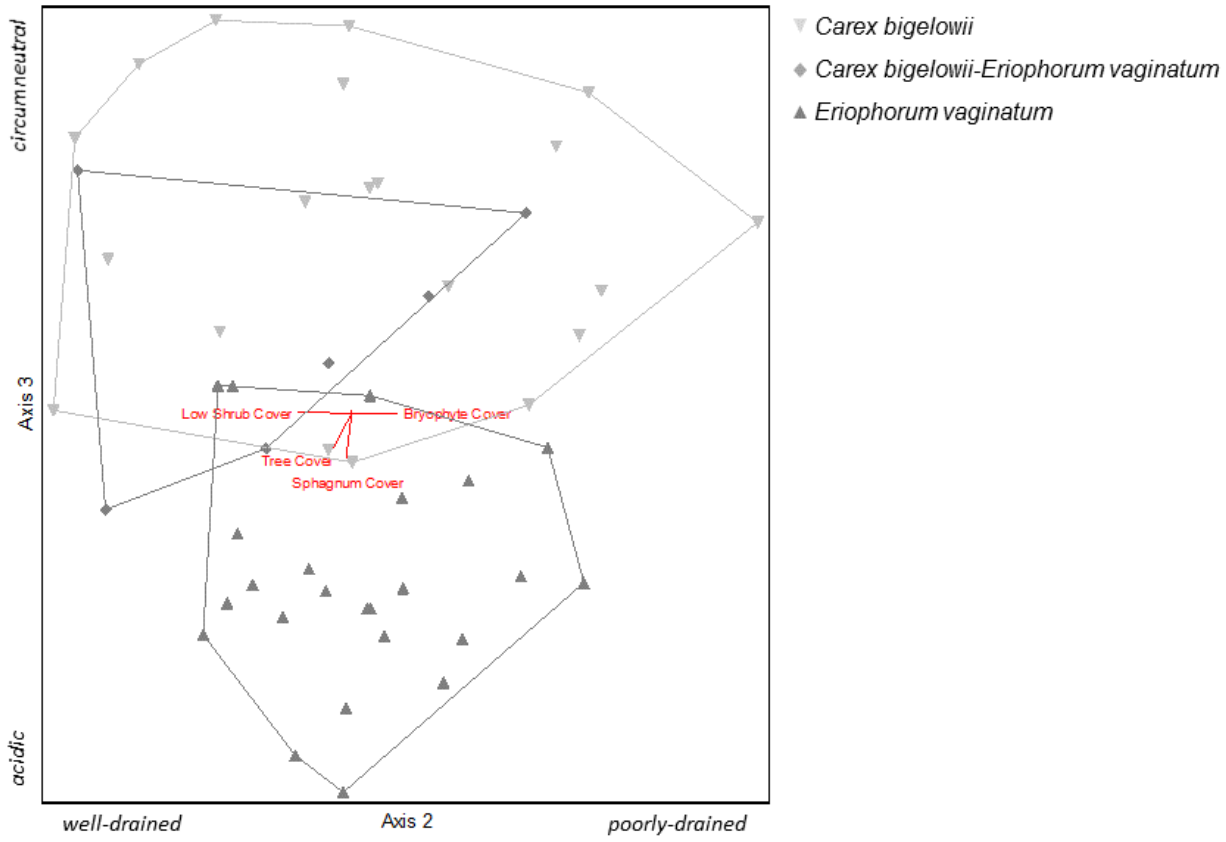

Figure 13. Ordination diagram of tussock tundra plots symbolized by dominant or co-dominant species and overlain by significant environmental variables.

Tussock tundra in Arctic and Subarctic Alaska is dominated or codominated by the tussock forming sedges, *Carex bigelowii* and/or *Eriophorum vaginatum*. While plots fall along a continuum with respect to the relative abundances of these sedges, it is informative to explore the environmental variables and cooccuring species that characterize tussock tundra plots that are clearly dominated (greater than 30% cover) by either *Carex bigelowii* or *Eriophorum vaginatum*

(Figure 14, Table 9). *Carex bigelowii*- dominated tussock tundra is characterized by an average pH of 6.3 (n = 5 measurements) as well as high constancy of the dwarf shrubs, *Salix reticulata*, and *Cassiope tetragona* with *Carex bigelowii* (p = 0.0006) and the dwarf shrub, *Dryas octopetala* (p = 0.0482) differentiating the type. Comparatively, *Eriophorum vaginatum*-dominated tussock tundra is characterized by an average pH of 5.5 (n = 13 measurements) as well as high constancy of the ericaceous dwarf shrub *Vaccinium vitis-idaea* and the low shrub *Betula nana*, with *Eriophorum vaginatum* (p = 0.0002), the low shrub *Ledum palustre* ssp. *decumbens* (p = 0.494) and the forb, *Rubus chamaemorus* (p = 0.544[3]) differentiating the type. Based on the characteristic species and higher average pH values, *Carex bigelowii* tussock tundra is considered a more productive and potentially younger type relative to mature *Eriophorum vaginatum* tussock tundra.

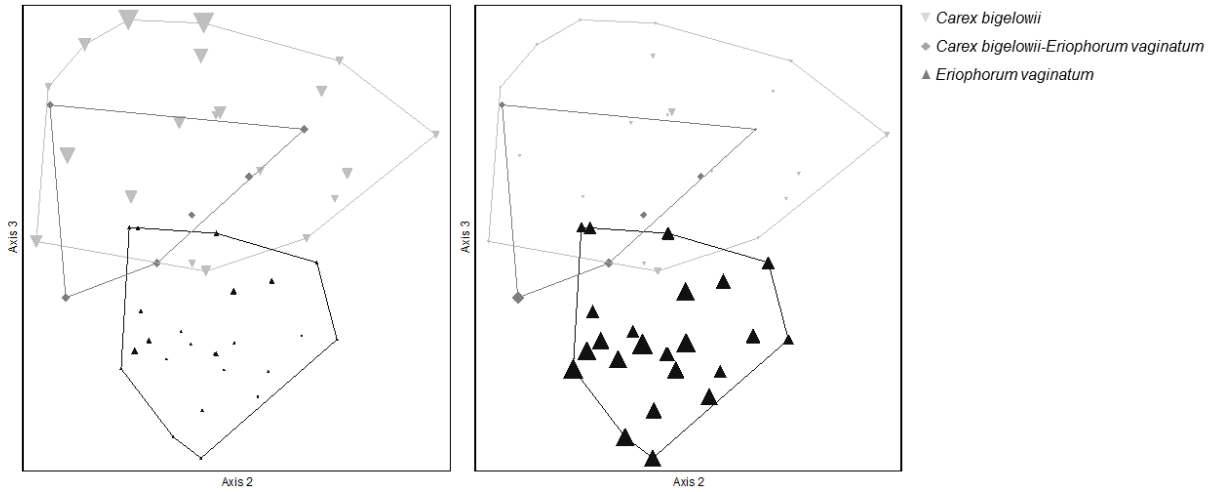

Figure 14. Tussock Tundra plots with symbols graduated by abundance of dominant species: *Carex bigelowii* (left) and *Eriophorum vaginatum* (right).

[3] Marginally significant

Table 9. Percent frequency and average cover of tussock tundra types, summarized by dominant species. Species with frequency equal to or less than 10 in either type are not included; significant ($p<0.05$) indicator species are in bold and highlighted. Tussock tundra plots (n=6) codominated by *Carex bigelowii* and *Eriophorum vaginatum* are not presented.

		***Carex bigelowii* Tussock Tundra** (n=20 plots)		***Eriophorum vaginatum* Tussock Tundra** (n=25 plots)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**	**Percent Frequency**	**Average Cover**
Tree	*Picea mariana*	5	1	16	4
Shrub	*Salix pulchra*	60	3	44	2
	Ledum palustre ssp. *decumbens*	55	6	**92**	**8**
	Betula nana	55	3	68	6
	Vaccinium uliginosum	55	3	44	2
	Betula glandulosa	10	2	12	2
	Salix glauca	10	4	4	1
	Salix richardsonii	10	14	4	1
	Alnus viridis ssp. *fruticosa*	5	1	12	3
Dwarf Shrub	*Salix reticulata*	50	3	8	4
	Cassiope tetragona	40	3	20	2
	Dryas octopetala	**40**	**3**	4	3
	Empetrum nigrum	35	1	40	3
	Vaccinium vitis-idaea	35	2	84	5
	Arctostaphylos alpina	20	4	8	2
	Salix phlebophylla	20	2	8	5
	Rhododendron lapponicum	15	1	-	-
	Andromeda polifolia	-	-	20	3
Fern & Ally	*Equisetum arvense*	15	12	-	-
Graminoid	*Carex bigelowii*	**100**	**10**	48	3
	Eriophorum vaginatum	35	3	**100**	**24**
	Eriophorum angustifolium	15	3	4	2
	Carex aquatilis	10	1	12	6
Forb	*Petasites frigidus*	15	1	8	1
	*Rubus chamaemorus**	10	2	**40**	**3**
Bryophyte	*Hylocomium splendens*	45	4	48	6
	Sphagnum	35	11	64	5
	Aulacomnium turgidum	10	2	44	2
	Dicranum	-	-	12	1
	Dicranum elongatum	-	-	12	3
	Polytrichum	-	-	16	3
	Rhytidium rugosum	-	-	12	2
Lichen	*Flavocetraria cucullata*	5	2	40	2
	Cladina rangiferina	-	-	16	5
	Dactylina arctica	-	-	16	2
	Thamnolia vermicularis	-	-	16	1

*Marginally significant indicator ($p = 0.054$)

Herbaceous Macrogroups and Groups

There is a great diversity of herbaceous types in the arctic and boreal biomes; however, due to the limited scope of this project, only a small portion of this diversity, capturing coastal types and an inland analogue, is analyzed here. Salt marshes and coastal and inland dunes are discrete, recognizable types that have been well-described for Alaska and are largely supported by plot data; as such, plots were not stratified beyond their group designations for analysis. These three types were combined in a single analysis to explore floristic overlap between topographically adjacent types (salt marsh and coastal dune), as well as geographically separate yet structurally similar types (coastal and inland dune). Although mature dunes are characterized by significant shrub cover, earlier successional stages are largely herbaceous and for this reason are included in the analysis of herbaceous systems. Analysis of the salt marsh and coastal and inland dune groups supported the existing structure of the NVC Hierarchy. Salt marsh and coastal and inland dune plot data spanned the following Macrogroups and Groups (note: one plot from M059.G498. North Pacific Maritime Coastal Scrub & Herb Beach & Dune was included for reference):

M055. North American Boreal Shrubland & Grassland
    G374. North American Arctic & Boreal Shrub & Herb Dune
M059. Pacific Coastal Beach & Dune Vegetation
    G498. North Pacific Maritime Coastal Scrub & Herb Beach & Dune
M402. North American Arctic & Boreal Coast Vegetation
    G612. Arctic & Boreal Coastal Herb & Dwarf-Shrub Beach & Dune
M403. North American Arctic Tidal Salt Marsh
    G535. North American Low Arctic Coastal Salt Marsh

A significant, three-dimensional NMS solution with final stress of 7.9 was selected for the salt marsh, coastal dune and inland dune ordination. The total variance explained was 30.1%, with 6.6, 16.5 and 7.1% of that variation partitioned along axis 1, 2 and 3, respectively. Although axes 2 and 3 explain the greatest cumulative variance, axis 1 and 2 were chosen for interpretation due to the greater orthogonality of environmental gradients relative to the groups and comparatively similar variance explained between axes 1 and 3 (*i.e.*, 6.6 v. 7.1). Axis 1 is interpreted as a continental gradient with salt marsh and coastal dune plots occupying the right end of the gradient and inland dunes occupying the left end. Axis 2 is interpreted as a compound moisture and salinity gradient with coastal plots clustering at the lower end and inland plots clustering towards the upper end of the gradient (Figure 15).

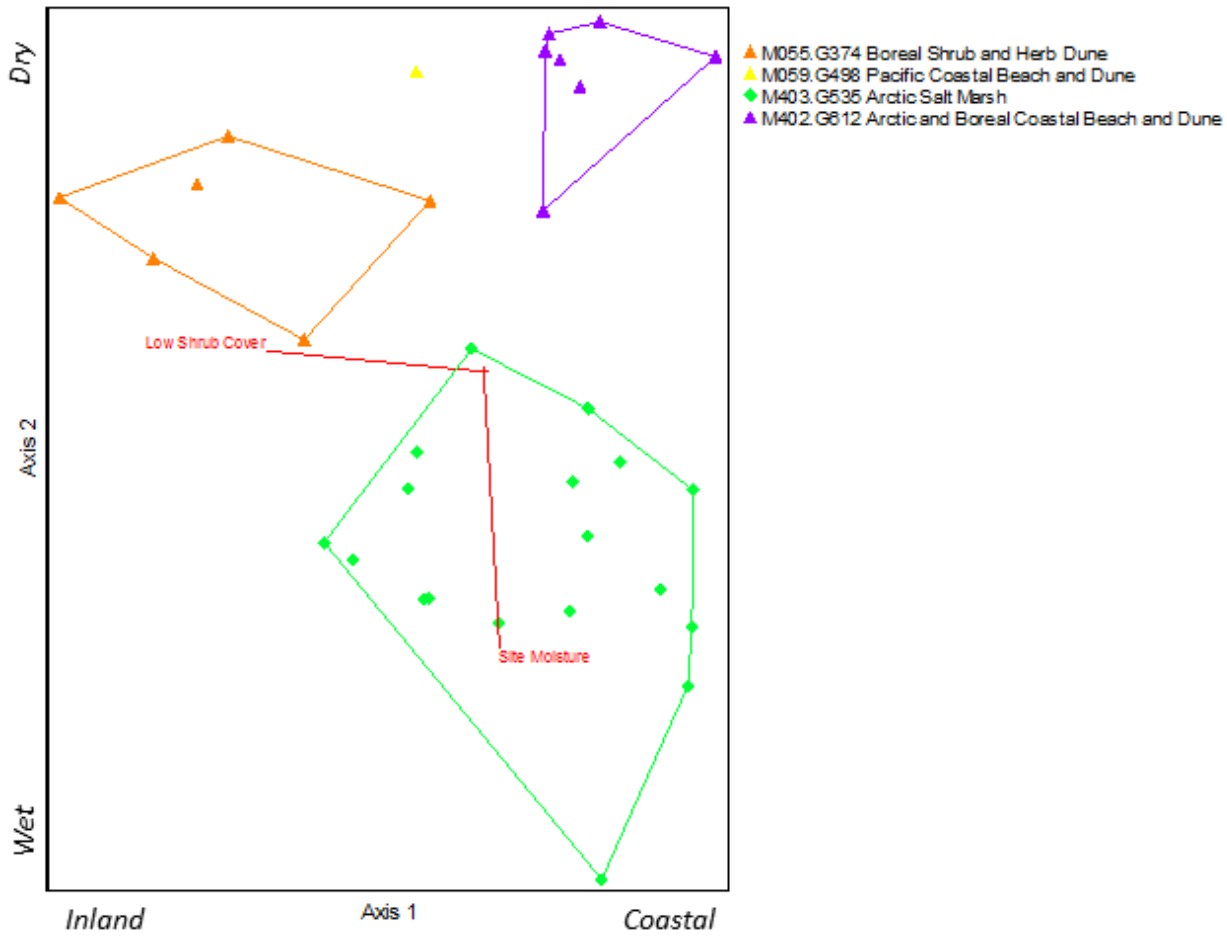

Figure 15. Ordination diagram of salt marsh and coastal and inland dune plots symbolized by group and overlain by significant environmental variables.

Correlations among axes, environmental variables, and species support the ecological interpretation of the gradients. Axis 1 is most significantly correlated to low shrub cover (r = -0.713) and height (r = -0.492), whereas axis 2 is most significantly correlated to site moisture (r = -0.803). The interpreted gradients are further supported by their species correlations. Numerous species characteristic of inland dunes, such as the willows *Salix glauca* and *Salix alaxensis*, the forbs *Astragalus alpinus*, *Eurybia sibirica*, and *Hedysarum alpinum*, and the grasses, *Elymus alaskanus* ssp. *alaskanus* and *Bromus inermis* ssp. *pumpellianus* are significantly correlated to the inland end of axis 1. Along the moisture gradient, the flood- and salt-tolerant grass *Puccinellia phryganodes* is significantly correlated to the wet end of axis 2, whereas species tolerant of desiccation such as the succulent forb *Honckenya peploides* and the beach grass *Leymus mollis* are positively correlated to the dry end of axis 2 (Table 10).

Table 10. Significant correlations of species to axes 1 and 2 of the salt marsh and coastal and inland dune ordination; 32 plots, r = +/- 0.344 is the critical value for directional test at α = 0.05.

Continental Gradient - Axis 1			
Correlation with Axis 1	Inland Species	Correlation with Axis 1	Coastal Species
-0.71	*Salix glauca*	0.33*	*Puccinellia phryganodes*
-0.59	*Astragalus alpinus*	0.31*	*Stellaria humifusa*
-0.55	*Salix alaxensis*		
-0.51	*Poa glauca*		
-0.49	*Cnidium cnidiifolium*		
-0.47	*Eurybia sibirica*		
-0.47	*Hedysarum alpinum*		
-0.47	*Salix reticulata*		
-0.46	*Artemisia tilesii*		
-0.38	*Equisetum arvense*		
-0.37	*Draba* spp.		
-0.37	*Tanacetum bipinnatum* ssp. *bipinnatum*		
-0.36	*Elymus alaskanus* ssp. *alaskanus*		
-0.36	*Bromus inermis* ssp. *pumpellianus*		
Moisture Gradient - Axis 2			
Correlation with Axis 2	Wet Site Species	Correlation with Axis 2	Dry Site Species
-0.42	*Puccinellia phryganodes*	0.54	*Honckenya peploides*
		0.52	*Leymus mollis*

* Not significant – listed for purposes of comparison

Salt Marsh Analysis

The Arctic Salt Marsh Group (G535) is located in the wet and coastal area of the ordination and is well separated from the dune groups along the moisture gradient (Axis 2). The group is characterized by high constancy (>40%) of the grass *Dupontia fisheri* and the forb *Stellaria humifusa*. Both *Dupontia fisheri*, *Stellaria humifusa* and the sedge, *Carex subspathacea* indicate the group, with the grass *Puccinellia phryganodes* and the sedge *Carex glareosa* occurring in local abundance (Appendix 1, Table 200).

Coastal and Inland Dune Analysis

The Coastal Beach and Dune (G612) and Boreal Shrub and Herb Dune (G374) Groups are equally positioned on the dry end of the moisture gradient (Figure 15), but despite similar moisture regime, substrate, and processes, the two groups are well separated by species diversity and composition. The Coastal Beach and Dune Group is characterized by low species diversity (n=10) coupled with high constancy (>40%) of the beach grass, *Leymus mollis* and the forb *Honckenya peploides.* Along with the legume *Lathyrus japonicus* var. *maritimus, Honckenya peploides* also indicates the group (Appendix 1, Table 18). Alternatively the Boreal Shrub and Herb Dune Group is characterized by a diverse assemblage of species (n=52) including high constancy (>40%) and abundance of the shrub willow *Salix glauca*, and high constancy of the horsetail *Equisetum arvense*, the grasses *Festuca rubra, Leymus mollis, Bromus inermis* ssp. *pumpellianus, Koeleria asiatica* and *Poa glauca*, and the forbs *Astragalus alpinus, Artemisia tilesii* and *Stellaria longipes* (Appendix 1, Table 17).

Within this analysis, the Boreal Dune Group is differentiated by numerous species, but *Salix glauca*, *Salix alaxensis*, *Dryas integrifolia* and *Koeleria asiatica* indicate active and stable types within the group (Komarkova and Webber 1980). Differences in species diversity and composition between coastal and inland dunes likely relate to greater exposure of the coastal dunes to severe weather, which delivers wind-born salt spray and holds systems in an early successional stage.

Discussion

Comparison of similar physiognomic groups among the arctic, alpine, and boreal biomes suggests that for some groups, local environmental conditions such as exposure and disturbance may override the influence of climate on the distribution of their component plant species. In the arctic and boreal biomes, these bioclimatic trends are particularly evident for tundra and shrublands. While the occurrence of species across biomes is not a new concept, the occurrence of vegetation types across biomes is not as well understood. Notably, the distribution of arctic and alpine tundra, floodplain shrublands, and inland dunes across arctic and boreal biomes, which is supported by the analyses presented here, was not previously captured by the NVC hierarchy.

Compositional similarity between arctic and alpine tundra groups likely relates to the replication of an arctic climate in high-elevation boreal environments. Specifically, mountainous habitat above elevational treeline in the boreal biome is characterized by high exposure with low annual precipitation, cool, short summers, and long, cold winters, which promote the development of permafrost. By comparison, compositional similarity between arctic and boreal floodplain shrublands and inland dunes likely relates to the perpetual maintenance of an early successional state by periodic disturbance; specifically, the seasonal inundation of floodplains and wind erosion across inland dunes. In these ruderal environments with disturbed mineral soils, pioneer species— those characterized by high growth and dispersal rates— are most successful, regardless of the climate. The greater importance of local environmental conditions relative to climate is expected to extend to saturated habitats such as salt marshes and freshwater marshes. In such wetlands, it is suspected that the moderating effects of water on the daily and annual ambient temperature (due to water's high specific heat) may create a habitat that is relatively consistent between biomes.

This analysis, the first quantitative analysis of vegetation plot data in Alaska to directly address the NVC, identified multiple objectives for future research. First, the documented bioclimatic trends draw attention to the importance of evaluating vegetation data across biome transitions. Future work within Alaska should review the compositional similarity among groups across the boreal and temperate as well as arctic and western Alaska biomes. International collaboration should also assess the commonality of groups between Alaska and Canada. Furthermore, as the original scope of work funded the description of only 15 arctic and boreal groups, there are many

vegetation units in these regions yet to be reviewed. Most important is the analysis of plots representing groups within the North American Arctic & Northern Boreal Freshwater Marsh, Wet Meadow & Shrubland Macrogroup (M870). Additional priorities include analysis of plots representing the proposed group concepts of arctic water tracks and moist, non-tussock, polygonal tundra; greater representation of plots in the Western North American Boreal Acidic Bog & Fen Group (G360) to refine analysis of black spruce dominated boreal forest types; and further differentiation of subarctic and subalpine forest types, specifically the Boreal Subalpine Woodland (G646) and the Western Subarctic Woodland (G633) groups. The continued verification of vegetation types will promote the adoption and use of the NVC in Alaska and foster a more precise understanding of ecological trends in the circumarctic and circumboreal north.

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Appendix I. Relationships of proposed NVC groups to established CBVM Level II Vegetation and CAVM Classes.

Circumarctic and circumboreal vegetation concepts interpreted from Raynolds et al. (2006) and Jorgenson and Meidinger (2015), respectively. Relationships are depicted by the following symbols: = indicates that the two concepts are equivalent, ~ indicates that the proposed group is approximately equivalent to the established concepts, < indicates the proposed group is included within the established concepts, > indicates the established concepts are included within the proposed concept, and <> indicates a contradiction in floristic and distribution relationships.

NVC Macrogroup Name	NVC Group Name	Relationship	CBVM Level II Vegetation Class	Relationship	CAVM Map Unit
M156. Alaskan-Yukon North American Boreal Forest	G579. Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest	=	Yukon Mixed Spruce-Birch-Aspen Forests	NA	no equivalent type
	G627. Alaskan-Yukon Boreal Moist White Spruce - Hardwood Forest	=	Southern Alaska Spruce-Birch-Herb Forests	NA	no equivalent type
	G350. Alaskan-Yukon Boreal Mesic-Moist Black Spruce Forest	<>	Yukon Subalpine Spruce Woodlands and Scrub	NA	no equivalent type
		<>	Northern Alaska-Yukon Spruce Woodlands and Scrub	NA	no equivalent type
	G349. Alaskan-Yukon Boreal Dry Aspen Forest	=	Yukon Dry Spruce-Aspen Forests	NA	no equivalent type
M179. North American Boreal Subalpine & Subarctic Woodland	G633. Western Subarctic Woodland	~	Northern Alaska-Yukon Spruce Woodlands and Scrub	NA	no equivalent type
	G646. Boreal Subalpine Woodland	>	Yukon Subalpine Spruce Woodlands and Scrub	NA	no equivalent type
		>	Southern Alaska Subalpine Spruce Woodlands and Scrub	NA	no equivalent type
M300. North American Boreal Rich Flooded & Swamp Forest	G548. Western Boreal Floodplain Forest	>	Yukon Floodplain Spruce-Poplar Forests and Scrub	NA	no equivalent type
		>	Southern Alaska Floodplain Spruce-Cottonwood Forests and Scrub	NA	no equivalent type

NVC Macrogroup Name	NVC Group Name	Relationship	CBVM Level II Vegetation Class	Relationship	CAVM Map Unit
M055. North American Boreal Shrubland & Grassland	G356. Western Boreal Scrub Birch Shrubland	<	Northern Alaska-Yukon Spruce Woodlands and Scrub		no equivalent type
		<	Yukon Subalpine Spruce Woodlands and Scrub		
		<	Southern Alaska Alder-Willow-Dwarf Birch Scrub	NA	
	G357. Western Boreal Mesic Alder - Willow Shrubland	<	Southern Alaska Alder-Willow-Dwarf Birch Scrub	<>	S2. Low-shrub communities
	G374. North American Arctic & Boreal Shrub & Herb Dune	NA	no equivalent type	NA	no equivalent type
M402. North American Arctic & Boreal Coastal Beach, Dune & Rocky Shore	G612. Arctic & Boreal Coastal Beach & Dune	NA	no equivalent type	NA	no equivalent type
M870. North American Arctic & Northern Boreal Freshwater Marsh, Wet Meadow & Shrubland	G830. North American Arctic & Subarctic Wet Shrubland	NA	no equivalent type	~	W3.4 Wet sedge communities in complex with shrub thickets
M403. North American Arctic Tidal Salt Marsh	G535. North American Arctic Coastal Salt Marsh	NA	no equivalent type	NA	no equivalent type
M404. Western Boreal Alpine Vegetation	G613. Western Boreal Alpine Dwarf Shrub Tundra	<>	Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows	<	B3. Prostrate dwarf-shrub, gramionid/lichen communities on acidic substrates
		<>	Southern Alaska-Yukon Alpine Dwarf Scrub and Meadows		
		>	Aleutian Heaths and Meadows		
M173. North American Arctic & Subarctic Tundra Macrogroup	G366. North American Arctic & Subarctic Dryas Dwarf Shrub Tundra	<	Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows	<	B4. Prostrate dwarf-shrub, gramionid/lichen communities on non-acidic substrates
	G367. North American Arctic & Subarctic Ericaceous Dwarf Shrub Tundra	<	Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows	<	B3. Prostrate dwarf-shrub, gramionid/lichen communities on acidic substrates
	G614. North American Arctic & Subarctic Dwarf Willow Shrub Tundra	<	Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows	<	B4. Prostrate dwarf-shrub, gramionid/lichen communities on non-acidic substrates
		<	Southern Alaska-Yukon Alpine Dwarf Scrub and Meadows		
	G827. North American Arctic & Subarctic Low Willow Tundra	<	Northern Alaska-Yukon Spruce Woodlands and Scrub	<	S1. Erect dwarf-shrub communities

NVC Macrogroup Name	NVC Group Name	Relationship	CBVM Level II Vegetation Class	Relationship	CAVM Map Unit
			Yukon Subalpine Spruce Woodlands and Scrub		S2.1 Low-shrub communities of willow or birch
	G828. North American Arctic & Subarctic Dwarf Birch Tundra	<	Northern Alaska-Yukon Spruce Woodlands and Scrub	<	S1. Erect dwarf-shrub communities
			Yukon Subalpine Spruce Woodlands and Scrub		S2.1 Low-shrub communities of willow or birch
	G(new). North American Arctic & Subarctic Moist Tundra	NA	no equivalent type	~	G3. Non-tussock, sedge, dwarf-shrub, moss communities
	G368. North American Arctic & Subarctic Tall Willow Tundra	NA	no equivalent type	<>	S2.1 Low-shrub communities of willow or birch
	G371. North American Arctic & Subarctic Tussock Tundra	NA	no equivalent type	=	G4. Tussock sedge, dwarf-shrub, moss communities

Appendix II. Revised Hierarchy Descriptions

1.B.4.Na. North American Boreal Forest & Woodland

M156. Alaskan-Yukon North American Boreal Forest

G579. Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest

Type Concept: This group is common throughout interior Alaska and extends eastward into Yukon. It occurs on well-drained soils derived from glacial deposits, hillside colluvium, residual soils, or loess. Forests contain all post-fire seral stages including needle-leaved evergreen, broad-leaved deciduous or mixed. Dominant canopy species include *Picea glauca, Betula neoalaskana*, and *Populus tremuloides*. Common shrubs include *Alnus viridis* ssp. *fruticosa, Betula nana, Betula glandulosa, Rosa acicularis, Ledum palustre* ssp. *decumbens, Ledum groenlandicum, Salix glauca, Vaccinium vitis-idaea, Vaccinium uliginosum, Empetrum nigrum,* and *Linnaea borealis*. The herbaceous layer is sparse and often species poor and may include *Calamagrostis canadensis, Equisetum arvense, Equisetum sylvaticum, Gymnocarpium dryopteris* or *Geocaulon lividum*. The most common moss is *Hylocomium splendens* (Table 111).

Classification Comments: The CBVM Vegetation Level II class "Yukon Mixed Spruce-Birch-Aspen Forests" is an equivalent concept (Jorgenson and Meidinger 2015).

Similar NVC Types: G627. Alaskan-Yukon Boreal Moist White Spruce - Hardwood Forest has a similar overstory composition, but occurs on moist substrates and has an herb-rich understory.

Diagnostic Characteristics: Canopies are dominated by *Picea glauca, Betula neoalaskana,* and *Populus tremuloides* or a mixture of one or more of these species. Indicator species in mid to late seral stages are the ericaceous low and dwarf shrubs *Ledum palustre* ssp. *decumbens, Ledum groenlandicum, Vaccinium vitis-idaea, Vaccinium uliginosum,* and *Empetrum nigrum*.

G627. Alaskan-Yukon Boreal Moist White Spruce - Hardwood Forest

Type Concept: This group is common throughout the sub-boreal region of Alaska and extends eastward to southwest Yukon and northwest British Columbia. It occurs on moist well-drained soils derived from glacial deposits, hillside colluvium, residual soils, or loess. Dominant canopy species include *Picea glauca* or *Picea xlutzii* and *Betula papyrifera var. kenaica* or *Betula neoalaskana*. *Tsuga mertensiana* may codominate with *Picea xlutzii* where their ranges overlap. Common shrubs include *Rosa acicularis, Viburnum edule, Menziesia ferruginea, Alnus viridis* ssp. *sinuata, Salix pulchra, Vaccinium ovalifolium*, and *Oplopanax horridus*. Common herbaceous species include *Calamagrostis canadensis, Equisetum arvense, Dryopteris expansa*, and *Gymnocarpium dryopteris* (Table 111).

Classification Comments: The Circumboreal Vegetation Map, Vegetation Level II class "Southern Alaska Spruce-Birch-Herb Forests" is an equivalent concept (Jorgenson and Meidinger 2015).

Similar NVC Types: G579. Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest has a similar overstory composition (*Picea glauca - Betula neoalaskana*) but it is less common than this group in the sub-boreal region. G579. Alaskan-Yukon Boreal Mesic White Spruce - Hardwood Forest differs from this group in that it has ericaceous shrub indicators, lower forb and fern diversity, and less *Calamagrostis canadensis*. Species composition in G548. Western Boreal Floodplain Forest can be similar to this group in late seral stands.

Diagnostic Characteristics: Canopies are dominated by *Picea glauca* or *Picea xlutzii* and *Betula papyrifera* var. *kenaica* or *Betula neoalaskana. Tsuga mertensiana* may codominate with *Picea xlutzii* where their ranges overlap. Forb and fern diversity is relatively high (contrasted with G579). Diagnostic species include *Alnus viridis* ssp. *sinuata, Calamagrostis canadensis*, *Equisetum arvense, Dryopteris expansa*, and *Gymnocarpium dryopteris* (Table 111). Regional indicators include *Oplopanax horridus, Menziesia ferruginea*, and *Vaccinium ovalifolium*.

Plot data in this analysis captured the southwest portion of the distribution, but did not encompass the central portion of the range in the Cook Inlet Basin and Kenai Peninsula. Several of the species indicators listed above reflect plant associations described from the Chugach National Forest (DeVelice et al. 1999), but those plots were not included in this analysis.

Table 11. Percent frequency and average cover of species within the Moist and Mesic White Spruce-Hardwood Forest Groups (G627 and G579) derived from 18 plots and 25 plots, respectively; significant (p<0.05) indicator species are in bold and highlighted.

Life Form	Species	Moist White Spruce-Hardwood Forest (G627)		Mesic White Spruce-Hardwood Forest (G579)		ISA Value*	*p*-value
		Percent Frequency	Average Cover	Percent Frequency	Average Cover		
Tree	*Picea glauca*	89	14	92	19		
	Betula papyrifera var. *kenaica*	50	23	32	11		
	Betula neoalaskana	17	4	**44**	**19**	37	0.04
	Populus balsamifera	11	1	-	-		
	Populus tremuloides	6	4	8	0		
	Picea mariana	-	-	12	1		
Shrub	***Vaccinium vitis-idaea***	50	3	**68**	**14**	56	0.03
	Salix pulchra	**39**	**11**	16	1	38	0.02
	Betula nana	33	2	16	2		
	Spiraea stevenii	28	1	32	1		
	Vaccinium uliginosum	28	2	**52**	**9**	43	0.05
	Betula glandulosa	17	1	20	3		
	Salix richardsonii	17	4	8	0		
	Empetrum nigrum	17	0	**36**	**4**	33	0.05
	Ledum groenlandicum	11	1	24	1		
	Rosa acicularis	11	0	24	2		
	Salix barclayi	11	4	4	1		
	Viburnum edule	11	1	8	0		
	Linnaea borealis	11	1	12	1		
	Alnus incana ssp. *tenuifolia*	6	2	16	4		
	Alnus viridis ssp. *fruticosa*	6	1	32	6		
	Alnus viridis ssp. *sinuata*	6	3	8	1		
	Ledum palustre* ssp. *decumbens	6	0	**36**	**3**	33	0.03
	Salix alaxensis	6	0	-	-		
	Salix arbusculoides	6	1	-	-		
	Salix bebbiana	6	0	8	0		
	Salix glauca	6	3	12	0		
Grass	***Calamagrostis canadensis***	**94**	**38**	36	2	90	0.0002
Fern & Ally	***Equisetum arvense***	**44**	**13**	24	2	39	0.04
	Equisetum sylvaticum	28	5	16	3		
	Gymnocarpium dryopteris	22	2	12	1		
	Athyrium filix-femina	6	0	-	-		
	Dryopteris expansa	6	1	4	0		
	Equisetum pratense	6	1	4	0		
Forb	*Rubus arcticus*	28	0	4	0		
	Cornus canadensis	22	2	12	1		
	Trientalis europaea	22	0	4	0		
	Geranium erianthum	17	0	-	-		
	Mertensia paniculata	17	1	16	1		
	Polemonium acutiflorum	17	0	-	-		
	Moehringia lateriflora	11	0	4	0		
	Petasites frigidus	11	0	-	-		
	Pyrola asarifolia	11	0	-	-		
	Rubus chamaemorus	11	0	8	0		
	Sanguisorba canadensis	11	1	-	-		
	Heracleum maximum	6	0	-	-		
Moss	***Sphagnum* spp.**	**33**	**10**	12	2	33	0.03
	Hylocomium splendens	22	6	44	18		
	Pleurozium schreberi	6	1	12	2		

*ISA values greater than 30 and p = 0.05 or less

G350. Alaskan-Yukon Boreal Mesic-Moist Black Spruce Forest

Type Concept: This group is widespread on upland slopes, inactive alluvial deposits, and north-facing slopes in the boreal region of Alaska. Sites are cold, acidic, and may be well-drained to somewhat poorly-drained. *Picea mariana* is the dominant species in mature stands, although *Picea glauca* may be codominant. In post-fire seral stages *Betula neoalaskana* or *Populus tremuloides* may codominate. Common understory species include *Alnus viridis* ssp. *fruticosa, Ledum groenlandicum, Ledum palustre* ssp. *decumbens Vaccinium vitis-idaea, Empetrum nigrum, Rosa acicularis, Spiraea stevenii, Calamagrostis canadensis, Equisetum sylvaticum,* and *Cornus canadensis*. Common mosses include *Hylocomium splendens* and *Pleurozium schreberi* (Table 122).

Classification Comments: Distinguished within M156 by the presence of black spruce. This group approximates two of the vegetation classes described by Jorgenson and Meidinger (2015). G350 differs from 'Alaska-Yukon Wet Black Spruce Woodlands and Scrub Coniferous' concept due to its lack of wetland indicator species and differs from the 'Northern Alaska-Yukon Spruce Woodlands and Scrub' concept in its dominance of *Picea mariana* instead of *Picea glauca*.

Similar NVC Types: None in Alaska

Diagnostic Characteristics: *Picea mariana* is the most constant overstory species. Stands may be codominated by *Betula neoalaskana, Picea glauca,* and *Populus tremuloides*. Total tree cover in mature stands typically ranges from 40 to 80%. Compared to the other forest types within M156 this is the least productive forest, however, of the black spruce forest types, it is the most productive and is the only black spruce type with a post-fire hardwood seral stage. This group can be differentiated from other black spruce forests by lack of wetland characteristics or peat formation, the presence of hardwood codominants, and understory indicators such as *Rosa acicularis, Spiraea stevenii, Calamagrostis canadensis,* and *Equisetum sylvaticum.*

Table 12. Percent frequency and average cover of species within the Alaskan-Yukon Boreal Mesic-Moist Black Spruce Forest (G350) derived from 7 plots. Species with frequency equal to or less than 10 are not included; important indicator species are in bold and highlighted.

		Mesic-Moist Black Spruce Forest (G350)	
Lifeform	**Species**	**Percent Frequency**	**Average Cover**
Tree	*Picea mariana*	**100**	**31**
	Betula neoalaskana	**71**	**29**
	Picea glauca	14	1
Shrub	*Alnus viridis* ssp. *fruticosa*	**71**	**11**
	Spiraea stevenii	71	1
	Vaccinium vitis-idaea	**57**	**4**
	Ledum palustre ssp. *decumbens*	43	11
	Rosa acicularis	29	1
	Vaccinium uliginosum	29	0.1
	Ledum groenlandicum	14	4
	Salix bebbiana	14	1
	Empetrum nigrum	14	1
Graminoid	*Calamagrostis canadensis*	71	2
	Carex bigelowii	14	1
Fern & Ally	*Equisetum sylvaticum*	**71**	**25**
	Lycopodium annotinum	29	0.1
	Equisetum arvense	14	1
Forb	*Cornus canadensis*	43	4
	Chamerion angustifolium	29	1
	Geocaulon lividum	29	1
	Mertensia paniculata	29	0.1
	Polygonum alpinum	29	0.1
	Saussurea angustifolia	29	0.1
Moss	*Hylocomium splendens*	**71**	**37**
	Polytrichum	29	4
	Sphagnum	29	9
	Pleurozium schreberi	14	3
Lichen	*Cladina*	14	7
	Cladonia	29	2

M179. North American Boreal Subalpine & Subarctic Woodland

G633. Western Subarctic Woodland

Type Concept: This group occurs primarily in the northern and western portion of the boreal region of Alaska, but is also found at higher elevations throughout the continental boreal zone. It typically occurs on gentle sideslopes, rolling hills, and inactive alluvial surfaces on soils underlain by continuous permafrost. Canopies are sparse to open and dominated by *Picea glauca* or *Picea mariana*. The shrub layer is composed of low and dwarf shrubs including *Ledum palustre* ssp. *decumbens*, *Betula nana*, *Betula glandulosa*, *Vaccinium uliginosum*, and *Vaccinium vitis-idaea*. Tussock forming sedges including *Carex bigelowii* and *Eriophorum vaginatum* may be abundant on some sites. Common mosses include *Hylocomium splendens* and *Sphagnum* species, with lichens, primarily those in the *Cladina* genus becoming an important component of the understory in mature stands.

Classification Comments: The CBMV Level II class "Northern Alaska-Yukon Spruce Woodlands and Scrub" is described as subarctic, but more information is needed to determine whether or not this class is equivalent to G633.

Similar NVC Types: G646. Subalpine Woodlands is similar, but occurs in both the boreal and sub-boreal. Comparatively, G633. Western Subarctic Woodland is distinguished by presence of continuous permafrost, and does not occur in the sub-boreal.

Diagnostic Characteristics: This group is defined as a woodland featuring short-statured trees and a sparse to open canopy dominated by *Picea glauca* or *Picea mariana*. The understory is typically dominated by *Betula nana*, low and dwarf ericaceous shrubs, or tussock-forming sedges.

G646. Boreal Subalpine Woodland

Type Concept: This group occurs on high-elevation or high-latitude sites in the boreal and sub-boreal regions of Alaska. Soils are thin and develop on residual soils or sideslope colluvium. Permafrost is generally absent in the sub-continental boreal but is discontinuous to continuous farther north. The forest canopy is woodland to open and dominated by *Picea glauca* or codominated by *Picea mariana*. The shrub layer is dominated by low and dwarf shrubs including *Betula nana*, *Betula glandulosa*, *Ledum palustre* ssp. *decumbens*, *Empetrum nigrum*, *Vaccinium uliginosum*, *Vaccinium vitis-idaea* and *Arctostaphylos rubra.* Ericaceous dwarf shrubs are diagnostic. Locally abundant shrubs may include *Alnus viridis* ssp. fruticosa (in the continental boreal), *Alnus viridis* ssp. *sinuata* (sub-continental boreal), *Salix pulchra* or *Salix glauca*. Herbaceous species are sparse, but lichens, primarily *Cladina* spp., are an important component of the understory.

Classification Comments: Two subalpine forest classes are described in the CBVM: "Yukon Subalpine Spruce Woodlands and Scrub" and "Southern Alaska Subalpine Spruce Woodlands and Scrub." The CBVM class "Northern Alaska-Yukon Spruce Woodlands and Scrub" is described as subarctic, but it has similarity with the boreal subalpine. It appears that both the CBVM classes may be included within G646, however more information is needed to confirm the relationships.

Similar NVC Types: This group may have a composition similar to G633. Subarctic Woodlands however, G633 always has permafrost and often supports tussock-forming graminoids, either *Eriophorum vaginatum* or *Carex bigelowii*.

Diagnostic Characteristics: This group is defined as a woodland group featuring a short-statured canopy dominated by *Picea glauca* or codominated by *Picea mariana.* Dwarf ericaceous shrubs including *Empetrum nigrum*, *Vaccinium uliginosum*, and *Vaccinium vitis-idaea* are common and diagnostic (Table 13). Other important species are *Betula nana*, *Betula glandulosa*, *Ledum palustre* ssp. *decumbens*, and *Ledum groenlandicum.* Lichens are often an important component of the understory.

Table 13. Percent frequency and average cover of species within the Western Subarctic Woodland (G633) and Boreal Subalpine Woodland (G646) Groups derived from 15 and 19 plots, respectively; significant (p<0.05) indicator species are in bold and highlighted.

		Subarctic Woodland (G633)		Subalpine Woodland (G646)	
Life form	Species	Percent Frequency	Average Cover	Percent Frequency	Average Cover
Tree	*Picea mariana*	100	29	32	8
	Picea glauca	-	-	68	14
	Betula papyrifera var. *kenaica*	-	-	32	3
Shrub	*Ledum palustre* ssp. *decumbens*	73	16	71	15
	Vaccinium uliginosum	73	7	84	11
	Betula glandulosa	60	6	32	7
	Betula nana	33	3	61	13
	Chamaedaphne calyculata	20	0.1	3	0.1
	Ledum groenlandicum	20	8	18	3
	Alnus viridis ssp. *fruticosa*	13	0.1	24	2
	Salix pulchra	13	3	24	1
	Dasiphora fruticosa	13	0.1	8	0.1
	Spiraea stevenii	7	0.1	16	0.1
	Salix glauca	-	-	37	2
Dwarf Shrub	*Vaccinium vitis-idaea*	80	5	84	7
	Empetrum nigrum	33	3	**66**	**13**
	Arctostaphylos rubra	7	1	21	0.1
Graminoid	***Eriophorum vaginatum***	**53**	**24**	3	0.1
	Carex bigelowii	**47**	**14**	11	1
	Calamagrostis canadensis	13	0.1	8	0.1
Forb	*Rubus chamaemorus*	87	5	8	0.1
	Petasites frigidus var. *sagittatus*	27	1	3	0.1
Moss	*Hylocomium splendens*	67	10	29	8
	Sphagnum (combined)	67	14	18	2
	Pleurozium schreberi	13	1	16	1
Lichen	***Cladina*** (combined)	33	3	**53**	**9**

1.B.5.Na. North American Boreal Flooded & Swamp Forest

M300. North American Boreal Rich Flooded & Swamp Forest

G548. Western Boreal Floodplain Forest

Type Concept: This group includes glacially-fed and non-glacially-fed, low and high-volume rivers and streams throughout the boreal and sub-boreal regions of Alaska. It occurs on active and inactive portions of the floodplain. The substrate is typically well-drained sand or cobble, although silts are found on higher terraces, distal floodplains, and in lower-energy systems. Frequent river channel migration, flooding, scour and other fluvial processes constitute the major disturbances in this type. Vegetation is variable, and may be dominated by short- or tall-statured *Populus balsamifera* ssp. *balsamifera, Populus balsamifera* ssp. *trichocarpa, Picea glauca, Salix* species, or *Alnus viridis* with mesic herbaceous species. Stands of full-statured *Populus balsamifera* often have an understory of tall willow, *Calamagrostis canadensis*, ferns and scattered forbs (see Table 14 for a list of the common species).

Classification Comments: Species composition is somewhat different between the sub-boreal and boreal, particularly at the subspecies level; however, here the variants are treated collectively as G548. This concept includes both the sub-boreal 'Southern Alaska Floodplain Spruce-Cottonwood Forests and Scrub' and the boreal 'Yukon Floodplain Spruce-Poplar Forests and Scrub' presented in the CBMV (Jorgenson and Meidinger 2015).

Similar NVC Types: This group is separated from the G254. North Pacific Lowland Riparian Forest & Woodland, G507. North Pacific Montane Riparian Woodland by transition in dominance from *Populus balsamifera* ssp. *balsamifera* in the boreal to *Populus balsamifera* ssp. *trichocarpa* in more temperate regions. G548 is distinguished from G368. Arctic Tall Willow (*Salix alaxensis* floodplains) by the presence of trees.

Diagnostic Characteristics: This group is characterized by deciduous or coniferous forest with *Populus balsamifera ssp. balsamifera* (continental boreal), *Populus balsamifera ssp. trichocarpa* (sub-boreal), and *Picea glauca*. The shrub canopy is typically dominated by *Alnus* spp. or *Salix* spp. especially *Alnus viridis, Alnus incana ssp. tenuifolia*, and *Salix alaxensis. Calamagrostis canadensis* and *Equisetum arvense* are often abundant in the understory.

Table 14. Percent frequency and average cover of species within the Western Boreal Floodplain Forest (G548) derived from 31 plots. Species with frequency less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Boreal Floodplain Forest	
Life Form	**Species**	**Percent Frequency**	**Average Cover**
Tree	***Populus balsamifera*** (combined)	**74**	**26**
	Picea glauca	71	16
	Betula papyrifera var. *kenaica*	19	3
Tall shrub	***Salix*** (low-tall) combined	**100**	**11**
	Salix alaxensis	32	4
	Salix barclayi	19	2
	Salix pulchra	13	1
	Alnus combined	**52**	**19**
	Alnus viridis ssp. *fruticosa*	32	12
	Alnus viridis ssp. *sinuata*	10	3
	Alnus incana ssp. *tenuifolia*	23	6
Low & Sub-shrub	*Rosa acicularis*	35	4
	Viburnum edule	32	2
	Dasiphora fruticosa	26	2
	Vaccinium uliginosum	19	3
	Arctostaphylos rubra	19	1
Grass	***Calamagrostis canadensis***	**52**	**21**
Fern & Ally	***Equisetum arvense***	**48**	**10**
	Gymnocarpium dryopteris	26	1
Forb	*Chamerion angustifolium*	39	2
	Aconitum delphiniifolium	32	0.1
	Galium boreale	26	0.1
	Rubus arcticus	26	2
	Cornus canadensis	19	2
	Trientalis europaea	19	0.1
	Hedysarum alpinum	16	1
	Mertensia paniculata	16	0.1
	Orthilia secunda	16	0.1
	Pyrola asarifolia	16	0.1
	Streptopus amplexifolius	16	0.1
	Viola sp.	16	0.1
	Geranium erianthum	13	0.1
	Sanguisorba canadensis	13	0.1
Moss	*Hylocomium splendens*	32	12

2.B.3.Na. North American Boreal Grassland & Shrubland

M055. North American Boreal Shrubland & Grassland

G356. Western Boreal Scrub Birch Shrubland

Type Concept: This shrubland group occurs on mesic, mid to upper slope sites throughout the boreal and sub-boreal regions of Alaska and is often matrix forming above coniferous treeline. *Betula glandulosa* dominates in the boreal with dominance transitioning to *Betula nana* in the sub-boreal region of southwest Alaska. *Vaccinium uliginosum* and *Ledum palustre* ssp. *decumbens* both have high constancy and canopy cover and may occasionally be canopy dominants. Other common shrubs include *Salix pulchra* and *Salix glauca.* Dwarf shrubs including *Vaccinium vitis-idaea* and *Empetrum nigrum* may be common below the low shrub layer. Herbaceous species are sparse and may include *Calamagrostis canadensis, Carex bigelowii*, *Rubus chamaemorus,* and *Chamerion angustifolium* ssp. *angustifolium*. Feathermosses such as *Hylocomium splendens* and *Pleurozium schreberi*, lichens in the *Cladina* genus, and *Sphagnum* species are common in the ground layer (Table 15). Wetland sites with organic soils are not included in this group.

Classification Comments: *Betula glandulosa* is dominant in the continental boreal, while *Betula nana* becomes more common in the sub-boreal region of southwest Alaska, which is beyond the central range of *Betula glandulosa*. G356 may be considered a narrower, non-forested type within the 'Northern Alaska-Yukon Spruce Woodlands and Scrub', 'Yukon Subalpine Spruce Woodlands and Scrub', and 'Southern Alaska Alder-Willow-Dwarf Birch Scrub' CBVM concepts described by Jorgenson and Meidinger (2015).

Similar NVC Types: This group is similar to G828. North American Arctic & Subarctic Dwarf Birch Shrubland, but is differentiated by an Arctic distribution and the lack of *Betula glandulosa*.

Diagnostic Characteristics: This group is defined as a boreal to sub-boreal shrubland dominated by *Betula glandulosa* in the boreal with dominance transitioning to *Betula nana* in the sub-boreal region of southwest Alaska. Diagnostic species include *Betula glandulosa, Vaccinium uliginosum, Ledum palustre* ssp. *decumbens,* and *Vaccinium vitis-idaea*.

Table 15. Percent frequency and average cover of species within the Western Boreal Scrub Birch Shrubland Group (G356) derived from 36 plots. Species with frequency equal to or less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Boreal Scrub Birch Shrubland (G356)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Tree	*Picea glauca*	50	1
	Picea mariana	14	0.1
Shrub	***Ledum palustre* ssp. *decumbens***	**78**	**17**
	Vaccinium uliginosum	**69**	**14**
	Betula glandulosa	**53**	**19**
	Salix pulchra	44	2
	Betula nana	39	11
	Salix glauca	33	2
	Spiraea stevenii	25	1
	Alnus viridis ssp. *fruticosa*	19	0.1
	Rosa acicularis	17	1
	Ledum groenlandicum	11	3
Dwarf Shrub	***Vaccinium vitis-idaea***	**78**	**4**
	Empetrum nigrum	36	3
	Vaccinium oxycoccos	14	0.1
	Arctostaphylos rubra	11	1
Fern & Ally	*Equisetum sylvaticum*	19	2
Graminoid	*Calamagrostis canadensis*	47	4
	Carex bigelowii	22	3
	Eriophorum vaginatum	17	1
Forb	*Rubus chamaemorus*	31	1
	Chamerion angustifolium ssp. *angustifolium*	25	1
	Pedicularis labradorica	19	0.1
	Saussurea angustifolia	19	0.1
	Cornus canadensis	17	0.1
	Petasites frigidus	11	0.1
	Polygonum bistorta	11	0.1
Moss	*Sphagnum*	33	9
	Pleurozium schreberi	19	1
	Polytrichum	17	2
	Hylocomium splendens	14	5
Lichen	*Cladonia*	28	2
	Cetraria	22	1
	Cladina rangiferina	17	1
	Stereocaulon	17	0.1
	Thamnolia	17	0.1
	Cladina	14	0.1

G357. Western Boreal Mesic Alder - Willow Shrubland

Type Concept: This common shrubland group occurs throughout the boreal region of Alaska and extends north into the low Arctic. Stands are dominated by the deciduous shrub species *Alnus viridis* ssp. *fruticosa* or *Salix pulchra* or a combination of the two. Willows such as *Salix glauca, Salix richardsonii, Salix barclayi,* or *Salix commutata* may be codominant but have low constancy within the group. Other shrub associates include *Vaccinium uliginosum, Empetrum nigrum, Betula nana* or *Betula glandulosa, Vaccinium vitis-idaea,* and *Ledum palustre* ssp. *decumbens.* Understory herbaceous species include *Calamagrostis canadensis, Equisetum arvense, Rubus arcticus, Chamerion angustifolium* ssp. *angustifolium,* and *Sanguisorba canadensis* (Table 166). This group occurs at low to mid elevations in broad valleys, on mountain sideslopes, and in avalanche zones. Soils develop on hillslope colluvium, glacial deposits, or residual substrates.

Classification Comments: Thickets of *Alnus viridis* ssp. *fruticosa* in the low arctic foothills of the Brooks Range are considered part of this group. G357 approximates the 'Southern Alaska Alder-Willow-Dwarf Birch Scrub' CBVM concept described by Jorgenson and Meidinger (2015) but differs in its dominance of *Alnus viridis* ssp. *fruticosa* rather than *Alnus viridis* ssp. *sinuata,* which gains dominance in more temperate regions.

Similar NVC Types: This type is similar to G354. Vancouverian Alder – Salmonberry – Willow Shrubland but is differentiated by its boreal distribution and absence of Rubus spectabilis as a dominant shrub. It is also similar to G368. North American Arctic & Subarctic Tall Willow Shrubland but is differentiated by the non-dominance of Salix alaxensis and location outside of active floodplains.

Diagnostic Characteristics: This group is defined by mesic willow- or alder-dominated shrublands. Differential species are *Alnus viridis* ssp. *fruticosa* and *Salix pulchra*.

Table 16. Percent frequency and average cover of species within the Western Boreal Mesic Alder - Willow Shrubland (G357), derived from 44 plots. Species with percent frequency less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Boreal Mesic Alder-Willow Shrubland (G357)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Shrub	***Salix pulchra***	**68**	**28**
	Alnus viridis* ssp. *fruticosa	**52**	**26**
	Vaccinium uliginosum	**45**	**10**
	Salix glauca	27	4
	Ledum palustre ssp. *decumbens*	23	1
	Betula nana	23	2
	Spiraea stevenii	23	1
	Salix alaxensis	18	2
	Betula glandulosa	16	5
	Salix barclayi	16	3
	Salix richardsonii	11	3
Dwarf Shrub	*Empetrum nigrum*	32	2
	Vaccinium vitis-idaea	25	1
Fern & Ally	*Equisetum arvense*	32	4
Graminoid	*Calamagrostis canadensis*	64	17
	Arctagrostis latifolia	14	1
	Carex bigelowii	11	1
	Festuca altaica	11	1
Forb	*Polemonium acutiflorum*	23	0
	Rubus arcticus	23	2
	Chamerion angustifolium ssp. *angustifolium*	18	0
	Comarum palustre	18	2
	Sanguisorba canadensis	18	0
	Rubus chamaemorus	16	1
	Viola epipsila	14	1
	Petasites frigidus	11	0
Moss	*Hylocomium splendens*	32	6
	Sphagnum	18	3

G374. North American Arctic & Boreal Shrub & Herb Dune

Type Concept: This group represents sparse to open cover of shrub and herbaceous vegetation developing on active, inland dunes in Arctic and Boreal Alaska and Canada. Characteristic species are the willow shrubs, *Salix glauca* and *Salix alaxensis*, the graminoids, *Festuca rubra*, *Koeleria asiatica*, *Juncus arcticus*, *Leymus mollis*, *Bromus inermis* ssp. *pumpellianus*, and the forbs *Artemisia campestris* ssp. *borealis* and *Packera hyperborealis* (Table 17). Dunes may be derived from Pleistocene-era sandsheets or more recent fluvial deposits. Patch size may be small to large. The main disturbance process, which creates and maintains dune systems, is the erosion, transport and deposition of sand by wind.

Classification Comments: While this group occupies small patches and is uncommon on the landscape, it is differentiated by numerous species, which speaks to its unique floristics and

validity as a discrete group. There are no equivalent types within the CBVM or CAVM classifications (Jorgenson and Meidinger 2015, Raynolds et al. 2006).

Similar NVC Types: The Arctic and Boreal Coastal Beach and Dune Group (G612) resembles the general environment and dynamics of this group but is well separated by its characteristic species and lower species diversity. The North American Arctic & Subarctic Tall Willow Tundra (G368) is also similar, but is separated by its greater constancy of *Salix alaxensis* and floodplain location.

Diagnostic Characteristics: This group is defined by shrub and herbaceous vegetation, often dominated by *Salix glauca* and *Leymus mollis*, developing on active, inland dunes in Arctic and Boreal Alaska and Canada.

Table 17. Percent frequency and average cover of species within the Boreal Shrub and Herb Dune Group (G374) derived from 6 plots. Species with percent frequency less than 20 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Boreal Shrub and Herb Dune (G374)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Shrub	***Salix glauca***	**83**	**46**
	Salix alaxensis	**33**	**2**
Dwarf Shrub	***Arctostaphylos rubra***	**33**	**8**
	Dryas integrifolia	**33**	**1**
Fern & Ally	***Equisetum arvense***	**67**	**8**
Graminoid	***Festuca rubra***	**67**	**6**
	Leymus mollis	67	4
	Bromus inermis* ssp. *pumpellianus	**50**	**2**
	Koeleria asiatica	**50**	**0**
	Poa glauca	**50**	**1**
	Poa pratensis ssp. *alpigena*	33	0
	Poa sublanata	**33**	**1**
Forb	***Astragalus alpinus***	**83**	**1**
	Artemisia tilesii	**67**	**0**
	Stellaria longipes	**50**	**0**
	Cnidium cnidiifolium	**33**	**0**
	Draba	**33**	**0**
	Packera hyperborealis	**33**	**0**
	Polemonium boreale	**33**	**0**
	Tanacetum bipinnatum* ssp. *bipinnatum	**33**	**0**

2.B.4.Nd. Arctic & Boreal Coastal Scrub & Herb Vegetation

M402. North American Arctic & Boreal Coastal Beach, Dune & Rocky Shore

G612. Arctic & Boreal Coastal Beach & Dune

Type Concept: This group is defined by grasslands developing on coastal beaches and dunes. *Leymus mollis* is the most constant and abundant species, with the salt-tolerant forbs, *Honckenya peploides* and *Lathyrus japonicus* var. *maritimus* indicating the group. Bryophytes, lichens and woody species are generally absent (Table 18). This group develops on coastal beaches above the elevation of maximum high tide as well as on dunes along mainland shores and barrier islands. Sites are not regularly inundated by tidal waters but are subject to salt spray and occasional inundation by storm surges. Soils are dry to mesic and typically sandy with small pebbles. Permafrost is present at depth along the Arctic Ocean coast but becomes discontinuous along the Bering Sea Coast.

Classification Comments: The inclusion of salt-killed tundra within this group is not recommended as, assuming storm surge disturbance is limited to the inundation and deposition of saline water and sediment, near-coast tundra is not likely to transition to a beach or dune type. It is more appropriate to describe salt-killed tundra within the various groups susceptible to storm surges such as tussock, dwarf and low shrub, and wet graminoid tundra. There are no equivalent types within the CBVM and CAVM classifications (Jorgenson and Meidinger 2015, Raynolds et al. 2006).

Similar NVC Types: The North American Arctic and Boreal Shrub and Herb Dune Group (G374) resembles the general environment and dynamics of this group but is well separated by its characteristic species and higher species diversity.

Diagnostic Characteristics: This group is defined by grasslands developing on coastal beaches and dunes. *Leymus mollis* is the most constant and abundant species, but the salt-tolerant forbs *Honckenya peploides* and *Lathyrus japonicus* var. *maritimus* indicate the group.

Table 18. Percent frequency and average cover of species within the Arctic and Boreal Coastal Beach and Dune Group (G612) derived from 7 plots. All species are included; significant (p<0.05) indicator species are in bold and highlighted.

		Coastal Beach and Dune (G612)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Graminoid	*Leymus mollis*	71	50
	Festuca baffinensis	14	0.1
	Poa arctica	14	0.1
Forb	***Honckenya peploides***	**86**	**6**
	Lathyrus japonicus* var. *maritimus	**29**	**30**
	Senecio pseudoarnica	29	0.1
	Androsace chamaejasme	14	0.1
	Gentianella propinqua	14	0.1
	Mertensia maritima	14	0.1
	Taraxacum officinale ssp. *ceratophorum*	14	0.1

2.C.4.Np. Circumpolar Arctic & Northern Boreal Freshwater Marsh, Wet Meadow & Shrubland

M870. North American Arctic & Northern Boreal Freshwater Marsh, Wet Meadow & Shrubland

G830. North American Arctic & Subarctic Wet Shrubland

Type Concept: This proposed concept describes gently sloping water tracks that form linear drainage networks in the foothills of northern Alaska. Water track wetlands conduct surface water from seasonal thaw and summer rainfall events. In these wetland features, runoff is confined to near surface due to shallow permafrost. Low shrub wetlands characterize vegetation in well-developed water tracks. The dominant vegetation community is *Salix pulchra / Eriophorum angustifolium* (Walker et al. 1994). Other important wetland sedges include *Carex aquatilis* and *Eriophorum russeolum.* Important mosses include *Calliergon stramineum, Sphagnum girgensohnii,* and *Sphagnum warnstorfii* (Table 19).

Classification Comments: This concepts needs further review. Plots with provisional membership to this group are displayed in Table 19, however they have not been formally analyzed. The 'W3.4 Wet sedge communities in complex with shrub thickets' type of the CAVM (Raynolds et al. 2006) approximates G830 but is not considered equivalent; there is no equivalent type within the CBVM classification (Jorgenson and Meidinger 2015).

Similar NVC Types: G(827). North American Arctic & Subarctic Low Willow Tundra includes *Salix pulchra* in the overstory but it occurs on mesic-moist sites. The group G617. North American Arctic & Subarctic Wet Meadow has a similar composition of wetland sedges and cottongrass, but it is an herbaceous group. G368. North American Arctic & Subarctic Tall Willow Tundra occurs in riparian areas, but substrates are well-drained, permafrost is absent near the surface, and *Salix alaxensis* is the dominant willow.

Diagnostic Characteristics: This wet shrubland group occurs in the foothills of northern Alaska along gently sloping water track drainage networks. Important species include *Salix pulchra*, *Carex aquatilis*, and *Eriophorum angustifolium*.

Table 19. Percent frequency and average cover of species within the North American Arctic & Subarctic Wet Shrubland Group (G830) derived from 17 plots. Species with frequencies less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Arctic & Subarctic Wet Shrubland Group (G830)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Shrub	***Salix pulchra***	**76**	**32**
	Betula nana	**71**	**7**
	Ledum palustre ssp. *decumbens*	24	0.5
	Vaccinium uliginosum	24	1
	Salix richardsonii	12	3
Dwarf Shrub	*Salix reticulata*	29	1
	Vaccinium vitis-idaea	29	1
	Salix arctica	18	3
	Salix fuscescens	18	1
	Dryas integrifolia	18	1
Fern & Ally	*Equisetum arvense*	18	0
Graminoid	***Carex aquatilis***	**76**	**33**
	Eriophorum angustifolium	**59**	**16**
	Eriophorum russeolum	18	3
	Eriophorum vaginatum	41	4
	Carex bigelowii	41	2
	Calamagrostis stricta	24	1
	Poa arctica	18	1
	Arctagrostis latifolia	18	0.1
Forb	*Petasites frigidus*	35	0.5
	Saxifraga nelsoniana	29	0.1
	Pyrola grandiflora	29	0.1
	Comarum palustre	24	0.1
	Pedicularis langsdorffii	24	0.1
	Rubus chamaemorus	18	1
	Stellaria longipes	18	0.2
	Polygonum viviparum	18	0.1
	Polemonium acutiflorum	12	0.1
	Polygonum bistorta var. *plumosum*	12	0.1
	Saxifraga hieraciifolia	12	0.1
	Saxifraga hirculus	12	0.1
	Pedicularis sudetica	12	0.1
Moss	***Sphagnum* spp.**	**88**	**16**
	***Aulacomnium* spp.**	**47**	**7**
	Polytrichum spp.	29	1
	Hylocomium splendens	18	3
	Dicranum groenlandicum	12	1
Lichen	*Peltigera* spp.	35	0.1
	Flavocetraria cucullata	12	0.1

G370. North American Arctic & Subarctic Freshwater Marsh

Plots with provisional membership to this group were not analyzed.

G617. North American Arctic & Subarctic Wet Meadow

Plots with provisional membership to this group were not analyzed.

2.C.5.Nk. Arctic Coastal Salt Marsh

M403. North American Arctic Tidal Salt Marsh

G535. North American Arctic Coastal Salt Marsh

Type Concept: This group is defined as sparse to closed assemblages of forbs and graminoids that are highly adapted to saturation and saline conditions that occupy the intertidal zone of the Bering Sea and Arctic Ocean coastlines. Characteristic species include the halophytic graminoids, *Puccinellia phryganodes, Carex subspathacea* and *Dupontia fisheri* and the succulent forbs, *Stellaria humifusa* and *Cochlearia groenlandica* (Table 20). Arctic Salt Marshes develop in protected coastal areas where relatively flat land receives periodic input of tidal waters. Depending on local topography and exposure, marshes may be small patch to matrix forming. Dynamics are chiefly driven by the inundation of tidal waters, which erode and redeposit salt marsh sediment. The severity and magnitude of these effects are compounded by storm events, ice rafting and thermal degradation of ice-rich coastal permafrost (where present).

Classification Comments: Several bases for distinction among Arctic salt marshes have been previously proposed. For example, differentiation by region (e.g. a Low Arctic Region versus a High Arctic Region), floristic province (e.g. Western North American versus Eastern North American), or intertidal zone (e.g. Low Salt Marsh (i.e., outer tidal) versus High Salt Marsh (inner tidal)). The description provided here pertains to Arctic Salt Marshes occupying the intertidal zone (land that experiences daily inundation by tidal waters – outer and inner tidal) of the Bering Sea and Arctic Ocean coastlines (low and high arctic in Western North America). There are no equivalent types within the CAVM or CBVM classifications (Jorgenson and Meidinger 2015, Raynolds et al. 2006).

Similar NVC Types: This group shares environmental characteristics and processes common to Temperate Pacific Tidal Salt Marsh (G499) but differs in species composition.

Diagnostic Characteristics: This group is defined as sparse to closed assemblages of forbs and graminoids that are highly adapted to saturation and saline conditions that occupy the intertidal zone of the Bering Sea and Arctic Ocean coastlines. Woody and non-vascular species are generally absent.

Table 20. Percent frequency and average cover of species within the Arctic Coastal Salt Marsh Group (G535) derived from 19 plots. Species with frequency equal to or less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Arctic Coastal Salt Marsh (G535)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Dwarf Shrub	*Salix ovalifolia*	37	17
Graminoid	***Dupontia fisheri***	**58**	**30**
	Carex subspathacea*	**37**	**39**
	Puccinellia phryganodes	32	53
	Eriophorum angustifolium	26	9
	Carex ursina	21	16
	Calamagrostis deschampsioides	16	2
	Poa arctica	16	4
	Carex aquatilis	11	60
	Carex glareosa	11	50
	Eriophorum scheuchzeri	11	18
	Puccinellia	11	51
Forb	***Stellaria humifusa***	**47**	**7**
	Cochlearia groenlandica	32	1
	Stellaria crassifolia	16	1
	Cerastium beeringianum	11	2
	Chrysanthemum arcticum	11	3
	Petasites frigidus	11	1
	Primula borealis	11	1
	Saxifraga cernua	11	3
Bryophyte	*Campylium stellatum*	16	6
	Polytrichastrum alpinum	11	5
	Aulacomnium palustre	5	2
Lichen	*Bryocaulon divergens*	11	18
	Thamnolia vermicularis	11	0.1

* Marginally significant (p = 0.054)

4.B.1.Nb. Western North American Alpine Tundra

M404. Western Boreal Alpine Vegetation

G613. Western Boreal Alpine Dwarf Shrub Tundra

Type Concept: This group is defined as tundra vegetation dominated by the dwarf shrub, *Empetrum nigrum* often in combination with other shrubs such as the low shrubs *Vaccinium uliginosum* and *Ledum palustre* ssp. *decumbens* and the dwarf shrubs *Loiseleuria procumbens* and *Salix arctica* (Table 21). Erect shrubs and trees provide less than 10% cover. The group occurs on mountain and hill slopes, low summits and ridges and valley bottoms across a range of soil types and hydrologies and is found in the Aleutian Islands and Boreal regions of Alaska, Canada, and possibly Greenland. Patch size is small to matrix forming.

Classification Comments: Despite significant overlap between arctic and boreal dwarf shrub types within the North American Arctic & Subarctic Tundra Macrogroup (M173), a distinctly boreal dwarf shrub type, characterized by *Empetrum nigrum* is evident in multivariate analysis. While *Empetrum nigrum* occurs throughout Alaska, it rarely dominates communities in the arctic and temperate zones. Thus, while expansion of the conceptual ranges of Dryas (G366),

Ericaceous (G367) and Willow (G614) Dwarf Shrub Groups as well as the Tussock Tundra Group (G371) is recommended to include alpine dwarf shrub types within the boreal ecoregion, also recommended is the preservation of the Western Boreal Alpine Dwarf Shrub Group (613) within the Western Boreal Alpine Vegetation Macrogroup (M404). This revision will restrict the Western Boreal Alpine Dwarf Shrub Group (613) to vegetation dominated by *Empetrum nigrum* and eliminate the Dryas, Dwarf Shrub, Dwarf Shrub-Lichen and Ericaceous variants formerly included within the group. The 'Aleutian Heaths and Meadows' concept described by Jorgenson and Meidinger (2105) may be considered a subset of G613. Floristically, G613 may be considered a subset of the 'Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows' and 'Southern Alaska-Yukon Alpine Dwarf Scrub and Meadows' CBVM concepts; however G613 has a broader distribution, thus the relationship is complex. With respect to the CAVM, G613 may be considered a narrower type within the 'B3. Prostrate dwarf-shrub, gramionid/lichen communities on acidic substrates' type (Raynolds et al. 2006). To generalize, the NVC, CBVM, and CAVM types resemble each other with respect to the dominance of *Empetrum nigrum* but differ in their associated species and geographic ranges.

Similar NVC Types: This group is similar to several arctic and subarctic tundra groups whose ranges extend into the Boreal, namely: North American Arctic & Subarctic Ericaceous Dwarf Shrub Tundra (G367), Dryas Dwarf Shrub Tundra (G366), and Willow Dwarf Shrub Tundra (G613). The Western Boreal Alpine Dwarf Shrub Tundra differs in its dominance of *Empetrum nigrum*.

Diagnostic Characteristics: This group is defined as tundra vegetation dominated by the dwarf shrub, *Empetrum nigrum* where erect shrubs and trees provide less than 10% cover. It is found in the Aleutian Islands and the boreal regions of Alaska, Canada, and possibly Greenland.

Table 21. Percent frequency and average cover of species within the Boreal Alpine Dwarf Shrub Tundra Group (G613) derived from 28 plots. Species with frequency equal to or less than 10 are not included; significant ($p<0.05$) indicator species are in bold and highlighted.

		Boreal Alpine Dwarf Shrub Tundra (G613)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Tree	*Picea glauca*	21	0.1
Shrub	***Vaccinium uliginosum***	**64**	**21**
	Ledum palustre ssp. *decumbens*	46	6
	Betula nana	32	6
	Salix pulchra	21	2
	Salix	18	5
	Betula glandulosa	11	4
	Salix barclayi	11	24
Dwarf Shrub	***Empetrum nigrum***	**96**	**29**
	Loiseleuria procumbens	**46**	**6**
	Salix arctica	46	6
	Vaccinium vitis-idaea	32	3
	Diapensia lapponica	29	5
	Rhododendron camtschaticum	**25**	**5**
	Arctostaphylos rubra	21	14
	Salix phlebophylla	18	4
	Cassiope tetragona	18	12
	Dryas octopetala	14	6
	Linnaea borealis	11	1
	Arctostaphylos alpina	11	4
Fern & Ally	*Lycopodium annotinum*	11	1
Graminoid	*Anthoxanthum monticola* ssp. *alpinum*	32	1
	Carex	29	2
	Carex spectabilis	21	1
	Trisetum spicatum	18	0.1
	Arctagrostis latifolia	14	10
	Festuca altaica	11	4
Forb	***Campanula lasiocarpa***	**29**	**0.1**
	Rhodiola integrifolia* ssp. *integrifolia	**21**	**0.1**
	Artemisia arctica	21	1
	Anemone narcissiflora	21	1
	Pedicularis	14	0.1
	Cornus canadensis	14	11
	Sanguisorba canadensis	11	0.1
	Arnica lessingii	11	0.1
	Minuartia arctica	11	0.1
	Chamerion angustifolium ssp. *angustifolium*	11	1
Bryophyte	*Polytrichum*	18	1
	Pleurozium schreberi	11	7
	Bryum	11	12
Lichen	*Cladina*	36	5
	Cetraria	29	5
	Thamnolia	21	2
	Stereocaulon	14	1
	Dactylina	14	1
	Cladonia	14	1

4.B.2.Xa. Arctic Tundra & Barrens

M173. North American Arctic & Subarctic Tundra Macrogroup

G365. North American Arctic & Subarctic Lichen - Sparse Dwarf Shrub Tundra

The Lichen – Sparse Dwarf Shrub Tundra Group is expected to be a highly variable type that is not well represented (n = 5 plots) within the dataset. Further analysis incorporating a greater number of plots is recommended to refine the formal description of this group.

G366. North American Arctic & Subarctic Dryas Dwarf Shrub Tundra

Type Concept: This tundra group is defined by vegetation dominated by the dwarf, broad-leaved evergreen shrub species, *Dryas octopetala* and/or *Dryas integrifolia*. In addition to its dominant species, Dryas Dwarf Shrub Tundra supports high constancy of the dwarf willows, *Salix reticulata, Salix arctica, Salix phlebophylla*, the ericaceous shrubs, *Cassiope tetragona* and *Vaccinium uliginosum*, the grass *Anthoxanthum monticola* ssp. *alpinum*, the sedge, *Carex scirpoidea*, and the lichens, *Thamnolia vermicularis* and *Flavocetraria nivalis* (Table 22). Dryas vegetation is common on exposed, windswept areas with little winter snow cover throughout arctic and subarctic Alaska, Canada, and possibly parts of Greenland. Types dominated by *Dryas octopetala* appear to be more common at high-elevation on alpine slopes and ridges, whereas types dominated by *Dryas integrifolia* are more common at high latitude in the arctic as well as on inactive floodplains and in drained lake basins. Substrates are typically mineral and are non-acidic to circumneutral. Patch size is small to matrix-forming.

Classification Comments: The dominance by *Dryas octopetala* versus *Dryas integrifolia* or the acidic versus non-acidic *Dryas* types may provide alliance-level distinctions. G366 is considered a subset of the 'Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows' concept described by Jorgenson and Meidinger (2015), which includes a variety of dwarf shrub types not necessarily dominated by *Dryas* species. Similarly, G366 may also be considered a subset of the 'B4. Prostrate dwarf-shrub, gramionid/lichen communities on non-acidic substrates' CAVM type of Raynolds et al. (2006).

Similar NVC Types: The range of this type overlaps and shares a number of species with Western Boreal Alpine Dwarf-Shrubland (G613) but is not dominated by *Empetrum nigrum*. It is also floristically similar to North American Arctic Gravel Floodplain Vegetation (G616) where this type is dominated by *Dryas drummondii*.

Diagnostic Characteristics: This group is defined by tundra vegetation dominated by the dwarf, broad-leaved, evergreen shrub species, *Dryas octopetala* and/or *Dryas integrifolia* in the arctic and subarctic regions of Alaska and Canada.

Table 22. Percent frequency and average cover of species within the *Dryas* Dwarf Shrub Tundra Group (G366) derived from 68 plots. Species with frequency equal to or less than 10 are not included; significant ($p<0.05$) indicator species are in bold and highlighted.

		Dryas Dwarf Shrub Tundra (G366)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Tree	*Picea glauca*	7	1
Shrub	*Vaccinium uliginosum*	44	8
	Betula nana	24	13
	Ledum palustre ssp. *decumbens*	16	2
	Salix pulchra	15	3
	Salix glauca	12	6
Dwarf Shrub	***Dryas octopetala***	**85**	**35**
	Salix reticulata	53	6
	Salix arctica	40	3
	Cassiope tetragona	37	15
	Salix phlebophylla	31	5
	Diapensia lapponica	21	5
	Vaccinium vitis-idaea	21	2
	Arctostaphylos rubra	19	6
	Dryas integrifolia	16	30
	Rhododendron lapponicum	13	4
	Empetrum nigrum	12	5
Graminoid	*Anthoxanthum monticola* ssp. *alpinum*	34	1
	Carex scirpoidea	29	4
	Arctagrostis latifolia	18	3
	Carex bigelowii	18	13
	Poa arctica	13	1
Forb	*Silene acaulis*	26	1
	Oxytropis nigrescens	25	1
	Pedicularis	24	0
	Minuartia macrocarpa	22	0
	Polygonum bistorta	18	0
	Polygonum viviparum	16	0
	Chamerion latifolium	15	1
	Saxifraga oppositifolia	15	1
	Anemone narcissiflora	13	0
	Anemone parviflora	12	0
	Geum glaciale	12	0
	Hedysarum alpinum	12	1
	Potentilla biflora	12	1
	Saussurea angustifolia	12	0
	Saxifraga nelsoniana	12	1
Bryophyte	*Hylocomium splendens*	16	22
	Racomitrium lanuginosum	12	4
Lichen	*Thamnolia vermicularis*	32	3
	Flavocetraria nivalis	26	3
	Flavocetraria cucullata	19	4
	Stereocaulon	18	2
	Dactylina arctica	16	1
	Cetraria	15	6
	Cladina rangiferina	13	3
	Asahinea chrysantha	12	3

G367. North American Arctic & Subarctic Ericaceous Dwarf Shrub Tundra

Type Concept: This tundra group is defined by vegetation dominated by dwarf to low ericaceous shrubs in the arctic and subarctic regions of Alaska and Canada. The group is characterized by high constancy of, and indicated by the presence of the ericaceous shrubs *Ledum palustre* ssp. *decumbens*, *Cassiope tetragona*, and *Vaccinium vitis-idaea*. The moss *Hylocomium splendens* and lichen species in the *Cladina* genus may exceed 20% cover. The low shrubs *Betula nana, Salix pulchra* and dwarf shrubs *Salix phlebophylla* and *Diapensia lapponica* may reach high abundances but do not assume dominance (Table 23). This group is common in semi-protected, mesic sites in the hills and mountains where snow cover is retained. Substrates are acidic to non-acidic; patch size is small to large.

Classification Comments: An alliance level split is suggested by coincident species abundances. Within the group, plots supporting high cover of *Ledum palustre* ssp. *decumbens* are also characterized by an abundance of lichen species in the *Cladina* genus, whereas plots supporting high cover of *Cassiope tetragona* are characterized by an abundance of bryophytes such as *Hylocomium splendens*. G367 is considered a subset of the 'Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows' concept described by Jorgenson and Meidinger (2015), which includes a variety of dwarf shrub types not necessarily dominated by ericaceous species. Similarly, G367 may be considered a subset of the 'B3. Prostrate dwarf-shrub, gramionid/lichen communities on acidic substrates' CAVM type described by Raynolds et al. (2006).

Similar NVC Types: The range of this type overlaps and shares a number of species with Western Boreal Alpine Dwarf-Shrubland (G613) but is not dominated by *Empetrum nigrum*. This type is also similar to North American Arctic & Subarctic Dwarf Willow Tundra (G614) but is not dominated by dwarf shrubs in the *Salix* genus.

Diagnostic Characteristics: This group is defined by tundra vegetation dominated by dwarf to low ericaceous shrubs in the arctic and subarctic regions of Alaska and Canada.

Table 23. Percent frequency and average cover of species within the Ericaceous Dwarf Shrub Tundra Group (G367) derived from 17 plots. Species with frequency equal to or less than 10 are not included; significant ($p<0.05$) indicator species are in bold and highlighted.

		Ericaceous Dwarf Shrub Tundra (G367)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Tree	*Picea glauca*	18	1
Shrub	***Ledum palustre* ssp. *decumbens***	**71**	**6**
	Vaccinium uliginosum	59	8
	Betula nana	35	10
	Salix pulchra	35	6
Dwarf Shrub	***Cassiope tetragona***	**71**	**27**
	Vaccinium vitis-idaea	**65**	**9**
	Salix phlebophylla	47	7
	Diapensia lapponica	35	9
	Dryas octopetala	29	4
	Empetrum nigrum	29	4

		Ericaceous Dwarf Shrub Tundra (G367)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
	Salix reticulata	29	3
	Arctostaphylos alpina	18	1
	Arctostaphylos rubra	18	18
	Dryas integrifolia	12	11
	Rhododendron lapponicum	12	2
	Salix arctica	12	1
Graminoid	*Anthoxanthum monticola* ssp. *alpinum*	47	3
	Luzula confusa	47	3
	Carex aquatilis	24	10
	Carex bigelowii	24	3
	Arctagrostis latifolia	18	7
	Carex microchaeta	18	8
	Eriophorum vaginatum	18	7
	Poa arctica	18	7
	Carex	12	0
Forb	*Petasites frigidus*	18	1
	Saxifraga nelsoniana	18	0
	Boykinia richardsonii	12	4
	Pedicularis capitata	12	0
	Polygonum bistorta var. *plumosum*	12	2
	Pyrola grandiflora	12	0
	Rubus chamaemorus	12	6
	Silene acaulis	12	0
	Stellaria longipes	12	0
Bryophyte	*Hylocomium splendens*	53	20
	Polytrichum	35	5
	Sphagnum	24	4
	Dicranum spadiceum	18	15
	Aulacomnium	12	15
	Aulacomnium turgidum	12	10
	Dicranum	12	2
Lichen	*Cladina*	35	27
	Dactylina arctica	35	2
	Flavocetraria cucullata	29	2
	Thamnolia vermicularis	29	2
	Stereocaulon	24	1
	Cladina rangiferina	18	16
	Flavocetraria nivalis	18	2
	Peltigera	18	0
	Cetraria	12	11
	Cetraria ericetorum	12	2
	Cladonia	12	1
	Cladonia gracilis	12	5
	Masonhalea richardsonii	12	1

G614. North American Arctic & Subarctic Dwarf Willow Shrub Tundra

Type Concept: This tundra group is dominated by dwarf willow shrubs and is commonly found on exposed sites in the arctic and subarctic regions of Alaska and Canada. The group is indicated by the dwarf willows, *Salix reticulata*, *Salix polaris*, *Salix rotundifolia*, and *Salix phlebophylla.* Characteristic species include the dwarf shrubs *Dryas octopetala* and *Cassiope tetragona*, the graminoids *Carex bigelowii* and *Arctagrostis latifolia*, the forb *Petasites frigidus*, and the lichens *Flavocetraria cucullata* and *Thamnolia vermicularis.* The erect shrub, *Salix pulchra* is constant at low cover (Table 24). This is a small patch type developing in shallow, well-drained, soils on non-acidic substrates underlain by permafrost.

Classification Comments: While this group occupies small patches and is uncommon on the landscape, it is significantly differentiated by numerous species, which speaks to its unique floristics and validity as a discrete group. G614 is considered a subset of the 'Central-Northern Alaska-Yukon Alpine Dwarf Scrub and Meadows' and 'Southern Alaska-Yukon Alpine Dwarf Scrub and Meadows' concepts described by Jorgenson and Meidinger (2015), which includes a variety of dwarf shrub types not necessarily dominated by willow species. Similarly, G614 may be considered a subset of the 'B4. Prostrate dwarf-shrub, gramionid/lichen communities on non-acidic substrates' CAVM type described by Raynolds et al. (2006).

Similar NVC Types: This type is similar to G367. North American Arctic & Subarctic Ericaceous Dwarf-Shrub Tundra but differs in its dominance by members of the *Salix* genus rather than ericaceous shrubs. It is also similar to G827. North American Arctic & Subarctic Scrub Willow Tundra but differs in its dominance by dwarf rather than erect willow species.

Diagnostic Characteristics: This group is defined as tundra vegetation dominated by prostrate to hemi-prostrate willow species found in the arctic and subarctic regions of Alaska, Canada, and possibly Greenland. Erect shrubs and trees provide less than 25% cover.

Table 24. Percent frequency and average cover of species within the Willow Dwarf Shrub Tundra Group (G614) derived from 15 plots. Species with frequency equal to or less than 10 are not included; significant ($p<0.05$) indicator species are in bold and highlighted.

		Willow Dwarf Shrub Tundra (G614)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Shrub	*Salix pulchra*	60	3
	Vaccinium uliginosum	27	14
	Betula nana	13	3
Dwarf Shrub	***Salix reticulata***	**67**	**22**
	Dryas octopetala	60	6
	Cassiope tetragona	47	4
	Salix rotundifolia	**40**	**15**
	Salix arctica	33	13
	Salix polaris	**20**	**18**
	Dryas integrifolia	20	3
	Salix phlebophylla	13	2
	Empetrum nigrum	13	1
	Rhododendron lapponicum	13	1
Graminoid	***Carex bigelowii***	**47**	**21**
	Arctagrostis latifolia	40	3

		Willow Dwarf Shrub Tundra (G614)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
	Eriophorum vaginatum	**33**	**3**
	Poa arctica	27	5
	Carex microchaeta	27	4
	Carex aquatilis	20	8
	Eriophorum angustifolium	**20**	**7**
	Luzula confusa	**20**	**4**
	Anthoxanthum monticola ssp. *alpinum*	20	3
	Luzula	**20**	**1**
	Poa	20	1
	Luzula arctica	**13**	**7**
	Trisetum spicatum	13	0
Fern & Ally	***Equisetum arvense***	**33**	**27**
	Equisetum variegatum	13	3
	Equisetum scirpoides	13	0
Forb	***Petasites frigidus***	**47**	**1**
	Polygonum bistorta* var. *plumosum	**33**	**3**
	Polygonum viviparum	27	1
	Boykinia richardsonii	20	4
	Polygonum bistorta	20	2
	Pedicularis	20	1
	Stellaria longipes	20	1
	Saxifraga nelsoniana	20	0
	Pedicularis langsdorffii	20	0
	Tephroseris atropurpurea* ssp. *frigida	**20**	**0**
	Anemone narcissiflora	13	0
	Artemisia arctica	13	0
	Tofieldia pusilla	13	0
Lichen	*Flavocetraria cucullata*	60	1
	Thamnolia vermicularis	47	1
	Dactylina arctica	33	2
	Flavocetraria nivalis	33	2
	Cladina rangiferina	27	1
	Masonhalea richardsonii	27	0
	Peltigera	20	2
	Cetraria	20	1
	Sphaerophorus globosus	20	1
	Alectoria nigricans	13	5
	Cetraria islandica	13	3
	Bryocaulon	13	2
	Cladina	13	1
Bryophyte	*Tomentypnum nitens*	27	40
	Hylocomium splendens	27	34
	Aulacomnium palustre	27	16
	Dicranum elongatum	27	13
	Sphagnum	20	10
	Aulacomnium	13	20
	Catoscopium nigritum	13	20
	Polytrichum	13	11
	Drepanocladus	13	8
	Polytrichum hyperboreum	13	7
	Racomitrium lanuginosum	13	3

G827. North American Arctic & Subarctic Low Willow Tundra

Type Concept: This shrub tundra group is common throughout arctic and subarctic Alaska on mesic to moist side slopes and ridges in the Brooks Range foothills and also high-centered polygonal tundra of the Arctic Coastal Plain. Vegetation is dominated by low shrub willows including *Salix richardsonii*, *Salix pulchra*, and *Salix glauca.* Associated shrubs that occur frequently at low cover include *Salix reticulata*, *Betula nana*, and *Vaccinium uliginosum*. Understory herbaceous species typically have low cover and may include *Equisetum arvense, Petasites frigidus, Arctagrostis latifolia, Carex bigelowii,* and *Poa arctica*. *Hylocomium splendens* is the most common moss; lichens are uncommon (Table 25).

Classification Comments: This group has some overlap with Western Boreal Mesic Alder - Willow Shrubland (G357) which also includes *Salix pulchra* types in its distribution. A review of alliances and associations for both groups will help to refine the distinctions between these two groups. G827 may be considered a non-forested subset of the 'Northern Alaska-Yukon Spruce Woodlands and Scrub' and the 'Yukon Subalpine Spruce Woodlands and Scrub' concepts described by Jorgenson and Meidinger (2015). G827 may also be considered a subset of the 'S1. Erect dwarf-shrub communities' and 'S2.1 Low-shrub communities of willow or birch' CAVM types described by Raynolds et al. (2006).

Similar NVC Types: This group is similar to G357. Western Boreal Mesic Alder - Willow Shrubland but is differentiated by its arctic-centric distribution as well as the non-participation of *Alnus viridis*. It is also similar to G830. North American Arctic & Subarctic Wet Shrubland but lacks a wet sedge understory.

Diagnostic Characteristics: This shrubland group is defined by its occurrence on moist to mesic sites and the dominance of low shrub willows (generally 40-150 cm tall with 25-90% canopy closure), including *Salix richardsonii*, *Salix pulchra,* and *Salix glauca.* Additional differential species include *Salix reticulata, Equisetum arvense,* and *Petasites frigidus.*

Table 25. Percent frequency and average cover of species within the North American Arctic & Subarctic Low Willow Tundra (G827), derived from 26 plots. Species with percent frequency less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted*.

		Arctic & Subarctic Low Willow Tundra (G827)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Shrub	*Vaccinium uliginosum*	50	3
	Salix richardsonii	**46**	**18**
	Salix glauca	**42**	**11**
	Salix pulchra	**42**	**17**
	Betula nana	35	2
	Salix alaxensis	19	1
	Salix arbusculoides	19	4
	Salix niphoclada	19	4
	Ledum palustre ssp. *decumbens*	15	1
Dwarf Shrub	***Salix reticulata***	**50**	**6**
	Arctostaphylos rubra	35	5
	Dryas integrifolia	23	1
	Dryas octopetala	23	1
	Arctostaphylos alpina	19	1
	Cassiope tetragona	19	1
	Empetrum nigrum	19	1
	Vaccinium vitis-idaea	19	1
Fern & Ally	***Equisetum arvense***	**54**	**5**
	Equisetum scirpoides	15	1
	Equisetum variegatum	15	5
Graminoid	*Arctagrostis latifolia*	35	1
	Carex bigelowii	31	4
	Poa arctica	31	1
	Anthoxanthum monticola ssp. *alpinum*	19	1
	Festuca altaica	19	0.1
	Eriophorum vaginatum	15	1
Forb	***Petasites frigidus***	**46**	**1**
	Hedysarum alpinum	31	1
	Polygonum viviparum	31	0.1
	Lupinus arcticus	27	2
	Pyrola grandiflora	27	0.1
	Polemonium acutiflorum	23	0.1
	Stellaria longipes	23	0.1
	Valeriana capitata	23	0.1
	Aulacomnium turgidum	23	2
	Pedicularis langsdorffii	19	0.1
	Anemone richardsonii	15	0.1
	Orthilia secunda	15	0.1
	Pedicularis capitata	15	0.1
	Saussurea angustifolia	15	0.1
	Saxifraga nelsoniana	15	0.1
	Senecio lugens	15	0.1
Moss	*Hylocomium splendens*	54	21
	Rhytidium rugosum	19	2
	Sphagnum	15	3
	Tomentypnum nitens	15	3
Lichen	*Flavocetraria cucullata*	15	0.1

*Indicator species in bold derived from an ISA comparing this group to Boreal Scrub Birch (G356) and Arctic Dwarf Birch (G828)

G828. North American Arctic & Subarctic Dwarf Birch Tundra

Type Concept: This group is dominated by *Betula nana* and is commonly found throughout the low Arctic on mesic to moist side slopes and ridges in the Brooks Range foothills and on high-centered polygonal tundra of the Arctic Coastal Plain. Vegetation is characterized by low and prostrate shrubs including *Betula nana, Ledum palustre* ssp. *decumbens, Vaccinium uliginosum,* and *Salix pulchra*. Dwarf-shrubs such as *Vaccinium vitis-idaea* and *Loiseleuria procumbens* may be common. Herbaceous species are sparse, but certain graminoids have high constancy including *Anthoxanthum monticola* ssp. *alpinum* in montane sites and sedges in moist tundra on the coastal plain. Fruticose lichens, particularly *Cladina rangiferina* and other *Cladina* species are often abundant in the ground layer. Common mosses include *Hylocomium splendens and Sphagnum, Aulacomnium,* and *Polytrichum* species (Table 26). Patch size is small to matrix-forming.

Classification Comments: G828 may be considered a non-forested subset of the 'Northern Alaska-Yukon Spruce Woodlands and Scrub' and the 'Yukon Subalpine Spruce Woodlands and Scrub' concepts described by Jorgenson and Meidinger (2015). G828 may also be considered a subset of the 'S1. Erect dwarf-shrub communities' and 'S2.1 Low-shrub communities of willow or birch' CAVM types described by Raynolds et al. (2006).

Similar NVC Types: This group is similar in composition to G356. Western Boreal Scrub Birch Shrubland, but lacks *Betula glandulosa* and is further differentiated by having an arctic distribution.

Diagnostic Characteristics: This group is characterized by mesic to moist sites dominated by *Betula nana* (25-90% cover) in a low or prostrate growth form. Additional differential species for this group include *Ledum palustre* ssp. *decumbens*, *Vaccinium uliginosum,* and *Cladina* spp.

Table 26. Percent frequency and average cover of species within the North American Arctic & Subarctic Scrub Birch Tundra (G828), derived from 13 plots. Species with percent frequency less than 10 are not included; indicator species are in bold and highlighted*.

		Arctic & Subarctic Scrub Birch Tundra (G828)	
Life Form	Scientific Name	Percent Frequency	Average Cover
Shrub	***Betula nana****	**100**	**51**
	Ledum palustre* ssp. *decumbens	**92**	**10**
	Vaccinium uliginosum	**77**	**4**
	Salix pulchra	62	2
	Salix glauca	23	1
Dwarf Shrub	***Vaccinium vitis-idaea***	**69**	**2**
	Loiseleuria procumbens*	**31**	**1**
	Cassiope tetragona	23	1
	Dryas octopetala	23	3
	Empetrum nigrum	23	2
	Andromeda polifolia	15	0.1
	Arctostaphylos rubra	15	0.1
	Salix fuscescens	15	0.1
	Vaccinium oxycoccos	15	0.1
Graminoid	*Anthoxanthum monticola* ssp. *alpinum*	31	1
	Eriophorum angustifolium*	**31**	**0.1**
	Poa arctica	23	0.1
	Carex bigelowii	15	2
	Carex rotundata	15	3
	Eriophorum vaginatum	15	1
	Festuca altaica	15	0.1
Forb	*Petasites frigidus*	23	0.1
	Rubus chamaemorus	23	1
	Pedicularis labradorica	15	0.1
	Polygonum bistorta	15	0.1
	Saussurea angustifolia	15	0.1
Moss	*Hylocomium splendens*	38	5
	Sphagnum	38	10
	Aulacomnium	23	5
	Polytrichum	23	6
	Dicranum	15	1
Lichen	*Cladina rangiferina*	46	16
	Cladina	23	1
	Cladonia	23	2
	Flavocetraria cucullata	23	1
	Peltigera	23	0.1
	Dactylina arctica	15	0.1
	Stereocaulon	15	0.1
	Thamnolia vermicularis	15	0.1

* denotes significant indicator species ($p<0.05$) identified through an Indicator Species Analysis comparing this group to Boreal Scrub Birch (G356) and Arctic Low Willow (G827). Because this Group shares many common species with G356, only those that differentiate its arctic composition are reflected in the ISA. A broader list of indicators has been highlighted to provide a more complete description. *Eriophorum angustifolium* was likely identified as an indicator for coastal plain sites because it occurs commonly in polygon troughs and in wet microsites which were included in the species composition for these plots, but these wet inclusions are part of a mosaic of vegetation communities found in polygonal tundra and not necessarily indicators for this type.

G(new). North American Arctic & Subarctic Moist Tundra

Type Concept: This proposed group is most common in the high arctic but also occurs in the low arctic. Moist Tundra types are associated with mesotopographic highs such as raised area along drainages, the centers of high-centered polygons and the ridges of low-centered polygons. Sites are underlain by permafrost and patch size is small. Shrubs are prostrate (low) to dwarf. Low shrub cover does not exceed 25% and dwarf shrub cover is variable. Common low shrub species are *Salix pulchra, Betula nana*, and *Ledum decumbens* with the participation of *Betula nana* decreasing in the high arctic. Common dwarf shrub species are *Vaccinium vitis-idea, Cassiope tetragona*, and *Dryas integrifolia*. Vegetation is dominated by sedges such as *Eriophorum angustifolium, Carex aquatilis* var. *stans,* and *Luzula arctica* and may include *Eriophorum vaginatum,* but sites are not tussocked, Moist- to dry-site mosses and lichens are abundant, with notable presence of crustose lichens.

Classification Comments: While this is a recognized type in the Arctic (e.g. the Moist Shrub Tundra on High-centered Polygons type of Jorgenson et al. 1994 and the 'G3. Non-tussock, sedge, dwarf-shrub, moss communities' CAVM type Raynolds et al. 2006), the paucity of plot data in our dataset precluded analysis. Conference with Canadian ecologists is recommended to further refine this group.

Similar NVC Types: This group is similar to G827. North American Arctic & Subarctic Low Willow Tundra and G828. North American Arctic & Subarctic Dwarf Birch Tundra; however, Moist Tundra has lower (<25%) cover of shrubs that are often dwarfed (<40 cm) due to their high arctic or coastal location. Species composition of the Moist Tundra group may also resemble G371. North American Arctic & Subarctic Tussock Tundra, however sites are not tussocked.

Diagnostic Characteristics: This proposed group is defined by tundra vegetation with less than 25% cover of prostrate (<40 cm) shrubs, most commonly *Salix pulchra*, and high constancy and abundance of sedges; sites have a moist hydrologic regime and are not tussocked.

G368. North American Arctic & Subarctic Tall Willow Tundra

Type Concept: This group is defined by tall willow shrublands found in floodplains and riparian corridors throughout the arctic, subarctic, and alpine boreal regions of Alaska. *Salix alaxensis* is the dominant shrub with canopy heights often exceeding 2 m. Other common willows are *Salix arbusculoides, Salix glauca*, *Salix niphoclada, Salix pulchra*, and *Salix richardsonii*. Dwarf shrubs include *Arctostaphylos* and *Dryas* species. In the herbaceous layer *Eurybia sibirica, Chamerion latifolium,* and *Equisetum arvense* have high constancy as do the grasses *Bromus inermis* ssp. *pumpellianus* and *Festuca rubra* and the legumes *Hedysarum alpinum, Astragalus alpinus, Lupinus arcticus*, and *Oxytropis campestris*. Mosses and lichens are uncommon in the ground layer (Table 277).

Classification Comments: North American Arctic Floodplain Group was absorbed into this group. Neither the CABVM nor the CAVM explicitly describes this group. While no equivalent types are recognized for the CABVM, the CAVM describes a 'S2.1 Low-shrub communities of willow or birch' type, however *Salix alaxensis* is not listed as a diagnostic or even associated species (Raynolds et al. 2006). The applicability of this group concept in Canada needs critical review.

Similar NVC Types: This group is similar to G357. Western Boreal Mesic Alder - Willow Shrubland but is differentiated by its arctic-centric distribution, floodplain occurrence as well as the infrequent occurrence of *Alnus viridis*. It also resembles G827. North American Arctic & Subarctic Low Willow Tundra but is separated by taller stature willows and floodplain location.

Diagnostic Characteristics: This group is defined by tall willow shrublands found in floodplains and riparian corridors. The dominant canopy species is *Salix alaxensis;* additional differential species include *Eurybia sibirica, Equisetum arvense, Chamerion latifolium Bromus inermis ssp. pumpellianus, Festuca rubra, Hedysarum alpinum, Astragalus alpinus, Lupinus arcticus*, and *Oxytropis campestris.* (Additional diagnostic species added from the NPRA Assessment Inventory and Monitoring Program summary of Arctic Floodplain Shrublands, Boucher et al. 2015.)

Table 27. Percent frequency and average cover of species within the North American Arctic & Subarctic Tall Willow Tundra (G368), derived from 41 plots. Species with percent frequency less than 10 are not included; significant (p<0.05) indicator species are in bold and highlighted.

		Arctic & Subarctic Tall Willow Tundra (G368)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Tree	*Populus balsamifera*	10	0.1
Shrub	***Salix alaxensis***	**100**	**44**
	Salix pulchra	29	4
	Salix richardsonii	15	2
	Vaccinium uliginosum	15	1
	Salix arbusculoides	12	1
	Salix glauca	12	1
	Salix hastata	10	0.1
	Salix niphoclada	10	1
	Shepherdia canadensis	10	0.1
Dwarf Shrub	*Salix reticulata*	24	4
	Dryas spp.	17	2
	Arctostaphylos spp.	12	0.1
Fern & Ally	*Equisetum arvense*	51	10
	Equisetum variegatum	20	1
	Equisetum scirpoides	10	0.1
Graminoid	*Bromus inermis* ssp. *pumpellianus*	22	1
	Arctagrostis latifolia	17	1
	Calamagrostis canadensis	15	4
	Festuca rubra	10	0.1
	Hierochloe odorata	10	0.1
	Poa arctica	10	1
Forb	***Chamerion latifolium***	**37**	**0.1**
	Eurybia sibirica	**37**	**1**
	Artemisia tilesii	27	1
	Hedysarum alpinum	27	1
	Polemonium acutiflorum	17	0.1
	Astragalus alpinus	15	0.1
	Stellaria longipes	15	0.1
	Achillea millefolium var. *borealis*	12	0.1
	Anemone parviflora	12	0.1
	Polygonum viviparum	12	0.1
	Astragalus umbellatus	10	0.1
	Comarum palustre	10	1
	Lupinus arcticus	10	0.1
	Mertensia paniculata	10	0.1
	Parnassia palustris	10	0.1
	Trientalis europaea	10	0.1
	Viola epipsila	10	0.1

*Indicator species identified from an ISA among Arctic Tall Willow (G368), Arctic Low Willow (Gn827, formerly G369), and Boreal Alder-Willow (G357).

G615. North American Arctic & Subarctic Mesic Herb Tundra

The Mesic Herb Tundra Group is an uncommon and potentially variable type that is represented by a single plot within the dataset. Further analysis incorporating a greater number of plots is recommended to refine the formal description of this group.

G371. North American Arctic & Subarctic Tussock Tundra

Type Concept: This tundra group is defined by tussock-forming sedges often in combination with dwarf and low shrubs occurring in the arctic and subarctic regions of Alaska and Canada. The cottongrass, *Eriophorum vaginatum* is the predominant tussock-former on older landscapes and acidic substrates. Tussock formation may transition to the sedge, *Carex bigelowii* across younger landscapes, disturbance-prone landforms and circumneutral substrates. *Carex bigelowii* tussock tundra is considered a more productive and type relative to mature *Eriophorum vaginatum* tussock tundra. *Eriophorum vaginatum* tussock tundra is characterized by high constancy of the dwarf shrub *Vaccinium vitis-idaea* and the low shrub *Betula nana*, with the low shrub *Ledum palustre* ssp. *decumbens* and the forb, *Rubus chamaemorus* indicating the type. By comparison, *Carex bigelowii* tussock tundra is characterized by high constancy of the dwarf shrubs, *Salix reticulata*, and *Cassiope tetragona* with the dwarf shrub, *Dryas octopetala* indicating the type. Where *Eriophorum vaginatum* and *Carex bigelowii* both contribute to tussock formation, the low shrub, *Vaccinium uliginosum* and the dwarf shrub, *Empetrum nigrum*, and the forb *Polygonum bistorta*, have high constancy; with the shrub, *Salix pulchra* indicating the type (Table 28). For tussock tundra occurring in wet areas of Alaska's Arctic Coastal Plain, shrub abundance appears to increase on microtopographic highs such high-centered polygons. On a broader scale, low shrub cover appears to increase in tussock tundra with increasing slope, with the participation of dwarf shrubs increasing in the subalpine. The presence of continuous, ice-rich permafrost renders sites cold and poorly-drained. Shallow organics in the intertussock hollows are underlain by silty mineral soils. Patch size is small to matrix-forming.

Classification Comments: An alliance-level split in accordance with *Carex bigelowii* or *Eriophorum vaginatum* dominance is suggested by characteristic species and pH values among plots. *Carex bigelowii* tussock tundra is characterized by an average pH of 6.3 as well as high constancy of the dwarf shrubs, *Salix reticulata*, and *Cassiope tetragona* with *Carex bigelowii* and the dwarf shrub, *Dryas octopetala* differentiating the type. Comparatively, *Eriophorum vaginatum* tussock tundra is characterized by an average pH of 5.5 as well as high constancy of the ericaceous dwarf shrub *Vaccinium vitis-idaea* and the low shrub *Betula nana*, with *Eriophorum vaginatum*, the low shrub *Ledum palustre* ssp. *decumbens* and the forb, *Rubus chamaemorus* differentiating the type. G371 is considered equivalent to the 'G4. Tussock sedge, dwarf-shrub, moss communities' CAVM type described by Raynolds et al. (2006); no equivalent types are described for the CBVM.

Similar NVC Types: This type is similar to both Western Subarctic Woodland (G633) and Subalpine Woodlands (G646) but does not support more than 10% cover of tree species. It may also resemble the floristics of North American Arctic & Subarctic Mesic Herb Tundra (G615) or

Western Boreal Mesic Grassland & Meadow (G358) when these are dominated by graminoids but is well separated by extensive tussock formation.

Diagnostic Characteristics: This tundra group is defined by tussock-forming sedges developing over continuous, ice-rich permafrost throughout arctic and subarctic regions of Alaska and Canada.

Table 28. Percent frequency and average cover of species within the Tussock Tundra Group (G371) derived from 51 plots. Species with frequency less than 10 are not included. Indicator species analysis was not completed as plots do not represent more than one group.

		Tussock Tundra (G371)	
Life Form	**Scientific Name**	**Percent Frequency**	**Average Cover**
Tree	*Picea mariana*	10	3
Shrub	*Ledum palustre* ssp. *decumbens*	75	7
	Betula nana	63	5
	Salix pulchra	57	4
	Vaccinium uliginosum	53	3
	Betula glandulosa	12	2
Dwarf Shrub	*Vaccinium vitis-idaea*	65	4
	Empetrum nigrum	35	2
	Cassiope tetragona	29	2
	Salix reticulata	27	3
	Dryas octopetala	22	2
	Salix phlebophylla	16	3
	Andromeda polifolia	12	3
	Arctostaphylos alpina	12	3
Graminoid	*Carex bigelowii*	75	7
	Eriophorum vaginatum	73	17
	Carex aquatilis	10	4
Forb	*Rubus chamaemorus*	27	3
	Petasites frigidus	10	1
Bryophyte	*Sphagnum*	53	7
	Hylocomium splendens	47	5
	Aulacomnium turgidum	29	2
Lichen	*Flavocetraria cucullata*	24	2
	Cladina rangiferina	10	4
	Dactylina arctica	10	2
	Masonhalea richardsonii	10	1
	Peltigera	10	2
	Thamnolia vermicularis	10	1