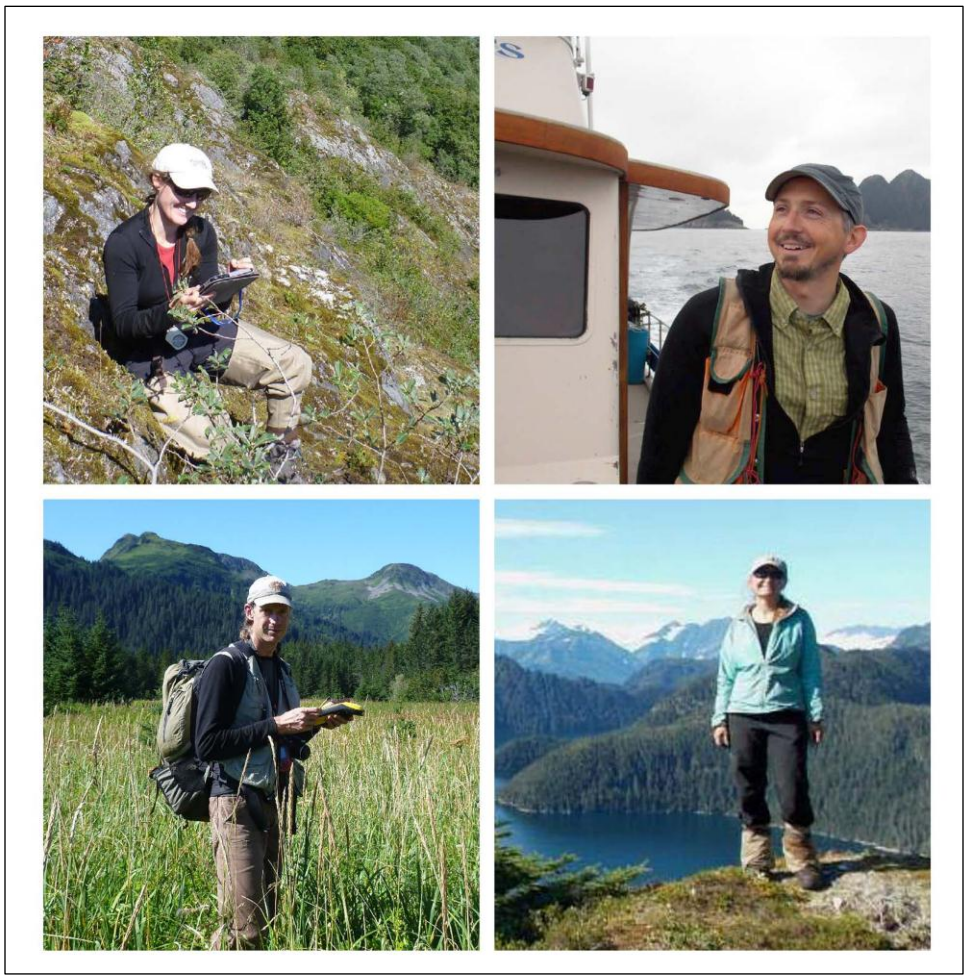
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Ecological Land Survey and Soil Landscapes Map for Kenai Fjords National Park, Alaska, 2013

Natural Resource Technical Report NPS/KEFJ/NRTR—2014/921





ON THIS PAGE
Clockwise from upper left:
Ellen Trainor collecting vegetation data on a recently deglaciated rock outcrop near Dinglestadt Glacier
Photograph by Aaron Wells.
Aaron Wells aboard the R/V *Outerlimits*. Photograph by Tracy Christopherson.
Tracy Christopherson takes in the view from a ridgeline above Paradise Cove. Photograph by Gerald "JJ" Frost.
Gerald "JJ" Frost amongst the beach rye at James Lagoon. Photograph by Tracy Christopherson.

ON THE COVER
Upper left: Unnamed glacier and moraine in Northwestern Lagoon, Kenai Fjords National Park, Alaska.
Upper right: Gerald "JJ" Frost collecting vegetation data near blooming *Sanguisorba stipulata* (foreground), Thunder Bay, Kenai Fjords National Park, Alaska.
Lower: Steep mountain slopes rise precipitously from the waters of Cliff Bay, southern Aialik Peninsula, Kenai Fjords National Park, Alaska.
Photographs by: Tracy Christopherson

Ecological Land Survey and Soil Landscapes Map for Kenai Fjords National Park, Alaska, 2013

Natural Resource Technical Report NPS/KEFJ/NRTR—2014/921

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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Contents

Page

Executive Summary xvii
Acknowledgments xix
Acronyms xix
Glossary xxi
How to Use this Ecological Land Survey and Mapping Product xxv
Overview xxv
Purpose and Limitations xxv
Guidelines for Use xxvi
Classification and Mapping: Field Applications xxvi
Classification and Mapping: Office Applications xxvii
Introduction 1
Study Area 5
Methods 7
Objectives 7
Field Surveys 7
Supplementary Field Data 10
Ecological Classification 11
Ecological Components 11
Ecotypes 11
Soils 14
Rock Samples 15
Ecosystem Components Synthesis 16
GIS and Remote Sensing Data Compilation 16
Overview 16
Naming Conventions 16
Existing GIS Data Sources 18
GIS Modeling and Ecosystem Component Synthesis 20
Physiography 20

Contents (continued)

Page

Bedrock Chemistry 25
Generalized Soil Texture 26
Land-Cover/Ecosystem/Physiography/Ecotype Crosswalk 26
Map Ecotypes 26
Soil Landscapes 26
Disturbance Landscapes 27
Results 28
Ecotypes and Plant Associations 28
Key to Ecotypes 35
Instructions 35
Ecotype Descriptions 86
Alpine Lake 86
Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub 86
Alpine Rocky Barrens 87
Alpine Rocky Luetkea Dwarf Shrub 88
Alpine Rocky Moist Sedge Meadow 89
Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub 90
Alpine Rocky-Loamy Mountain Heather Dwarf Shrub 91
Coastal Brackish Water 92
Coastal Rocky-Sandy Barrens 93
Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat 94
Coastal Rocky-Sandy Brackish Seaside Sandplant Beach 95
Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow 96
Coastal Sandy-Rocky Beach Pea Meadow 97
Coastal Sandy-Rocky Beach Rye Meadow 98
Coastal Sandy-Rocky Bluejoint-Forb Meadow 99
Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat 100
Glacial Lake 101

Contents (continued)

Page

Glacial Rocky Alder-Willow Tall Shrub 102
Glacial Rocky Barrens 103
Glacial Rocky Fireweed 104
Glaciers and Permanent Snowfields 104
Human-modified Barrens 104
Lacustrine Aquatic Forb Marsh 105
Lowland Lake 105
Lowland Organic-rich Wet Sedge Meadow 106
River 107
Riverine Rocky Dwarf Fireweed 107
Riverine Rocky Dwarf Shrub 108
Riverine Rocky-Sandy Willow Low and Tall Shrub 109
Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub 110
Riverine Sandy-Loamy-Rocky Black Cottonwood Forest 111
Riverine Sandy-Loamy-Rocky Sitka Spruce Forest 111
Subalpine Rocky Alder Tall Shrub 112
Subalpine Rocky Barrens 113
Subalpine Rocky Dwarf Mountain Hemlock Woodland 114
Subalpine Rocky Fireweed-Forb Meadow 115
Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow 116
Subalpine Rocky-Loamy Moist Graminoid Meadow 117
Subalpine Rocky-Loamy Sitka Spruce Woodland 118
Subalpine Rocky-Loamy-Organic Copperbush Low Shrub 119
Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen 120
Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow 122
Subalpine Rocky-Loamy-Organic Fern Meadow 123
Upland Loamy-Organic Deer Cabbage Slope Fen 124
Upland Organic-rich Wet Sedge Slope Fen 125

Contents (continued)

Page

Upland Rocky Black Cottonwood Forest 126
Upland Rocky Sitka Spruce-Alder Forest 127
Upland Rocky Sitka Spruce-Feathermoss Forest 128
Upland Rocky-Loamy Moist Lady Fern Meadow 129
Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest 130
Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest 131
Upland Rocky-Loamy-Organic Salmonberry Low Shrub 132
Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest 133
Upland Rocky-Organic Alder Tall Shrub 134
Relationships Among Ecological Components 136
Landscape Relationships 136
Hierarchical Organization of Ecological Components 142
Environmental Characteristics 143
Vegetation Composition 145
Ecosystem Mapping 159
Soil Landscapes 174
Summary of Soil Characteristics 174
Single-factor Comparisons by Subgroup 178
Classification and Description of Soil Landscapes 178
Soil Landscapes Mapping 183
Factors Affecting Landscape Evolution and Ecosystem Development 184
Climate 184
Tectonic Setting and Physiography 185
Volcanism 186
Glaciations 187
Coastal Processes 188
Geomorphology and Soils 192
Landscape Change 196

Contents (continued)

Page

Summary and Conclusions 197

Literature Cited 201

Figures

Page

Figure 1. Interaction of interrelated state factors that control the structure and function of ecosystems (a) and the scale at which they operate (b). 2

Figure 2. Sampling locations and study area boundary for the ecological land survey and soil landscapes mapping for Kenai Fjords National Park (KEFJ), southcentral Alaska, 2013..... 6

Figure 3. Map of recent glacial history for Kenai Fjords National Park, southcentral Alaska. 21

Figure 4. Key to Physiography Class for Kenai Fjords National Park, southcentral Alaska, 2013. 42

Figure 5. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Quicksand Cove, Kenai Fjords National Park, southcentral Alaska. 137

Figure 6. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Agnes Cover, Kenai Fjords National Park, southcentral Alaska. 138

Figure 7. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Exit Glacier, Kenai Fjords National Park, southcentral Alaska. 139

Figure 8. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils in Alpine physiography, Alaska Natural Heritage Program Transect 80, southwest of the Resurrection River, Kenai Fjords National Park, southcentral Alaska. 140

Figure 9. Non-metric multidimensional scaling of species composition for Alpine ecotypes in Kenai Fjords National Park, southcentral Alaska. 146

Figure 10. Non-metric multidimensional scaling of species composition for Subalpine ecotypes in Kenai Fjords National Park, southcentral Alaska. 147

Figure 11. Non-metric multidimensional scaling of species composition for Upland and Riverine forested ecotypes in Kenai Fjords National Park, southcentral Alaska 148

Figure 12. Non-metric multidimensional scaling of species composition for Upland, Glacial, and Riverine shrub ecotypes in Kenai Fjords National Park, southcentral Alaska. 149

Figure 13. Non-metric multidimensional scaling of species composition for Upland, Lowland, and Lacustrine ecotypes in Kenai Fjords National Park, southcentral Alaska. 150

Figure 14. Non-metric multidimensional scaling of species composition for Coastal ecotypes in Kenai Fjords National Park, southcentral Alaska. 151

Figure 15. Physiography map for Kenai Fjords National Park, southcentral Alaska. 155

Figures (continued)

Page

Figure 16. Ecological systems map for Kenai Fjords National Park, southcentral Alaska. Adapted from KEFJ land-cover map of Boggs et al. (2008). 156

Figure 17. Land-cover map for Kenai Fjords National Park, southcentral Alaska. Adapted from KEFJ land-cover map of Boggs et al. (2008). 157

Figure 18. Map ecotypes for Kenai Fjords National Park, southcentral Alaska. 158

Figure 19. Soil Landscapes map for Kenai Fjords National Park, southcentral Alaska. 171

Figure 20. Disturbance Landscapes map for Kenai Fjords National Park, southcentral Alaska. 172

Figure 21. Northwestern Fjord seen from Harris Bay in 1909 (U. Grant) and 2013 (G. Frost), Kenai Fjords National Park, southcentral Alaska. Glacial retreat has been the dominant landscape-change mechanism in KEFJ since the end of the Little Ice Age (circa 1850) 189

Figure 22. Three Hole Point on western side of Aialik Peninsula seen in 1909 (U. Grant) and 2013 (G. Frost), Kenai Fjords National Park, southcentral Alaska 191

Tables

Page

Table 1. Description of ten generalized soil texture classes used in ecotype classification and mapping, including texture range and predominant soil orders. 13

Table 2. Pre-existing and derived GIS and remote-sensing data compiled for the ecological land survey and soils mapping for Kenai Fjords National Park, southcentral Alaska. 17

Table 3. Crosswalk of abbreviated ecotype names with full ecotype name, plant communities, and Alaska Vegetation Classification level IV vegetation classes in Kenai Fjords National Park, southcentral Alaska 29

Table 4. Ecotype Key for Kenai Fjords National Park. 36

Table 5. Mean elevation, slope gradient, surface organic thickness, and pH for ecotypes with sample size ≥3, Kenai Fjords National Park, Alaska, 2013. 43

Table 6. Mean percent cover by plant species and species richness for alpine ecotypes, Kenai Fjords National Park, Alaska, 2013 45

Table 7. Mean percent cover by plant species and species richness for subalpine ecotypes, Kenai Fjords National Park, Alaska, 2013 54

Table 8. Mean percent cover by plant species and species richness for upland forest and shrub ecotypes, Kenai Fjords National Park, Alaska, 2013 65

Table 9. Mean percent cover by plant species and species richness for glacial, lacustrine, lowland, riverine, and upland non-forest, ecotypes, Kenai Fjords National Park, Alaska, 2013 73

Table 10. Mean percent cover by plant species and species richness for coastal ecotypes, Kenai Fjords National Park, Alaska, 2013 82

Table 11. Typical soil stratigraphy for the ecotype Coastal Sandy-Rocky Beach Rye Meadow, plot number KEFJ_Tqc_03_2013, Kenai Fjords National Park, 2013. 98

Table 12. Typical soil stratigraphy for the ecotype Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat, plot number KEFJ_Tpb2_02_2013, Kenai Fjords National Park, 2013 100

Table 13. Typical soil stratigraphy for the ecotype Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub, plot number KEFJ_Tdg_01_2013, Kenai Fjords National Park, 2013. 110

Table 14. Typical soil stratigraphy for the ecotype Subalpine Rocky Dwarf Mountain Hemlock Woodland, plot number KEFJ_Tpac_02_2013, Kenai Fjords National Park, 2013 114

Table 15. Typical soil stratigraphy for the ecotype Subalpine Rocky Fireweed-Forb Meadow, plot number KEFJ_Tsb1_02_2013, Kenai Fjords National Park, 2013. 115

Tables (continued)

Page

Table 16. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow, plot number KEFJ_Tagc2_02_2013, Kenai Fjords National Park, 2013. 116

Table 17. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen, plot number KEFJ_Tagc2_01_2013, Kenai Fjords National Park, 2013. 121

Table 18. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow, plot number KEFJ_Tpb1_02_2013, Kenai Fjords National Park, 2013. 122

Table 19. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Fern Meadow, plot number KEFJ_Tpb1_01_2013, Kenai Fjords National Park, 2013..... 124

Table 20. Typical soil stratigraphy for the ecotype Upland Rocky Black Cottonwood Forest, plot number KEFJ_Teg1_02_2013, Kenai Fjords National Park, 2013 126

Table 21. Typical soil stratigraphy for the ecotype Upland Rocky Sitka Spruce-Feathermoss Forest, plot number KEFJ_Tjl_01_2013, Kenai Fjords National Park, 2013 128

Table 22. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy Moist Lady Fern Meadow, plot number KEFJ_Tcb2_01_2013, Kenai Fjords National Park, 2013..... 129

Table 23. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest, plot number KEFJ_Tagc2_03_2013, Kenai Fjords National Park, 2013. 130

Table 24. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest, plot number KEFJ_Tqc_04_2013, Kenai Fjords National Park, 2013. 131

Table 25. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Salmonberry Low Shrub, plot number KEFJ_Tsb1_03_2013, Kenai Fjords National Park, 2013..... 132

Table 26. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest, plot number KEFJ_Tpb2_04_2013, Kenai Fjords National Park, 2013 133

Table 27. Typical soil stratigraphy for the ecotype Upland Rocky-Organic Alder Tall Shrub, plot number KEFJ_Tsb1_04_2013, Kenai Fjords National Park, 2013..... 135

Table 28. Area (km^2) of physiographic classes mapped in Kenai Fjords National Park, southcentral Alaska. 160

Table 29. Area (km^2) of ecological systems mapped in Kenai Fjords National Park, southcentral Alaska. Ecological systems classification follows Boggs et al. (2008).*..... 161

Tables (continued)

Page

Table 30. Area (km^2) of land-cover classes mapped in Kenai Fjords National Park, southcentral Alaska. Land-cover classification follows Boggs et al. (2008).* 162

Table 31. Crosswalk of map ecotypes with abbreviated ecotype names, soil landscapes, and disturbance landscapes identified in Kenai Fjords National Park, southcentral Alaska. 165

Table 31. Continued. 166

Table 32. Area of map ecotypes in Kenai Fjords National Park, southcentral Alaska. 169

Table 33. Area (km^2) of soil landscape classes mapped in Kenai Fjords National Park, southcentral Alaska. 173

Table 34. Area (km^2) of disturbance landscape classes mapped in Kenai Fjords National Park, southcentral Alaska 173

Table 35. Description of soil subgroups found in Kenai Fjords National Park, Alaska, 2013 175

Appendices

Page

Appendix A. List of vascular species encountered by ABR in Kenai Fjords National Park, southcentral Alaska, 2013. ..... A-1

Appendix B. List of non-vascular species encountered by ABR in Kenai Fjords National Park, southcentral Alaska, 2013. ..... B-1

Appendix C. Chemical and physical laboratory data for 38 soil samples across 34 plots, Kenai Fjords National Park, southcentral Alaska, 2013. ..... C-1

Appendix D. Identification of rock types from 15 plots, Kenai Fjords National Park, southcentral Alaska, 2013. ..... D-1

Appendix E. Crosswalk between map ecotypes and the ecosystem and land-cover classes of Boggs et al. (2008), and the total area (km^2) of each unique combination of ecotypes and classes, Kenai Fjords National Park, southcentral Alaska, 2013. ..... E-1

Appendix F. Relationship between soil landscape classes and soil order. F-1

Executive Summary

The primary objective of this study was to classify and map soils and vegetation in the ecosystems of Kenai Fjords National Park (KEFJ) in southcentral Alaska. Soil conditions strongly influence vegetation composition, structure, and succession, hydrology, trace gas fluxes, and environmental state-factors that affect the sensitivity of ecotypes (local-scale ecosystems) to landscape disturbance and climate changes. Soil development is dynamically linked to a suite of physical, biological, and climate processes that function over a continuum of spatial and temporal scales. We conducted an ecological land survey (ELS) to collect soils, vegetation, and geomorphology data from a network of 486 field plots across KEFJ, and integrated the field data with an archive of contemporary and historical Geographic Information System (GIS) and remote-sensing (RS) data pertaining to land-cover, topography, and glacial history.

Glacial dynamics have played a dominant role in shaping the landscapes of KEFJ; nearly half of the park remains occupied by the Harding Icefield, its outlet glaciers, and isolated alpine cirque glaciers. Virtually all of today's ice-free landscape has been glaciated at some point since the early Pleistocene, from the long-deglaciated, partially-submerged ridges and cirques of the outer peninsulas, to very young landscapes exposed by glacial retreat since the end of the Little Ice Age (late nineteenth century). As a result of recent and ongoing glacial activity, soils are young and poorly-developed across most of KEFJ; bedrock is often present at or near the surface. Soil development is most advanced in the long-deglaciated outer fjordlands, where indicators of soil development are common, including fine-textured mineral material (loam), heavy peat accumulations, and the development of distinct soil horizons (spodosols).

To identify and map spatial patterns of soil landscape distribution, we partitioned KEFJ into physiographic units that integrate key geomorphic processes, landscape history attributes, and the environmental gradients controlling landform and soils development across KEFJ (e.g., coastal, upland, alpine, glacial). We then identified the central tendencies and interrelationships of vegetation, soils, and state-factors at field plots to classify ecotypes (local-scale ecosystems) that occur in predictable patterns across the park. From the ecotypes, we classified and mapped soil landscapes—groups of ecotypes that share similar soils and are related to one another through disturbance and successional processes—by assigning ecotype and soil landscape attributes to map polygons within an existing land-cover map. The majority of non-glaciated landscapes correspond to four physiographic classes: Upland (14.0% of park), Glacial (13.5%), Alpine (10.9%), and Subalpine (9.9%). Within the Glacial physiographic class (deglaciated since the late nineteenth century), a productive vegetation cover is often present but soils require a much longer time period to develop. As a result, Entisols are typically the dominant soil class, characterized by organic mat thicknesses that range from absent to thin (0–14 cm) and little to no diagnostic soil characteristics. Soil development is also weak in steeply-sloping areas with active hillslope processes such as mass wasting, landslides, and avalanche. Soils in more advanced stages of development do occur, however, in stable landscape positions. In the Alpine physiography, the pace of soil development is very slow because of low rates of plant productivity and organic decomposition. Loamy material resulting from eolian deposition and weathering *in situ* can be retained in the soil profile, however,

on stable sites that have remained ice-free for long periods of time. In the Subalpine physiography, loams are frequently associated with concave landscape positions that accumulate deep snowpacks. Loamy soils and spodic horizons also develop in old-growth forest ecotypes of the outer fjordlands. Peat accumulation (paludification) is an important soil development process on bedrock-dominated slopes, where the bedrock prevents the infiltration of the abundant rainfall, and the accumulation of organic matter initiates feedbacks that promote saturated soil conditions and further organic buildup. The ELS presented in this report describes and maps these, and other landform-vegetation-soils relationships across KEFJ, and provides guidance on applying the ELS to support ongoing and future research, monitoring, and management objectives related to the natural resources of KEFJ.

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Acronyms

ABR—ABR, Inc. Environmental Research and Services

AKNHP—Alaska Natural Heritage Program

ALA—Herbarium at the University of Alaska Fairbanks

ALAG—Alagnak Wild River

ANIA—Aniakchak National Monument and Preserve

AVC—Alaska Vegetation Classification (Viereck et al. 1992)

BLM—Bureau of Land Management

CIR—color infrared

DBH—Diameter at Breast Height

DU—Ducks Unlimited

EC—electrical conductivity

DEM—Digital Elevation Model

ELS—Ecological Land Survey

EPA—Environmental Protection Agency

GIS—Geographic Information System

GLIMS—Global Land Ice Measurement from Space

GPS—Geographic Positioning System

GRI—Geologic Resources Inventory

I&M—Inventory and Monitoring

ITU—Integrated Terrain Unit

I&M—Inventory and Monitoring

KATM—Katmai National Park and Preserve

KEFJ—Kenai Fjords National Park

LACL—Lake Clark National Park and Preserve

LIA—Little Ice Age

NF—National Forest

NIR—near infrared

NLDC—National Land Cover Database

NMDS—Non-metric Multidimensional Scaling

NPS—National Park Service

NRCS—Natural Resource Conservation Service

NSIDC—National Snow and Ice Data Center

PAM—Partitioning Around Medoids

R—R Project for statistical computing (http://www.r-project.org/)

RS—remote sensing

R/V—research vessel

SWAN— Southwest Alaska Inventory and Monitoring Network, National Park Service

UA—University of Alaska

USDA—United States Department of Agriculture

USGS—United States Geological Survey

XRF—X-ray florescence spectroscopy

Glossary

A-horizon—mineral soil horizon dominated by an accumulation of organic carbon related to high amounts of fine root decomposition. Typically occurs at or near the soil surface where fine roots from forbs and grasses are most abundant.

Acidic—soils with a pH value ≤5.5 in the upper 40 cm of the soil profile.

Alkaline—soils with a pH value >7.3 in the upper 40 cm of the soil profile.

Aluminum-Humus Complexes—soil particles formed from the binding of negatively charged organic particles to positively charged aluminum ions.

Andic—unique properties of soils developing in volcanic ejecta (e.g., volcanic ash, pumice, cinders, or lava) and/or volcaniclastic materials (e.g., lahar deposits) characterized by an abundance of volcanic glass; a smeary, almost oily feel when rubbed between two fingers; and a low bulk density (i.e., a given volume of soil feels lighter than it appears). See page 15 (Diagnostic Soil Characteristics for Mineral Soils: Andic Soil Properties) in Soil Survey Staff (2010) for more details.

Ash—tephra deposits whose intermediate axis measures 2mm or less, which coincides with the size class requirements for soil particles (Schoenberger and Wysocki 2002).

Brackish—soils with an electrical conductivity (EC) >800 µ and <16,000 µ in the upper 40 cm of the soil profile.

Base Saturation—the relative availability of cations, calculated from cation exchange capacity.

Cations—positively charged soil particles (e.g., Ca, Mg, K, Na and H).

Cation Exchange Capacity—describes the holding capacity of a particular soil for positively-charged elements (i.e., cations).

Chroma—a soil color characteristic related to the degree of color saturation as per the Munsell® Soil Color Chart. Lower chroma soils colors are often indicative of the loss of soil materials from a portion of the soil profile through translocation. Typically denoted in soil descriptions along with Hue (primary color) and Value (degree of color lightness) as "Hue Value/Chroma"; e.g., 10YR 3/2.

Circum-acidic—soils with a pH value of approximately 5.6–6.6 in the upper 40 cm of the soil surface.

Circum-alkaline—soils with a pH value of approximately 6.7–7.3 in the upper 40 cm of the soil profile.

Circum-neutral—soils that span the pH range of circum-acidic and circum-alkaline (5.6–7.3).

Cryic—soil temperature regime that occurs in cold-temperate climates. Soils in the cryic temperature regime have a mean annual soil temperature of 0–8°C at 50 cm depth and do not have permafrost.

Cryoturbation—heaving and displacement of soils and rock fragments due to freeze-thaw processes.

Disturbance Landscapes—Aggregations of ecotypes with similar disturbance pathways. The focus of this effort was to aggregate similarities in disturbance regimes across physiography, soil and vegetation classes.

Ecotype—Conceptually, ecotypes are local-scale ecosystems classified by aggregating the field data for individual ecological components (e.g., soils, geomorphology, vegetation), using a hierarchical approach. Three naming conventions for ecotypes are used in this report:

- Full Ecotype Name—Complete ecotype name based on the aggregated ecological components, including physiography, soil chemistry, soil texture, and vegetation; e.g., Alpine Moist Acidic Loamy-Rocky Crowberry-Blueberry Dwarf Shrub.
- Abbreviated Ecotype Name—Shortened ecotype name designed to emphasize primary characteristics of the class and facilitate discussion (e.g., Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub). In this report, including text, tables and figures, abbreviated ecotype names have been used unless specifically stated otherwise.
- Map Ecotype—Aggregations of ecotypes with similar vegetation distinguished in the ecotype map. Some ecotypes with similar vegetation properties could not be reliably distinguished from one another during mapping; the focus of the map ecotype aggregation was on vegetation type and structure, with less emphasis on soils (e.g., Alpine Meadows and Dwarf Shrub). Thus, map ecotypes represent aggregations of similar or closely associated vegetation types that may have differing soil textures.

Fibric—organic soil materials that have undergone the least amount of decomposition. The source of the organic material (e.g., deciduous leaves, moss fibers) and often the species from which the organic material was derived remains identifiable. Abbreviated as "Oi" in soil horizon descriptions.

Folistic epipedon—an accumulation of organic material at the surface that is ≥15 cm thick and is not saturated for 30 or more cumulative days in a normal growing season. Folistic epipedons often occur on stable slopes or well-drained glaciofluvial deposits in forested plant communities.

Halophyte—a plant adapted to living in a saline environment

Hemic—organic soil materials in an intermediate state of decomposition, more advanced than fibric soil materials, but less than sapric soil materials. The source of the organic material and the plant life-form from which it was derived remain identifiable, but species distinctions can no longer be made. Abbreviated as "Oe" in soil horizon descriptions.

Histic epipedon—an accumulation of organic material at the surface that is ≥20 cm and is saturated for ≥30 cumulative days in a normal growing season. Histic epipedons primarily occur on poorly drained soils in bogs and fens, but in temperate climates, may also form on steep mountain slopes on top of bedrock, or on late snowbed nivation hollows.

Little Ice Age—period of moderate global cooling that began approximately 500 years ago and ended approximately 160 years ago, during which time glaciers advanced in high-latitude regions of the world (Dahms 2002).

O-horizon—a soil horizon dominated by organic materials and subdivided into fibric, hemic, and sapric components based on the degree of decomposition.

Permafrost—soil material that remains below 0° C for two or more consecutive years. Divided into ice-rich (≥50% ice content) and ice-poor (<50% ice content).

Plant Associations—also called Floristic Associations or Plant Communities. Assemblages of plants with similar composition that repeat predictably across space. Plant associations are characterized by one (occasionally two) dominant species, and one to several indicator species that occur consistently and are indicative of specific environmental conditions.

Podzolization—a process of soil formation especially in humid regions involving organic complexes contributing to the leaching of iron or alumina into subsurface horizons. This process contributes to the formation of Spodosol soil orders.

Redoximorphic depletions—low-chroma zones from which iron and manganese oxide or a combination of iron and manganese oxide and clay has been removed due to translocation. These zones are indications of the chemical reduction of iron resulting from saturation (Soil Survey Staff 2010).

Saline—soils with an electrical conductivity (EC) >16,000µ in the upper 40 cm of the soil profile.

Sapric—organic soil materials that have undergone the highest amount of decomposition. The source of the organic material, and the lifeform and species from which it was derived is unidentifiable. Abbreviated as “Oa” in soil horizon descriptions.

Soil Landscapes—Aggregations of ecotypes with similar soils for use in mapping. The focus of the soil landscape aggregation was on soils, with less emphasis on vegetation (e.g., Alpine Rocky Barrens and Sedge Meadows). Soil landscape classes represent aggregations of similar or closely associated soil types with different vegetation types that are typically associated with a successional sequence.

Tephra—a general term used to describe volcanic ejecta of any size.

Translocation—movement of materials (e.g, organic carbon, iron, aluminum) through time from the upper to the lower soil profile via the forces of chemical weathering and gravity.

Udic—soil moisture regime that occurs in humid temperate climates. A udic soil moisture regime is one in which the upper meter of soil remains moist to wet throughout the growing season.

Vitric—ash particles that are typically coarse-ash grain size (0.062–2 mm) and have a 1500 kPa water retention of 15 percent or less on air-dried samples (Soil Survey Staff 2010).

Water Retention—the degree to which soils can retain water within the pore spaces between individual soil particles; measured in terms of the soil water content of a given volume of soil that remains in the soil when a set amount of pressure (i.e., kilopascals) is applied to a soil sample in the laboratory.

How to Use this Ecological Land Survey and Mapping Product

Overview

An Ecological Land Survey (ELS) and land classification, in conjunction with a land-cover map, enables resource managers to more effectively evaluate land resources and develop appropriate management strategies. An ELS is an integrated approach of inventorying and classifying ecological characteristics from the "bottom up," while using environmental and GIS modeling to better differentiate the distribution of ecosystems across space from the "top down." An ELS can be used to efficiently allocate inventory and monitoring efforts, to partition information for analysis of ecological relationships, to develop predictive models, and to improve techniques for assessing and mitigating impacts to land resources. This section provides guidance on how to use this ELS and associated map products.

Purpose and Limitations

The purpose of an ELS is to classify and describe (with the support of field data) local-scale (thousands of square meters, to tens and hundreds of hectares) ecosystems while simultaneously informing the analysis and mapping of ecosystem components at the landscape scale (hundreds to thousands of hectares, to hundreds to thousands of square kilometers). Hence, an ELS provides useful products for land managers and scientists at both the local and landscape scales. While the products from the two spatial scales may be useful independent of one another, the real power of an ELS lies in the products derived from where the two spatial scales overlap. Depending on the objectives of the end user, the two are often used in conjunction with one another.

This ELS provides robust classification and mapping products; however, these products are not without their limitations. First, while steps were taken during the planning phase to design a balanced, well-stratified sample design, the constraints of weather, a relatively short sampling period, and the overall remote and diverse character of KEFJ resulted in a low sample size for some vegetation types, soils, and ecosystems. Therefore, the classification of ecotypes should not be considered exhaustive of the possible vegetation and soil types in KEFJ. Second, the short sampling window did not allow us to conduct an accuracy assessment of the maps provided as part of this ELS. Third, the map series produced as part of this ELS provides a landscape-scale view of ecosystem components with an 8-ha minimum map polygon size at a map scale of 1:36,000 to 1:40,000. While this scale of mapping is appropriate for large, remote parks like KEFJ, it does limit the usefulness for some applications. Applications for which the mapping series are useful and appropriate include landscape-scale analyses of ecological components (e.g., terrain suitability and wildlife habitat), broad-scale management and planning, and development of stratified sampling designs for landscape-scale inventory and monitoring studies. Applications for which ELS mapping is not appropriate include site-specific management, planning, analysis, and study design. An Integrated Terrain Unit (ITU) approach (Jorgenson et al. 2003, Wells et al. 2012) to mapping geomorphology, soils, vegetation, and ecotypes is better suited for these finer-scale applications.

Guidelines for Use

Guidelines for two likely scenarios for using this ELS and associated mapping products are provided below. In both scenarios it is assumed that the researcher(s) has basic knowledge of common plant species in KEFJ and soil sampling and GIS techniques. Additionally, the researcher(s) should use the KEFJ land-cover report entitled *Landcover Classes, Ecological Systems and Plant Associations, Kenai Fjords National Park* by Boggs et al. (2008) to supplement this document as needed.

Classification and Mapping: Field Applications

Under the first scenario, land managers and/or researchers are interested in classifying ecotypes and are either in the field in KEFJ collecting data or in the office reviewing field data. If in the field, first locate a relatively homogeneous patch of vegetation with a suggested minimum area ranging between 314 m^2 (the area of an ELS plot) to 1,000 m^2 (one-tenth of one hectare) that is obviously associated with a specific landform or slope position. Landforms are any physical, recognizable form or feature on the earth's surface with a characteristic shape and range in composition that is created by natural processes (Schoenberger and Wysocki 2002).

An appropriate sample site should be located firmly on a landform and not near the boundary between two landforms. Plots should be roughly 314 m^2 in size and circular (10 m radius). On long, narrow landforms, such as in steep, narrow riparian zones, the shape of the plot may be changed to fit on the landform, so long as the area of the plot is approximately the same as above. Next, go to the Physiography and Ecotype Keys (see Figure 4 and Table 4, respectively) and follow the instructions to determine the ecotype. Once the ecotype has been determined, the user is directed to:

- The ecotype descriptions (see Results: Ecotypes and Plant Associations, below) for information regarding general environment, vegetation, and soils;
- Table 3, which provides a cross-walk between ecotypes (abbreviated and full), plant communities, and Viereck et al. (1992) Level IV vegetation classes included in each ecotype;
- Table 5, which includes summaries of environment data by ecotype, and Tables 6–10, which include a summary of plant species frequency and cover by ecotype;
- Tables 1 and 35, which provide descriptions of generalized soil texture classes (used in the ecotype names) and soil subgroups described in the ecotype descriptions, respectively;
- Table 31, which provides a cross-walk between abbreviated ecotype names, Map Ecotype classes (see Figure 18), Soil Landscape classes (see Figure 19), and Disturbance Landscape classes (see Figure 20).
- Refer to the Plant Associations section on page 111 of Boggs et al. 2008 for descriptions of plant associations mentioned in the ecotype descriptions.

The ecotype descriptions, descriptive tables of ecotype components (e.g., generalized soil texture classes), and ecotype key provide valuable information for classifying and describing ecotypes in the field and in the office from field data. Additionally, the Ecotype, Soil Landscape, and Disturbance Landscape maps in conjunction with the crosswalks in Appendix E and Table 31 provide the user with the spatial context of each ecotype in KEFJ as it relates to the above three maps. The crosswalks also allow the user to see the relationship between a given ecotype classified using the ecotype key and other closely related ecotypes and soils (both spatially and through successional sequences).

Guidelines for using the ecotype classification in conjunction with the Ecotype, Soil Landscape, and Disturbance Landscapes maps are provided below:

1) Use the Ecotype Key (Table 4) to determine the ecotype (e.g., Alpine Moist Acidic Loamy-Rocky Crowberry-Blueberry Dwarf Shrub);
2) Refer to the ecotype descriptions (see Results: Ecotypes and Floristic Associations, below) for information regarding general environment, vegetation, and soils;
3) Refer to Tables 1, 5, 6–10, and 35 for detailed information regarding the vegetation and soil characteristics of the ecotype;
4) Refer to Table 31 and locate the abbreviated ecotype name of interest in the list (e.g., Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub);
5) Follow the crosswalk in Table 31 to determine the Map Ecotype (e.g., Alpine Dwarf Shrub), Soil Landscape (e.g., Alpine Rocky-Loamy Dwarf Shrub), and Disturbance Landscape (e.g., Mass wasting and Landslide, Avalanche) classes within which the ecotype was aggregated for mapping. Additionally, Table 31 allows the user to see the other ecotypes aggregated with the ecotype of interest into each map class (e.g., Mass Wasting and Landslide, Avalanche).

Classification and Mapping: Office Applications

In the second scenario, KEFJ land managers and/or researchers are in the office and are interested in the location of specific park resources (e.g., soils) in designing a landscape-scale management plan; a stratified sample design for inventory and monitoring; or in conducting landscape-level analyses (e.g., habitat assessment, landscape sensitivity). In this scenario, users are directed to the series of mapping products provided with this ELS, which include printed (see Figures 3, and 15–20) and digital (ArcGIS geodatabase) versions. The base maps, including Glacial History (Figure 3), Physiography (Figure 15), Ecosystems (Figure 16), and Land Cover (Figure 17) represent useful stand-alone products that may be used in conjunction with one another. For more information regarding these map products the user is directed to 1) the results section for each base map (see Results: Ecosystem Mapping), and 2) Boggs et al. (2008) for the Ecosystems and Land Cover mapping products.

The ecotype map (Figure 19) was developed by spatially overlaying the base layers to create strata, and then assigning those strata to aggregations of ecotypes with similar vegetation (termed map ecotypes). The map ecotypes were then aggregated into classes with similar soils (termed Soil Landscapes) and similar disturbance pathways (termed Disturbance Landscapes) to create the Soil Landscapes (Figure 19) and Disturbance Landscapes (Figure 20) maps. Users of these aggregated maps are directed to:

- The results section for each aggregated map (see Results: Ecosystem Mapping)
- Tables 28–30 and 32–34, which provide summaries of the areal extent of each map unit within each respective map;
- Table 31, which provides a cross-walk between abbreviated ecotype names, Map Ecotype classes (see Figure 18), Soil Landscape classes (see Figure 19), and Disturbance Landscape classes (see Figure 20);
- Appendix E, which provides a cross-walk between the Boggs et al. (2008) ecosystem and landcover classes and the map ecotype classes;

- Appendix F, which provides a flow chart depicting Soil Landscape classes and common soil types;
- Additionally, descriptions of Soil Landscape classes are provided (see Results: Soil Landscapes). Descriptions of map ecotypes are not provided. Instead, the user is directed to the descriptions of individual ecotypes that were aggregated to create each map ecotype class (see below).

Guidelines for using the Ecotype, Soil Landscape, and Disturbance Landscape maps in conjunction with the ecotype classification are provided below.

1) Refer to the Ecotype, Soil Landscape, or Disturbance Landscape maps (Figures 18–20) and choose the map class of interest (e.g., Map Ecotype "Alpine Barrens and Partially Vegetated");
2) Refer to Table 31 and locate the map class of interest in the sorted list;
3) Follow the crosswalk in Table 31 to determine the abbreviated ecotype names (e.g., Alpine Rocky Barrens), Soil Landscape (e.g., Alpine Rocky Barrens and Sedge Meadows), and Disturbance Landscape (e.g., Mass Wasting and Landslide, Avalanche) class within which the Ecotype was aggregated for mapping.
4) Refer to the Ecotype descriptions (see Results: Ecotypes and Plant Associations, below), Soil Landscape descriptions (see Results: Soil Landscapes), and Tables 1, 5, 6–10, and 35 for information regarding general environment, vegetation, and soils of the ecotypes and soil landscapes identified in Step C, above.

Introduction

To obtain baseline condition information and an understanding of long-term trends relating to changes in landscape characteristics and processes in KEFJ, the National Park Service (NPS) has developed Inventory and Monitoring (I&M) programs for vegetation, terrestrial wildlife, fish, weather, and coastal and glacial processes. These programs help the NPS to detect natural changes in ecosystem structure and function; determine the role that human activities (e.g., invasive species, land disturbances) and large-scale forces (e.g., climate change, glacial dynamics, volcanism, wildfire) play in the changes observed; and inform predictions of future ecosystem trajectories. The I&M programs also help the NPS focus their efforts in managing and protecting park resources for the future. Soils provide fundamental controls on landscape and vegetation dynamics by greatly influencing plant community structure and composition, successional processes, food web dynamics, and a host of other ecosystem functions, and are therefore a key component of the I&M program. In support of these objectives, ABR, Inc.—Environmental Research & Services (ABR) worked with the NPS to initiate an Ecological Land Survey (ELS) designed to classify and map soils and vegetation in KEFJ.

The structure, function, and distribution of ecosystems are regulated largely along complex environmental gradients of energy, moisture, nutrients, and disturbance. These gradients are affected by many physical and biological landscape components, including climate, physiography, geomorphology, soils, hydrology, vegetation, and animals, which are referred to as state factors (Barnes et al. 1982, ECOMAP 1993, Bailey 1996). We used the state-factor approach (Jenny 1941, Van Cleve et al. 1990, Vitousek 1994, Bailey 1996, Ellert et al. 1997) to evaluate relationships among individual ecological components, and to classify and to map local-scale ecosystems (ecotypes) in KEFJ (Figure 1). We then integrated information from the ecotype classification with ancillary datasets to map soil landscapes across KEFJ.

An ecological land classification also involves organizing ecosystem components within a hierarchy of spatial and temporal scales (Wiken 1981, Allen and Starr 1982, Driscoll et al. 1984, O'Neil et al. 1986, Delcourt and Delcourt 1988, Klijn and Udo de Haes 1994, Forman 1995, Bailey 1996). Official systems for classifying ecosystems across scales have been developed for both the United States (ECOMAP 1993) and Canada (Wiken and Ironside 1977). Local-scale features (e.g., geomorphic units, vegetation) are nested hierarchically within landscape- and regional-scale components, (e.g., physiography and climate). At the global scale, climate—particularly temperature and precipitation—accounts for most of the variation and zonation of ecosystem structure and function (i.e., biomes) (Walter 1979, Vitousek 1994, Bailey 1998). Within a given climatic zone, landscape physiography (i.e., characteristic geologic substrate, topography, disturbance regime, and microclimate) controls the rates and spatial arrangements of geomorphic processes and energy flow. These processes result in the formation of geomorphic units with characteristic lithologies, soil textures, and surface forms, which in turn affect soil properties and the movement of water (Wahrhaftig 1965, Swanson et al. 1988, Bailey 1996). The movement of water through soil strongly influences both plant water balance and the availability of nutrients, and is therefore a critical factor in determining the distribution and characteristics of vegetation (Fitter and Hay 1987, Oberbauer et

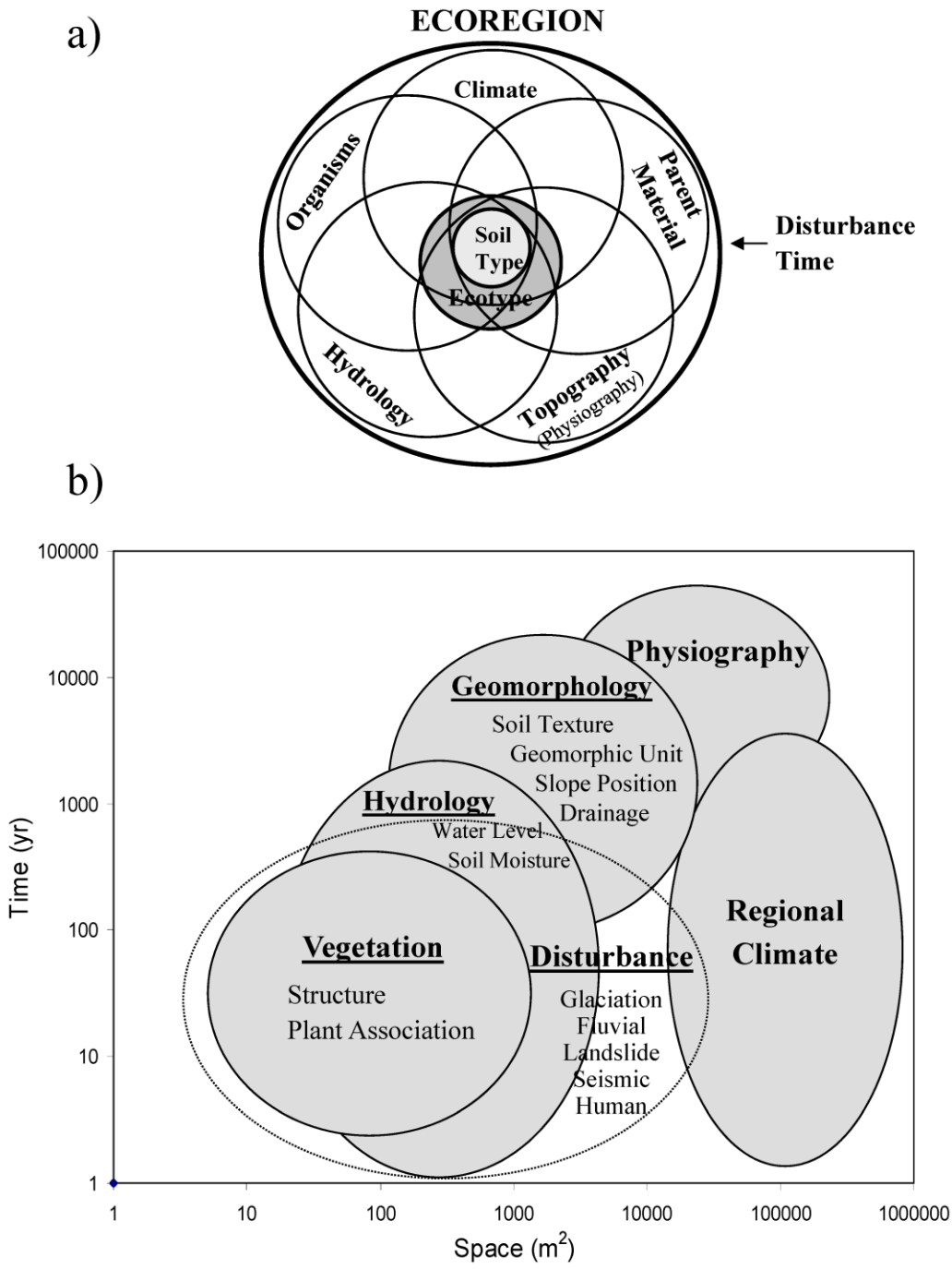


Figure 1. Interaction of interrelated state factors that control the structure and function of ecosystems (a) and the scale at which they operate (b).

al. 1989). Finally, vegetation provides habitat structure and energy that affect the distribution of many wildlife species. The interacting processes that operate across these ecosystem components at various spatio-temporal scales can also be sources of disturbance that greatly influence ecosystem development and succession (Watt 1947, Pickett et al. 1989, Walker and Walker 1991, Forman 1995).

To implement the ecological land classification, we used a hierarchical approach to mapping landscape-soil-vegetation relationships that incorporates readily mapped and/or modeled landscape features, including physiography, surface form (primarily slope characteristics), geomorphic unit, and vegetation. The hierarchical mapping approach, along with analysis of field data, allows for the classification and mapping of an enhanced set of ecotypes (local-scale ecosystems) and soil landscapes from existing land-cover maps. This integrated approach has several benefits. First, it incorporates the important effects of geomorphic processes on natural disturbance regimes (e.g., landslides, channel migration) and the flow of energy and material. Second, it captures the diversity of environmental characteristics within the classification. Finally, it uses a systematic approach to classify landscape features for applied analyses across a range of spatial scales (patch to local to regional). For example, we can overlay the footprint of areas that have been deglaciated at different points in time on the land-cover map of KEFJ prepared by the Alaska Natural Heritage Program (AKNHP) (Boggs et al. 2008) to delineate post-glacial seral communities that may have been previously unmapped. To demonstrate an application of this approach, we analyzed the relationships among soils and ecotypes, and used these relationships to develop maps of soil and disturbance landscapes as part of the KEFJ study effort. The maps can serve as a spatial database with differing ecological components to aid resource managers in evaluating ecological impacts and developing land management strategies appropriate for a diversity of landscape conditions. Additionally, the maps provide information that can support the design and implementation of a range of field- and remote-sensing based natural resources studies, as well as provide important context and a basis for stratification during subsequent data analysis. This report summarizes the results of an ELS to classify and map the ecosystems and soils of KEFJ.

Study Area

The ELS and mapping study area included the full legislative boundary of KEFJ, including private inholdings and Alaska state parklands, totaling 2,693 km^2 (Figure 2). This study area excluded marine waters but included inland and estuarine waterbodies. Nuka Island, which is currently administered by the State of Alaska as part of Kachemak Bay State Park, was included in the study area because it is within the legislative boundary of KEFJ. Neither we nor AKNHP collected field data on the island, however, and the most recent base imagery mosaic for KEFJ does not cover the island. Therefore, we caution that mapping for Nuka Island is somewhat provisional and may not capture the full range of existing vegetation and soil conditions.

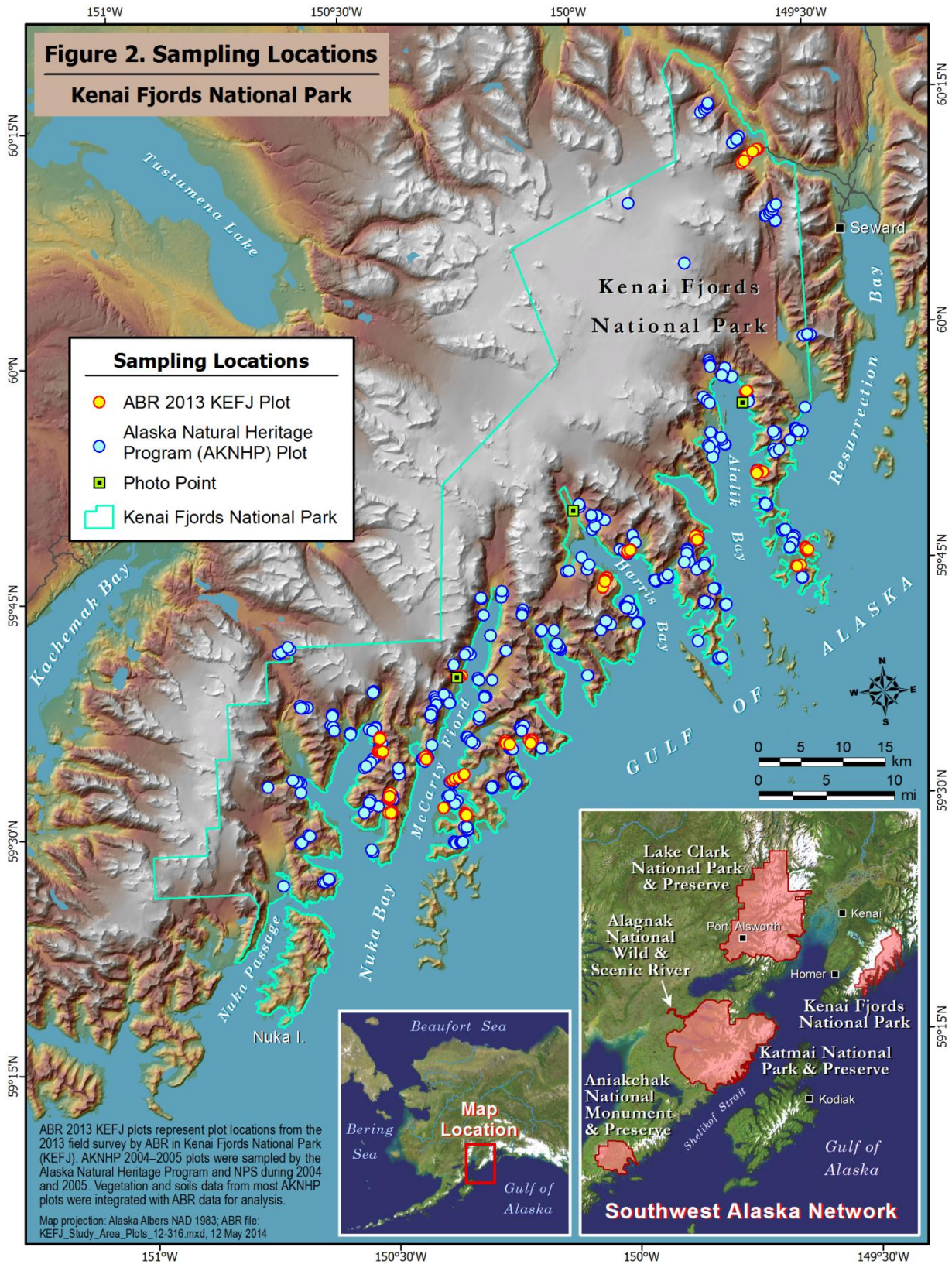


Figure 2. Sampling locations and study area boundary for the ecological land survey and soil landscapes mapping for Kenai Fjords National Park (KEFJ), southcentral Alaska, 2013.

Methods

Objectives

To classify and map ecosystems and soils of KEFJ, we first compiled existing field-based vegetation and soils data, as well as ancillary Geographic Information System (GIS) and remote sensing (RS) environmental datasets from a variety of sources to develop a preliminary spatially-explicit conceptual model of soils in KEFJ and identify data gaps. We then used the conceptual model to develop a stratified, gradient-oriented sampling scheme to collect field verification data in August 2013. We used our field verification data, in combination with the AKNHP KEFJ land-cover map and field data (Boggs et al. 2008) to create a soils map, following the soil landscape approach used by Jorgenson et al. for Wrangell-St. Elias National Park and Preserve (2008) and the Arctic Network of National Parks (2009). This approach included incorporating historical glacier extents, several additional existing GIS and RS data layers, rule-based modeling, and the analysis of geomorphology-soils-vegetation relationships. Specific objectives of this project were to:

1) Compile pre-existing data to prepare conceptual soils model and identify data gaps;
2) Conduct field inventories of vegetation, soils and environmental characteristics in KEFJ;
3) Input the comprehensive terrain-soil-vegetation dataset to classify ecotypes based on analysis of vegetation characteristics and relationships among ecosystem components;
4) Classify soil types based on field soil profile descriptions and laboratory analysis data;
5) Develop maps using an existing land-cover map, ancillary datasets, and rule-based modeling;
6) Apply Near Infrared (NIR) spectroscopic analyses to soil samples from KEFJ and add these spectra to the NIR spectroscopy library initiated for the SWAN parks in 2010; and
7) Synthesize the results of the ELS and mapping for map users.

Field Surveys

We sampled a total of 16 transects (toposequences) in coastal and inland portions of KEFJ during 18–30 August 2013. The marine research vessel (R/V) *Outer Limits* served as a mobile base camp to access the fjordlands of KEFJ; we used a rigid-hulled inflatable boat to land crews on the shoreline each day from the R/V. Additionally, field crews worked out of the town of Seward to access the northernmost part of the park in the vicinity of Exit Glacier. Sampling was conducted on foot along transects stratified within the major geologic units, physiographic units, and glacial histories that occur within the park. Transect locations were selected using a gradient-directed sampling scheme (Austin and Heyligers 1989) to gather the range of ecological conditions present within KEFJ, and to provide the spatially-related data needed to interpret ecosystem and soils development. Coastal transects also had to meet several logistical criteria associated with the use of boats for access. Transects had to begin near a landable beach, avoid dangerously steep terrain (slope angle >45 degrees), and had to be oriented so as to allow crews to return to a landable beach at the end of the field day. As a result of these constraints, our ability to access high-elevation environments was limited. We were able to supplement our field dataset, however, with vegetation data collected by AKNHP using very similar sampling protocols (see Boggs et al. 2008).

We collected data at 94 full plots ("t-plots") and 11 rapid verification plots ("v-plots") for a total of 105 plots along 16 transects. At t-plots we collected the complete suite of data variables described below. V-plots are designed to maximize efficiency in the field while simultaneously collecting the most salient variables required for ecotype classification. Thus at v-plots we collected a reduced set of data. In the following 2 paragraphs, data variables collected at both t- and v-plots are distinguished by bold font below the variable name.All plots types were circular in shape with an approximate radius of 10 m, and were situated entirely within a single distinct vegetation type or photo-signature identified on high-resolution imagery. The plot center was established intuitively by the field crew leader in a homogeneous patch of vegetation that was at least 1/2 ha in area, and away from transitional areas between distinct vegetation types (ecotones). All plot locations were marked on high-resolution satellite imagery, and geospatial coordinates and approximate elevations were recorded using Trimble GeoXT handheld, mapping-grade GPS receivers (accuracy ±5 m). After the field surveys, we differentially corrected the field-collected coordinates using the GPS receiver metadata, base station data from the Seward Continuously Operating Reference Station (CORS), and proprietary Trimble postprocessing routines. Most of the differentially corrected plot coordinates achieved horizontal accuracies of ±1 m or less. A series of digital photographs were taken at each plot, including representative landscape and ground cover views, as well as photos of the soil pit face.

Geologic and geomorphic variables recorded at each plot included **physiography**, **geomorphic unit**, **slope gradient**, **slope aspect**, **surface form**, and height of microrelief. Hydrologic variables measured included the **depth of surface water** (if present) above (+) or below (-) ground and the depth to saturated soil. Soil chemistry measurements included **soil pH**, **water pH** (if present), and **soil and water electrical conductivity** (EC). When free water was not present in the soil pit, EC and pH were measured from a saturated soil paste prepared using distilled water. Soil chemistry measurements (pH and EC) were made using Oakton portable meters that were calibrated daily with standard solutions.

Ground-surface variables included the percent cover of surface fragments (i.e., gravel-sized and larger material with particle size >2 mm) and percent cover of frost boils. **Disturbance class** was recorded to document recent (less than approximately 5 to 6 years old) disturbances. We sampled soils using a combination of the general physical and chemical soils data, rapid stratigraphic descriptions, complete stratigraphic descriptions, and laboratory analysis of soil samples (see below). Detailed soil stratigraphic descriptions are time consuming to complete and, given the short duration of the field trip, a hybrid approach was required. Using this approach allowed us to maximize efficiency in the field while capturing the maximum amount of soils information in a short amount of time. The general soils data variables were collected at all plots and were selected because they represent soils information that is important for soil taxonomy and classification of ecotypes but that is rapid to collect. For instance, the surface organic mat thickness combined with soil moisture and depth to saturated soil are important criteria for determining if a soil has a histic epipedon. Rapid soil stratigraphy descriptions provide more detail about a soil profile while allowing flexibility to complete some descriptors opportunistically. For instance, if a soil profile has a dark surface horizon that might meet the criteria for a mollic or umbric epipedon, which have specific color and base

saturation requirements, then soil color would be described and a soil sample analyzed for base saturation. Full soil stratigraphy descriptions provide the most detailed soils information but require the most time to complete. We focused on sampling complete soil stratigraphy for soils that were representative of common ecosystems in KEFJ.

General soils data were collected from shallow soil pits (40–50 cm deep) at all plots. Soil data collected at each plot include the **surface organic mat thickness**, the cumulative thickness of all organic horizons in the upper 40 cm, the cumulative thickness of loess (eolian silt) in the upper 40 cm, the cumulative thickness of volcanic ash in the upper 40 cm, depth of common roots, depth to low chroma matrix or depletion mottles, **soil moisture class**, soil drainage class, presence of cryoturbation, **coarse fragment depth** (i.e, the depth to the upper boundary of >15% by volume gravel-sized particles or larger), the depth to lithic (bedrock) contact, and the presence/absence of effervescence in any soil horizon using a dilute hydrochloric acid (HCl) solution. Soil texture was assessed by hand-texturing after using a 2 mm mesh sieve to remove coarse fragments. Finally, we assigned a **dominant texture** class to each soil profile. The dominant texture class is a single, simplified texture descriptor (e.g., loamy, sandy, ashy, organic) characterizing the dominant soil texture in the upper 40 cm of each soil profile for ecotype classification.

Complete soil stratigraphic descriptions were obtained at 15 plots. Soil descriptions followed standard Natural Resources Conservation Service (NRCS) protocols (USDA NRCS 2007), with the exception of the depth requirements of soil pits. Soils were classified to the subgroup level using the 11th edition of the *Keys to Soil Taxonomy* (Soil Survey Staff 2010). Soil pits for full stratigraphic descriptions were excavated to a depth of at least 40 cm, plus the cumulative thickness of surface and buried organic layers (see below) to a maximum depth of 60 cm. In stratified soils (e.g., floodplains), individual strata were grouped into broader horizons and denoted as such with notes describing the interbedded soil materials. Buried organic horizons ≥1 cm thick were designated as unique horizons, while those horizons <1 cm thick were grouped with adjacent mineral soils with descriptive notes included. A rapid soil stratigraphy was described in the field notes at an additional 43 plots, and included horizon top and bottom depths, texture, and field horizonation. Munsell® soil color was recorded opportunistically if required for classification to soil subgroup.

Soil samples were collected from 36 plots, 11 of which had a complete soil stratigraphy described. A total of 67 distinct soil horizons were sampled across all plots. Samples were collected from mineral horizons only. Samples were taken from a maximum of three mineral horizons within the upper 20 cm of mineral soil at each pit. Each sample consisted of approximately 250 g (9 oz) of sieved (particle size <2 mm), moist soil. Soil samples were collected within each horizon from the center ~10 cm for those horizons >10 cm thick, and from the entire horizon for those horizons ≤10 cm. If the lower boundary of the lowest horizon within the sampling zone extended below the sampling zone, only that portion of the horizon that was within the sampling zone was sampled. An exception to this sampling rule was for thin (0.5–1.5 cm) horizons of ash, which were sampled exclusively for volcanic glass estimates. Soils from each horizon were collected in quart size Ziploc™ freezer bags for transport to the laboratory. All remaining soil samples were returned to the NPS after analyses were completed.

Vegetation composition and structure data were collected semiquantitatively. At t-plots, we visually estimated the live cover of all vascular and non-vascular plants present. At v-plots we estimated cover for six to ten dominant (typically ≥5% cover) plant species. At t-plots we also estimated the percent cover of each plant growth form (e.g., needleleaf tree, tall shrub, low shrub, forb, moss, etc.), as well as the total cover of *Sphagnum* mosses, feathermosses, and combined *Cladonia*/*Cladina* lichen species. Cover was estimate to the nearest 1% for species or growth forms with <10% cover, and to the nearest 5% for species or growth forms with 10–100% cover. Isolated individuals or species with very low cover were assigned a "trace" cover value of 0.1%. The total cover of each plant growth form was estimated independently of the cover estimates for individual species; these cover estimates were cross-checked to ensure that the summed cover values for individual species within a growth form category was similar to the total cover estimated for that growth form. At both t- and v-plots a generalized vegetation structure category (e.g., low shrub, broadleaf forest) and Alaska Vegetation Classification (AVC) Level IV vegetation class (Viereck et al. 1992) was also recorded. Taxonomic nomenclature was based on Viereck and Little (2007) for trees and shrubs, and Hultén (1968) for all other vascular taxa. An exception is *Elymus mollis* in which we use the National Plants Database (USDA NRCS 2014) name *Leymus mollis*. Voucher specimens were collected for species that were difficult to identify in the field; these were subsequently identified by Carolyn Parker at the University of Alaska Museum of the North Herbarium (ALA) in Fairbanks, AK. Nomenclature for bryophytes (mosses and liverworts) and lichens followed the National Plants Database. Identification of bryophytes and lichens during field sampling was generally limited to dominant, readily-identified species. Dominant non-vascular species that we could not identify with confidence in the field were collected and sent to the Komarov Botanical Institute in St. Petersburg, Russia. Comprehensive lists of vascular and non-vascular plant species identified in KEFJ are shown in Appendices A and B, respectively. All plant specimens have been returned to the NPS.

Supplementary Field Data

We supplemented our field dataset with ground-based vegetation and soils data collected by AKNHP and NPS personnel. This dataset was used to support land-cover mapping for KEFJ and was collected using field sampling protocols and metrics that were comparable to our methods. A comprehensive description of AKNHP field methods can be found in Boggs et al. (2008).

The AKNHP field dataset was especially useful for alpine and subalpine plant communities, which were usually impractical for us to access on foot from coastal landing sites. The complete AKNHP dataset consists of 429 field plots, of which 381 plots had sufficient soils data for use in this study. The criteria used for including an AKNHP plot in our analysis were the presence of surface organic thickness and dominant soil texture information in the upper 40 cm of the soil profile. In addition to the above two soil variables, we also added several ABR data fields to the AKNHP dataset. These included AVC Level IV vegetation class, vegetation structure class (e.g., needleleaf forest, tall shrub, forb meadow), soil moisture class (e.g., moist, wet), presence/absence of lithic contact in the upper 50 cm of the soil profile, physiography class (e.g., Alpine), and surface geomorphic unit (e.g., hillside colluvium). We attributed those fields with our standard classification and coding system, such that data from AKNHP and ABR plots could be pooled for analysis. We used the vegetation species-cover data provided in the AKNHP dataset to assign AVC Level IV vegetation class and

vegetation structure class. Physiography and surface geomorphic unit were assigned using a combination of plot data review, and interpretation of high-resolution satellite imagery and other GIS data sources in the immediate vicinity of the field plot, such as digital elevation models (DEM) and historical glacier extents. We standardized the vegetation datasets by creating a crosswalk between the vascular plant taxonomy used in the AKNHP vegetation dataset (nomenclature from the National Plants Database [USDA NRCS 2014]), and the taxonomic names in our dataset. The standardized vegetation and site data for the 381 AKNHP plots were pooled with vegetation and soils data from the 105 ABR plots from August 2013, providing a total of 486 plots for the ecotype analysis and classification of soil landscapes.

Ecological Classification

We classified ecosystems at two levels. First, individual ecological components were classified and coded using standard classification systems developed for Alaska. Second, these ecological components were integrated to classify ecotypes (local-scale ecosystems) that best partitioned the range of variation for all of the measured biophysical components.

Ecological Components

Geomorphic units were classified according to a system based on landform-soil relationships for Alaska, originally developed by Kreig and Reger (1982) and the Alaska Division of Geological and Geophysical Survey (1983), and modified for this study. We emphasized materials near the surface (<2 m), because they have the greatest influence on ecological processes. Within the geomorphic classification, we also classified waterbodies based on their water depth, salinity, and genesis. Surface forms (macrotopography) were classified according to a system modified from that of Schoeneberger et al. (2002). Microtopography was classified according to the periglacial system of Washburn (1973). Vegetation was generally classified in the field to AVC Level IV vegetation class. Plant associations were classified following the "Key to Plant Associations" in Boggs et al. (2008), which was modified from a floristic survey by DeVelice et al. (1999) in the Chugach National Forest.

Ecotypes

We classified ecotypes using a three-step process: (1) the ecological components were individually classified for each field plot; (2) relationships along transects were examined to characterize trends across the landscape; and (3) contingency tables were used to identify the common relationships and central tendencies among ecological components. In developing the ecotype classes, we emphasized ecological characteristics (primarily geomorphology and vegetation structure) that can be interpreted from aerial photographs. We used a nomenclature for ecotypes similar to that used by Jorgenson et al. (2008, 2009) that describes ecological characteristics (e.g., ecoregion, physiography, soil temperature, soil chemistry, soil texture, moisture, vegetation structure, and dominant species) using a terminology that can be easily understood.

To reduce the number of ecotype classes, we aggregated the field data for individual ecological components (e.g., soil stratigraphy or vegetation composition) using a hierarchical approach. Geomorphic units were assigned to physiographic settings based on their erosional or depositional processes. Surface forms were aggregated into a reduced set of slope elements (e.g., crest, upper slope, lower slope, toe, and flat).

For vegetation, we used the structural levels of the AVC system (Viereck et al. 1992), because they are readily identifiable on aerial photographs and use a typical species common name (e.g., Sitka Spruce Forest). We used ordination and cluster analysis to aid in aggregating floristically-similar plots in the ecotype analysis. Unknown taxa, taxa identified to the genus level only, and species occurring at <1% cover in a plot were sequentially removed from the analysis. The data were then ingested in R, an open-source language and environment for statistical computing (R Development Core Team, 2013). We split the dataset by physiographic class and analyzed plots within each physiography separately. For each physiography group, vegetation was clustered using the fixed clustering algorithm Partitioning Around Medoids (PAM) (Kaufman and Rousseeuw 1990). A Bray/Curtis dissimilarity matrix (Bray and Curtis 1957) was used to develop preliminary groupings of similar vegetation. We applied non-metric multidimensional scaling (NMDS) (Shepard 1962a&b, Kruskal 1964a&b) to the dissimilarity matrix to chart the plots in species space to assess their dispersion and identify outliers. For the ecotype analysis, we used the ordination plotting functions provided in the *vegan* (Oksanen et al. 2013) and *rgl* (Adler et al. 2014) R libraries to plot the NMDS ordinations as 3-dimensional; dynamic plots that could be rotated graphically and viewed from multiple perspectives. For the report figures, we plotted the ordinations in 2 dimensions and displayed each ecotype using a unique symbol.

We grouped soils based on similarities in general texture class (e.g., rocky, loamy, organic); Table 1 provides descriptions of general texture classes used in the classification of ecotypes. We often grouped textural classes, because the vegetation associated with them was similar (e.g., Rocky-Sandy), and vegetation structures (e.g., open and closed shrub) were often grouped because their species composition and soils were similar. Additionally, soil subgroups were often combined because they featured soils with similar morphological and developmental characteristics and degree of soil development, with similar interpretation for use and management (e.g., Typic Humicryods and Typic Haplocryods).

Common relationships among ecosystem components were identified using contingency tables. The contingency tables sorted plots by physiography, soil texture, geomorphic unit, slope position, drainage, soil chemistry (pH and salinity), vegetation structure, and plant association. From these tables, common associations were identified and unusual associations either were combined with those having similar characteristics or excluded as atypical (outliers). Full ecotype names were then assigned based on the aggregated ecological components; e.g., Alpine Rocky-Loamy Moist Acidic Mountain Heather Dwarf Shrub. Finally, the full ecotype names were abbreviated (referred to hereafter as "ecotype") to emphasize the primary characteristics of the class and facilitate discussion (e.g., Alpine Rocky-Loamy Mountain Heather Dwarf Shrub).

Table 1. Description of ten generalized soil texture classes used in ecotype classification and mapping, including texture range and predominant soil orders.

Generalized texture class	Texture range (< 2 mm)	Description	Predominant Soil Order(s)
Loamy-organic	Silt loam to Sandy loam	Soils with moderately thick (10–40 cm) to thick (≥40 cm) surficial organics over loamy mineral soil, >15% rock fragments rare, bedrock contact very common within 50cm of the soil surface.	Histosols, Entisols (mostly Lithic soil Subgroups)
Loamy-Rocky	Silt loam to Sandy loam	In upper 40 cm, mineral textures predominantly loamy, >15% rock fragments (>2 mm) common, bedrock contact very common within 50cm of the soil surface.	Entisols (mostly Lithic soil Subgroups)
Organic-rich	Silt loam to Sandy loam	Soils with thick (≥40 cm) surficial organic horizons.	Histisols, Inceptisols, Entisols
Rocky	Sandy loam to Sand	In upper 40 cm, >15% rock fragments (>2 mm) very common, includes sandier soil textures.	Inceptisols and Entisols
Rocky-Loamy	Silt loam to Sandy loam	In upper 40 cm, >15% rock fragments (>2 mm) very common, mineral textures predominantly loamy, bedrock contact may occur within 50cm of soil surface.	Inceptisols and Entisols
Rocky-Loamy-Organic	Silt loam to Sandy loam	In upper 40 cm, >15% rock fragments (>2 mm) very common, mineral textures predominantly loamy, with moderately thick (10–40 cm) surficial organics.	Histisols, Spodosols, Inceptisols
Rocky-Organic	Sandy loam to Sand	In upper 40 cm, >15% rock fragments (>2 mm) very common, includes sandier soil textures, with moderately thick (10–40 cm) surficial organics.	Inceptisols and Entisols
Rocky-Sandy	Sandy loam to Sand	In upper 40 cm, >15% rock fragments (>2 mm) very common, includes sandier soil textures.	Entisols
Sandy-Loamy-Rocky	Silt loam to Sand	In upper 40 cm, a variety of textures ranging from loamy to sandy, >15% rock fragments (>2 mm) common.	Inceptisols and Entisols
Sandy-Rocky	Sandy loam to Sand	In upper 40 cm, mineral textures predominantly sandy, >15% rock fragments (>2 mm) common.	Entisols

Soils

Soil Chemical Analyses and Classification:

Soils samples were air-dried and sieved through a 2 mm USDA standardized sieve for separating the fine earth fraction (i.e., sand, silt, and clay). Priority for selecting plots for analysis was based on secondary diagnostic horizons requiring laboratory data for taxonomic classification, spatial distribution within KEFJ, and whether or not a full soil characterization had been completed for the plot.

An 84 g mixed soil sample was prepared for plots featuring 2 or more mineral soil horizons in the upper part of the soil profile. Mixed soil sample were prepared for each plot by combining a portion of each mineral soil horizon in the upper 20 cm of mineral soil based on a weighted average. The weighted averages were calculated based on the thickness of each horizon in the upper 20 cm of mineral soil. The use of mixed soil samples for the KEFJ laboratory analysis was consistent with how ABR has analyzed for andic, chemical and near infrared (NIR) soil properties in other national parks (Wells et. al. 2013), with one exception. In Lake Clark National Park (LACL), the weighted averages were calculated based on the upper 40cm of the mineral soil, as opposed to the upper 20 cm of mineral in KEFJ. This method alteration for KEFJ was necessary due to the prevalence of shallow bedrock-controlled and extremely rocky soils that often prevent sample collection at greater depths. For plots with one horizon in the upper 20 cm of the mineral soil the entire horizon was included in the laboratory analysis. The use of mixed samples allowed for continuity of maximum mineral depth analyzed across all plots. Thirty-eight soil samples, including 23 mixed samples and 15 un-mixed samples, from 34 plots were selected for laboratory analysis. Since no single lab performed all of the analyses required, we utilized three laboratories including the University of Alaska Anchorage (UAA), Palmer Research Center (Laurie Wilson, Lab Manager); Colorado State University (CSU) (James R. Self, Lab Manager); and Alaska Beget Consulting (ABC) (Dr. James Beget, UAF). Soils sent to more than one lab were split, with a portion of the sample sent to each lab.

Thirty-four samples were sent to UAA for analysis. UAA analyzed the soil samples for percent total carbon (C) and total nitrogen (N) using the combustion method with a LECO TruSpec CHN 1000 instrument. Particle size analysis was also conducted to determine the total percent of sand, silt and clay (Michaelson et al. 1992). The percent base saturation indicates what percent of the exchange sites are occupied by cations; percent base saturation can be calculated by dividing the milliequivalents of each cation from the CEC, by the total cation exchange capacity (CEC) (Michaelson et al. 1992). Additionally, the 34 samples sent to UAA were designated for Near Infrared (NIR) spectroscopy, a technique that measures the spectral signature of a material as defined by its reflectance and absorbance properties, as a function of wavelength (Shepard and Walsh 2002). The laboratory methods for NIR were consistent with prior analyses in LACL; a comprehensive description of laboratory methods can be found in Wells et. al. (2013). Lastly, ammonium oxalate extracts of Iron (Fe), Aluminum (Al) and Silicon (Si) and percent phosphate retention (New Zealand P Method) were run on 10 of the 34 samples to provide data for substantiating andic soil properties for those plots with an accumulation of volcanic ash in the soil profile (Michaelson et al. 1992).

CSU analyzed samples (see weighted average description) from 10 plots to identify soils with Andic soil properties. Percent water retention at 1,500 kPa was necessary for differentiating between the Andic and Vitric subgroups in NRCS soil taxonomy, 11th edition (Soil Survey Staff 2010). Vitric soils have a 1500 kPa Water Retention of less than 15% on air-dried samples and tend to have coarser, sandier ash grains and/or pumice within the soil profile.This data was acquired using Water Retention Methods described in Klute (1986). ABC analyzed 13 soil samples for percent volcanic glass. Volcanic glass content is the percent (by grain count) of glass, glass-coated mineral grains, glass aggregates, and glassy materials in the 0.02–2.0 mm fraction (Soil Survey Staff 2010). Dr. Beget utilized the dispersal procedure as a means to separate the coarse silt and sand fraction for analyses, described in Step 7.11 on p. 43 of the Soil Survey Laboratory Methods Manual, version 42 (USDA NRCS, 2004). After one hour of agitation, the fine silt and clay soil fraction that is in suspension is decanted from the beaker and the remaining sediment (0.02 to 2.0 mm) dried in an oven at 50° C. The *Keys to Soil Taxonomy* (Soil Survey Staff 2010) require that volcanic glass be quantified based off analysis of medium, coarse, and very coarse sand in order to classify Andic soil properties and Vitrandic subgroups. Wilson et. al (1999) suggests that a cost-effective alternative to analyzing each individual grain fraction for volcanic glass is analyzing a mixed 10 g sample with all three grain sizes at once. Beget analyzed the mixed 10 g sample (0.02–2.0 mm fraction) for tephra content by examining a grain mount thin section under a petrographic microscope. The percentage of glass in each sample was determined by identifying the volcanic material using optical mineralogical techniques, including the use of double light polarizing plates. Standard petrographic charts published by the American Geological Institute were then used to determine the percentage of volcanic particles present. The volcanic glass estimates are presented in Appendix C and the modal grain size and relevant notes are stored in the database deliverable.

We classified soils data for 105 ABR plots to the subgroup level according to NRCS soil taxonomy, 11th Edition (Soil Survey Staff 2010). In some instances the data needed for the taxonomic keys were missing for a given plot, in which case soil subgroups were assigned using the available field data (e.g., photos, rapid horizonation, colors, textures, pH, etc.) and by drawing inferences from the soil classifications from plots with full stratigraphic descriptions and soils laboratory data. For instance, Haplocryepts were differentiated from Dystrocryepts based on a cutpoint of 5.5 for the pH reaction, although the actual diagnostic criterion is 50% base saturation from laboratory analyses. Due to data limitations, we were unable to classify AKNHP plots to the subgroup level.

Rock Samples

Sixteen rock samples were collected across KEFJ for verification of bedrock geology (Appendix D). Basic lithologic descriptions were made by Dr. Rainer Newberry, Department of Geology and Geophysics, University of Alaska Fairbanks. The initial identification of the rock samples was by visual examination of freshly broken faces. Rock samples that could not be identified with reasonable certainty were slabbed, and a representative fraction of each sample was crushed and analyzed by pressed pellet x-ray florescence spectroscopy (XRF) for major oxides. Two rock samples identified by XRF as quartz syenite and quartz diorite were stained for feldspars in order to distinguish the feldspars from each other and from quartz, as a secondary check on the classification. All rock samples have been returned to NPS.

Ecosystem Components Synthesis

A primary objective of this study was to identify relationships between ecosystem components (state-factors), vegetation, soil properties, and disturbance regimes. The purpose of ecosystem components synthesis is to identify the biophysical processes that underlie these relationships, thereby providing organizing principles by which to map ecological themes of interest using available GIS and RS data (see next section). We accomplished this by integrating the multivariate datasets described above for vegetation and soils into contingency tables. This process identifies common biophysical processes, such as sedimentation and paludification, that govern the development of vegetation and soils across the landscape. Knowledge of these processes and the environments in which they function provides a basis for "crosswalking" each ecotype into classifications pertaining to other ecosystem properties, such as soils and disturbance landscapes. The contingency table analysis also helps to evaluate how reliably specific landform-vegetation-soils relationships can be used to inform landscape interpretation and mapping. During ecosystem components synthesis, we grouped field plots that shared similar vegetation (ecotypes) and/or soil properties (soil landscapes). We also identified "outlier" field plots with unique or unusual combinations of physiography, texture, geomorphology, drainage, soil chemistry, vegetation, or other properties, and iteratively removed them from the contingency tables. We excluded outlier plots, because our primary goal was to identify widespread landform-vegetation-soil relationships for which generalization is appropriate and useful, and that can be readily and consistently mapped. The outliers may represent ecotones, rare types, or locations where vegetation and soils have been affected by local disturbance or other historical factors that are not readily interpreted.

GIS and Remote Sensing Data Compilation

Overview

We evaluated available archives of GIS and RS data to support the description and mapping of soil landscapes within KEFJ. These ancillary datasets pertain to a range of biological, physical, and climatic parameters (Table 2). Available GIS and RS datasets were integrated with field-based data, and analyzed to characterize and map the major biophysical components of the landscape that influence soil development and the spatial distribution of soil groups. These biophysical components include ecoregion, physiography, geologic parent material, generalized soil texture, vegetation, disturbance processes, and glacial history. Unique combinations of these biophysical components were distinguished, and similar combinations aggregated together, using guidance from the field data and soil laboratory analysis to map the distribution of ecotypes and soil landscapes within KEFJ. We briefly describe each dataset below and summarize any GIS pre-processing steps that were executed to support analyses and mapping of soil landscapes.

Naming Conventions

Throughout this section, GIS and RS datasets are referred to in italics, using a descriptive name (e.g., *AKNHP Land-Cover Map*). Text references of the names of individual data fields within GIS and RS datasets are italicized and placed in quotation marks (e.g., *AKNHP Land-Cover Map "Ecosystem"* field). Text references to the attributes stored in fields are presented in plain text, and are quoted in the case of non-numeric fields; e.g., *AKNHP Land-Cover Map, "Ecosystem"* value of "Recently

Table 2. Pre-existing and derived GIS and remote-sensing data compiled for the ecological land survey and soils mapping for Kenai Fjords National Park, southcentral Alaska.

Dataset Description	Type	Path	Origin
GeoEye DEM, 30 m	Single band TIFF	PDS\DEM\GeoEye\KEFJ\kefj_a83	Pre-existing
GeoEye DEM Hillshade, 30 m	Single band TIFF	PDS\DEM\GeoEye\KEFJ\kefj_a83hs	Pre-existing
Historical Glacier Extent—LIA	Polygon feature class	PDS\Albers\parks\kefj\base\physical\statewid\maxglac	Pre-existing
Historical Glacier Extent—1951	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\Map_Base\KEFJ_GlacierExtent_1951	Pre-existing
Recent Glacier Extent—2005	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\Map_Base\KEFJ_GlacierExtent_2005	Pre-existing
AKNHP Land-Cover Map	Polygon feature class	PDS\Albers\parks\kefj\base\biologic\statewid\KEFJ_LC2008.gdb\KEFJ_LC2008	Pre-existing
AKNHP Field Plots	Point feature class	Deliverable\KEFJ_Soils_ELS.gdb\AKNHP_Plots\AKNHP_Plots	Derived
Geologic Map	Polygon feature class	PDS\Albers\parks\kefj\GRI\GeologyKEFJ.gdb	Pre-existing
IKONOS Mosaic—CIR	Layer file for symbolizing multiple 4-band TIFFs	Deliverable\Layer_Files\KEFJ_IKONOS_Mosaic_CIR.lyr	Pre-existing
IKONOS Mosaic—Natural Color	Layer file for symbolizing multiple 4-band TIFFs	Deliverable\Layer_Files\KEFJ_IKONOS_Mosaic_NaturalColor.lyr	Pre-existing
Airphoto Mosaic—2003–2004	Mosaic dataset	PDS\OrthoPh\OrthoPhotoKEFJ.gdb\CIR2003_2004	Pre-existing
Physiography	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\ABR_Mapping\KEFJ_ABR_Mapping	Derived
Map Ecotypes	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\ABR_Mapping\KEFJ_ABR_Mapping	Derived
Soil Landscapes	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\ABR_Mapping\KEFJ_ABR_Mapping	Derived
Disturbance Landscapes	Polygon feature class	Deliverable\KEFJ_Soils_ELS.gdb\ABR_Mapping\KEFJ_ABR_Mapping	Derived

Deglaciated Tall Shrub." We also reference datasets that we evaluated, but did not use; these datasets are referred to without italics.

The format and origin of datasets that we used to support the classification and mapping of ecosystem properties are provided in Table 2. Many of the ancillary datasets were obtained from the existing NPS data archive. Some datasets—particularly those that were modified, derived, or synthesized by us—are provided in the GIS deliverable package accompanying this report. The filename and file path of each dataset in the deliverable package is also provided in Table 2.

Existing GIS Data Sources

Digital Elevation Models (DEM)

We reviewed several available DEM datasets for KEFJ, including the *National Elevation Dataset* (2 arc-seconds), the *Shuttle Radar Topography Mission DEM* (2 arc-seconds), the *ASTER Global DEM* (version 2; 1 arc-second), and finally the *GeoEye DEM* (30 m) that was generated to support development of the IKONOS base imagery mosaic for the park. The high spatial resolution and comparative lack of artifacts of the *GeoEye DEM* made it superior for mapping and spatial analysis applications at KEFJ. We also used the *GeoEye DEM Hillshade*, which is a copy of the *GeoEye DEM* symbolized to represent 3-dimensional terrain in an intuitive way to facilitate interpretation and map production.

Recent and Historical Glacier Extents

Spatial data pertaining to the modern and historical extent of glaciers were a critical input due to the widespread extent of glaciers and the central role they play in landscape development in KEFJ. The most recent glacier extent data come from the Global Land Ice Measurement from Space (GLIMS) Glacier Database. The GLIMS Glacier Database is a global-scale product that is hosted and periodically updated by the National Snow and Ice Data Center (GLIMS and NSIDC 2005). GLIMS glacier extent is based on spectral analysis of recent Landsat Enhanced Thematic Mapper (ETM+) imagery acquired during late summer at 30-m resolution. Visual comparison of the GLIMS data with the *IKONOS Mosaic, Natural Color* (see below) generally indicated good agreement in apparent glacier extent, except that the GLIMS dataset misidentified most nunataks as glacier. To remedy this deficiency, we evaluated a glacier extent map for 2005 *(Recent Glacier Extent—2005)* produced using a combination of automated and manual digitization techniques using the IKONOS KEFJ base imagery mosaic (Arendt et al. 2014). Although glacial extents are mapped using imagery that is older than that used in the GLIMS database, review of *Recent Glacier Extent—2005* indicates very good agreement between mapped and apparent ice extent throughout the entire study area. We concluded that the *Recent Glacier Extent—2005* best represents the modern-day extent of glaciers for analysis and mapping applications.

GIS datasets are also available that depict glacier extents for several time periods in the past: 1986, 1974, circa 1951, and the Little Ice Age (LIA) maximum glacier extent (circa 1850). The *Historical Glacier Extent—1951* was developed by USGS cartographers to depict glaciers in USGS topographic maps, using visual interpretation of airphotos acquired 1950–1951. The *Historical Glacier Extent—LIA* portrays the estimated maximum extent of glacial ice at the end of the LIA (circa 1850). LIA

maximum extents were estimated using a variety of field-collected, cartographic, and remotely-sensed data, such as tree-ring chronologies, fjord bathymetry (i.e., the location of the submerged terminal moraines of large tidewater glaciers), and photo-interpretation of terminal moraine locations. Unlike the glacier extent data layers described above, the LIA extents do not represent a single snapshot in time, but rather the maximum extent reached by individual glaciers during the latter part of the LIA. We did not make systematic use of the 1986 and 1974 extents in this study because our interpretation of Glacial physiography included extensive areas that became deglaciated well prior to those years.

Land Cover

Three land-cover maps exist for KEFJ. The *Ducks Unlimited Land-Cover Map* was developed in 1999 by Ducks Unlimited (DU) and the Bureau of Land Management (BLM) (Ducks Unlimited and Spatial Solutions 1999). This map was produced using a spectral classification of Landsat imagery (30-m resolution) informed by field data, which partitioned individual pixels into land-cover classes according to their spectral characteristics. The *NLCD Land-Cover Map* comes from the National Land Cover Database (NLCD), which provides a land-cover map for the entire state of Alaska. Like the preceding land-cover map, the *NLCD Land-Cover Map* was produced using 30-m resolution Landsat base imagery, but it groups land-cover types into far fewer, more general categories that could be applied over a statewide mapping domain. Finally, the *AKNHP Land-Cover Map* was completed in 2008 by the Alaska Natural Heritage Program (AKNHP) and NPS (Boggs et al. 2008). Unlike the preceding land-cover maps, the *AKNHP Land-Cover Map* was produced by visual interpretation and on-screen digitizing over a high-resolution ortho-mosaic assembled from vertical aerial photographs acquired in 2004–2005. Mapping was informed by an extensive field dataset *(AKNHP Field Plots)* that was collected according to field protocols similar to our own.

We chose to use the *AKNHP Land-Cover Map* to support our classification and mapping of ecotypes and soil landscapes for several reasons. First, the AKNHP map was based on more recent imagery than the other maps and consequently, more accurately captures modern-day vegetation in the highly dynamic, recently-deglaciated landscapes of KEFJ. Second, the AKNHP map applied a polygon-based, rather than pixel-based mapping approach so map unit boundaries follow the edges of individual land-cover patches, rather than pixel boundaries. Third, the map units (polygons) in the AKNHP map are coded according to two useful classification systems, "*Land Cover*" and "*Ecosystem."* The "*Land Cover*" classification emphasizes vegetation structural attributes that are readily interpreted in terms of field vegetation data and photo-signatures on high-resolution imagery. Many polygons in the original *AKNHP Land-Cover Map* were assigned both a primary and secondary land-cover class to reflect combinations of land-cover classes; we only used the primary land-cover class because the widespread, recurring land-cover mosaics in KEFJ were already identified as stand-alone classes within the land-cover classification (e.g., "Closed Tall Alder-Mesic Herbaceous Mosaic"). The "*Ecosystem"* classification partitions the landscape largely according to geomorphic environments (e.g., "Floodplain," "Active Colluvial Slopes," "Cobble Beach and Beach Meadow") and the full range of successional stages that occur within them. As a result, this multivariate classification is more readily applied to the mapping of soil landscapes than a land-cover

map alone. Finally, the AKNHP map was informed by data from field plots, which were readily pooled and analyzed with our own field plot data collected in 2013.

Geologic Map

The distribution and characteristics of geologic parent materials are a key factor influencing soil properties and development. We applied the Digital Geologic Map of KEFJ and Vicinity, Alaska *(Bedrock Geology)*, which synthesizes a variety of unpublished datasets and pre-existing geologic maps as part of the Geologic Resources Inventory (GRI) program. Geologic mapping for KEFJ primarily come from Wilson et al. (2008) and Wilson and Hults (2012).

IKONOS Mosaic

NPS provided a base imagery mosaic for KEFJ that was developed using ortho-rectified, high-resolution imagery acquired by the IKONOS commercial satellite in 2005. The mosaic was based on pan-sharpened, dynamic-range-adjusted imagery with a pixel size of 1 m. Four bands (R/G/B/NIR) were provided; these bands were used to produce natural color *(IKONOS Mosaic—Natural Color)* and color-infrared *(IKONOS Mosaic—CIR)* imagery products to support a variety of landscape interpretation and mapping tasks. Although the vast majority of the map products presented in this report are derived from the *AKNHP Land-Cover Map* map (which utilized 2003–2004 airphotos; see below), we used the IKONOS mosaic as a basemap for additional linework in some coastal and recently-deglaciated areas that were not accurately represented in the AKNHP map. The IKONOS mosaic covered all of the study area, except Nuka Island.

2003–2004 Aerial Orthophotos

The *AKNHP Land-Cover Map* was produced by delineating polygons by hand over an ortho-photo mosaic composed of aerial photographs acquired in 2003–2004. This mosaic included Nuka Island, which was omitted from the IKONOS base mosaic. We referred to the 2003–2004 imagery *(Airphoto Mosaic—2003–2004)* for interpretation and mapping tasks for Nuka Island, as well as other areas of KEFJ that were obscured by cloud in the IKONOS base mosaic.

GIS Modeling and Ecosystem Component Synthesis

Physiography

We delineated the landscape into nine physiographic units that partition the key geomorphic processes, environmental gradients, and landscape history attributes that control the development of landforms, vegetation, and soils across KEFJ. We developed a physiography map for KEFJ by assigning each map polygon in the *AKNHP Land-Cover Map* to a physiographic class. Many polygons were readily assigned to physiographic units based on their "*Ecosystem"* or *"Land-cover Class"* attributes alone. For example, the "*Ecosystem"* class "Sandy Beach and Meadow" obviously corresponded to Coastal physiography, and the *"Land-cover Class"* of "Dwarf Shrub" could be automatically assigned to Alpine physiography. For AKNHP map classes with wide spatial and elevational distributions (primarily low and tall shrub classes), and to delineate the Glacial physiography type—which is contingent on spatial location relative to recent and historical glacier extents—we assigned physiographic units using criteria based on supplementary GIS data sources related to topography and glacial history. For each polygon, we extracted elevation summary

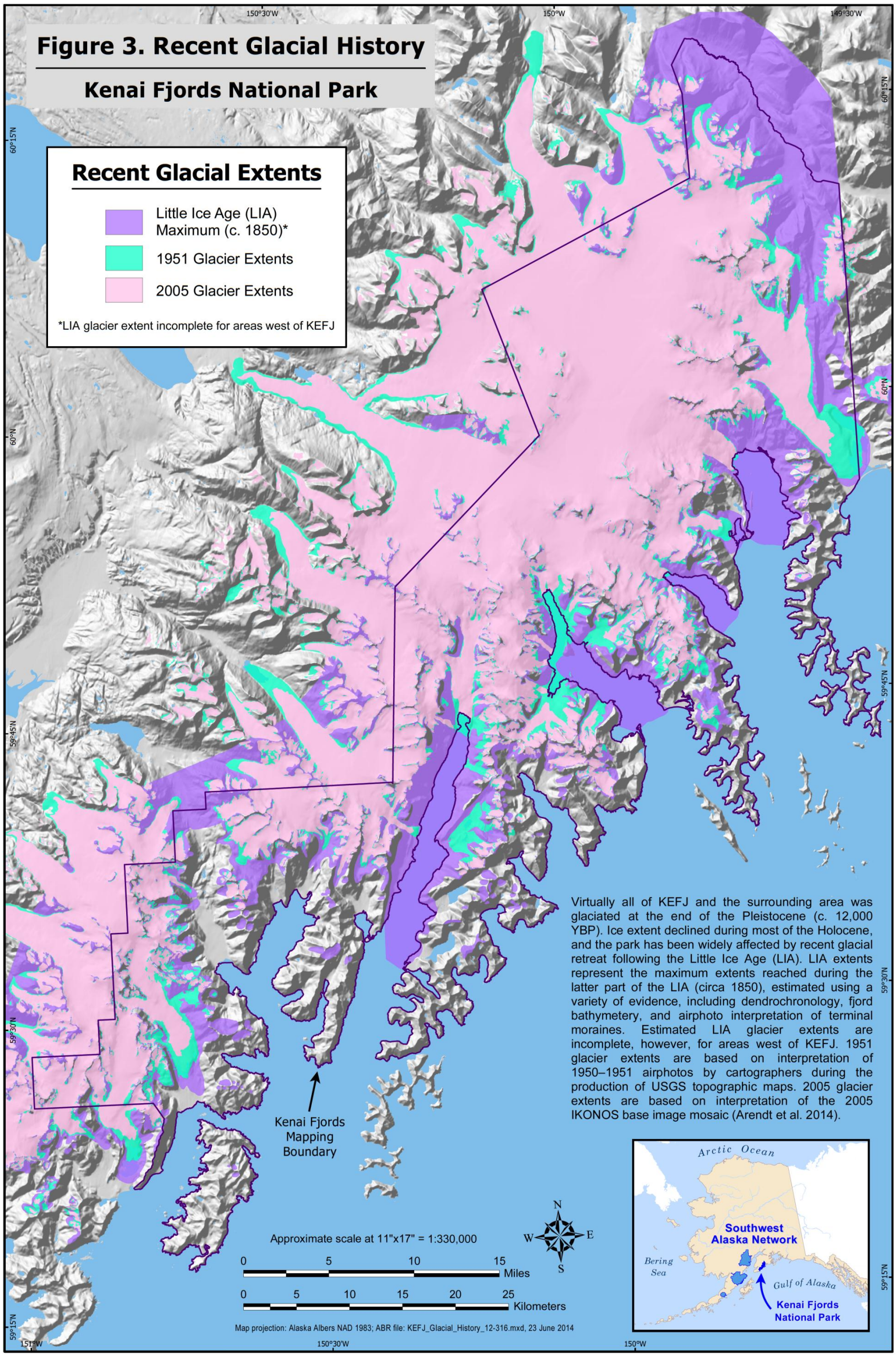


Figure 3. Map of recent glacial history for Kenai Fjords National Park, southcentral Alaska.

statistics (mean, minimum and maximum) from the *GeoEye DEM*; these statistics were primarily used to distinguish Upland, Subalpine, and Alpine physiographies. Additionally, we calculated the percentage of each polygon that intersected the *Historical Glacier Extent—1951* and *Historical Glacier Extent—LIA* to guide the delineation of Glacial physiography.

Below we present brief definitions of the physiographic units and the criteria used to assign AKNHP map polygons. Because some map polygons could potentially be assigned to more than one physiographic class (e.g., estuaries could belong to either Coastal or Riverine physiography), we assigned physiography classes in the order presented below. Once a polygon had been assigned to a physiographic class, it was not reassigned to another class in a subsequent step.

Glacier

The modern extent of glaciers and perennial snowfields was determined using the *Recent Glacier Extent—2005*, which is based on the same IKONOS base imagery mosaic that we used for landscape interpretation and mapping (Figure 3). Although the *AKNHP Land-Cover Map* distinguished "Snow and Ice" polygons, these polygons were based on visual interpretation of CIR airphoto ortho-mosaics from 2002–2003, which included extensive areas of deep shadow, seasonal snow cover, and high-elevation barrens adjacent to glaciers and the Harding Icefield. We therefore clipped non-glaciated areas (i.e., that did not overlap the *Recent Glacier Extent—2005*) and assigned the resultant polygons to the appropriate physiography in subsequent steps.

Coastal

The Coastal physiographic unit includes intertidal and supratidal substrates that are regularly influenced by salt water, such as beaches, tidal flats, spits, and lagoons. The Coastal physiographic unit was primarily assigned according to the "Ecosystem" and "Land-cover Class" of each *AKNHP Land-Cover Map* polygon. The classification system used in the *AKNHP Land-Cover Map* includes several classes that are defined by marine and coastal processes and/or halophytic vegetation, and are diagnostic of Coastal physiography. However, some *AKNHP Land-Cover Map* classes mapped near the coast were ambiguous with respect to the degree of saltwater influence. For example, the "Coastal Cliff" ecosystem primarily encompasses substrates that are well above the influence of salt water and salt spray. We therefore visually reviewed instances of the Coastal physiography class, and reassigned polygons that extended well above sea level as appropriate (usually to Upland).

Riverine

The Riverine physiographic unit encompasses channels, islands, and riverbanks (floodplains) that are regularly flooded (flood return period ~100 years) under the modern flow regime. Most watersheds in KEFJ are small, so Riverine areas are limited in extent and mostly correspond to small meandering streams and the glaciofluvial outwash plains below receding, non-tidewater glaciers. The Riverine physiographic unit does not include abandoned floodplain surfaces that are no longer regularly flooded. We identified potential Riverine polygons by recoding polygons that belonged to the "Floodplain" or "Alpine Floodplain" ecosystems of the *AKNHP Land-Cover Map.* We then reviewed "Floodplain" polygons in which the "*Land-cover Class*" corresponded to relatively mature land-cover classes (e.g., coniferous forest) that are indicative of abandoned portions of floodplains. We recoded these polygons as appropriate, generally to Upland or Lowland.

Glacial

Glacial physiography refers to recently-deglaciated areas with very young, poorly-developed soils and early-successional vegetation. We delineated the Glacial class using multiple lines of evidence, including field data and maps of historical glacier extent (Figure 3). We calculated the percentage the area of each *AKNHP Land-Cover Map* polygon that intersected the *Historical Glacier Extent—1951* and *Historical Glacier Extent—LIA*. Map polygons that lie entirely within the LIA Maximum extent and that did not belong to the physiographic units listed above were flagged as candidates for Glacial physiography. We automatically assigned polygons that intersected the 1951 glacier extent to Glacial physiography, except for large polygons that barely intersected the 1951 glacier extent, as well as smaller polygons that represented areas of late-successional vegetation (e.g., "Sitka Spruce" ecosystem and related land-cover classes). We reviewed Glacial candidate polygons in the vicinity of large valley glaciers that have a recent history of dramatic retreat, such as McCarty and Northwestern Fjords. Fjordlands in these areas tend to be dominated by intensely scoured, bedrock-dominated slopes. We identified the uppermost occurrences of coniferous forest cover and mapped as Glacial those candidate polygons that occur up-valley. We also reviewed nunataks and other high-elevation polygons that had small areas of overlap with historical glacier extents and assigned them to Alpine or Subalpine physiography as described below.

Alpine

The Alpine class encompasses high-elevation, non-glaciated mountain terrain that is dominated by alpine tundra and barrens. Trees and tall shrubs are absent, plant productivity is low, and soil development is largely linked to hillslope and periglacial (freeze-thaw) processes. Most Alpine areas were delineated based on "*Ecosystem*" and *"Land-cover Class"* attributes of the map polygons. For example, the AKNHP classes "High Alpine Herbaceous" and "Dwarf Shrub" were diagnostic for Alpine physiography. For problematic land-cover classes that also occurred below treeline (e.g., Mesic Herbaceous), we distinguished Alpine physiography based on elevation thresholds that were developed to differentiate Alpine, Subalpine, and Upland physiographic classes. We modeled elevation thresholds by first generating 200 random points within polygons that belonged to the problematic land-cover classes. We then photo-interpreted the Upland/Subalpine and Subalpine/Alpine breakpoints up- and downslope of the random points, and extracted the elevations of these breakpoints using the *GeoEye DEM*. After discarding outliers, we calculated the mean elevation of Upland/Subalpine/Alpine breaks, and compared these means to the mean elevation of the unclassified map polygons. Polygons with a mean elevation above 503 m (1,650 ft) were assigned to Alpine. We visually reviewed large map polygons with mean elevation >503 m, but that extended to much lower elevations and assigned them to Alpine or Subalpine, based on the dominant vegetation.

Subalpine

Subalpine physiography corresponds to montane areas that lie above treeline but support tall shrublands within a complex mosaic that includes patches of herbaceous meadow, dwarf shrub tundra, barrens, and late-lying snowbeds. Isolated patches of trees, commonly with dwarf, "krumholz" growth form may be present. The redistribution of snow by wind and avalanche is a key process in the Subalpine belt that results in high spatial variability in the depth and persistence of the

snowpack, local disturbance regime, the physiognomy of vegetation, and therefore the characteristics and evolution of soils. Polygons belonging to a few *"Ecosystem"* and *"Land-cover"* classes were assigned to Subalpine physiography regardless of their elevation (e.g., "Krumholz). For the most part, however, delineation of Subalpine physiography was difficult because many of the common *"Ecosystem"* and *"Land-cover"* classes also occur above or below the subalpine belt. We therefore developed elevation thresholds using the methods described above. Polygons with a mean elevation below 503 m (1,650 ft), but above 238 m (780 ft) were flagged as candidates for Subalpine. Candidate polygons that encompassed forest (non-Krumholz) vegetation were assigned to Upland regardless of their elevation (see below). Additionally, we visually reviewed large polygons that extended well below 238 m and recoded them according to the dominant vegetation.

Upland

The Upland unit corresponds to low-elevation hillslopes that are above the influence of saltwater intrusion and spray, and are below the elevational limit of forest development. All unclassified map polygons belonging to forested (non-Krumholz) Ecosystems and Land-cover Classes were assigned to Upland. Additionally, other land-cover classes were assigned to Upland according to the elevation thresholds described above.

Lowland

Lowland physiography pertains to topographically flat (not necessarily low-elevation) areas that are not associated with modern floodplains or recently-drained lake basins. Lowland soils are generally poorly-drained, organic-rich, and tend to support hydrophytic vegetation. The extent of Lowlands is very limited in KEFJ due to the rugged topography and very recent glacial history. We visually reviewed the physiography map in areas of flat terrain, almost exclusively along larger riparian corridors such as the Resurrection River. Most Lowland polygons corresponded to old portions of floodplains with mature vegetation (e.g., Sitka spruce), in which there is no evidence of recent sedimentation or other fluvial processes.

Lacustrine

Lacustrine areas correspond to freshwater lakes and ponds, shorelines, and recently-drained lake basins (~ <50 years). In KEFJ, Lacustrine areas range from large, deepwater lakes (e.g., Desire Lake) to small kettle ponds. Most Lacustrine polygons were identified based on their *"Ecosystem"* and *"Land-cover Class"* attributes. In a few cases, we also edited the original linework in the *AKNHP Land-Cover Map* to delineate lakes and ponds that were not visible (shadowed or ice-covered) in the airphotos used by AKNHP in the original mapping. We then coded as Glacial Lake, all lakes and ponds that occurred adjacent to glaciers. Finally, we distinguished the remaining lacustrine waterbodies as either Lowland Lake or Alpine Lake based on elevation. All waterbodies that were above 238 m elevation, or that intersected Subalpine or Alpine physiography, were coded as Alpine Lake. Low-elevation waterbodies were coded as Lowland Lake.

Bedrock Chemistry

The chemistry of both dominant bedrock types in KEFJ (granitic and metasedimentary) is acidic to circumacidic. Bedrock chemistry was therefore not a primary driver of soil variability, so we did not incorporate a bedrock chemistry layer into the ecotype and soils landscape models.

Generalized Soil Texture

We did not develop a generalized soil texture layer for use in the ecotype and soils landscape models because of the relatively simple bedrock geology of KEFJ (two major bedrock types). In addition, soils are dominated by very young (recently-deglaciated) soils comprising coarse fragments and/or bedrock in most of the park.

Land-Cover/Ecosystem/Physiography/Ecotype Crosswalk

After completing the ecotype classification, we created a table of all unique combinations of physiography, and *"Land-Cover Class*" and *"Ecosystem*" values assigned to polygons in the original *AKNHP Land-Cover Map*. After referring to the keys and descriptions of land-cover classes in Boggs et al. (2008), and the plant associations (DeVelice et al. 1999) with which they were affiliated, we then assigned each of the unique combinations to ecotype(s) (Appendix E). Combinations of physiography, *"Land-Cover Class*" and *"Ecosystem,*" could often be assigned to a single ecotype because many of the classes developed by AKNHP and ABR emphasize the species and growth form of the dominant, canopy-forming vegetation. However, some AKNHP land-cover classes, such as "Mesic Herbaceous," were associated with multiple ecotypes and required aggregating similar ecotypes into map ecotypes (see below). The process of identifying unique combinations of *"Land-Cover Class*" and *"Ecosystem*" also helped to reveal unusual combinations that reflected errors in the digitizing of the *AKNHP Land-Cover Map* from the original, hand-drawn mapping on mylar prints.

Map Ecotypes

Polygons in the *AKNHP Land-Cover Map* were delineated based on interpreting photo-signatures in the high-resolution aerial photography. These photo-signatures are produced almost entirely by the structure (growth-form and density) of the uppermost, canopy-forming layer of vegetation; attributes that are seen from the birds-eye view of a passing aircraft or satellite. As a result, ecotypes with similar vegetation structure (e.g., dwarf shrub) often share virtually identical photo-signatures but have a different species composition (e.g., dwarf blueberry versus crowberry). To maintain distinctions between ecotypes with differences in soils, vegetation, and/or disturbance regime and to reduce the total number of ecotype classes mapped, we aggregated ecotypes with similar vegetation structure into a reduced set of map ecotypes, which could be readily crosswalked to the *AKNHP Land-Cover Map* polygons.

Soil Landscapes

Soil-landscape associations, hereafter "soil landscapes," were identified to characterize and map landscape-scale relationships between soil type, physiography, and vegetation class (the latter usually related to one another via a successional sequence). Map ecotypes were aggregated into a reduced set of soil landscape classes to achieve the level of generalization appropriate for mapping across the entire study domain. Aggregating ecotypes to map ecotypes emphasized similarities in vegetation structure (e.g., Subalpine Mesic Herbaceous Meadow), but the focus of the soil landscape aggregation was on soils. Map ecotypes represent similar vegetation types with potentially different soil textures, whereas soil landscapes represent aggregations of similar soil types. The soil landscapes were developed by cross-tabulating ecotypes and soil subgroups within contingency tables to identify associations of similar ecotypes with similar soil subgroups. The resulting associations were named

based on physiography, soil texture, and the structure of canopy-forming vegetation (e.g., forest, tall shrub, dwarf shrub).

We did not use the standard NRCS term "soil association," because that term is defined to include very different soils that are associated with each other along toposequences that repeat across the landscape. In addition, soil associations are recognized in soil mapping to be large map units with aggregated soil types. In this study, the term "soil landscape" refers to closely related soil types, and the mapping is based on patch-scale polygons.

Disturbance Landscapes

Disturbance processes play a central role in the genesis and evolution of landforms, vegetation, and soils. Important disturbance processes in KEFJ, such as glaciation, landslide, and windthrow, operate across a range of spatial scales, frequencies, and intensities. Nonetheless, many of the map ecotypes and soil landscapes can be grouped according to common disturbance regimes. Disturbance regime-landscape associations, or Disturbance Landscapes, were developed to characterize and map broad-scale relationships among soil type, physiography, vegetation, and the natural disturbance processes with which they are associated. The resulting associations were named after the suite of processes and disturbance agents identified for each aggregated ecotype.

Results

Ecotypes and Plant Associations

We identified a total of 49 ecotypes in KEFJ based on analysis of field data obtained by AKNHP in 2004–2005 and ABR in 2013. Five additional ecotypes were identified based on qualitative field observations (no data): Human-modified Barrens, Alpine Lake, Glacial Lake, River, and Riverine Sandy-Loamy-Rocky Black Cottonwood Forest. The spatial distribution, typical landscape position and geomorphic affinities, plant associations, dominant soil texture and chemistry, soil hydrologic characteristics, and soil subgroups of each ecotype are summarized in the Ecotype Descriptions section below. We also included a key to ecotypes to aid in the identification of ecotypes in the field.

A total of 87 previously described plant associations and 7 undefined vegetation types were represented within the 49 ecotypes classified from the field data (Table 3). Plant associations for KEFJ were primarily based on floristic analysis of vegetation in the Chugach National Forest (NF) by DeVelice et al. (1999). These plant associations were subsequently modified by Boggs et al. (2008) as part of the AKNHP land-cover mapping effort for KEFJ; these modifications primarily entailed the addition of new associations. Because we mapped ecotypes across KEFJ using the AKNHP land-cover map, we relied on the plant associations used by Boggs et al. (2008) to summarize the floristic attributes of the ecotypes.

Twenty-seven ecotypes were associated with one or two plant associations, and 59 plant associations described only one ecotype. These primarily represent narrowly-defined ecotypes (based on vegetation) with low within-ecotype variability in species composition, and plant associations that correspond to unique environmental conditions. For instance, the ecotype Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat and the plant association Goose Tongue represent a unique combination of ecotype and plant association. This ecotype occurs on tidal flats and is dominainted by *Plantago maritima* and very few other species. Twenty-two ecotypes had three or more plant associations (Table 3). These include ecotypes that are more broadly defined (based on vegetation) with higher within ecotype variability in species composition. These ecotypes were often aggregated at the vegetation series level and so are similar based on the dominant species but have variable understory species composition. An example is the ecotype Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub, which is associated with 5 plant associations, including Crowberry, Crowberry-Alpine Bearberry, Crowberry-Bog Blueberry, Crowberry-Bog Blueberry/Deer Cabbage, and Crowberry-Bog Blueberry/Tufted Bulrush. These 5 plant associations have a common dominant species, *Empetrum nigrum*, and the consistent presence of *Vaccinium uliginosum*, but have otherwise unique species compositions. Additionally, 35 plant associations described more than one ecotype. This was primarily related to plant associations that occur in a variety of environments dominated by species with high environmental plasticity. For example, the plant association Sitka Alder-Salmonberry/Lady Fern occurs in 4 ecotypes representing 4 physiography classes, including Glacial Rocky Alder-Willow Tall Shrub, Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub, Subalpine Rocky Alder Tall Shrub, and Upland Rocky-Organic Alder Tall Shrub. This plant association is co-dominated by *Alnus sinuata* and *Rubus spectabilitis,* two species that tolerate a diverse set of environmental conditions and disturbance processes.

Table 3. Crosswalk of abbreviated ecotype names with full ecotype name, plant communities, and Alaska Vegetation Classification level IV vegetation classes in Kenai Fjords National Park, southcentral Alaska. Plant community classification follows DeVelice et al. (1999) and Boggs et al. (2008). Vegetation classes follow Viereck et al. (1992).

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Alpine Lake	Alpine Lake	(none)	(none)
Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Loamy-Rocky Acidic Crowberry-Blueberry Dwarf Shrub	Crowberry, Crowberry-Alpine Bearberry, Crowberry-Bog Blueberry, Crowberry-Bog Blueberry/Deer Cabbage, Crowberry-Bog Blueberry/Tufted Bulrush	Crowberry Dwarf Shrub Tundra, Vaccinium Dwarf Shrub Tundra
Alpine Rocky Barrens	Alpine Rocky Dry Barrens and Partially Vegetated	Sparse	Alpine Herbs, Ericaceous–Lichen Dwarf Shrub Tundra, Partially Vegetated
Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Acidic Luetkea Dwarf Shrub	Arctic Willow/undefined, Nootka Lupine/Luetkea	Luetkea Dwarf Shrub Tundra, Alpine Herbs, Mixed Herbs
Alpine Rocky Moist Sedge Meadow	Alpine Rocky Moist Acidic Sedge Meadow	Small awned Sedge, undefined Graminoid Herbaceous type	Moist Sedge Meadow Tundra, Moist Sedge–Herb Meadow Tundra, Alpine Herbs
Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Steller's Cassiope-Luetkea	Cassiope Dwarf Shrub Tundra, Ericaceous Dwarf Shrub Tundra, Luetkea Dwarf Shrub Tundra, Open Low Alder
Alpine Rocky-Loamy Mountain Heather Dwarf Shrub	Alpine Rocky-Loamy Moist Acidic Mountain Heather Dwarf Shrub	Aleutian Mountain Heather/Deer Cabbage, Aleutian Mountain Heather/undefined, Aleutian Mountain Heather-Steller's Cassiope	Luetkea Dwarf Shrub Tundra, Mountain-heath Dwarf Shrub Tundra, Cassiope Dwarf Shrub Tundra, Crowberry Dwarf Shrub Tundra, Ericaceous Dwarf Shrub Tundra
Coastal Brackish Water	Coastal Brackish Water	(none)	(none)
Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Moist Circumneutral Barrens and Partially Vegetated	Dwarf Alkaligrass, Seaside Sandplant, Sparse, unvegetated	Barren, Partially Vegetated

Table 3. Continued.

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	Coastal Rocky-Sandy Wet Brackish Dwarf Alkali Grass Tidal Flat	Dwarf Alkaligrass	Halophytic Grass Wet Meadow, Halophytic Grass Wet Meadow, brackish, Halophytic Herb Wet Meadow
Coastal Rocky-Sandy Brackish Seaside Sandplant Beach	Coastal Rocky-Sandy Moist Brackish Seaside Sandplant Beach	Seaside Sandplant	Halophytic Herb Wet Meadow
Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	Coastal Sandy-Loamy-Rocky Wet Brackish Sedge Meadow	Common Spikerush, Lesser Saltmarsh Sedge, Lyngbye's Sedge, Lyngbye's Sedge/Mixed Herb, Lyngbye's Sedge/Seaside Buttercup	Halophytic Sedge Wet Meadow, brackish, Halophytic Sedge Moist Meadow, brackish, Halophytic Sedge–Grass Wet Meadow, Halophytic Sedge Wet Meadow, saline
Coastal Sandy-Rocky Beach Pea Meadow	Coastal Sandy-Rocky Moist Circumneutral Beach Pea Meadow	Beach Pea	Elymus, Mixed Herbs
Coastal Sandy-Rocky Beach Rye Meadow	Coastal Sandy-Rocky Moist Circumneutral Beach Rye Meadow	Beach Rye, Beach Rye/Mixed Herbaceous, Beach Rye/Yarrow, Tall Fireweed-Beach Rye	Elymus, Fireweed
Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Sandy-Rocky Moist Circumneutral Bluejoint-Forb Meadow	Bluejoint Reedgrass, Tall Fireweed	Bluejoint Meadow, Bluejoint-Herb, Fireweed, Mixed Herbs
Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat	Coastal Sandy-Rocky Wet Brackish Goosetongue Tidal Flat	Goose Tongue	Halophytic Herb Wet Meadow
Glacial Lake	Glacial Lake	(none)	(none)
Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Moist Circumacidic Alder-Willow Tall Shrub	Sitka Alder, Sitka Alder/Bluejoint Reedgrass, Sitka Alder/Wood Fern, Sitka Alder-Salmonberry/Lady Fern, Sitka Alder-Sitka Willow, Sitka Alder-Sitka Willow/Bluejoint Reedgrass,	Open Low Alder, Open Tall Alder, Closed Tall Alder, Closed Tall Alder-Willow, Open Low Alder–Willow, Open Tall Alder-Willow
Glacial Rocky Barrens	Glacial Rocky Moist Circumneutral Barrens and Partially Vegetated	Alder/Sparse, undefined Bryoid, unvegetated	Barren, Dry Bryophyte

Table 3. Continued.

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Glacial Rocky Fireweed	Glacial Rocky Moist Circumneutral Fireweed	Dwarf Fireweed, Tall Fireweed	Bluejoint-Herb, Seral Herbs
Glaciers and Perennial Snowfields, Lacustrine Aquatic Forb Marsh	Glaciers and Perennial Snowfields	Unvegetated, *Sparganium* sp., Swamp Horsetail, undefined Forb Herbaceous type	Barren, Burreed, Emergent Horsetail, Subarctic Lowland Herb Wet Meadow
Lowland Lake	Lowland Lake	(none)	(none)
Lowland Organic-rich Wet Sedge Meadow	Lacustrine Aquatic Circumneutral Forb Marsh	Tall Cottongrass, Tall Cottongrass/undefined, Tufted Bulrush	Subarctic Lowland Sedge Bog Meadow, Wet Sedge–Herb Meadow Tundra, Subarctic Lowland Sedge Wet Meadow
River	River	(none)	(none)
Riverine Rocky Dwarf Fireweed	Riverine Rocky Moist Circumneutral Dwarf Fireweed	Dwarf Fireweed	Seral Herbs
Riverine Rocky Dwarf Shrub	Riverine Rocky Moist Circumneutral Dwarf Shrub	Arctic Willow/undefined, Arctic Willow-Crowberry	Ericaceous Dwarf Shrub Tundra, Crowberry Dwarf Shrub Tundra
Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Rocky-Sandy Moist Circumneutral Willow Low and Tall Shrub	Sitka Willow	Closed Low Willow, Closed Tall Willow, Open Low Willow, Open Tall Willow
Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Riverine Sandy-Loamy-Rocky Moist Circumneutral Alder-Willow Tall Shrub	Sitka Alder, Sitka Alder/Splendid Feather Moss, Sitka Alder/undefined, Sitka Alder-Barclay Willow, Sitka Alder-Devil's Club, Sitka Alder-Feltleaf Willow, Sitka Alder-Feltleaf Willow/Bluejoint Reedgrass, Sitka Alder-Salmonberry, Sitka Alder-Salmonberry/Lady Fern, Sitka Alder-Sitka Willow, Sitka Alder-Sitka Willow/Bluejoint Reedgrass, undefined Low Scrub type	Open Tall Alder, Open Low Alder, Closed Tall Alder, Closed Low Alder–Willow, Closed Tall Alder-Willow, Open Tall Alder-Willow,
Riverine Sandy-Loamy-Rocky Sitka Spruce Forest	Riverine Sandy-Loamy-Rocky Moist Sitka Spruce Forest	Sitka Spruce/Salmonberry-Devil's Club, Sitka Spruce/Sitka Alder	Open Sitka Spruce Forest, Open Tall Alder-Willow

Table 3. Continued.

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Riverine Sandy-Rocky Black Cottonwood Forest	Riverine Sandy-Rocky Circumneutral Moist Black Cottonwood Forest	Black Cottonwood/Sitka Alder	Open Black Cottonwood, Closed Black Cottonwood
Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Acidic Moist Alder Tall Shrub	Sitka Alder/Bluejoint Reedgrass, Sitka Alder/Lady Fern, Sitka Alder/undefined, Sitka Alder-Barclay Willow, Sitka Alder-Salmonberry, Sitka Alder-Salmonberry/Lady Fern	Mixed Herbs, Closed Tall Alder, Open Tall Alder-Willow, Closed Low Salmonberry, Open Low Alder, Open Tall Alder
Subalpine Rocky Barrens	Subalpine Rocky Moist Acidic Barrens and Partially Vegetated	Sparse, unvegetated	Alpine Herbs, Partially Vegetated, Barren
Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Moist Acidic Dwarf Mountain Hemlock Woodland	Mountain Hemlock/Steller's Cassiope	Open Dwarf Mountain Hemlock
Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky Moist Acidic Fireweed-Forb Meadow	Northern Geranium, Tall Fireweed, undefined Forb Herbaceous type	Mixed Herbs
Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Acidic Luetkea-Mountain Hairgrass Meadow	Longawned Sedge, Luetkea/Mountain Hairgrass, Nootka Lupine/Luetkea	Moist Sedge Meadow Tundra, Ericaceous Dwarf Shrub Tundra, Luetkea Dwarf Shrub Tundra, Mixed Herbs
Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Moist Acidic Graminoid Meadow	Bluejoint Reedgrass, Bluejoint Reedgrass/Willow, Longawned Sedge, Smallflowered Woodrush, undefined Herbaceous type	Bluejoint-Herb, Midgrass–Herb, Mixed Herbs, Hair-grass, Moist Sedge–Herb Meadow Tundra, Moist Sedge Meadow Tundra,
Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy Moist Acidic Sitka Spruce Woodland	Sitka Spruce/Sitka Alder, Sitka Spruce/undefined	Sitka Spruce Woodland
Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Moist Acidic Copperbush Low Shrub	Copperbush	Open Low Ericaceous Shrub

Table 3. Continued.

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Moist Acidic Deer Cabbage Slope Fen	Aleutian Mountain Heather/Deer Cabbage, Crowberry-Bog Blueberry/Deer Cabbage, Deer Cabbage, Sitka Spruce/undefined	Crowberry Dwarf Shrub Tundra, Ericaceous Dwarf Shrub Tundra, Mountain-heath Dwarf Shrub Tundra, Open Dwarf Mountain Hemlock, Subarctic Lowland Herb Wet Meadow, Sitka Spruce Woodland
Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow	Subalpine Rocky-Loamy-Organic Moist Acidic Deer Cabbage-Forb Meadow	Deer Cabbage	Mixed Herbs
Subalpine Rocky-Loamy-Organic Fern Meadow	Subalpine Rocky-Loamy-Organic Moist Acidic Fern Meadow	Lady Fern, Salmonberry/Lady Fern	Ferns, Mixed Herbs
Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Loamy-Organic Wet Acidic Deer Cabbage Slope Fen	Deer Cabbage	Mixed Herbs, Subarctic Lowland Herb Wet Meadow
Upland Organic-rich Wet Sedge Slope Fen	Upland Organic-rich Wet Circumneutral Sedge Slope Fen	Deer Cabbage/Tufted Bulrush, Fewflower Sedge, Tall Cottongrass/undefined, Tall Cottongrass-Tufted Bullrush, Tufted Bulrush	Wet Sedge–Herb Meadow Tundra, Subarctic Lowland Sedge Wet Meadow, Subarctic Lowland Sedge Bog Meadow, Subarctic Lowland Sedge Bog Meadow,
Upland Rocky Black Cottonwood Forest	Upland Rocky Moist Circumneutral Black Cottonwood Forest	Black Cottonwood/Sitka Alder	Open Black Cottonwood Forest
Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Moist Acidic Sitka Spruce-Alder Forest	Sitka Spruce/Devil's Club, Sitka Spruce/Early Blueberry-Devil's Club, Sitka Spruce/Salmonberry-Devil's Club, Sitka Spruce/Sitka Alder, Sitka Spruce/Sitka Alder-Devil's Club	Closed Sitka Spruce, Open Sitka Spruce Forest, Sitka Spruce Woodland, Mixed Conifer Woodland, Closed Sitka Spruce
Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky Moist Acidic Sitka Spruce-Feathermoss Forest	Mountain Hemlock-Sitka Spruce/undefined, Sitka Spruce/Splendid Feather Moss, Sitka Spruce/undefined	Open Mixed Coastal Conifer, Closed Sitka Spruce, Open Sitka Spruce Forest, Sitka Spruce Woodland
Upland Rocky-Loamy Lady Fern Meadow	Upland Rocky-Loamy Moist Acidic Lady Fern Meadow	Lady Fern	Ferns, Mixed Herbs

Table 3. Continued.

Abbreviated Ecotype Name	Full Ecotype Name	Plant Community	Vegetation Class (Level IV)
Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Acidic Moist Mountain Hemlock-Early Blueberry Forest	Mountain Hemlock/Bog Blueberry, Mountain Hemlock/Early Blueberry, Mountain Hemlock/Early Blueberry-Copperbush, Mountain Hemlock/Early Blueberry-Deer Cabbage, Mountain Hemlock/Early Blueberry-Devil's Club, undefined Forest type	Open Dwarf Mountain Hemlock, Closed Mountain Hemlock, Open Mountain Hemlock, Closed Mixed Coastal Conifer
Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Acidic Moist Mountain Hemlock-Sitka Spruce Forest	Mountain Hemlock-Sitka Spruce/Early Blueberry, Mountain Hemlock-Sitka Spruce/Early Blueberry/Wood Fern, Mountain Hemlock-Sitka Spruce/Early Blueberry-Devil's Club, Mountain Hemlock-Sitka Spruce/Early Blueberry-Salmonberry, Mountain Hemlock-Sitka Spruce/undefined	Closed Mixed Coastal Conifer, Open Mixed Coastal Conifer, Closed Sitka Spruce,
Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Moist Acidic Salmonberry Low Shrub	Salmonberry, Salmonberry/Lady Fern	Closed Low Salmonberry, Open Tall Alder, Closed Low Salmonberry
Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Loamy-Organic Acidic Moist Sitka Spruce-Early Blueberry Forest	Sitka Spruce/Devil's Club, Sitka Spruce/Early Blueberry, Sitka Spruce/Early Blueberry-Devil's Club, Sitka Spruce/Early Blueberry-Wood Fern, Sitka Spruce/Salmonberry-Devil's Club	Closed Sitka Spruce, Open Sitka Spruce Forest, Sitka Spruce Woodland,
Upland Rocky-Organic Alder Tall Shrub	Upland Rocky-Organic Moist Acidic Alder Tall Shrub	Sitka Alder/Lady Fern, Sitka Alder/undefined, Sitka Alder/Wood Fern, Sitka Alder-Devil's Club, Sitka Alder-Salmonberry, Sitka Alder-Salmonberry/Lady Fern	Closed Tall Alder, Open Tall Alder, Closed Low Salmonberry, Closed Tall Alder, Open Tall Alder-Willow

Key to Ecotypes

The Key to Ecotypes (Table 4) for KEFJ provides the end-user of this Ecological Land Survey and Soils Landscape study with an organized means by which to identify ecotypes in the field. While not technically a dichotomous key, the ecotype key is very similar, leading the user through a series of logical conditions that include both vegetation composition and environment, including physiography, soils, slope, and elevation. The criteria used in the key were chosen for ease of identification in the field. A Geographic Positioning System (GPS), inclinometer (used for measuring slope gradient), and Electrical Conductivity (EC) meter (for coastal ecotypes) are useful tools to have available when using this key in the field. Additionally, an understanding of basic soil properties, including general soil texture (e.g., loamy vs. sandy) and access to a shallow (40 cm) soil pit or plug are useful in some cases for identifying ecotypes using this key. However, technical soil properties, including epipedon, diagnostic subsurface horizons, particle size, and soil depth were purposefully excluded from the Ecotype Key as these are often difficult to determine in the field. Extra time and specialized equipment and skills are required to excavate a full (1 m) soil pit for proper data collection and description. When determining an ecotype using the Key to Ecotypes, it is recommended that the user compare the description (vegetation, soils, general environment) of the ecotype at the terminal node to that observed in the field before finalizing their selection. See below for instructions on using the Ecotype Key. See also the section entitled "How to use this Ecological Land Survey and Mapping" at the beginning of this document for more information on when to use this Ecotype Key.

Instructions

1) When in the field in KEFJ, select a homogeneous patch of vegetation at least 314 to 1,000 m² in area, avoiding transitions between vegetation types, landforms, or slope positions (i.e., ecotones).
2) Use the Key to Physiography Class for Kenai Fjords National Park (Figure 4) to determine the physiography class of the site selected in Step 1.
3) Go to the appropriate physiography section in the Key to Ecotypes and follow the leads to determine the ecotype in the area selected in Step 1.
4) To help verify the ecotype determined above refer to the Ecotype Descriptions section (below), the environmental site-factor summaries (Table 5), and the constancy/cover tables (Tables 6–10) and find the ecotype determined above. Read through the vegetation and environment description and review the common (≥60% frequency of occurrence) species in the constancy/cover table. Compare this to vegetation and environment observed at the site selected in Step 1.
5) If the Key to Ecotypes leads to an "undefined" type go back to the beginning of the physiography section and work back through the key and subtract 5% from the species or lifeform cover cutpoints.

Table 4. Ecotype Key for Kenai Fjords National Park.

Alpine Ecotype Key

1a. Permanent waterbody ..... Alpine Lake

1b. Not a waterbody 2

2a. Total vascular plant cover <30% ..... Alpine Rocky Barrens

2b. Vegetation cover (vascular species only) ≥30% 3

3a. Combined cover of dwarf shrubs ≥25% (sometimes as low as 15%) 4

4a. Vegetation is dominated (≥15%) by *Phyllodoce aleutica* ..... Alpine Rocky-Loamy Mountain Heather Dwarf Shrub

4b. Vegetation is co-dominated (combined cover ≥15%) by *Cassiope stelleriana* and *Luetkea pectinata* ..... Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub

4c. Vegetation is dominated (cover ≥10–15%) by *Luetkea pectinata* 5

5a. *Luetkea pectinata* cover <20%, *Artemisia arctica* and/or *Sibbaldia procumbens* typically present ..... Alpine Rocky Luetkea Dwarf Shrub

5b. *Luetkea pectinata* cover less than ≥20%, *Vahlodea atropurpurea* typically present ..... Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow

4d. Vegetation is dominated (cover ≥15%) by *Empetrum nigrum*, and *Vaccinium uliginosum* presen ..... Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub

4e. Vegetation is dominated by species other than above ..... Undefined alpine dwarf shrub type

3b. Dwarf shrub cover <25% 6

6a. Vegetation is dominated (cover >15%) either singly or in combination by sedges, most commonly *Carex microchaeta* or *C. nesophila*, and/or woodrushes, most commonly *Luzula arcuata* ssp. *unalaschensis*, and/or *L. wahlenbergii* ssp. *piperi* ..... Alpine Rocky Moist Sedge Meadow

6b. Vegetation not as above ..... Undefined alpine herbaceous type or try Subalpine Ecotype Key

Coastal Ecotype Key

1a. Permanent waterbody ..... Coastal Brackish Water

1b. Not a waterbody 2

2a. Site is located on active beach deposits, tidal flats, or sea cliffs and vegetation is barren or partially vegetated where total vascular plant cover <30%[1] ..... Coastal Rocky-Sandy Barrens

2b. Vegetation cover (vascular species only) ≥30% 3

3a. Site is located at or below average high tide line on active tidal flat, alluvial-marine deposits, or lagoon deposits and experiences regular flooding by salt water 4

4a. Vegetation is dominated by *Puccinellia nutkaensis* ..... Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat

4b. Vegetation is dominated by *Plantago maritima* ..... Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat

4c. Vegetation is dominated by *Carex lyngbyaei* ..... Coastal Sandy-Loamy-Rocky Wet Brackish Sedge Meadow

4d. Vegetation is dominated by species other than above ..... Undefined coastal type

3b. Site is located at or above average high tide line on active or inactive beach deposits, beach ridges, or sand dunes, is not affected by normal high tides, but is affected regularly or irregularly by storm surges and/or salt spray 5

5a. Vegetation is dominated by *Leymus mollis* ..... Coastal Sandy-Rocky Beach Rye Meadow

5b. Vegetation is dominated by *Calamagrostis canadensis* and *Epilobium angustifolium* ..... Coastal Sandy-Rocky Bluejoint-Forb Meadow

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[1] Lifeform and species cover cutpoints represent approximate guidelines; classification should also rely on dominant indicator species and landscape position.

Table 4. (continued) Ecotype Key for Kenai Fjords National Park.

5c. Vegetation is dominated by *Lathyrus maritimus* ..... Coastal Sandy-Rocky Beach Pea Meadow

5d. Vegetation is dominated by *Honckenya peploides* .....Coastal Rocky-Sandy Brackish Seaside Sandplant Beach

5e. Vegetation is dominated by species other than above ..... Undefined coastal type

Glacial, Alpine Glacial, and Glacier Ecotype Key

1a. Ice cap, glacier, or permanent snow field.....Glaciers and Permanent Snow Fields

1b. Not an ice cap, glacier, or permanent snow field.....2

2a. Permanent waterbody..... Glacial Lake

2b. Not a waterbody.....3

3a. Physiography is Glacial Alpine ..... Go to Alpine Ecotype Key

3b. Physiography Glacial.....4

4a. Total vascular plant cover <30% ..... Glacial Rocky Barrens

4b. Vegetation cover (vascular species only) ≥30% 5

5a. Combined cover of tall (>1.5 m) shrubs ≥25%.....6

6a. Vegetation is dominated (≥25%) by *Alnus sinuata*, and Salix spp., most commonly *S. sitchensis*, often co-dominant .....Glacial Rocky Alder-Willow Tall Shrub

6b. Vegetation not as above..... Undefined glacial tall shrub type

5b. Tall shrub cover <25%.....7

7a. Vegetation is dominated (≥25%) by low and dwarf shrub cover.....Undefined glacial type

7b. Low and dwarf shrub cover less than 25%, herbaceous species dominant 8

8a. Epilobium latifolium with the greatest cover of any vascular plant ..... Glacial Rocky Fireweed

8b. Vegetation is dominated by herbaceous species other than *Epilobium latifolium* .....Undefined glacial herbaceous type

Lowland and Lacustrine Ecotype Key

1a. Permanent waterbody and vascular species cover <10%.....2

2a. Waterbody is located at greater than or equal to approximately 500 m (+/- 100 m) above mean sea level AND is above timberline ..... Alpine Lake

2b. Waterbody is located at less than 500 m (+/- 100 m) above mean sea level AND is below timberline.....Lowland Lake

1b. Not a waterbody or vascular species cover ≥10%.....3

3a. Site is a waterbody or portion thereof (i.e., lake margin) and vascular species cover is ≥10% 4

4a. Forb species, most commonly *Equisetum fluviatile* or *Sparganium angustifolium*, with the greatest cover (either singly or combined) of any vascular plant..... Lacustrine Forb Marsh

4b. Vegetation dominated by a lifeform other than forbs .....Undefined lacustrine type

3b. Not a waterbody.....5

5a. Site located in a recently drained lake basin .....Undefined lacustrine type

5b. Site located not as above 6

6a. Sedge species with the greatest cover (either singly or combined) of any vascular plant, most commonly *Carex aquatilis*, *Eriophorum angustifolium*, and/or *Trichophorum alpinum* ..... Lowland Wet Sedge Meadow

6b. Vegetation not as above.....Undefined lowland type

Table 4. (continued) Ecotype Key for Kenai Fjords National Park.

Riverine Ecotype Key

1a. Permanent waterbody ..... River

1b. Not a waterbody 2

2a. Site is located on river bars and active channel deposits on alluvial fans and vegetation is barren or partially vegetated where total vascular plant cover <30% ..... Riverine Rocky Barrens

2b. Vegetation cover (vascular species only) ≥30% 3

3a. Vegetation is forest (>25% tree cover) or woodland (10–25% tree cover) 4

4a. Site is dominated (contributing >75% of tree cover) by *Picea sitchensis* ..... Riverine Sandy-Loamy-Rocky Sitka Spruce Forest

4b. Less than 75% of tree cover is contributed by *Picea sitchensis*, and over 75% of tree cover is contributed by *Populus trichocarpa* ..... Riverine Sandy-Rocky Black Cottonwood Forest

4c. Vegetation not as above ..... Undefined riverine forested type

3b. Vegetation is dominated (≥25% foliar cover) by shrub or herbaceous species 5

5a. Vegetation dominated by low (0.2 to 1.5 m) and/or tall (>1.5 m) shrubs 6

6a. Vegetation is dominated or co-dominated (>25% foliar cover) by *Alnus sinuata*; *Salix* spp. may or may not be co-dominant ..... Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub

6a. Vegetation is dominated *Salix* spp. (most commonly *S. barclayi* and/or *S. sitchensis*) and *Alnus sinuata,* when present, occurs at low abundance (<25% foliar cover) ..... Riverine Rocky-Sandy Willow Low and Tall Shrub

5b. Vegetation dominated by dwarf (<0.2 m) shrubs, namely *Salix arctica*, *Empetrum nigrum*, *Cassiope stelleriana*, and/or *Phyllodoce aleutica* ..... Riverine Rocky Dwarf Shrub

5c. Vegetation dominated by herbaceous vegetation 7

7a. *Epilobium latifolium* with the greatest cover of any vascular plant ..... Riverine Rocky Dwarf Fireweed

7b. Vegetation is dominated by herbaceous species other than *Epilobium latifolium* ..... Undefined riverine herbaceous type

Subalpine Ecotype Key

1a. Total vascular plant cover <30% ..... Subalpine Rocky Barrens

1b. Vegetation cover (vascular species only) ≥30% 2

2a. Vegetation is forest (>25% tree cover) or woodland (10–25% tree cover), site is dominated by *Picea sitchensis* and/or *Tsuga mertensiana* 3

3a. Vegetation is woodland and trees are dwarf (<3 m in height) in stature due to environmental constraints, e.g., high elevation 4

4a. Dominant tree species is *Tsuga mertensiana* ..... Subalpine Rocky Dwarf Mountain Hemlock Woodland

4b. Dominant tree species is *Picea sitchensis* ..... Subalpine Rocky-Loamy Sitka Spruce Woodland

3b. Vegetation is forest or woodland and trees are not dwarf in stature ..... Undefined subalpine type

2b. Vegetation is not forest or woodland 5

5a. Vegetation is dominated (≥25% foliar cover) by dwarf (<0.2 m), low (0.2–1.5 m), or tall shrubs (>1.5 m) 6

6a. Vegetation dominated (≥25%) by tall shrubs 7

7a. Vegetation dominated by *Alnus sinuata* ..... Subalpine Rocky Alder Tall Shrub

7b. Vegetation dominated by species other than *A. sinuata* ..... Undefined subalpine tall shrub type

Table 4. (continued) Ecotype Key for Kenai Fjords National Park.

6b. Vegetation dominated by low shrubs 8

8a. Vegetation dominated by *Alnus sinuata* ..... Subalpine Rocky Alder Tall Shrub

8b. *Cladothamnus pyrolaeflorus* cover greater than any other individual low shrub species ..... Subalpine Rocky-Loamy-Organic Copperbush Low Shrub

8b. Vegetation dominated by species other than *Cladothamnus pyrolaeflorus* ..... Undefined subalpine low shrub type

6c. Vegetation dominated (≥25%) by dwarf shrubs, herbaceous species sometimes overtopping prostrate shrubs and appearing to be dominant 9

9a. Vegetation is dominated (≥15%) by *Phyllodoce aleutica* or is co-dominated by *Cassiope stelleriana* and *Luetkea pectinata* ..... Go to Alpine Ecotype Key

9b. Vegetation is dominated (cover ≥10–15%) by *Luetkea pectinata* 10

10a. Luetkea pectinata cover <20%, Artemisia arctica and/or Sibbaldia procumbens typically present ..... Alpine Rocky Luetkea Dwarf Shrub

10b. *Luetkea pectinata* cover less than ≥20%, *Vahlodea atropurpurea* typically present ..... SubalpineRocky-LoamyLuetkea-Mountain Hairgrass Meadow

10c. Vegetation not as above ..... Undefined subalpine dwarf shrub type

5b. Vegetation not dominated by shrubs 11

11a. Vegetation dominated by herbaceous species 12

12a. Graminoid species cover dominates (≥25% combined cover) 13

13a. Dominant graminoids most commonly include *Trichophorum caespitosum*, *Eriophorum angustifolium*, *Carex pauciflora*, and/or *Carex nigricans*, Sphagnum spp.
and *Geum calthifolium* common (≥5%), soils wet ..... Go to Upland Ecotype Key

13b. Dominant graminoids most commonly *Carex macrochaeta*
and/or *Calamagrostis canadensis*, soils moist ..... Subalpine Rocky-Loamy, Moist Graminoid Meadow

13c. Vegetation or soils not as above ..... Undefined subalpine graminoid type OR try Alpine Ecotype Key

12b. Graminoid species cover not dominant 14

14a. *Epilobium angustifolium* with the greatest cover of any vascular plant ..... Subalpine Rocky Fireweed-Forb Meadow

14b. Vegetation is dominated (≥20%) by *Athyrium filix-femina* ..... Subalpine Rocky-Loamy-Organic Fern Meadow

14c. Vegetation dominated by (≥25%) *Fauria crista-galli* 15

15a. *Phyllodoce aleutica*, Sphagnum spp., and *Geum calthifolium* common (≥5%) ..... Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen

15b. *Phyllodoce aleutica*, Sphagnum spp., and *Geum calthifolium* rare (<5%), *Sanguisorba stipulata* and *Veratrum viride* ssp. *eschscholtzii* common (≥5%), *Vahlodea atropurpurea* and/or *Carex macrochaeta* often present at low abundance ..... Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow

Table 4. (continued) Ecotype Key for Kenai Fjords National Park.

15c. Vegetation not as above .... Undefined *Fauria crista-galli* subalpine type

14d. Vegetation not dominated by above species .....Undefined herbaceous subalpine type

12c. Vegetation not as above..... Undefined subalpine type

Upland Ecotype Key

1a. Total vascular plant cover <30% .....Undefined upland type

1b. Vegetation cover (vascular species only) ≥30%.....2

2a. Vegetation is forest (>25% tree cover) or [rarely] woodland (10–25% tree cover).....3

3a. Site is dominated (contributing >75% of tree cover) by needleleaf (conifer) tree species, namely *Picea sitchensis* and/or *Tsuga mertensiana*.....4

4a. Trees are dwarf (<3 m in height) in stature due to due to environmental constraints, e.g., high elevation..... Go to Subalpine Ecotype Key

4b. Trees are not dwarf in stature.....5

5a. *Picea sitchensis* and *Tsuga mertensiana* each contribute 25 to 75% to the tree cover..... .....Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest

5b. *Tsuga mertensiana* is at least 75% of the total tree cover.....6

6a. *Vaccinium ovalifolium* cover is at least 15% .....Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest

6b. Total cover of understory vascular plant species is less than 15% and feathermosses, most commonly *Rhytidiadelphus loreus*, *Hylocomium splendens*, *Pleurozium schreberi*, and/or *Ptilium crista-castrensis*, abundant (combined cover ≥25%) .... Upland Rocky Sitka Spruce-Feathermoss Forest

6c. Vegetation not as above.....Undefined upland *Tsuga mertensiana* type

5c. *Picea sitchensis* is at least 75% of the total tree cover.....7

7a. *Alnus sinuata* cover ≥15%.....Upland Rocky Sitka Spruce-Alder Forest

7b. *Alnus sinuata* cover <15% and *Vaccinium ovalifolium* cover is at least 15% .....Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest

7c. Total cover of understory vascular plant species is less than 15% and feathermosses, most commonly *Rhytidiadelphus loreus*, *Hylocomium splendens*, *Pleurozium schreberi*, and/or *Ptilium crista-castrensis* abundant (combined cover ≥25%) .... Upland Rocky Sitka Spruce-Feathermoss Forest

7d. Vegetation not as above..... Undefined upland *Picea sitchensis* type

3b. Less than 75 percent of tree cover is contributed by needleleaf (conifer) species, and over 75% of tree cover is contributed by *Populus trichocarpa* .....Upland Rocky Black Cottonwood Forest

3c. Vegetation not as above ..... Undefined upland forested type

2b. Vegetation is not forest or woodland.....8

8a. Vegetation is dominated (≥25%) by dwarf (<0.2 m), low (0.2–1.5 m), or tall shrubs (>1.5 m) 9

9a. Vegetation dominated by tall shrubs 10

10a. *Alnus sinuata* cover ≥25%.... Upland Rocky-Organic Alder Tall Shrub

10b. *Alnus sinuata* cover <25%.....Undefined upland tall shrub type

9b. Vegetation dominated by low shrubs 11

11a. *Rubus spectabilis* cover greater than any other individual low shrub species.....Upland Rocky-Loamy-Organic Salmonberry Low Shrub

11b. *Cladothamnus pyrolaeflorus* cover greater than any other individual low shrub species..... Go to Subalpine Ecotype Key

11c. Vegetation not as above.....Undefined upland low shrub type

Table 4. (continued) Ecotype Key for Kenai Fjords National Park.

9c. Vegetation dominated by dwarf shrubs ..... Go to Subalpine Ecotype Key

8b. Vegetation not dominated by shrubs 12

12a. Vegetation dominated by herbaceous species 13

13a. Graminoid species cover dominates (≥25% combined cover) 14

14a. Dominant graminoids most commonly include *Trichophorum caespitosum*, *Eriophorum angustifolium*, *Carex pauciflora*, and/or *Carex nigricans*, Sphagnum spp. and *Geum calthifolium* common (≥5%), soils wet..... Upland Organic-rich Wet Sedge Slope Fen

14b. Dominant graminoids most commonly *Carex macrochaeta* and/or *Calamagrostis canadensis*, soils moist..... Go to Subalpine Ecotype Key

14c. Vegetation or soils not as above..... Undefined upland graminoid type

13b. Graminoid species cover not dominant 15

15a. Vegetation is dominated (≥20%) by *Athyrium filix-femina* ..... Upland Rocky-Loamy Lady Fern Meadow

15b. Vegetation dominated by (≥25%) *Fauria crista-galli* 16

16a. *Phyllodoce aleutica*, Sphagnum spp., and *Geum calthifolium* common (≥5%) ..... Go to Subalpine Ecotype Key

16b. *Sanguisorba stipulata* and *Veratrum viride* ssp. *eschscholtzii* common (≥5%),*Vahlodea atropurpurea* and/or *Carex macrochaeta* often present at low abundance ..... Go to Subalpine Ecotype Key

16c. P*hyllodoce aleutica* absent or rare (<5%), Sphagnum spp. and *Geum calthifolium* common (≥5%) ..... Upland Loamy-Organic Deer Cabbage Slope Fen

16d. Vegetation not as above..... Undefined upland Fauria crista-galli type

13c. Vegetation not dominated by above species ..... Undefined upland herbaceous type

12b. Vegetation not as above..... Undefined upland type

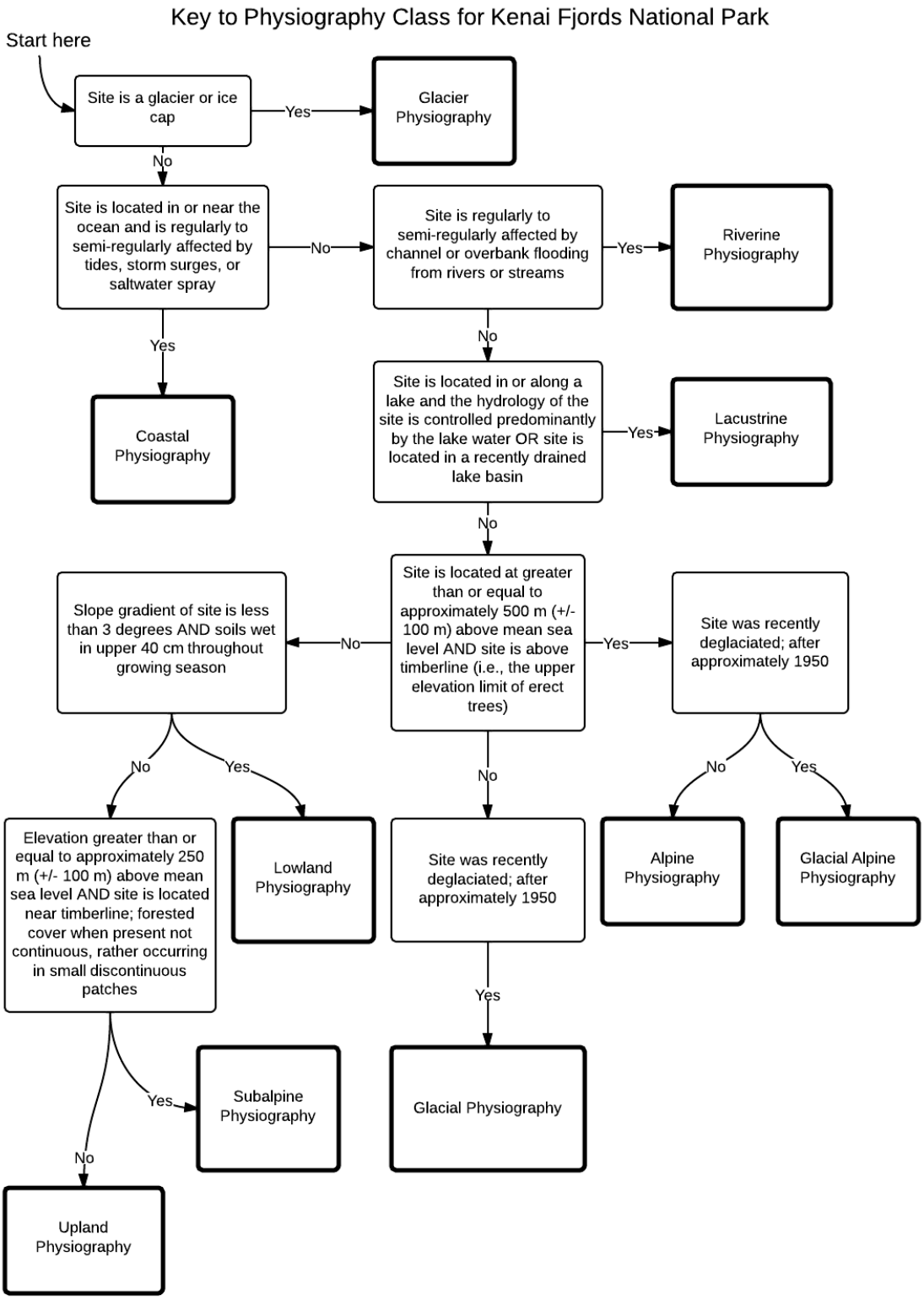


Figure 4. Key to Physiography Class for Kenai Fjords National Park, southcentral Alaska, 2013.

1) If, after adjusting the cover cutpoints, the Key to Ecotypes once again leads to an "undefined" type there are several additional resources that may be of use in understanding the vegetation and environment at the site selected in Step 1, including:
   a) Land-cover classes, ecosystems and plant associations of Kenai Fjords National Park (Boggs et al. 2008).
   b) Plant community types of the Chugach National Forest: southcentral Alaska (DeVelice et al. 1999).

Table 5. Mean elevation, slope gradient, surface organic thickness, and pH for ecotypes with sample size ≥3, Kenai Fjords National Park, Alaska, 2013.

	Elevation (m)		Slope (°)		Surface Organic Thickness (cm)		pH	
Plot Ecotype	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	608	235	16	6	5.4	4.4	5.1	0.5
Alpine Rocky Barrens	957	336	15	13	2.0	3.7	5.9	1.0
Alpine Rocky Luetkea Dwarf Shrub	753	120	24	21	4.8	4.9	5.2	0.4
Alpine Rocky Moist Sedge Meadow	1,037	285	8	6	2.5	2.7	5.4	0.7
Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	623	269	17	12	3.8	4.1	4.9	0.8
Alpine Rocky-Loamy Mountain Heather Dwarf Shrub	565	190	26	12	5.3	3.4	5.1	0.8
Coastal Rocky-Sandy Barrens	9	6	32	41	0.9	1.9	6.8	1.6
Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	5	4	2	3	1.4	1.5	7.6	1.2
Coastal Rocky-Sandy Seaside Sandplant Beach	6	4	7	5	0.0	0.0	7.2	0.8
Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	9	5	0	0	4.3	8.2	6.7	0.6
Coastal Sandy-Rocky Beach Pea Meadow	9	2	0	1	2.1	2.2	6.2	0.8
Coastal Sandy-Rocky Beach Rye Meadow	10	9	2	3	1.7	1.7	6.4	0.8
Coastal Sandy-Rocky Bluejoint-Forb Meadow	7	6	4	9	2.9	1.6	6.6	1.4
Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat	8	7	1	1	0.1	0.4	7.4	0.5
Glacial Rocky Alder-Willow Tall Shrub	63	53	26	19	3.3	2.4	5.7	0.9
Glacial Rocky Barrens	89	79	20	15	0.3	0.5	6.1	0.7
Glacial Rocky Fireweed	437	383	28	16	1.0	1.7	6.2	1.2
Lowland Organic-rich Wet Sedge Meadow	100	86	2	2	38.8	31.4	5.2	0.5
Riverine Rocky-Sandy Willow Low and Tall Shrub	105	180	0	1	2.8	2.3	5.9	0.9
Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	19	12	5	13	2.6	3.6	5.8	0.9

Table 5. (continued)

Plot Ecotype	Elevation (m)		Slope (°)		Surface Organic Thickness (cm)		pH	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	19	12	5	13	2.6	3.6	5.8	0.9
Subalpine Rocky Alder Tall Shrub	364	152	23	10	11.1	9.1	4.9	0.6
Subalpine Rocky Barrens	98	67	46	39	0.0	0.0	5.2	0.2
Subalpine Rocky Dwarf Mountain Hemlock Woodland	308	271	13	10	8.7	4.0	5.1	1.9
Subalpine Rocky Fireweed-Forb Meadow	259	180	22	12	3.2	2.5	5.2	0.4
Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	383	254	28	7	4.9	3.3	5.1	0.5
Subalpine Rocky-Loamy Moist Graminoid Meadow	343	265	22	12	3.9	4.2	5.2	0.8
Subalpine Rocky-Loamy Sitka Spruce Woodland	516	125	38	4	6.0	3.6	5.0	1.0
Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	310	96	27	15	13.3	5.8	4.6	0.3
Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	223	102	12	13	7.6	5.7	4.7	0.4
Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow	371	35	23	21	16.0	5.6	5.1	0.7
Subalpine Rocky-Loamy-Organic Fern Meadow	286	147	30	7	9.9	6.5	5.2	0.8
Upland Loamy-Organic Deer Cabbage Slope Fen	137	128	27	18	31.4	13.9	5.2	0.9
Upland Organic-rich Wet Sedge Slope Fen	90	81	15	16	36.3	24.1	5.4	0.9
Upland Rocky Black Cottonwood Forest	139	20	2	4	8.6	1.8	5.4	0.7
Upland Rocky Sitka Spruce-Alder Forest	25	26	7	13	4.7	3.4	4.9	0.8
Upland Rocky Sitka Spruce-Feathermoss Forest	31	16	6	7	7.8	4.9	4.6	0.5
Upland Rocky-Loamy Lady Fern Meadow	44	37	19	8	3.4	1.8	5.4	0.9
Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	92	80	23	13	16.6	12.5	4.8	0.6
Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	85	94	25	14	14.3	10.0	4.5	0.8
Upland Rocky-Loamy-Organic Salmonberry Low Shrub	71	59	33	12	7.0	6.2	5.1	1.0
Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	42	18	26	13	19.4	8.7	4.3	0.6
Upland Rocky-Organic Alder Tall Shrub	55	48	26	13	7.7	6.2	4.7	1.1

Table 6. Mean percent cover by plant species and species richness for alpine ecotypes, Kenai Fjords National Park, Alaska, 2013. Ecotypes with sample size <3 are excluded. Bold text indicates species with a constancy (frequency of occurrence) ≥60%. Average cover of 0 indicates presence at trace cover.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Sample Size		9	8	5	6	20	15
Deciduous shrubs	*Alnus sinuata*	0		1		8	1
	Arctostaphylos alpina	6					
	Cladothamnus pyrolaeflorus					2	2
	Oplopanax horridus					0	
	Rubus spectabilis			5			
	Salix arctica	0	1	10		1	2
	Salix barclayi					3	
	Salix polaris		0				
	Salix rotundifolia	10	2	1	8	2	7
	Salix sitchensis					2	
	Salix stolonifera						1
	Spiraea beauverdiana	0					
	Vaccinium alaskensis						4
	Vaccinium caespitosum						0
	Vaccinium ovalifolium	1				0	0
	Vaccinium uliginosum	**24**	1		0	8	**4**
Evergreen shrubs	*Cassiope lycopodioides*					0	1
	Cassiope stelleriana	3			1	**40**	**16**
	Cassiope tetragona	0				0	
	Diapensia lapponica	1	**1**		1	1	
	Dryas integrifolia	6					
	Empetrum nigrum	**26**	3	2	2	7	14
	Loiseleuria procumbens	5	1	3	1	2	1

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Evergreen shrubs (continued)	*Luetkea pectinata*	2	1	**14**	**4**	**21**	**18**
	Phyllodoce aleutica	3	0	**7**	**3**	**7**	**41**
	Vaccinium vitis-idaea	1	2				0
Evergreen tree	*Picea sitchensis*	1				1	1
	Tsuga mertensiana	4				2	2
Forbs	*Achillea borealis*	10					
	Achillea millefolium			0			
	Aconitum delphinifolium	0					0
	Anemone narcissiflora	1				0	1
	Angelica lucida					0	
	Antennaria alpina		0		0		
	Antennaria monocephala	0	0	0	1		
	Antennaria rosea		0	0		0	
	Arabis lyrata kamchatica		0	1			
	Arnica latifolia			0			
	Arnica lessingii	0					0
	Artemisia alaskana	1					
	Artemisia arctica	**5**	**1**	**10**	**4**	1	4
	Athyrium filix-femina cyclosorum	0		0			0
	Campanula lasiocarpa	0	**0**	2	1	0	1
	Campanula rotundifolia		0				
	Campanula uniflora		0				
	Cardamine bellidifolia		1		0	0	
	Castilleja unalaschcensis						0
	Cornus canadensis	2					0
	Cornus suecica						3

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Forbs (continued)	*Cryptogramma crispa*		0	0		1	
	Cryptogramma crispa var. acrostichoides		0	0			
	Cryptogramma crispa var. sitchensis						0
	Dodecatheon jeffreyi	1					0
	Draba stenoloba			0			
	Dryopteris dilatata americana			0		1	0
	Epilobium anagallidifolium			0		0	0
	Epilobium angustifolium	1		0		0	1
	Epilobium hornemannii			2		0	
	Epilobium latifolium		5	0		3	
	Epilobium leptocarpum						1
	Equisetum arvense					0	0
	Erigeron peregrinus	1		2		1	3
	Euphrasia mollis	0		0			
	Fauria crista-galli	8				7	24
	Fritillaria camschatcensis					0	
	Gentiana douglasiana	2					
	Gentiana glauca	1	1		0	0	0
	Gentiana platypetala	1				0	1
	Geranium erianthum	1		1			1
	Geum calthifolium	3				2	4
	Geum macrophyllum macrophyllum	3					
	Heuchera glabra		0	1		1	1
	Hieracium triste	0		3		1	**1**
	Listera cordata						0

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Forbs (continued)	*Lloydia serotina*	0					
	Lupinus nootkatensis	**5**	0	**22**		5	5
	Lycopodium alpinum	1	1	1	3	1	1
	Lycopodium annotinum	0					
	Lycopodium complanatum			1	3		1
	Lycopodium sabinaefolium var. sitchense	0			15	1	1
	Lycopodium selago	0	0	0	0	0	0
	Minuartia arctica		2				
	Minuartia biflora		1				
	Minuartia macrocarpa		0		0		
	Oxyria digyna		0			0	
	Pedicularis labradorica		0				
	Pedicularis verticillata	0		0	0		
	Petasites frigidus					0	
	Petasites hyperboreus						0
	Pinguicula vulgaris	0					0
	Platanthera dilatata						0
	Polemonium pulcherrimum		0	1			
	Polygonum viviparum	1	0	1		0	1
	Potentilla hyparctica		0		0		
	Potentilla uniflora		1				
	Potentilla villosa		1				
	Prenanthes alata					0	0
	Primula cuneifolia		0			0	0
	Pyrola secunda secunda					2	

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Forbs (continued)	*Rubus arcticus*					1	
	Rubus pedatus	0					0
	Sanguisorba stipulata					0	0
	Saxifraga bronchialis		2	1		0	
	Saxifraga exilis	0					
	Saxifraga ferruginea					0	
	Saxifraga nivalis		0		0	0	
	Saxifraga punctata nelsoniana		0				
	Saxifraga rivularis		1				
	Sedum rosea integrifolium	1	**0**	0	**0**	0	1
	Senecio triangularis			20			
	Sibbaldia procumbens		**1**	**3**	**2**	1	0
	Silene acaulis	1	2		0		
	Solidago multiradiata			0			
	Stellaria calycantha		0				
	Stellaria longipes				0		
	Stellaria sitchana var. bongardiana					1	
	Streptopus amplexifolius						0
	Swertia perennis						0
	Thelypteris limbosperma						0
	Thelypteris phegopteris						0
	Tofieldia coccinea	1					
	Trientalis europaea	1				1	0
	Veratrum viride eschscholtzii			0		0	0
	Veronica wormskjoldii		0	1			0
	Viola adunca					0	

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Forbs (continued)	*Viola langsdorffii*	5				1	0
	Woodsia ilvensis		0				
Grasses	*Agrostis alaskana*	1					
	Agrostis borealis	0	0	1	3	0	0
	Agrostis exarata	1	0	0			
	Agrostis thurberiana					0	1
	Arctagrostis latifolia						
	Calamagrostis canadensis	0		0		0	1
	Calamagrostis nutkaensis						0
	Deschampsia beringensis	3		0		1	1
	Deschampsia caespitosa	0		3		0	1
	Elymus alaskanus						
	Festuca altaica	2					
	Festuca brachyphylla	0	1	0	0		
	Festuca rubra						2
	Hierochloe alpina	1	**0**		0	0	1
	Phleum commutatum var. americanum	1		2		0	0
	Poa alpina		1				
	Poa arctica				0	1	
	Poa glauca		1	1		0	
	Poa lanata		0	2	0		
	Poa paucispicula		2		3		
	Poa pseudoabbreviata				5		
	Podagrostis aequivalvis	1					0
	Trisetum spicatum molle	1	1	1	10		1

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Grasses (continued)	*Vahlodea atropurpurea*	1		1		1	**1**
Lichens	*Cetraria ericetorum*	1			1	2	1
	Cetraria islandica islandica		6			1	2
	Cladina arbuscula					1	1
	Cladina mitis	4				0	0
	Cladina rangiferina	1	0				2
	Cladina stellaris	6	6			0	0
	Cladonia bellidiflora	1			3		0
	Nephroma arcticum	1					
	Stereocaulon alpinum	1	1	0	1	0	
	Thamnolia vermicularis	3	2		5	0	
Liverworts	*Anastrophyllum assimile*						0
	Anthelia julacea						5
	Diplophyllum albicans						0
	Lophozia sudetica						0
	Macrodiplophyllum imbricatum						7
	Mylia taylorii						5
Mosses	*Dicranum majus*						10
	Dicranum scoparium					40	20
	Hylocomium splendens						2
	Pleurozium schreberi						3
	Pogonatum alpinum						0
	Ptilium crista-castrensis						0
	Racomitrium aciculare	6			12	20	
	Racomitrium canescens				4		2

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Mosses (continued)	*Racomitrium heterostichum*					15	
	Racomitrium lanuginosum	12	1	1			2
	Racomitrium sudeticum				15	20	
	Rhytidiadelphus loreus						2
	Sphagnum	3				0	10
	Sphagnum compactum						3
	Sphagnum girgensohnii						3
	Sphagnum papillosum						2
	Sphagnum subsecundum						3
Sedges	*Carex anthoxanthea*	2				4	1
	Carex brunnescens					0	
	Carex circinnata	4	0	0	3	1	1
	Carex dioica gynocrates						3
	Carex glareosa				1		
	Carex gmelinii	0					
	Carex lachenalii		1		1	0	
	Carex macloviana			1			
	Carex macrochaeta	1	2	**1**	1	2	2
	Carex microchaeta	6	2		**11**	1	1
	Carex nardina				10	1	
	Carex nesophila	2	5		7	3	1
	Carex nigricans					2	1
	Carex phaeocephala		0	3			
	Carex pluriflora	1					
	Carex pyrenaica micropoda	10	2	6	1	1	1
	Carex scirpoidea	0					

Table 6. Continued.

Ecotype Name	Species name	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub	Alpine Rocky Barrens	Alpine Rocky Luetkea Dwarf Shrub	Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub	Alpine Rocky-Loamy Mountain Heather Dwarf Shrub
Sedges (continued)	*Carex stylosa*	2					
	Eriophorum viridi-carinatum						3
	Juncus biglumis			0		5	
	Juncus drummondii					1	
	Juncus mertensianus	0		0		1	
	Juncus triglumis	0					
	Luzula arcuata		1		3		
	Luzula arcuata unalaschensis	1	1		**5**	0	
	Luzula parviflora		8	**1**	0	2	0
	Luzula spicata		0				
	Luzula wahlenbergii piperi	0	3	1	15	1	
	Trichophorum caespitosum	10				5	1
	Species Richness[1] Summaries						
	Vascular Species Richness	84	69	63	46	89	89
	Non-Vascular Species Richness	11	6	2	7	12	27
	Total Species Richness	95	75	65	53	101	116

[1]Species richness is the total number of unique species occurrences in each plot ecotype.

Table 7. Mean percent cover by plant species and species richness for subalpine ecotypes, Kenai Fjords National Park, Alaska, 2013. Ecotypes with sample size <3 are excluded. Bold text indicates species with a constancy (frequency of occurrence) ≥60%. Average cover of 0 indicates presence at trace cover.

Ecotype Group	Species Name	**Subalpine Rocky Alder Tall Shrub**	**Subalpine Rocky Barrens**	**Subalpine Rocky Dwarf Mountain Hemlock Woodland**	**Subalpine Rocky Fireweed-Forb Meadow**	**Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow**	**Subalpine Rocky-Loamy Moist Graminoid Meadow**	**Subalpine Rocky-Loamy Sitka Spruce Woodland**	**Subalpine Rocky-Loamy-Organic Copperbush Low Shrub**	**Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen**	**Subalpine Rocky-Loamy-Organic Fern Meadow**
Sample Size		8	5	3	6	12	11	3	3	7	8
Deciduous shrubs	*Alnus sinuata*	**40**	5	**3**	0	1	2	**10**	**1**	**2**	2
	Arctostaphylos rubra										
	Cladothamnus pyrolaeflorus	11	1	**3**		1		**4**	**33**	**5**	5
	Menziesia ferruginea					0			1	2	
	Oplopanax horridus	1						0			1
	Rubus spectabilis	53	5		5		4	**5**		0	14
	Salix arctica	0			5						
	Salix barclayi	50									
	Salix phlebophylla										
	Salix rotundifolia						2				
	Salix sitchensis						5				
	Sambucus racemosa	0				1	2				
	Sorbus sitchensis	1		**2**					1	2	
	Spiraea beauverdiana	5					1				
	Vaccinium alaskensis			5						1	
	Vaccinium caespitosum			10						0	
	Vaccinium ovalifolium	**3**	0	**6**	6	0	3	**1**	**2**	2	2
	Vaccinium uliginosum	2		3	3	1		**17**	3	**8**	
Evergreen shrubs	*Andromeda polifolia*									0	
	Cassiope stelleriana	1		**13**		5		5	**3**	**5**	2
	Empetrum nigrum	0		**9**	5	8		**11**	**9**	13	
	Loiseleuria procumbens							1		0	
	Luetkea pectinata	14	0	23		47	10	4	12	1	9

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Evergreen shrubs (continued)	*Phyllodoce aleutica*	1		**18**	2	6	0	**13**	**4**	**16**	
	Vaccinium vitis-idaea			0	2			1			
Evergreen tree	*Picea sitchensis*	12		**4**		1		**34**	**2**	6	1
	Tsuga mertensiana	1		**28**		1		**3**	1	**5**	0
Forbs	*Achillea borealis*				**11**	3	2		2		1
	Achillea millefolium		0						1		
	Aconitum delphinifolium	1				1	2	1	1		1
	Anemone narcissiflora							**1**	1	1	1
	Angelica lucida										1
	Antennaria monocephala					0					
	Antennaria rosea	0									
	Apargidium boreale						0				
	Aquilegia formosa				5		0				1
	Arabis lyrata kamchatica					1	0				
	Arnica latifolia						1		2		
	Artemisia alaskana										
	Artemisia arctica	8	0	0	10	7	4	**1**		1	2
	Aruncus sylvester		1		5		3				1
	Aster subspicatus										0
	Athyrium distentifolium americanum					0					
	Athyrium filix-femina cyclosorum	8	1		**3**	2	3	1	**10**		**35**
	Blechnum spicant			0							
	Botrychium lanceolatum				1						1

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Forbs (continued)	*Botrychium lunaria*				0						
	Campanula lasiocarpa					1					
	Campanula rotundifolia					1	1				0
	Cardamine bellidifolia						0				
	Cardamine umbellata						0				0
	Castilleja caudata				2						
	Castilleja unalaschcensis				2		1			1	
	Circaea alpina										0
	Claytonia sibirica										1
	Conioselinum chinense	1			0	0	0		1	0	**1**
	Coptis trifolia									1	0
	Cornus canadensis	1		4				**3**		1	
	Cornus suecica	0							20	9	0
	Cryptogramma crispa	0	0		3	0	1				
	Cryptogramma crispa var. sitchensis					0					
	Dodecatheon jeffreyi			0						2	
	Drosera rotundifolia									0	
	Dryopteris dilatata americana	4			3	1	1	1		0	3
	Epilobium anagallidifolium	1			1	0	0		1	1	3
	Epilobium angustifolium	1		1	**17**	2	16	**1**	2	1	**4**
	Epilobium clavatum		0								
	Epilobium glandulosum				1						
	Epilobium hornemannii				1	0	0				
	Epilobium latifolium	3	0	1		3	3				

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Forbs (continued)	*Epilobium leptocarpum*					1					
	Epilobium palustre					1					
	Equisetum arvense				10		1				
	Erigeron peregrinus	5		**1**	5	5	2	**1**	1	0	2
	Euphrasia mollis	0									
	Fauria crista-galli	16	1	**10**		1		**17**	**33**	**49**	11
	Fritillaria camschatcensis						0	**1**			0
	Galium trifidum trifidum						0				
	Galium triflorum										0
	Gentiana douglasiana									0	
	Gentiana glauca										
	Gentiana platypetala				1			**1**	2	2	1
	Geranium erianthum	10			**9**	4	4		**2**	10	**6**
	Geum calthifolium	20		**1**	2	1		**2**	**2**	**3**	3
	Geum macrophyllum macrophyllum					15					
	Gymnocarpium dryopteris	1		1			2	1		2	4
	Heracleum lanatum	2			**10**		1				5
	Heuchera glabra	2			1	0	7				
	Hieracium triste			0	1	2	0	1	2		1
	Iris setosa									1	
	Lagotis glauca glauca				0						
	Ligusticum scoticum				0						
	Listera cordata									1	
	Lupinus nootkatensis	2		1	**4**	**16**	5	4	**4**	6	3
	Lycopodium alpinum					2		1	1	1	

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Forbs (continued)	*Lycopodium annotinum*									1	
	Lycopodium complanatum									5	0
	Lycopodium sabinaefolium var. sitchense							0	1	5	
	Lycopodium selago			0					1	0	0
	Mimulus guttatus										
	Minuartia rubella					0					
	Mitella pentandra										1
	Moneses uniflora							3			
	Osmorhiza purpurea					1					1
	Oxyria digyna		0				1				
	Pedicularis verticillata	1			1						
	Petasites frigidus				2	2	1				1
	Petasites hyperboreus		0			5					
	Pinguicula vulgaris									1	
	Platanthera saccata										1
	Polemonium acutiflorum				1		2				
	Polygonum viviparum	0						0			
	Prenanthes alata	1	0		3	0	2			0	**2**
	Primula cuneifolia							0			
	Ranunculus eschscholtzii					0					
	Rhinanthus minor borealis						0				
	Rubus arcticus				1	0	5				1
	Rubus pedatus	1		**3**				30	5	1	
	Rumex fenestratus						0				

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Forbs (continued)	*Sanguisorba stipulata*	7	3		**8**	4	**16**	2	**4**	1	**19**
	Saxifraga bronchialis					0					
	Saxifraga davurica										
	Saxifraga ferruginea		0			0					
	Saxifraga nelsoniana carlottae										1
	Saxifraga nivalis						4				
	Saxifraga punctata					0					
	Saxifraga punctata nelsoniana		1				0				0
	Sedum rosea integrifolium			**0**	2	0	1		0		3
	Selaginella selaginoides								0	0	
	Senecio triangularis	0			14	1	1		1		**1**
	Sibbaldia procumbens	10				1	1	0			
	Stellaria calycantha										0
	Stellaria crispa										1
	Stellaria sitchana var. bongardiana				0	3					
	Streptopus amplexifolius	0	0		0		0				**1**
	Thelypteris limbosperma	1		1					3	2	5
	Thelypteris phegopteris	12				0	4	3	**3**	2	**2**
	Tiarella trifoliata				0	0	1	0			1
	Trientalis europaea	0		0	2	3	2	0	0	0	2
	Valeriana sitchensis							0			3
	Veratrum viride eschscholtzii	**2**		0	**3**	1	8	0	**1**	4	**8**

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Forbs (continued)	*Veronica wormskjoldii*				0	0	1				
	Viola adunca										0
	Viola epipsila repens						4				
	Viola glabella						4				2
	Viola langsdorffii	2	0		**12**		3	5	1	0	10
Grasses	*Agrostis alaskana*			0			0			0	
	Agrostis borealis	3				1	1	**0**		1	
	Agrostis exarata				1					1	
	Agrostis thurberiana					3			1	2	
	Arctagrostis latifolia						20				
	Calamagrostis canadensis	**9**	**1**		**9**	6	**37**	**1**	**3**	1	**9**
	Calamagrostis nutkaensis			0		1				2	
	Danthonia intermedia					1			0	0	
	Deschampsia beringensis		0			1	50	2	**1**	2	
	Deschampsia caespitosa	5	1		2	2	12	**2**		3	
	Festuca altaica				2			1			1
	Hierochloe alpina				0			0			
	Phleum commutatum var. americanum	5			0	2	1				1
	Poa arctica										0
	Poa glauca						2				
	Poa lanata	6			0	1					
	Poa nemoralis				1						
	Podagrostis aequivalvis									20	

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Grasses (continued)	*Trisetum spicatum molle*					1	1				
	Vahlodea atropurpurea			**2**	10	**4**	14	1	**1**	1	3
	Cetraria islandica islandica									0	
	Cladina arbuscula			1						1	
	Cladina mitis			**0**				1		0	
	Cladina rangiferina				2						
	Cladina stellaris							0		3	
	Cladonia bellidiflora								1		
	Stereocaulon alpinum							0			
Liverworts	*Anthelia julacea*					3				8	
	Diplophyllum albicans					1					
	Haplomitrium hookeri					0					
	Lophozia pacifica					2					
	Lophozia sudetica					0					
	Macrodiplophyllum imbricatum					0					
	Macrodiplophyllum plicatum									5	
	Mylia taylorii									2	
	Pleurocladula albescens					0					
Mosses	*Brachythecium campestre*										5
	Calliergon stramineum			0							
	Dicranum bonjeanii										3
	Dicranum majus			5						2	
	Hylocomium splendens			5		5				4	
	Hypnum dieckei									5	

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Mosses (continued)	*Kiaeria falcata*					3					
	Lescuraea saxicola		2			2					
	Paraleucobryum enerve									8	
	Plagiomnium medium										3
	Plagiothecium cavifolium		0								
	Pleurozium schreberi			10	3	0	2	3			
	Pogonatum alpinum		0								
	Polytrichastrum alpinum					15					
	Polytrichum commune										0
	Polytrichum juniperinum		0								
	Ptilium crista-castrensis			0						2	
	Racomitrium canescens						15			3	
	Racomitrium ericoides		1								
	Racomitrium heterostichum					3					
	Racomitrium lanuginosum			0						3	
	Rhizomnium glabrescens						0	20			13
	Rhytidiadelphus loreus		0	20	45	18		20		20	1
	Sanionia uncinata									0	
	Sphagnum			1					1	5	
	Sphagnum angustifolium			0						8	
	Sphagnum capillifolium			0							
	Sphagnum compactum									10	

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Mosses (continued)	*Sphagnum girgensohnii*			2		2				5	
	Sphagnum papillosum									12	
	Tomentypnum nitens									20	
Sedges	*Carex anthoxanthea*			**1**		1				8	
	Carex dioica gynocrates			0		6					
	Carex lachenalii						15				
	Carex mackenziei				2	2					
	Carex macloviana					0	15				
	Carex macrochaeta	**14**	3		**1**	9	**19**	1	**2**	1	**6**
	Carex mertensii				2						
	Carex microchaeta	7	1					2			
	Carex nesophila							1			
	Carex nigricans			0		16			1	1	
	Carex pyrenaica micropoda	2				2	10				
	Carex spectabilis				1						
	Eriophorum viridi-carinatum									0	
	Juncus biglumis					2	1				
	Juncus drummondii					0					
	Juncus mertensianus					1	1				
	Luzula arctica			0							
	Luzula arcuata unalaschensis						1				
	Luzula parviflora	1	2		1	3	12		**1**		0
	Luzula wahlenbergii wahlenbergii					2					

Table 7. (continued)

Ecotype Group	Species Name	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Fireweed-Forb Meadow	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky-Loamy Moist Graminoid Meadow	Subalpine Rocky-Loamy Sitka Spruce Woodland	Subalpine Rocky-Loamy-Organic Copperbush Low Shrub	Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Subalpine Rocky-Loamy-Organic Fern Meadow
Sedges (continued)	*Trichophorum caespitosum*							2	0	3	
	Species Richness[1] Summaries										
	Vascular Species Richness	60	27	39	64	83	79	54	51	70	72
	Non-Vascular Species Richness	0	6	13	3	15	3	6	2	22	6
	Total Species Richness	60	33	52	67	98	82	60	53	92	78

[1]Species richness is the total number of unique species occurrences in each plot ecotype.

Table 8. Mean percent cover by plant species and species richness for upland forest and shrub ecotypes, Kenai Fjords National Park, Alaska, 2013. Ecotypes with sample size <3 are excluded. Bold text indicates species with a constancy (frequency of occurrence) ≥60%. Average cover of 0 indicates presence at trace cover.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Sample Size		5	16	14	19	19	11	16	25
Deciduous shrubs	*Alnus sinuata*	**48**	**28**	**4**	2	6	**7**	2	**55**
	Alnus tenuifolia	0							
	Cladothamnus pyrolaeflorus		0	0	8	0	1	0	6
	Menziesia ferruginea		1	0	2	3	10	**3**	3
	Oplopanax horridus	**3**	**9**	4	**2**	**4**	11	**8**	**7**
	Ribes bracteosum					0	7		10
	Ribes glandulosum	3							3
	Ribes hudsonianum		0						
	Ribes laxiflorum		4						
	Ribes triste	0							
	Rubus spectabilis		**14**	3	**3**	**6**	**67**	**11**	**40**
	Salix alaxensis	3		0					
	Salix barclayi	3	6	1					30
	Salix brachycarpa niphoclada			1					
	Salix scouleriana	3	25						
	Salix sitchensis	5	6	3					2
	Sambucus racemosa	0	5	0		1	**7**	1	**13**
	Sorbus sitchensis				1	0			
	Spiraea beauverdiana		2	0		0			
	Vaccinium alaskensis		3		12	17		8	
	Vaccinium caespitosum			5	10	4		4	
	Vaccinium ovalifolium		21	**4**	**53**	**44**	40	**25**	4
	Vaccinium uliginosum		0	3	3				
	Viburnum edule	1				0	2	1	4
Deciduous tree	*Populus trichocarpa*	**44**							

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Deciduous tree (continued)	*Cassiope stelleriana*			1	6	3			
	Empetrum nigrum				5	0			
	Linnaea borealis			0					
	Luetkea pectinata				4	4			2
	Phyllodoce aleutica				4				
	Vaccinium vitis-idaea								
Evergreen tree	*Picea sitchensis*	**5**	**37**	**53**	**7**	**30**	4	**48**	3
	Tsuga heterophylla			2				4	1
	Tsuga mertensiana	**0**	4	8	**42**	**25**	5	4	1
Forbs	*Achillea borealis*	0	0						1
	Achillea millefolium		0			0			0
	Aconitum delphinifolium								0
	Actaea rubra	**2**							
	Amerorchis rotundifolia				0				
	Anemone narcissiflora				0	0			
	Angelica lucida		0						10
	Aquilegia formosa								0
	Artemisia arctica	0							0
	Artemisia arctica arctica					0			
	Aruncus sylvester	1	1	0	0	8	2		6
	Athyrium filix-femina cyclosorum	**3**	5	1	4	1	**10**	3	**8**
	Blechnum spicant				2	1	1	1	
	Cardamine bellidifolia								1
	Cardamine umbellata						0		
	Circaea alpina		2				3	2	2
	Conioselinum chinense					0			0
	Coptis asplenifolia							15	
	Coptis trifolia				0	1		0	
	Cornus canadensis		2	1	**5**	**3**	20	**3**	
	Cornus suecica							0	0
	Cryptogramma crispa					0	0		

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Forbs (continued)	*Cystopteris fragilis*							0	
	Dodecatheon jeffreyi				2				
	Drosera rotundifolia				0				
	Dryopteris dilatata americana	**1**	**9**	4	1	**5**	4	**9**	**9**
	Epilobium anagallidifolium								0
	Epilobium angustifolium	**0**	0	0			0		4
	Epilobium glandulosum								0
	Epilobium hornemannii					0	0		
	Equisetum arvense		0	0					3
	Equisetum palustre	0							
	Erigeron peregrinus				0	0			0
	Fauria crista-galli				4	0			1
	Fritillaria camschatcensis								0
	Galium triflorum	**2**							0
	Gentiana douglasiana				0				
	Geranium erianthum								0
	Geum calthifolium				4	0			1
	Geum macrophyllum macrophyllum	0							1
	Gymnocarpium dryopteris	11	6	1	3	**5**	4	**6**	4
	Heracleum lanatum	**0**	0				2		3
	Heuchera glabra		1			0	1	0	1
	Impatiens noli-tangere								0
	Lathyrus maritimus maritimus								5
	Ligusticum scoticum								0
	Listera cordata	0	0	**2**	0	0		0	
	Lupinus nootkatensis			0					
	Lycopodium annotinum				1	1		0	
	Lycopodium clavatum		2	0	0			0	
	Lycopodium complanatum						0		
	Lycopodium selago		2		0	0		0	

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Forbs (continued)	*Lysichiton americanum*				15	0			
	Maianthemum dilatatum		1					0	
	Moneses uniflora	**0**	1	0	1	0		0	
	Petasites frigidus								0
	Pinguicula vulgaris				0				
	Platanthera obtusata	**0**							
	Prenanthes alata		0	2	0	0		2	1
	Pyrola asarifolia	**18**							
	Pyrola minor			0					
	Pyrola secunda	3	0	1				0	
	Pyrola secunda secunda	**1**	2	1					
	Ranunculus bongardi								0
	Rubus arcticus								1
	Rubus pedatus		19	4	**9**	**7**	10	**12**	1
	Sanguisorba stipulata				0	0			4
	Saxifraga ferruginea		0						
	Saxifraga mertensiana					0			
	Saxifraga nelsoniana pacifica								0
	Saxifraga punctata								0
	Stellaria calycantha		2						
	Stellaria crassifolia								0
	Stellaria crispa		1				2		0
	Stellaria sitchana var. bongardiana								0
	Stellaria sitchana var. stichana		0						
	Streptopus amplexifolius	**1**	**1**	0	0	1	0	**0**	**0**
	Tellima grandiflora								1
	Thalictrum sparsiflorum								0
	Thelypteris limbosperma			0	3				
	Thelypteris phegopteris		0	1	3	3	3	**4**	3
	Tiarella trifoliata		2	0	0	**1**	0	**1**	1

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Forbs (continued)	*Trientalis europaea*	0			0	0	2		0
	Valeriana capitata						0		
	Valeriana sitchensis	0							
	Veratrum viride eschscholtzii	0	0	0	1	0	1	0	1
	Viola adunca								2
	Viola epipsila repens		0						
	Viola langsdorffii				0	0	1		1
Grasses	*Agrostis alaskana*				0	0			
	Bromus sitchensis				0				
	Calamagrostis canadensis	**0**	1	1	5	3	**3**	1	**3**
	Calamagrostis nutkaensis				1	2		1	1
	Cinna latifolia								1
	Deschampsia beringensis				1	1			2
	Deschampsia caespitosa		0						0
	Festuca altaica								0
	Festuca rubra					0			
	Festuca rubra aucta								0
	Leymus mollis								10
	Trisetum cernuum		0			2	5	0	
	Vahlodea atropurpurea				3	0	0		
Lichens	*Cladina arbuscula*			0					
	Cladonia bellidiflora			1	0				
	Cladonia chlorophaea	0							
	Cladonia squamosa			0					
	Cladonia subfurcata	0							
	Lobaria linita	0	0	0		0		0	0
	Lobaria pulmonaria	0							
	Nephroma parile	0							
	Peltigera aphthosa								0
	Peltigera britannica			0					
	Peltigera canina	0							
	Peltigera kristinssonii			0					

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Lichens (continued)	*Peltigera membranacea*		0		0				
	Platismatia glauca			0					
	Sphaerophorus globosus			1					
Liverworts	*Anastrophyllum assimile*					3			
	Anthelia julacea				5				
	Barbilophozia lycopodioides	0							
	Macrodiplophyllum plicatum				5				
	Ptilidium ciliare			3					
	Scapania bolanderi			0					
Mosses	*Antitrichia curtipendula*				0				
	Brachythecium campestre		0						0
	Brachythecium oedipodium								3
	Brachythecium reflexum	1	5						0
	Brachythecium salebrosum	**0**							
	Climacium dendroides							20	5
	Dicranum angustum		1	3				3	
	Dicranum fuscescens			1		7			
	Dicranum laevidens			7					
	Dicranum majus	0	15	2				8	2
	Dicranum polysetum		5						
	Dicranum scoparium				30	20		2	
	Ditrichum flexicaule							0	
	Herzogiella turfacea			0					
	Hylocomiastrum pyrenaicum	1						0	
	Hylocomium splendens	0	**16**	**18**	**22**	15		**19**	4
	Hypnum dieckei				3				
	Hypnum revolutum	**0**							
	Lescuraea atricha						5		4
	Paraleucobryum enerve				8				
	Plagiomnium cuspidatum		15						

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
Mosses (continued)	*Plagiomnium medium*	**3**					3		0
	Plagiothecium cavifolium						13		3
	Plagiothecium nemorale								6
	Pleuroziopsis ruthenica							2	
	Pleurozium schreberi	1	21	25	4	0		2	3
	Pogonatum contortum							1	
	Polytrichastrum alpinum						0		1
	Polytrichum commune		1	0		1	0	1	1
	Polytrichum juniperinum	0							
	Pseudoleskea patens								3
	Ptilium crista-castrensis			1	0				3
	Racomitrium ericoides			7					
	Racomitrium lanuginosum			15					
	Rhizomnium glabrescens		10	0	2			2	
	Rhizomnium nudum			2					
	Rhizomnium punctatum				1			5	
	Rhytidiadelphus loreus	**1**	**41**	**71**	**47**	**49**	2	**63**	13
	Rhytidiadelphus triquetrus				0				
	Sanionia uncinata	**1**	2	0			2		7
	Sphagnum				6	13		7	
	Sphagnum angustifolium				12				
	Sphagnum girgensohnii		3		4	4	1	5	
	Sphagnum papillosum				12				
	Sphagnum squarrosum		3					2	
	Stereodon callichrous				3				3
	Syntrichia norvegica	0							
Sedges	*Carex anthoxanthea*				2				
	Carex macrochaeta		2		2	2		4	3
	Carex mertensii	0	1			1	5	0	0
	Eriophorum viridi-carinatum				1				
	Trichophorum caespitosum				4				

Table 8. Continued.

Ecotype Name	Species Name	Upland Rocky Black Cottonwood Forest	Upland Rocky Sitka Spruce-Alder Forest	Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Organic Alder Tall Shrub
	Species Richness[1] Summaries								
	Vascular Species Richness	38	53	41	58	60	38	42	76
	Non-Vascular Species Richness	19	17	25	20	10	9	18	21
	Total Species Richness	57	70	66	78	70	47	60	97

[1]Species richness is the total number of unique species occurrences in each plot ecotype.

Table 9. Mean percent cover by plant species and species richness for glacial, lacustrine, lowland, riverine, and upland non-forest, ecotypes, Kenai Fjords National Park, Alaska, 2013. Ecotypes with sample size <3 are excluded. Bold text indicates species with a constancy (frequency of occurrence) ≥60%. Average cover of 0 indicates presence at trace cover.

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Sample Size		15	5	3	3	8	5	21	5	10	5
Deciduous shrubs	*Alnus sinuata*	**49**	**1**	3		3	**11**	**53**	**1**	2	**3**
	Cladothamnus pyrolaeflorus					1			**5**	3	5
	Malus fusca								1		
	Menziesia ferruginea	0				2			1		
	Oplopanax horridus	1						4			1
	Rubus spectabilis	2					3	33	1		**6**
	Salix alaxensis	2	0				6	13			
	Salix barclayi	8				1	**15**	17			
	Salix bebbiana							2			
	Salix brachycarpa niphoclada	15	2					0			
	Salix commutata						5				
	Salix sitchensis	**15**	0	5			**56**	**19**			
	Sambucus racemosa	8						16	0		
	Sorbus sitchensis								1		
	Vaccinium ovalifolium					1		0	**4**	2	1
	Vaccinium uliginosum					**1**			4	**8**	
	Viburnum edule								0		0
Deciduous tree	*Populus trichocarpa*	5	0				2	4			
Evergreen shrubs	*Andromeda polifolia*									1	
	Cassiope stelleriana					1			1	4	
	Empetrum nigrum					0			2	**2**	
	Loiseleuria procumbens					0			3	2	
	Luetkea pectinata	5		**1**		1	1		1	2	
	Oxycoccus microcarpus									0	
	Phyllodoce aleutica					1			1	5	

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Evergreen tree	*Picea sitchensis*	5	0		0	0	2	4	**2**	1	
	Tsuga mertensiana	0				1	1	0	**6**	**2**	
Forbs	*Achillea borealis*	4	1	1	0		2	1			
	Achillea millefolium	0						10			
	Aconitum delphinifolium										0
	Anaphalis margaritacea	1	0	2							
	Anemone narcissiflora								0	0	
	Angelica lucida						1				
	Antennaria alpina			1							
	Aquilegia formosa						0	0			
	Arabis hirsuta eschscholtziana		0								
	Arabis lyrata kamchatica	0	1					0			
	Arnica latifolia										0
	Artemisia arctica			3			1	0	0		
	Artemisia tilesii	0	0					5			
	Aruncus sylvester	0					1	2	1		3
	Astragalus robbinsii harringtoni			1							
	Athyrium filix-femina cyclosorum	**8**		**2**	1		10	10	0	1	**49**
	Blechnum spicant								2	0	
	Botrychium lunaria										
	Campanula rotundifolia	2	1	2							
	Cardamine umbellata	1						0			
	Castilleja unalaschcensis	0		**2**			0				
	Circaea alpina							25			
	Conioselinum chinense								0	0	0
	Coptis trifolia					0			0	0	
	Corallorrhiza trifida	0									
	Cornus canadensis					0			**1**	0	
	Cryptogramma crispa		2								

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Forbes (continued)	*Cryptogramma crispa var. acrostichoides*	0									
	Cryptogramma crispa var. sitchensis	1		2							
	Dodecatheon frigidum					1			5	3	
	Dodecatheon jeffreyi					1			8	2	
	Dodecatheon pulchellum					1				1	
	Draba glabella			0							
	Drosera rotundifolia					0			1	2	
	Dryopteris dilatata americana	3		1			4	5			
	Epilobium anagallidifolium			1			2		0		
	Epilobium angustifolium	2					3	6			2
	Epilobium behringianum	2									
	Epilobium ciliatum	2									
	Epilobium glandulosum	10						1			
	Epilobium hornemannii	2	0	**1**	0		0	0			0
	Epilobium latifolium	1	**0**	**22**			1	1			
	Equisetum arvense	10				1	**0**	1			
	Equisetum fluviatile				90	2					
	Equisetum palustre						0				
	Equisetum variegatum	0						0			
	Erigeron peregrinus					1			**1**	**1**	0
	Fauria crista-galli					**18**			**41**	**15**	13
	Fritillaria camschatcensis					0			**0**		0
	Galium trifidum trifidum				15		1				
	Galium triflorum	2						3			
	Gentiana douglasiana					1			**2**	**1**	
	Gentiana platypetala								0	1	
	Geranium erianthum						0		0	0	2
	Geum calthifolium					**4**			**2**	**3**	
	Geum macrophyllum macrophyllum	1			5		3	0			
	Gymnocarpium dryopteris				0		8	3			

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Forbes (continued)	*Heracleum lanatum*	5		2	5		5	2			2
	Heuchera glabra	5	0	**4**			1	1			
	Hieracium triste			0							
	Iris setosa									1	
	Lathyrus maritimus maritimus							5			
	Leptarrhena pyrofolia						0				
	Ligusticum scoticum						0	0			
	Lupinus nootkatensis			1				0			2
	Lycopodium alpinum									0	
	Lycopodium annotinum								0	0	
	Lycopodium clavatum									0	
	Lycopodium sabinaefolium var. sitchense								0	0	
	Lycopodium selago					0					
	Lysichiton americanum				5						
	Minuartia rubella										
	Mitella pentandra	3									
	Montia fonata fontana					0					
	Osmorhiza purpurea						1				
	Oxyria digyna			**1**				0		4	
	Oxytropis deflexa							0			
	Pedicularis parviflora parviflora									0	
	Petasites frigidus						2				
	Pinguicula vulgaris								0	0	
	Platanthera dilatata									1	
	Platanthera hyperborea								0	0	
	Platanthera saccata	1							4		
	Polemonium acutiflorum						4	0			
	Polemonium pulcherrimum			2							
	Polygonum viviparum				0	1	1				
	Potentilla egedii										
	Potentilla villosa		1					1			

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Forbes (continued)	*Prenanthes alata*	3						0			1
	Pulsatilla patens multifida										
	Pyrola asarifolia	2					1	2			
	Pyrola minor	4									
	Pyrola secunda	0									
	Pyrola secunda secunda	2		0			**1**	0			
	Rorippa islandica				0						
	Rubus arcticus	0						2			
	Rubus arcticus arcticus						2				
	Rubus pedatus					0		0	5		
	Rumex fenestratus						0				
	Sanguisorba stipulata					0	4	0	2	0	1
	Saxifraga bronchialis		0	**1**				0			
	Saxifraga Lyallii Hultenii						0				
	Saxifraga nivalis		0								
	Saxifraga punctata						0				
	Saxifraga punctata nelsoniana	1		**1**							
	Saxifraga tricuspidata	0									
	Sedum rosea integrifolium						1				
	Selaginella selaginoides					1				0	
	Senecio lugens	1		1							
	Senecio triangularis						1				
	Senecio vulgaris										
	Sibbaldia procumbens			2							
	Silene acaulis			1							
	Sparganium angustifolium				30						
	Sparganium hyperboreum										
	Spiranthes romanzoffiana					0				0	
	Stellaria calycantha	0					1	0			
	Stellaria crassifolia	1									
	Stellaria crispa	2		1			0	0			

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Forbes (continued)	*Stellaria longifolia*	0		**2**							
	Stellaria longipes	30									
	Stellaria monantha						0				
	Stellaria sitchana var. bongardiana	1						4			
	Stellaria sitchana var. stichana						0	0			
	Streptopus amplexifolius	1			0		1	0			**1**
	Swertia perennis					2					
	Taraxacum officinale										
	Tellima grandiflora							0			
	Thelypteris limbosperma								**24**		
	Thelypteris phegopteris							0	0		
	Tiarella trifoliata	1						0	1	0	3
	Tofieldia glutinosa								0		
	Trientalis europaea					1	0	3	0		**1**
	Utricularia vulgaris macrorhiza								0		
	Valeriana sitchensis										1
	Veratrum viride eschscholtzii						1	0	3	0	**8**
	Veronica wormskjoldii						1				
	Viola epipsila repens					1	0				
	Viola glabella										
	Viola langsdorffii							15	0		
Grasses	*Agropyron violaceum violaceum*							1			
	Agrostis alaskana	2				0	0				
	Agrostis borealis		0					0			
	Agrostis exarata	2		**1**			1	0	1		
	Agrostis scabra	0						0			
	Agrostis thurberiana		1								
	Arctagrostis latifolia							1			
	Calamagrostis canadensis	**13**		**11**		2	**2**	**5**	3	0	**4**

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Grasses (continued)	*Calamagrostis nutkaensis*						3			1	
	Cinna latifolia							10			
	Danthonia intermedia								0	0	
	Deschampsia beringensis	0			0	0	1	0	2	1	
	Deschampsia caespitosa					1		1	0	0	
	Elymus trachycaulus							0			
	Festuca brachyphylla							0			
	Festuca rubra	1									
	Festuca rubra aucta							40			
	Glyceria striata				0						
	Hordeum brachyantherum							2			
	Leymus mollis						0	1			
	Phleum commutatum var. americanum	1		0							
	Poa alpina	0									
	Poa arctica	0		1			0				
	Poa glauca	3		**4**				1			
	Poa palustris						0				
	Poa pratensis	0									
	Poa stenantha		0								
	Podagrostis aequivalvis					1			**4**	**3**	
	Trisetum spicatum molle	1		**1**				0			
	Trisetum spicatum spicatum	0	1					0			
	Vahlodea atropurpurea					1	1		0	0	2
Lichens	*Cladina mitis*								4		
	Cladina stellaris								4		
	Cladonia chlorophaea	1									
	Cladonia cornuta ssp. groenlandica	1									
	Cladonia verruculosa		0								
	Stereocaulon grande	4	1								
Liverworts	*Anthelia julacea*									13	
	Scapania paludosa						7				

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Mosses	*Brachythecium campestre*						30				
	Brachythecium reflexum	3									
	Brachythecium salebrosum	0									
	Ceratodon purpureus		0								
	Dicranoweisia crispula	1									
	Hylocomium splendens	6				2		1			
	Lescuraea saxicola		0								
	Philonotis fontana						7				
	Plagiomnium insigne	0									
	Plagiomnium medium	3						3			
	Pleurozium schreberi						0				
	Pogonatum alpinum							3			
	Pogonatum urnigerum							10			
	Polytrichum commune					25	2	0			
	Polytrichum juniperinum	0	0					4			
	Ptilium crista-castrensis	3									
	Racomitrium canescens	20						17			
	Racomitrium ericoides	25	32					24			
	Racomitrium lanuginosum		0					2	25	23	
	Racomitrium panschii	2	0								
	Rhizomnium glabrescens	3									
	Rhytidiadelphus loreus	32					4	19			4
	Rhytidiadelphus squarrosus							33			
	Sanionia uncinata	3					5	0			
	Sphagnum					63			48	20	
	Sphagnum angustifolium					65					
	Sphagnum compactum					5					
	Sphagnum papillosum					10				45	
	Sphagnum russowii					45					
	Sphagnum squarrosum						2				
	Warnstorfia exannulata						7				

Table 9. Continued

Ecotype Name	Species Name	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens	Glacial Rocky Fireweed	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Sedge Meadow	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Upland Loamy-Organic Deer Cabbage Slope Fen	Upland Organic-rich Wet Sedge Slope Fen	Upland Rocky-Loamy Lady Fern Meadow
Sedges	*Carex anthoxanthea*					2			1	1	
	Carex aquatilis aquatilis					50					
	Carex kelloggii					5					
	Carex laeviculmis						0				
	Carex lyngbyaei					1		0	40		
	Carex macrochaeta	1				15	2	5	**15**	0	
	Carex mertensii	**2**	0	1			1	1		0	
	Carex nesophila	0				1					
	Carex nigricans					3					
	Carex pauciflora									15	
	Carex phaeocephala			1							
	Carex pluriflora					0					
	Carex saxatilis										
	Carex stylosa									1	
	Eleocharis palustris										
	Eriophorum angustifolium					**36**				**27**	
	Eriophorum angustifolium triste									4	
	Juncus arcticus sitchensis										
	Juncus drummondii									0	
	Juncus mertensianus					3			5	1	
	Luzula arcuata unalaschensis			1							
	Luzula parviflora	0									
	Trichophorum alpinum					60					
	Trichophorum caespitosum					3			**4**	**32**	
	Species Richness[1] Summaries										
	Vascular Species Richness	75	24	40	16	54	66	80	63	61	28
	Non-Vascular Species Richness	17	8	0	0	7	9	12	4	4	1
	Total Species Richness	92	32	40	16	61	75	92	67	65	29

[1]Species richness is the total number of unique species occurrences in each plot ecotype.

Table 10. Mean percent cover by plant species and species richness for coastal ecotypes, Kenai Fjords National Park, Alaska, 2013. Ecotypes with sample size <3 are excluded. Bold text indicates species with a constancy (frequency of occurrence) ≥60%. Average cover of 0 indicates presence at trace cover.

Ecotype Group	Species Name	Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	Coastal Rocky-Sandy Seaside Sandplant Beach	Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	Coastal Sandy-Rocky Beach Pea Meadow	Coastal Sandy-Rocky Beach Rye Meadow	Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat
Sample Size		7	5	4	16	8	16	8	7
Algae	Unidentified algae	1	18	5	5				2
Deciduous shrubs	*Alnus sinuata*	2				0	3	0	
	Oplopanax horridus								
	Rubus spectabilis						0	0	
	Salix barclayi							0	
	Sambucus racemosa						1	9	
Evergreen tree	*Picea sitchensis*	0					5	1	
Forbs	*Achillea borealis*	0						1	
	Angelica lucida					1	0	**3**	
	Artemisia arctica	1							
	Athyrium filix-femina cyclosorum						0	1	
	Cakile edentula		1		0				
	Campanula rotundifolia	2						0	
	Castilleja unalaschcensis							2	
	Cicuta virosa							3	
	Circaea alpina						0	1	
	Cochlearia officinalis	0							
	Cochlearia sessilifolia	3							
	Conioselinum chinense	0			0		0	0	
	Draba hyperborea	0	0						
	Dryopteris dilatata americana						0	2	
	Epilobium angustifolium					1	1	**31**	
	Epilobium ciliatum						0		
	Epilobium glandulosum						4		
	Epilobium latifolium	1				0	0		
	Fritillaria camschatcensis							**1**	
	Galium aparine			4			4	1	
	Galium trifidum trifidum				0		0	1	
	Glaux maritima				10				28

Table 10. continued

Ecotype Group	Species Name	Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	Coastal Rocky-Sandy Seaside Sandplant Beach	Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	Coastal Sandy-Rocky Beach Pea Meadow	Coastal Sandy-Rocky Beach Rye Meadow	Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat
Forbs (continued)	*Gymnocarpium dryopteris*						0	0	
	Heracleum lanatum					0	2	5	
	Heuchera glabra	1							
	Honckenya peploides	8	**3**	**51**		5	2	1	1
	Iris setosa							0	
	Lathyrus maritimus maritimus	5		7		**60**	19	8	
	Ligusticum scoticum		0		0		1	0	
	Lupinus nootkatensis	1						2	
	Mertensia maritima			1		1			
	Plantago maritima	0	**47**		8		0		**51**
	Polemonium acutiflorum							1	
	Polygonum bistorta				0			0	
	Polypodium vulgare	0							
	Potentilla egedii		2		3		0		2
	Potentilla palustris				0			0	
	Potentilla villosa	3							
	Prenanthes alata							1	
	Rhinanthus minor borealis					15		0	
	Rorippa islandica						0		
	Rubus arcticus				5		0	17	
	Rumex fenestratus				0	0	1	0	
	Ruppia spiralis				90				
	Sagina maxima	1							
	Sanguisorba stipulata	1						8	
	Sedum rosea integrifolium	0							
	Senecio pseudoarnica					0	2		
	Senecio triangularis						0	0	
	Spergularia canadensis								11
	Stellaria borealis						4		
	Stellaria crassifolia		5						
	Stellaria humifusa		**12**		1		1		1
	Stellaria longifolia				15		2		

Table 10. continued

Ecotype Group	Species Name	Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	Coastal Rocky-Sandy Seaside Sandplant Beach	Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	Coastal Sandy-Rocky Beach Pea Meadow	Coastal Sandy-Rocky Beach Rye Meadow	Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat
Forbs (continued)	*Stellaria sitchana var. bongardiana*							0	
	Stellaria sitchana var. stichana						0		
	Streptopus amplexifolius						0		
	Trientalis europaea				1		0	**0**	
	Triglochin maritimum				2				3
	Valeriana sitchensis							1	
	Veratrum viride eschscholtzii						0	2	
Grasses	*Agrostis exarata*							1	
	Calamagrostis canadensis				5	8	9	**28**	
	Calamagrostis deschampsioides				0				
	Calamagrostis nutkaensis				1	0	22	0	
	Deschampsia beringensis	2			1	0			
	Deschampsia caespitosa	0							
	Festuca altaica				1				
	Festuca rubra		12		4	4	6	1	0
	Festuca rubra aucta					0			
	Hordeum brachyantherum				1	0	2	0	
	Leymus mollis	2	1	**7**	3	**23**	**65**	**5**	2
	Phleum commutatum var. americanum							0	
	Poa eminens				2	0	3		
	Poa macrocalyx					7	1		
	Poa nemoralis					1			
	Poa palustris							0	
	Podagrostis aequivalvis					10			
	Puccinellia grandis		5						
	Puccinellia nutkaensis	1	**49**	4	0		5		**10**
	Vahlodea atropurpurea								
Mosses	*Drepanocladus polycarpus*				2				
	Racomitrium ericoides						3		
	Rhytidiadelphus loreus					20	36		
	Sanionia uncinata						0		

Table 10. continued

Ecotype Group	Species Name	Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat	Coastal Rocky-Sandy Seaside Sandplant Beach	Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow	Coastal Sandy-Rocky Beach Pea Meadow	Coastal Sandy-Rocky Beach Rye Meadow	Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat
Sedges	*Carex circinnata*	1							
	Carex glareosa				31				40
	Carex lyngbyaei	0	5		**59**	0	5		**3**
	Carex macrochaeta	4			2			0	
	Carex mertensii					0			
	Carex microchaeta							0	
	Carex pluriflora				10				
	Carex ramenskii				5				
	Eleocharis palustris				8				
	Juncus arcticus				0	1			5
	Juncus arcticus alaskanus				1				
	Juncus effusus				0				
	Species Richness[1] Summaries								
	Vascular Species Richness	28	14	7	36	25	43	48	14
	Non-Vascular Species Richness	0	0	0	1	1	3	0	0
	Total Species Richness	28	14	7	37	26	46	48	14

[1]Species richness is the total number of unique species occurrences in each plot ecotype.

Ecotype Descriptions

Alpine Lake



This ecotype refers to lakes and ponds at mid- to high elevations, in both alpine and subalpine physiography. These waterbodies tend to be small (mean area 0.2 km^2; maximum 4.2 km^2). Unlike Lowland Lakes (see below), Alpine Lakes are covered by snow and ice for much of the year. Vegetation is generally absent, although trace cover of aquatic emergent herbaceous plants may be present in shallow water near shore. Most Alpine Lakes occupy tarn basins excavated by ice scour; however, these lakes pre-date the Little Ice Age and most do not receive runoff from modern-day glaciers.

Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub





This alpine tundra ecotype occurs at high elevations, ranging between 202−814 m with a mean of 608 m, on a variety of geomorphic units, most commonly Upland Loess, Bedrock–Residual Soil, and Bedrock. This ecotype is generally not found in recently-deglaciated terrain. Vegetation is dominated by the dwarf shrubs *Empetrum nigrum* and *Vaccinium uliginosum*. Forbs and graminoids are common, but their total cover is low and there is often substantial cover of frost-shattered rock. Nonetheless, species richness is usually high. This ecotype was generally recorded on moderately-steep alpine slopes (5–23°) of variable aspect. Soils are moist and acidic (pH range 4.4–5.9). A surface organic mat was present at all field plots; surface organic thickness averaged 5 cm and ranged from 1–13 cm. The upper 40 cm of the soil profile is often dominated by loam, although bedrock is frequently present at shallow depth (< 20 cm). Due to the lack of detailed soils data available for alpine areas of KEFJ, we did not determine

soil subgroups for this ecotype. Common plant associations included Crowberry-Bog Blueberry/Deer Cabbage, Crowberry-Bog Blueberry, and several other crowberry-dominated associations. For mapping, we aggregated this ecotype with other alpine, dwarf shrub-dominated ecotypes and mapped them as Alpine Dwarf Shrub. Additionally, this ecotype often formed mosaics with Alpine Rocky Moist Sedge Meadow (see below); we mapped these areas as Alpine Dwarf Shrub–Herbaceous Mosaic.

Alpine Rocky Barrens





Alpine Rocky Barrens are widespread on rugged, high-elevation terrain that is too exposed and/or unstable to support continuous vegetation cover, such as nunataks, bedrock slopes, fellfields, and talus. It is one of the most extensive ecotypes in KEFJ. Common geomorphic units include Talus, Younger Till, and Bedrock. Cover of live vegetation is typically low (<30%) and is composed of scattered forbs, and lichens. Species richness may be high despite the low cover; when present, vegetation is primarily made up of Arctic-alpine species such as *Diapensia lapponica, Artemisia arctica, Campanula lasiocarpa, Sedum rosea, Sibbaldia procumbens,* and *Hierochloë alpina.* This ecotype was recorded at high elevations (mean elevation 957 m) on a variety of slope positions, from ridgecrests to steep alpine slopes on all aspects (mean slope angle 15°). Most of the ground surface is covered by coarse fragments or bedrock. Soil development is minimal, pH ranges from acidic to neutral, and soils are dry due to the very coarse soil texture and the lack of organics. Soils are typically blocky or bouldery, and bedrock is often present at very shallow depth. We did not determine soil subgroups for this ecotype. All field plots corresponded to a single, floristically variable plant association—Sparse. This ecotype shares many attributes in common with Glacial Rocky Barrens; however, the Alpine Rocky Barrens ecotype occurs in areas that have remained deglaciated for long periods of time.

Alpine Rocky Luetkea Dwarf Shrub





This alpine tundra ecotype is common on high-elevation slopes, and is present on some nunataks. It also occupies recently-deglaciated surfaces at high elevation. Common geomorphic units include Younger Till, Hillside Colluvium, and Talus. Vegetation is similar to other alpine dwarf shrub ecotypes, but the dwarf shrub mat tends to be less well-developed and is dominated by *Luetkea pectinata*. Herbaceous plants—particularly the forb *Lupinus nootkatensis*—are prominent and many overtop the dwarf shrub mat. Other common herbs include *Artemisia arctica, Sibbaldia procumbens, Carex macrochaeta,* and *Luzula parviflora.* This ecotype was recorded strictly at high-elevation (613–896 m) on moderate- to very steep slopes at a variety of aspects; it is often found on sites with deep, late-lying snowpacks. Surface rocks are usually abundant; soils are gravelly to blocky and a thin, discontinuous organic mat (mean thickness 4 cm) is usually present. Soils are dry to moist, and acidic (mean pH 5.2). We did not determine soil subgroups for this ecotype; however, soil subgroups are presumably similar to those of the Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow ecotype (see below). Most field plots in the Alpine Rocky Luetkea Dwarf Shrub ecotype belonged to the Nootka Lupine/Luetkea plant association. Occurrences of this ectoype in recently-deglaciated areas were mapped as Glacial Alpine Dwarf Shrub. In alpine physiography, we aggregated this ecotype with other alpine dwarf shrub ecotypes and mapped them as Alpine Dwarf Shrub. Complex mosaics with Alpine Rocky Moist Sedge Meadow (see below) were mapped as Alpine Dwarf Shrub–Herbaceous Mosaic.

Alpine Rocky Moist Sedge Meadow





This is a widespread alpine tundra ecotype on rugged slopes, ridges, and nunataks. It occurs on a variety of geomorphic units, including Talus, Upland Loess, Hillside Colluvium, and several post-glacial units. Vegetation cover is discontinuous and is dominated by a diverse assemblage of small herbaceous plants, particularly sedges such as *Carex microchaeta C. pyrenaica* ssp. *micropoda*, and wood-rushes such as *Luzula arcuata*. Arctic-alpine species, such as *Silene acaulis*, *Minuartia macropcarpa*, and *Artemisia arctica* are often present. Mosses, especially *Racomitrium* spp., can make up much of the live cover. Dwarf shrubs are usually present, but their total cover is <25%. Alpine Rocky Moist Sedge Meadow extends to higher elevations than alpine dwarf shrub ecotypes; it was recorded on moderately-steep slopes and a variety of aspects, as high as 1,422 m (mean elevation 1,037 m). Soils are usually moist, with acidic to neutral pH (mean pH 5.4). Surface fragments are usually present and surface organic material is thin or lacking (mean organic thickness 3 cm). The dominant soil texture in the upper 40 cm is rather variable; loams are not uncommon, but soils are usually fragmental and bedrock can be present at shallow depths. We did not determine soil subgroups for this ecotype. Alpine Rocky Moist Sedge Meadow is associated with a single plant association, Smallawned Sedge. This ecotype frequently formed mosaics with alpine dwarf shrub ecotypes; these mosaics were mapped as Alpine Dwarf Shrub–Herbaceous Mosaic. Alpine Rocky Moist Sedge Meadow also occurs in recently-deglaciated terrain at high elevation; we mapped these occurrences as Glacial Alpine Sedge Meadow.

Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub





This is the most widely-distributed alpine tundra ecotype in KEFJ. It occurs on a variety of geomorphic units, including Younger Till, Hillside Colluvium, Avalanche Deposits, and several other units related to bedrock or post-glacial deposits. The dwarf shrubs *Cassiope stelleriana* and *Luetkea pectinata* are co-dominant and form extensive mats; however, many herbaceous species occur among the dwarf shrubs and species richness is usually high. This ecotype occurs mostly on moderately- to very steep slopes at high elevation (mean elevation 623 m), but it is occasionally present at low elevation in association with avalanche deposits and other microsites with late-lying snow. This ecotype occupies recently-deglaciated sites more quickly than other alpine dwarf shrub ecotypes. Soils are moist and tend to be very acidic (mean pH 4.9; range 3.1–7.0). Dominant soil texture is usually blocky or boulder, although loams are also common. Bedrock is often present at shallow depth. A thin organic mat is usually present (mean organic thickness 4 cm). We did not determine soil subgroups for this ecotype due to the lack of detailed soils data available for alpine areas. Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub was associated with a single plant association, Steller's Cassiope-Luetkea. We mapped occurrences of this ecotype in recently-deglaciated areas as Glacial Alpine Dwarf Shrub. Elsewhere, we aggregated the alpine dwarf shrub ecotypes and mapped them as Alpine Dwarf Shrub. Alpine Dwarf Shrub often forms mosaics with Alpine Rocky Moist Sedge Meadow (see below); we mapped these areas either as Alpine Dwarf Shrub–Herbaceous Mosaic.

Alpine Rocky-Loamy Mountain Heather Dwarf Shrub

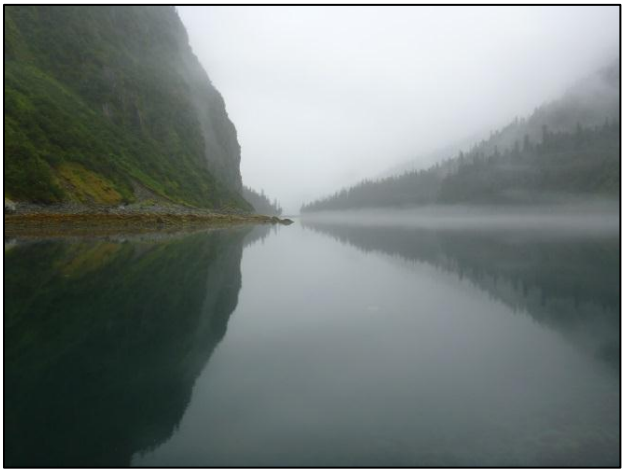




Alpine Rocky-Loamy Mountain Heather Dwarf Shrub is common in lower portions of the alpine zone of KEFJ. It was mostly found in association with Hillside Colluvium and Upland Loess, and occasionally in bedrock-related geomorphic units. Dwarf shrubs form a thick, dense mat. Ericaceous species are prominent, especially *Phyllodoce aleutica; Cassiope stelleriana* and *Luetkea pectinata* are also common. Many herbaceous species are usually present among the dwarf shrubs, and species richness is high. Few species, however, have high constancy; a few of the more common species include *Hieracium triste, Fauria crista-galli,* and *Lupinus nootkatensis*. This ecotype was found at relatively low elevation compared to other alpine ecotypes (mean elevation 565 m), on all aspects of moderately- to very steep slopes (mean slope angle 26°). It also occurs locally in the subalpine zone on ridgecrests and other exposed microsites. Soils are moist and acidic (mean pH 5.1). The surface organic mat is relatively thick (mean thickness 5 cm; range 1–15 cm) compared to other alpine ecotypes. Soils are often loamy, but can be dominated by coarse fragments or bedrock. This ecotype appears to require substantial time to develop and is generally absent from recently-deglaciated terrain. Although we usually could not determine soil subgroups in the alpine zone, one field plot in this ecotype was associated with the Lithic Cryorthent soil subgroup. Alpine Rocky-Loamy Mountain Heather Dwarf Shrub was primarily associated with the Aleutian Mountain Heather-Steller's Cassiope plant association. For mapping, we aggregated this ecotype with other alpine dwarf shrub ecotypes and mapped them as Alpine Dwarf Shrub. We mapped complex mosaics of Alpine Dwarf Shrub and Alpine Rocky Moist Sedge Meadow as Alpine Dwarf Shrub-Herbaceous Mosaic.

Coastal Brackish Water

This ecotype includes the nearshore waters of the Gulf of Alaska and numerous bays and lagoons in KEFJ. The water ranges from saline in the Gulf of Alaska, to brackish further into the fjords and bays, where freshwater from rivers and glacial melt mix with saltwater to create estuarine conditions.



Coastal Rocky-Sandy Barrens





This unvegetated ecotype is found on Active Gravelly Marine Beach, Coastal Inactive Dune, Coastal Bedrock Cliff, and Active Tidal Flat deposits along the coast and along lagoon margins. Vegetation is sparse to completely absent and bare soil (sands, silts, and gravels) or bedrock predominates. Common species occurring at trace (<1%) cover include *Honckenya peploides* and *Lathyrus maritimus* on beaches; *Heuchera glabra* and *Campanula rotundifolia* on coastal cliffs; *Puccinellia nutkaensis* on tidal flats; and *Achillea borealis* and *Lupinus nootkatensis* on dunes. Average slope gradient was 32º and ranged from 1º on tidal flats to sheer, low coastal cliffs. Slope aspect was variable. Wrack lines are common in this ecotype on tidal flats and beaches. Soil moisture ranges from dry to moist, and soil pH ranges from acidic on coastal cliffs, to alkaline on tidal flats and beaches. Surface organic layers are usually absent in this ecotype. Exposed bedrock predominates on coastal cliffs where fine soil material (<2 mm fraction) is absent. On tidal flats, beaches, and dunes soil texture in the upper 40 cm is predominantly sands, or sands with gravels or boulders. Common soil subgroups included Oxyaquic Cryorthents on tidal flats and beaches. Soils on coastal cliffs ranged from rock outcrop to Lithic Cryorthents on ledges and in cracks where thin mantles of fine soil material have accumulated. Detailed soils data were lacking for this ecotype on dunes and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order and are similar to soils in the Coastal Sandy-Rocky Beach Rye Meadow ecotype. Common plant communities included Sparse, Dwarf Alkaligrass, and Seaside Sandplant. On tidal flats and beaches this ecotype occurs below the high tide line and is regularly inundated with brackish water. On coastal cliffs, this ecotype is affected by salt spray and ocean waves.

Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat

This ecotype is found most commonly on Alluvial-Marine Deposits at or below the high tide line in coastal physiography. Vegetation is dominated by the halophytic grass *Puccinellia nutkaensis*; common halophytic associates include *Plantago maritima* and *Stellaria humifusa*. Average slope gradient was 2º and ranged up to 5º. Wrack lines are common in this ecotype. Soils are predominantly wet, brackish, and soil pH ranges from circumneutral to alkaline. Average surface organic thickness was 1 cm (range 0–3 cm). Soil texture in the upper 40 cm is predominantly sandy, or sandy with gravels or cobbles. Common soil subgroups included Oxyaquic Cryofluvents. Common plant communities included Dwarf Alkaligrass. This ecotype is subject to daily inundation due to regular tidal fluctuations. For mapping, we aggregated this ecotype with Coastal Sandy–Rocky Wet Brackish Goosetongue Tidal Flat, and mapped them as Coastal Brackish Tidal Flat.





Coastal Rocky-Sandy Brackish Seaside Sandplant Beach





This distinctive ecotype is restricted to Active Gravelly Marine Beach and Active Sandy Marine Beach deposits along the coast. Vegetation is dominated by the halophytic forb *Honckenya peploides*, and common associates include *Leymus mollis*, *Lathyrus maritimus*, and *Puccinellia nutkaensis*. Woody plants are typically absent, and bare soil (sands and gravels) is usually extensive. Average slope gradient was 7º and ranged up to 14º. Storm-deposited driftwood and wrack lines are common in this ecotype. Soil moisture ranges from dry to moist, and soil pH ranges from circumneutral to alkaline (pH range 6.4–7.9). Surface organic layers are absent in this ecotype. Soil texture in the upper 40 cm is predominantly sandy or sandy with gravels or boulders. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order and are similar to soils in the Coastal Rocky-Sandy Barrens and Coastal Sandy-Rocky Beach Rye Meadow ecotypes. Common plant communities included Seaside Sandplant. This ecotype is typically located at or above the normal high tide range, but is subject to storm surges and saltwater spray. This ecotype is problematic to map, because it typically occurs in narrow belts between active beaches and other coastal meadow ecotypes that are less frequently inundated, such as Coastal Sandy–Rocky Moist Circumneutral Beach Rye Meadow. We therefore consolidated this ecotype with other coastal moist herbaceous ecotypes, and mapped them as Coastal Moist Herbaceous Meadow. No soil photos were available for this ecotype.

Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow

This ecotype is found on Coastal Lagoon Deposit, Alluvial-Marine Deposit, and Inactive Tidal Flat and Active Tidal Flat deposits near sea level. Vegetation is dominated by rank stands of the semi-halophytic sedge *Carex lyngbyaei*; common associates include *Leymus mollis*, *Poa eminens*, and *Deschampsia beringensis*. Slope gradient was typically ≤1º. Wrack lines are common in this ecotype. Soils are predominantly wet, brackish, and soil pH ranges from circumneutral to alkaline. Average surface organic thickness was 4 cm and ranged from 0 up to 30 cm. Soil texture in the upper 40 cm is predominantly sandy, or sandy with gravels, cobbles, or boulders. Thin interbedded layers of sands and silts are common indicating frequent sedimentation. Common soil subgroups included Histic Cryaquepts, Typic Cryaquents, Oxyaquic Haplocryepts. Common plant communities included Lyngbye's Sedge, Lyngbye's Sedge/Seaside Buttercup, and Lyngbye's Sedge/Mixed Herb. Less common vegetation types included Lesser Saltmarsh Sedge and Common Spikerush.





Coastal Sandy-Rocky Beach Pea Meadow

This ecotype occurs in small patches on Inactive Sandy Marine Beach, Coastal Active Dune, and Coastal Inactive Dune along the upper margin of the coastal zone (mean elevation 9 m a.s.l.). Vegetation is dominated by the forb *Lathyrus maritimus* and common associates include *Honckenya peploides* and *Leymus mollis*. Average slope gradient was <1º and ranged up to 2º. Wrack lines are common in this ecotype. Soil moisture ranges from dry to moist, and soil pH is typically circumneutral. Average surface organic thickness was 2 cm and ranged from 0 to 5 cm. Soil texture in the upper 40 cm is predominantly sandy. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order and are similar to soils in the Coastal Sandy-Rocky Beach Rye Meadow ecotype. Common plant communities included Beach Pea. This ecotype was problematic to map, because it usually occurs as small patches in association with other coastal moist herbaceous ecotypes. We therefore aggregated these ecotypes and mapped them as Coastal Moist Herbaceous Meadow.





Coastal Sandy-Rocky Beach Rye Meadow

This ecotype was commonly found on Active Gravelly Marine Beach, Inactive Sandy Marine Beach, and Eolian Active Sand Dune deposits at the upper margin of the coastal zone (mean elevation 10 m). Vegetation is dominated by the grass *Leymus mollis*; common associates include forbs such as *Lathyrus maritimus* and *Achillea millefolium*, and grasses such as *Calamgrostis canadensis* and *Festuca rubra*. While *Picea sitchensis* seedlings may sometimes be found in this ecotype, in general, woody plants are absent. Average slope gradient was 2º and ranged up to 10º. Drift wood and other flotsam commonly occur in this ecotype. Soil moisture ranged from dry to moist, and soil pH ranged from circumneutral to alkaline. Average surface organic thickness was 2 cm and ranged up to 5 cm. Soil texture in the upper 40 cm was predominantly sandy, or sandy with gravels or boulders. Fine and medium roots were common in the upper 50 cm of the soil profile. A typical soil profile is pictured at right and described in Table 11, below. Common soil subgroups include Typic Cryopsamments and Typic Cryorthents. Common plant communities included Beach Rye, Beach Rye/Mixed Herbaceous, and Beach Rye/Yarrow. This ecotype is above the normal high tide range but is subject to storm surges and saltwater spray. For mapping, we aggregated this ecotype with other coastal moist herbaceous ecotypes, and mapped them as Coastal Moist Herbaceous Meadow.





Table 11. Typical soil stratigraphy for the ecotype Coastal Sandy-Rocky Beach Rye Meadow, plot number KEFJ_Tqc_03_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−2	--	--	--
2	Oe	2−4	--	--	--
3	C1	4−6	--	Coarse sand	--
4	Oe	6−8	--	--	--
5	C2	8−66+	--	Coarse sand	One cobble observed at 55 cm

Coastal Sandy-Rocky Bluejoint-Forb Meadow

This ecotype occurs on Inactive Sandy Marine Beach and Coastal Inactive Dune well above the high tide line (mean elevation 7 m a.s.l.). The vegetation is dominated by *Calamagrostis canadensis* and *Epilobium angustifolium;* common associates include *Angelica lucida*, *Fritillaria camschatcensis*, *Trientalis europaea*, and *Leymus mollis*. Woody species occasionally occur in this ecotype at low abundance, including *Picea sitchensis* seedlings and saplings, *Alnus sinuata*, and *Sambucus racemosa*. Average slope gradient was 4º and ranged up to 24º. Soil moisture is typically moist, and soil pH is typically circumneutral. Average surface organic thickness was 3 cm and ranged up to 5 cm. Soil texture in the upper 40 cm was predominantly sandy. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order and are similar to soils in the Coastal Sandy-Rocky Beach Rye Meadow ecotype. Common plant communities included Tall Fireweed and Bluejoint Reedgrass. This ecotype is above the normal high tide range and is rarely if ever flooded by saltwater. For mapping, we aggregated this ecotype with other coastal moist herbaceous ecotypes, and mapped them as Coastal Moist Herbaceous Meadow.





Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat

This ecotype is found on Coastal Lagoon Deposit, Alluvial-Marine Deposit, and Active Gravelly Marine Beach and Active Tidal Flat deposits at or below high tide line. Vegetation is dominated by the halophytic forb *Plantago maritima;* common associates include *Leymus mollis*, *Puccinellia nutkaensis*, and *Carex lyngbyaei*. Average slope gradient was <1º and ranged up to 2º, and slope aspect was variable. Wrack lines are common in this ecotype. Soil moisture ranges from wet (low tide) to aquatic (high tide), brackish, and soil pH ranges from circumneutral to alkaline. Surface organic layers are typically absent. Soil texture in the upper 40 cm is predominantly sandy, or sandy with gravels and cobbles. A typical soil profile is pictured at right and described in Table 12, below. Common soil subgroups included Oxyaquic Cryofluvents. Common plant communities included Goose Tongue. For mapping, we aggregated this ecotype with Coastal Rocky–Sandy Wet Brackish Goosetongue Tidal Flat, and mapped them as Coastal Brackish Tidal Flat.





Table 12. Typical soil stratigraphy for the ecotype Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat, plot number KEFJ_Tpb2_02_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	C1	0−6	Very channery	Sandy loam	Abundant roots
2	C2	6−27	Extremely channery	Sandy loam	--
3	C3	27−42+	--	Channers	--

Glacial Lake

The Glacial Lake ecotype represents young, usually moraine-dammed lakes that have developed following glacial retreat since the Little Ice Age. This ecotype includes the largest lake in KEFJ, "Bear Lake," below the terminus of Bear Glacier (pictured right), Pedersen Lagoon, and a large unnamed Glacial Lake below Yalik Glacier. Glacial Lake shorelines are subject to rapid change associated with continued glacial retreat, thaw of ice-cored moraine, and in the case of ice-dammed lakes, sudden drainage. Waters are turbid and aquatic vegetation is generally absent.



Glacial Rocky Alder-Willow Tall Shrub

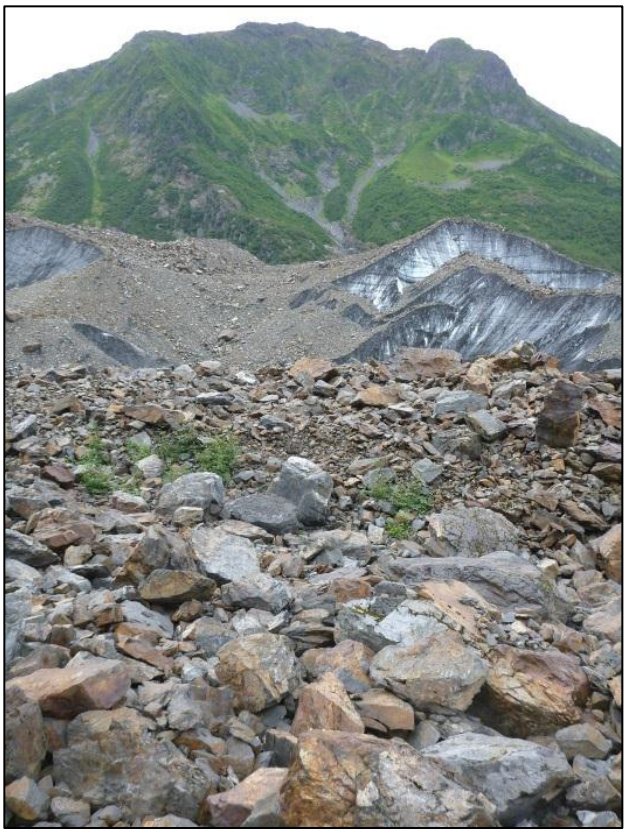




Widespread in recently-deglaciated, early-successional environments below retreating valley glaciers, Glacial Rocky Alder-Willow Tall Shrub occurs on post-glacial geomorphic units such as Younger Moraine, Younger Till, Glaciofluvial Outwash Deposits, and ice-scoured Bedrock. This ecotype is dominated by fast-growing shrubs, primarily *Alnus sinuata*, *Salix sitchensis,* and *S. niphoclada*. Herbaceous plants, such as *Athyrium filix-fimina, Calamagrostis canadensis,* and *Carex mertensii* are common in canopy gaps. Mosses such as *Racomitrium* spp. and *Rhytidiadelphus loreus* can be abundant in older stands. This ecotype develops within decadal timescales as shrubs colonize Glacial Rocky Barrens (see below) and rapidly develop into dense, tall canopied shrublands. This ecotype is widespread at low elevation (plot elevation range 6–179 m) on flat to steeply-sloping sites (slope range 0–65°). Soils are usually moist, and acidic to alkaline (mean pH 5.7; range 4.6–7.7). Surface organic matter is thin, or lacking altogether in young stands (mean thickness 3 cm). Soil texture is dominated by fragmental material or bedrock, and soil development is minimal. Soil subgroups identified in this ecotype were Typic Cryorthent and Lithic Cryorthent. Numerous, closely-related plant associations were identified in Glacial Rocky Alder-Willow Tall Shrub; most common were Sitka Alder-Sitka Willow, Sitka Alder-Sitka Willow/Bluejoint Reedgrass, Sitka Alder/Bluejoint Reedgrass. This ecotype commonly forms complex mosaics with herbaceous ecotypes such as Glacial Rocky Fireweed (see below); we mapped these areas as Glacial Tall Shrub-Herbaceous Mosaic.

Glacial Rocky Barrens

Glacial Rocky Barrens are common on very young surfaces exposed by recent glacial retreat. One of the most extensive ecotypes in KEFJ, it is found at all elevations, near both low-elevation valley glaciers, and high-elevation cirque glaciers and the Harding Icefield. Common geomorphic units include Bedrock, Younger Till, and Ice-cored Moraine. Vegetation is sparse (<20% live cover) or absent; common colonizing plants include *Racomitrium ericoides* and other saxicolous mosses, as well as vascular plants such as *Alnus sinuata* and *Epilobium latifolium.* This ecotype is highly transient at low elevations, where bare surfaces are invaded by shrubs. It can persist for long periods, however, on exposed, high-elevation surfaces where plant succession and soil development are much slower. Glacial Rocky Barrens were recorded on all aspects and hillslope positions. Soils are dry to moist, and pH is usually circumneutral. Surface organic material is virtually absent. Soil texture is dominated by fragmental material or bedrock. Two soil subgroups were identified in this ecotype—Lithic Cryorthent and Typic Cryorthent. Plant associations include Alder/Sparse and Bryoid-undefined; many sites lack any significant vegetation cover.





Glacial Rocky Fireweed



Glacial Rocky Fireweed is found in recently-deglaciated terrain at low- to mid-elevation, usually occurring as small patches interspersed with Glacial Rocky Alder-Willow Tall Shrub. This ecotype was usually recorded on the post-glacial geomorphic unit, Younger Till. Vegetation is dominated by herbaceous plants; the forb *Epilobium latifolium* is often dominant, but other saxicolous forbs such as *Heuchera glabra, Oxyria digyna,* and *Saxifraga* spp., and several grasses including *Calamagrostis canadensis* and *Poa glauca* often compose much of the live cover. Shrubs are usually present, but do not provide much cover. Glacial Rocky Moist Fireweed was found across a broad elevation range (124–864 m) on a variety of aspects and hillslope positions. Soils are moist, and soil pH is acidic to alkaline (mean pH 6.2). Typical soil profiles include a very thin surface organic layer (measured range 1–3 cm) overlying blocky glacial deposits. Bedrock is often present at shallow depth. Available data did not permit the determination of soil subgroups for this ecotype, and no soils photo is available. Two plant associations were recorded—Tall Fireweed and Dwarf Fireweed. Glacial Rocky Fireweed frequently occurs in small patches within a matrix of Glacial Alder-Willow Tall Shrub; these mosaics were mapped as Glacial Tall Shrub-Herbaceous Mosaic.

Glaciers and Permanent Snowfields



This ecotype represents present-day glaciers and the Harding Icefield. In spite of rapid retreat since the Little Ice Age, this is the most extensive ecotype by far in KEFJ and comprises nearly half of the park. Soils are generally non-existent, although glacier ice is sometimes covered by a thin veneer (<0.5 m) of rocky till. Crevasses, seracs, and moulins are common surface features in this ecotype. Hundreds of glaciers occur in KEFJ, ranging in size from small, unnamed cirque glaciers, to large valley glaciers extending to tidewater, such as McCarty Glacier. Most of the valley glaciers drain the Harding Icefield, which comprises over one-third of KEFJ. Vegetation is absent except in low-elevation ablation zones, where early-successional species, such as *Alnus sinuata*, can become established on thick till overlying the ice.

Human-modified Barrens

Direct human disturbance is very rare within KEFJ; recent disturbance is limited to the visitor access road and facilities at Exit Glacier in the northernmost portion of the park.

Lacustrine Aquatic Forb Marsh

This aquatic ecotype occurs on Glaciolacustrine Deposits, in Shallow Isolated Dune Lakes, and along the margins of Lowland Lakes. Species richness is very low in this ecotype; individual patches are usually dominated by a single species, such as *Equisetum fluviatile* or *Sparganium angustifolium.* Woody plants are absent. Soil moisture is aquatic and water pH is circumneutral in these freshwater marshes. Surface organics ranged from absent to 5 cm thick, and soil texture in the upper 40 cm is predominantly sandy. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Cryaquents Great Group and Aquic subgroups of Cryorthents. The extent of this ecotype is extremely limited in KEFJ. Therefore it was aggregated with Lowland Wet Sedge Meadow for mapping purposes. No soil photos were available for this ecotype.





Lowland Lake

This ecotype includes freshwater lakes at elevations below subalpine within the survey boundary that are no longer associated with active glaciers. These lakes vary in size from the 4 km long Delight Lake, to small kettle lakes. Water pH is typically circumneutral. Emergent vegetation is generally absent, except in shallow water near shore, where narrow belts of Lacustrine Aquatic Forb Marsh sometimes occur.



Lowland Organic-rich Wet Sedge Meadow

This sedge-dominated ecotype is found on Bogs, Glaciolacustrine Lowland Deposits, and Organic Fens. It is not extensive in KEFJ and is restricted to flat, poorly-drained sites. Elevation averaged 100 m and ranged between 8 and 271 meters. Vegetation is dominated by hydrophytic sedges, including *Eriophorum angustifolium*, *Carex aquatilis*, and *Trichophorum alpinum*. Common associates include the forbs *Geum calthifolium*, and *Fauria crista-galli*, and the ericaceous shrub *Vaccinium uliginosum*. Average slope gradient was 2º and ranged up to 5º, and slope aspect was generally northerly. Soils are wet and soil pH ranges from acidic to circumneutral (measured range 4.7–6.0). Average surface organic thickness was 39 cm and soil texture in the upper 40 cm is predominantly peat or organic-rich over sand, loam, or lithic-contact. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Histosols soil order and Histic subgroups of Inceptisols. Common plant communities included Tall Cottongrass and Tufted Bulrush.





River

This ecotype refers to perennial rivers and streams. Well-developed floodplains are not extensive in KEFJ because most watersheds are small; most watercourses have very high gradients and flow in incised channels. The most extensive floodplains are found along the Resurrection River in the northernmost part of the park, and Nuka River near the southwestern boundary. Both of these rivers receive substantial glacial runoff and have braided floodplains.



Riverine Rocky Dwarf Fireweed

This ecotype is uncommon and occurs at high elevations on Glaciofluvial Outwash Active-cover Deposit, Glaciofluvial Outwash Active-Channel Deposit, and Braided Coarse Active Channel Deposit. Vegetation is dominated by *Epilobium latifolium* and common associates include *Arabis lyrata*, *Poa alpina*, *Vahlodea atropurpurea*, and the moss *Racomitrium canescens*. This ecotype was only recorded on wide floodplains at high elevation (e.g., upper Nuka River); average slope gradient was 2º and ranged up to 4º, and slope aspect was variable. Soils are moist and soil pH ranges from acidic to circumneutral. Surface organics are typically absent and soil texture in the upper 40 cm is predominantly rubbly or gravelly. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order. Common plant communities included Dwarf Fireweed.





Riverine Rocky Dwarf Shrub



This rare ecotype was recorded on Glaciofluvial Outwash Inactive-cover Deposit and Braided Fine Inactive Channel Deposits along high-elevation floodplains in the study area. The vegetation is dominated by dwarf shrubs, including *Salix arctica*, *Empetrum nigrum*, *Cassiope stelleriana*, and *Phyllodoce aleutica*. Common associates include *Epilobium latifolium*, *Lycopodium annotinum*, and *Sibbaldia procumbens*. Slope gradient is typically less than 5 degrees, and slope aspect is variable. Soil moisture ranges from dry to moist, and soil pH is acidic. Surface organics are typically absent and soil texture in the upper 40 cm is predominantly blocky. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Entisols soil order. Common plant communities included Arctic Willow-Crowberry and Arctic Willow/undefined. No soil photos were available for this ecotype. Due to the extremely limited extent of this ecotype and similarity in soil attributes, we aggregated it with Riverine Rocky Dwarf Fireweed, and mapped them as Riverine Dwarf Fireweed and Barrens.

Riverine Rocky-Sandy Willow Low and Tall Shrub

This ecotype was recorded on Glaciofluvial Outwash Inactive-cover Deposit, Alluvial Fan Active Deposit, Glaciofluvial Outwash Active-Channel Deposit, Braided Coarse Active Channel Deposit, and Braided Active Overbank Deposit at lower to middle elevations (mean 105 m) along rivers and on alluvial fans in the study area. Vegetation is dominated by low (0.2−1.5 m) or tall (>1.5 m) willows, including *Salix barclayi* and *S. sitchensis*. *Alnus sinuata* commonly co-occurs at low abundance (<10–15%). Common associates include *Equisetum arvense*, *Pyrola secunda*, and *Calamagrostis canadensis*. Slope gradient is typically less the 1º on floodplains but may range higher on alluvial fans, and slope aspect is variable. Soil moisture ranges from dry to wet depending on river stage, and soil pH is typically circumneutral (mean pH 5.9). Average surface organic thickness was 3 cm and ranged up to 5 cm. Soil texture in the upper 40 cm was predominantly sandy or loamy with gravels or boulders. Thin interbedded layers of sands and silts are common in the upper part of the soil profile, indicating frequent sedimentation. Common soil subgroups include Fluventic Dystrocryepts and Aquic Cryofluvents. Common plant communities included Sitka Willow.





Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub





This is by far the most common ecotype in KEFJ within riverine physiography. It was recorded on Glaciofluvial Outwash Inactive-cover Deposit, Glaciofluvial Outwash Active-Channel Deposit, Glaciofluvial Outwash Active-cover Deposit, Alluvial Fan Active Deposit, Braided Coarse Active Channel Deposit, and Braided Active Overbank Deposit at lower elevations along rivers and on alluvial fans in the study area. Vegetation is dominated by tall (>1.5 m) *Alnus sinuata* with various willow species, most commonly *Salix sitchensis*. Herbaceous associates include *Athyrium filix-fimina* and *Calamagrostis canadensis*. Slope gradient is typically less than 3º on floodplains, but may range higher on alluvial fans and glaciofluvial deposits. Slope aspect is variable. Soil moisture is predominantly moist, and soil pH ranges from acidic to circumneutral. Average surface organic thickness was 3 cm and ranged up to 13 cm on sites where fluvial disturbance is less frequent. Soil texture in the upper 40 cm was predominantly sandy or loamy with gravels or boulders. A typical soil profile is pictured at right and described in Table 13, below. Common soil subgroups include Typic Cryorthents and Typic Cryofluvents. Common plant communities included Sitka Alder-Sitka Willow, Sitka Alder-Barclay Willow, Sitka Alder-Salmonberry/Lady Fern, Sitka Alder/undefined, and Sitka Alder/Splendid Feather Moss.

Table 13. Typical soil stratigraphy for the ecotype Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub, plot number KEFJ_Tdg_01_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−1	--	--	--
2	Oe	1−3	--	--	--
3	C1	3−17	Extremely cobbly	Loamy sand	Abundant medium and fine roots
4	C2	17−42+	Extremely cobbly	Loamy sand	--

Riverine Sandy-Loamy-Rocky Black Cottonwood Forest



This forest ecotype is locally common on active and inactive overbank deposits, and inactive channels of the Resurrection River. Vegetation is characterized by open- to closed stands of *Populus trichocarpa*. A dense understory of tall shrubs, such as *Alnus sinuata* and *Salix* spp., is often present. This ecotype is similar to Upland Rocky Black Cottonwood, but it is regularly subject to fluvial disturbance such as flooding, sedimentation, and channel migration. Detailed soils data are lacking for this ecotype; however, soils are likely very similar to those of Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub. We did not determine soil subgroups; the main plant association is Black Cottonwood/Sitka Alder. No soils photos are available for this ecotype.

Riverine Sandy-Loamy-Rocky Sitka Spruce Forest



This forest ecotype is locally common on Meander Active Overbank Deposit and Glaciofluvial Outwash Inactive-cover Deposit at low elevations along rivers and on alluvial fans. Vegetation is dominated by *Picea sitchensis* and features a dense understory shrub layer which commonly includes *Alnus sinuata*, *Oplopanax horridus*, *Rubus spectabilis*, *Salix sitchensis*, and *Vaccinium ovalifolium*. Common herbaceous associates include *Dryopteris dilatata*, *Heracleum lanatum*, and *Streptopus amplexifolius*. Slope gradient is typically less than 1º, and slope aspect is variable. Soil moisture is predominantly moist and soil pH ranges from acidic to circumneutral. Surface organic accumulations were thin, and averaged 3 cm. Soil texture in the upper 40 cm was predominantly sandy or loamy. Thin interbedded layers of sands, silts, and organics are common in the upper part of the soil profile indicating frequent sedimentation. Detailed soils data were lacking for this ecotype and therefore soil subgroups were not classified. However, soils likely fall within the Cryofluvents great group and Fluventic subgroups of the Cryepts suborder. Common plant communities included Sitka Alder-Sitka Willow, Sitka Alder-Barclay Willow, Sitka Alder-Salmonberry/Lady Fern, Sitka Alder/undefined, and Sitka Alder/Splendid Feather Moss. No soil photos were available for this ecotype.

Subalpine Rocky Alder Tall Shrub

This ecotype is conspicuous and widespread in the subalpine zone of KEFJ. It occurs on numerous geomorphic units associated with rocky, steep hillslopes, including Talus, Hillslope Colluvium, and Avalanche Deposits. Vegetation is strongly dominated by the thicket-forming shrub, *Alnus sinuata*. The shrub canopy usually exceeds 1.5 m in height, although low-statured stands are locally common on exposed microsites and at the subalpine-alpine ecotone. The shrub canopy tends to be less closed in this ecotype compared to alder-dominated ecotypes at lower elevation. *Rubus spectabilis* is usually prominent in canopy gaps, as are forbs. The forb understory is floristically variable; common species include *Athyrium filix-fimina, Veratrum viride, Calamagrostis canadensis*, and *Carex macrochaeta.* Subalpine Rocky Alder Tall Shrub was recorded on all aspects of moderate- to steep slopes at middle elevations (mean elevation 364 m; maximum 509 m); the altitudinal limit of alder growth demarcates the subalpine-alpine physiographic boundary for much of KEFJ. Soils are moist, and usually acidic (mean pH 4.9; range 4.2–6.0). Surface organic depth is rather variable (mean depth 11 cm; range 1–30 cm); dominant texture in the upper 40 cm is typically gravelly or coarser, and bedrock can be present near the surface; however, this ecotype is occasionally associated with loamy or even organic-rich soils. We did not determine soil subgroups for this ecotype due to sparse data in the subalpine zone. Field plots correspond to seven, rather similar plant associations, including Sitka Alder-Salmonberry, Sitka Alder-Salmonberry/Lady Fern, Sitka Alder/Bluejoint Reedgrass, and Sitka Alder-Barclay Willow. This ecotype frequently forms extensive, complex mosaics with Subalpine Rocky Acidic Moist Alder Tall Shrub; we mapped these mosaic landscapes as Upland Alder Tall Shrub–Lady Fern Meadow.





Subalpine Rocky Barrens

This ecotype is similar to Alpine Rocky Barrens, but it occurs at much lower elevations in association with Bedrock cliffs and Avalanche Deposits that are too frequently disturbed and/or late to melt out to support substantial vegetation. Scattered dwarf shrubs, such as *Luetkea pectinata*, and saxicolous herbs such as *Oxyria digyna* may be present, but total live cover is <20%. This ecotype typically occurs in linear patches that extend well downslope of most of the subalpine zone (e.g., avalanche tracks and runouts); field plots averaged only 98 m elevation (range 38–173 m). Soils are acidic (measured pH range 5.0–5.4) and moist; surface organic material is generally absent and the dominant texture is rubbly, blocky, or lithic. This ecotype was correlated with the Typic Cryorthent soil subgroup, and the Sparse and Unvegetated plant associations.





Subalpine Rocky Dwarf Mountain Hemlock Woodland



Subalpine Rocky Dwarf Mountain Hemlock Woodland is locally common on moderate-elevation ridgecrests and upper slopes of the outer fjordlands (e.g., Aialik Peninsula). Common geomorphic units include Hillside Colluvium, Upland Loess, and Colluvial Fan Deposit. Vegetation is characterized by stunted stands of *Tsuga mertensiana* exhibiting Krumholz growth form; most trees do not exceed 3 m in height. Species diversity is generally high and can include species typical of both alpine dwarf shrub ecotypes (e.g., *Luetkea pectinata* and *Cassiope stelleriana*), and slope fen ecotypes (e.g., *Fauria crista-galli*, *Geum calthifolium*). This ecotype occurs across a wide elevation range within the subalpine zone (mean plot elevation 308 m); stands at higher elevations demarcate the local subalpine-alpine physiographic boundary. Soils are moist, and acidic to circumneutral (pH range 3.4–7.1). Typical soil profiles consist of a dense organic mat (measured range 5–13 cm) overtopping blocky or bouldery material. A typical soil profile is pictured at right and described in Table 14, below. Available soils data are sparse for this ecotype; however, one field plot correlated to the Lithic Dystrocryept soil subgroup. All field plots corresponded to one plant association, Mountain Hemlock/Steller's Cassiope. For mapping, we aggregated this ecotype with the structurally-similar ecotype Subalpine Rocky-Loamy Sitka Spruce Woodland, and mapped them as Subalpine Dwarf Woodland.



Table 14. Typical soil stratigraphy for the ecotype Subalpine Rocky Dwarf Mountain Hemlock Woodland, plot number KEFJ_Tpac_02_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−5	--	--	--
2	Oa	5−11	--	--	--
3	A	11−21	--	Silt loam	--
4	BA	21−33	Very bouldery	Loam	small pockets of volcanic ash
5	Oa/Ab	33−36	Very bouldery	Silt loam	platy frost-related structure
6	R	36+	--	--	bedrock

Subalpine Rocky Fireweed-Forb Meadow



This ecotype primarily occurs on rocky, colluvial slopes that experience episodic disturbance such as landslide or avalanche. We recorded it in several geomorphic units, primarily Avalanche Deposit, Landslide Deposit, Talus, and Hillside Colluvium. Vegetation is dominated by forbs; low shrubs are usually present but their total cover is <25%. These meadows are often species-rich, but *Epilobium angustifolium* is usually dominant or co-dominant. Other common species include forbs such as *Achillea borealis, Geranium erianthum, Sanguisorba stipulata, Veratrum viride,* and *Viola langsdorffii,* and graminoids such as *Calamagrostis canadensis,* and *Carex macrochaeta.* This ecotype was found within a wide elevation range (37–562 m), usually on moderately steep slopes (mean slope 22.1°) with late-lying snow. Soils were moist and moderately acidic (measured pH range 4.6–5.8). Rounded or angular coarse fragments dominate the upper 40 cm of the soil profile, and the surface organic mat is thin or lacking (measured range 0–5 cm). A typical soil profile is pictured at right and described in Table 15, below. Typic Cryorthent was the sole soil subgroup identified for this ecotype. Tall Fireweed was the most common plant association in this ecotype. For mapping, this ecotype was consolidated with other subalpine moist herbaceous ecotypes, and mapped as Subalpine Moist Herbaceous Meadow.



Table 15. Typical soil stratigraphy for the ecotype Subalpine Rocky Fireweed-Forb Meadow, plot number KEFJ_Tsb1_02_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	A	0−13	Extremely gravelly	Sandy loam	--
2	CB	13−24	Extremely gravelly	Sandy clay loam	--
3	C	24−52+	Extremely stony	Sandy clay loam	--

Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow



Subalpine Rocky-Loamy Moist Luetkea-Mountain Hairgrass Meadow occurs on rocky hillslopes with late-lying snow; it was commonly recorded on the geomorphic units Hillside Colluvium, Talus, and Avalanche Deposit. This species-rich ecotype is similar to Alpine Rocky Luetkea Dwarf Shrub, but it occurs at lower elevations, there is less shrub cover, and it supports higher cover of Pacific coastal species, such as the grass *Vahlodea atropurpurea* the sedge *Carex macrochaeta*, and the forb *Lupinus nootkatensis.* Arctic-alpine species are less common. This ecotype was recorded across a wide range of elevations (37–817 m) on steep hillslopes that retain snow well into summer. Soils are moist, and acidic to circumneutral (mean pH 5.1; measured range 4.6–6.5. Surface organic accumulations were present at all plots (mean thickness 4.9 cm), usually overlying rubbly or blocky material, although loamy soils were occasionally recorded. A typical soil profile is pictured at right and described in Table 16, below. Soil subgroups identified in this ecotype were Typic Cryorthent and Folistic Dystrocryept. This ecotype is associated with three plant associations, Luetkea/Mountain Hairgrass, Nootka Lupine/Luetkea, and Longawned sedge. For mapping, Subalpine Rocky-Loamy Moist Luetkea-Mountain Hairgrass Meadow was aggregated with other subalpine moist herbaceous ecotypes, and mapped as Subalpine Moist Herbaceous Meadow.



Table 16. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow, plot number KEFJ_Tagc2_02_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−1	--	--	--
2	Oe	1−3	--	--	--
3	Oa	3−5	--	--	--
4	AC	5−17	Very cobbly	Sandy loam	weak, very friable granular to subangular blocky structure
5	C	17−41+	Extremely gravelly	Sandy loam	

Subalpine Rocky-Loamy Moist Graminoid Meadow



This ecotype was commonly found on somewhat unstable geomorphic units associated with hillslopes, such as Avalanche Deposit, Talus, and Hillside Colluvium; it is often associated with late-lying snowbeds. Vegetation tends to be species-rich and is dominated by graminoids, including grasses such as *Calamagrostis canadensis* and *Deschampsia beringensis*, sedges such as *Carex macrochaeta*, and wood-rushes such as *Luzula wahlenbergii*. Forbs, such as *Sanguisorba stipulata* are common associates. This ecotype was found across a very wide elevational range (11–702 m) and is associated with persistent snowpacks; occurrences at low elevation are usually associated with avalanche runouts. Soils are moist, and acidic to circumneutral (measured pH range 4.2–6.4). Surface organic material tends to be thin (mean thickness 4 cm) and the dominant soil texture is typically blocky or rubbly. We did not determine soil subgroups for this ecotype. Most plots in this ecotype corresponded to one of two plant associations, Bluejoint Reedgrass or Longawned Sedge. For mapping, this ecotype was consolidated with other subalpine moist herbaceous ecotypes, and mapped as Subalpine Moist Herbaceous Meadow.



Subalpine Rocky-Loamy Sitka Spruce Woodland





Subalpine Rocky-Loamy Sitka Spruce Woodland is an uncommon ecotype found on steep, south-facing slopes at the altitudinal limit of tree growth. Hillside Colluvium was the most common geomorphic unit at field plots. This ecotype is characterized by scattered thickets of dwarf, wind-flagged Sitka spruce; available data suggest that dwarf spruce stands occur primarily in the southwesternmost portion of the park. Throughout KEFJ, small, isolated groves of larger trees commonly occur on favorable subalpine microsites that are protected from avalanche and melt out early; however, these stands are usually too small to map individually. Additional data for subalpine Sitka spruce stands would be very useful. This ecotype was only recorded on south-facing slopes across a rather wide elevation range (376–516 m). Soils are moist and usually acidic (mean pH 5.0). The dominant soil texture is loamy to gravelly, with a thin surface organic layer (mean organic thickness 6 cm). We did not determine soil subgroups for this ecotype due to the lack of available soils data. Plant associations identified in this ecotype are Sitka Spruce/Sitka Alder and Sitka Spruce/undefined. For mapping, we aggregated this ecotype with the structurally-similar ecotype Subalpine Rocky Mountain Hemlock Dwarf Woodland, and mapped them as Subalpine Dwarf Woodland.

Subalpine Rocky-Loamy-Organic Copperbush Low Shrub





Subalpine Rocky-Loamy-Organic Copperbush Low Shrub is locally common in snowbed habitats in the uppermost part of the subalpine zone, on steep, rocky slopes. Hillside Colluvium was the only recorded geomorphic unit. This ecotype is floristically distinctive, with high species richness; it is easily recognized by well-developed stands of the low shrub, *Cladothamnus pyrolaeflorus*. Gaps among the shrubs are occupied by a diverse assemblage of forbs, such as *Fauria crista-galli, Sanguisorba stipulata, Athyrium filix-fimina,* and *Geranium erianthum;* dwarf shrubs, such as *Luetkea pectinata* and *Phyllodoce aleutica*, are also common. This ecotype was recorded on moderate to steep slopes (10–38°) that develop deep, persistent snowpacks; soils are moist and very acidic (mean pH 4.6), likely due in part to leaching by the abundant snowmelt. Dominant soil texture appears to be quite variable; the ecotype was recorded on blocky, loamy, and organic-rich soils with a well-developed organic mat (mean thickness 13 cm). We did not identify soil subgroups due to the lack of detailed soils data. This ecotype corresponded to a single plant association, Copperbush. This ecotype is challenging to map, because patch sizes are typically small and it is difficult to distinguish them from herbaceous meadows in satellite imagery. For mapping, we therefore consolidated it with subalpine mesic herbaceous ecotypes and mapped them as Subalpine Moist Herbaceous Meadow.

Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen





This ecotype is found on subalpine slopes in which subsurface bedrock impedes the infiltration of water, resulting in a shallow water table that promotes paludification and the development of wetland (fen) vegetation. Subalpine Rocky-Loamy-Organic Moist Deer Cabbage Slope Fens were primarily recorded on Bedrock and Hillside Colluvium. Vegetation is dominated by the forb, *Fauria crista-galli*; common associates include forbs such as *Geum calthifolium*, as well as ericaceous shrubs such as *Cladothamnus pyrolaeflorus*, *Phyllodoce aleutica* and *Vaccinium uligonosum*. Mosses, such as *Sphagnum* spp. and liverworts are abundant. Closely related ecotypes include Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow, and Upland Loamy-Organic Deer Cabbage Slope Fen; however, the former is not strongly dominated by *Fauria crista-galli* and soils are better-drained, while the latter is wetter, tends to support thicker organic soils, and is more strongly dominated by hydrophytic species. Subalpine Rocky-Loamy-Organic Moist Deer Cabbage Slope Fens were found on all aspects within a wide elevation range in the subalpine zone (mean elevation 223 m; range 47–360 m), usually on moderate to steep slopes (mean slope 13°). Soils are moist to wet, and acidic (pH range 4.2–5.5). Dominant soil texture in the upper 40 cm ranges from loamy to bouldery, and bedrock is often present at shallow depth. Mineral material is capped by a well-developed organic mat; however, there is much microsite variation in organic thickness (measured range 1–17 cm). A typical soil profile is pictured at right and described in Table 17, below. Two soil subgroups were identified in this ecotype—Histic Lithic Cryaquepts and Lithic Cryofolists. Common plant associations associated with this ecotype include Aleutian Mountain Heather/Deer Cabbage, Deer Cabbage, and Crowberry-Bog Blueberry/Deer Cabbage. For mapping, this ecotype was aggregated with the similar and more widespread upland slope fen ecotypes, and mapped as Upland Herbaceous Slope Fen.

Table 17. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen, plot number KEFJ_Tagc2_01_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−1	--	--	--
2	Oe	1−4	--	--	--
3	Oa	4−9	--	--	--
4	C	9−11	--	Sandy loam	volcanic ash
5	Oa/C	11−28	--	Sandy loam	thin discontinuous layers of volcanic
6	Cr	28−42	Gravelly	Loam	
7	R	42+	--	--	bedrock

Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow

This forb-dominated ecotype is patchily distributed in the subalpine zone in late-lying snowbeds. We recorded it on two geomorphic units, Hillside Colluvium and Upland Loess. A species-rich ecotype, *Fauria crista-galli* is dominates but many forb species are typically present with low cover. Common associates include *Sanguisorba stipulata, Viola langsdorffii, Aster subspicatus, Thelypteris limbosperma,* and *Gentiana platypetala*. The low shrub *Cladothamnus pyrolaeflora* is usually present but total shrub cover is well below 25%. We recorded this ecotype in the lower part of the subalpine zone (mean elevation 371 m). Soils are moist, and acidic to circumneutral (measured pH range 4.5–5.8). The surface organic mat is well-developed (measured thickness range 10–21 cm) and bedrock is often present at shallow depth (<20 cm). A typical soil profile is pictured at right and described in Table 18, below. Two soil subgroups were identified—Typic Cryorthent and Andic Dystrocryept. Field plots in this ecotype corresponded to a single plant association—Deer Cabbage. Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen is a somewhat similar ecotype, but slope fen soils are wetter and there is higher cover of hydrophytic species and bryophytes. For mapping, Subalpine Rocky-Loamy-Organic Moist Deer Cabbage-Forb Meadow was aggregated with other subalpine moist herbaceous ecotypes, and mapped as Subalpine Moist Herbaceous Meadow.





Table 18. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow, plot number KEFJ_Tpb1_02_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oa	0−21	--	--	Small pocket of volcanic ash at at 10cm
2	A	21−40+	Cobbly	Silt loam	--

Subalpine Rocky-Loamy-Organic Fern Meadow





This ecotype is common on subalpine hillslopes, often forming complex mosaics with other subalpine ecotypes such as Subalpine Rocky Alder Tall Shrub. Subalpine Rocky-Loamy-Organic Fern Meadow was recorded on numerous geomorphic units; most common were Hillside Colluvium, Talus Upland Loess, and Ash-laden Loess. Vegetation is characterized by dense growth of forbs, particularly the fern *Athyrium filix-fimina.* Other common forbs in this species-rich ecotype include *Sanguisorba stipulata*, *Epilobium angustifolium, Senecio triangularis,* and *Veratrum viride.* Graminoids, such as the grass *Calamagrostis canadensis*, and the sedge *Carex macrochaeta*, are also common but they do not provide much cover. Shrubs, especially *Rubus spectabilis*, are often intermixed with herbaceous plants but total shrub cover is <25%. Subalpine Rocky-Loamy-Organic Fern Meadow was recorded across a very broad elevation range (40–565 m), generally on steep slopes (measured range 16–37°) that retain snow cover until early summer. Soils are moist, and acidic to circumneutral (pH range 4.6–6.6). The dominant soil texture is variable in this ecotype, with some examples found in association with deep loams and others on bouldery substrates. A well-developed surface organic layer is usually present (measured thicknesses 4–20 cm). A typical soil profile is pictured at right and described in Table 19, below. This ecotype was associated with Typic Cryorthent and Andic Dystrocryept soil subgroups; plant associations were Lady Fern and Salmonberry/Lady Fern. This ecotype frequently forms extensive, complex mosaics with Subalpine Rocky Alder Tall Shrub; we mapped these mosaic landscapes as Subalpine Alder Tall Shrub–Herbaceous Meadow.

Table 19. Typical soil stratigraphy for the ecotype Subalpine Rocky-Loamy-Organic Fern Meadow, plot number KEFJ_Tpb1_01_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−14	--	--	Small pocket of volcanic ash at at 10cm
2	Oa	14−20	--	--	--
3	Bs	20−28	--	Silt loam	Volcanic ash
4	Oa	28−30	--	--	
5	C	30−31	--	Very fine sandy loam	--
6	Oa	31−33	--	--	
7	Ab	33+	--	Silt loam	Strong, medium, angular blocky structure

Upland Loamy-Organic Deer Cabbage Slope Fen



Upland Loamy-Organic Deer Cabbage Slope Fen occurs below treeline on bedrock slopes with perched water tables that promote organic soil buildup and paludification. This ecotype is primarily found on the granitic outer peninsulas of KEFJ (e.g., Aialik Peninsula), which have been deglaciated for long periods and where the resistant bedrock creates an impermeable barrier preventing infiltration.Geomorphic units recorded for this ecotype are Intrusive Igneous Bedrock, Bog, and Hillside Colluvium. Vegetation is dominated by hydrophytic forbs and graminoids. *Fauria crista-galli* is dominant; common associates include *Thelypteris limbosperma*, *Geum calthifolium,* and *Carex macrochaeta.* Mosses, especially *Sphagnum* spp. and *Racomitrium lanuginosum*, are usually abundant. Stunted conifers and ericaceous shrubs are usually also present, but provide little cover. This ecotype is only found below treeline, on hillslopes or occasionally flat benches (mean slope 27°). Soils are similar to those in the Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen. Soils are wet, and pH is usually acidic (mean pH 5.2; range 4.3–6.6). There is a thick organic mat (mean thickness 31 cm; maximum 45 cm) and the dominant texture is peaty or occasionally loamy. A representative soil photo was not available for this ecotype. We did not determine soil subgroups for this ecotype. Vegetation corresponds to a single plant association: Deer Cabbage. This ecotype is similar to Subalpine Rocky–Loamy–Organic Deer Cabbage Slope Fen, except it occurs at lower elevation, there is greater cover of low shrubs and dwarf trees, and the organic mat tends to be thicker. These two slope fen ecotypes, and Upland Organic-rich Wet Sedge Slope Fen were aggregated together and mapped as Upland Herbaceous Slope Fen.

Upland Organic-rich Wet Sedge Slope Fen





Upland Organic-rich Wet Sedge Slope Fen occurs on bedrock slopes with perched water tables that have developed heavy accumulations of peat; this ecotype is only present in areas that have been deglaciated for long periods of time (e.g., granitic outer peninsulas). Geomorphic units associated with Upland Organic-rich Wet Sedge Slope Fen include Intrusive Igneous Bedrock, Slope Bog, Bog, and Bedrock-Residual Soil. Vegetation is characterized by sparse vascular plant cover growing on a nearly-continuous mat of mosses (mainly *Sphagnum* spp.) and liverworts (e.g., *Anthelia julacea*). Vascular plants are dominated by hydrophytic sedges, mainly *Trichophorum caespitosum* and *Eriophorum angustifolium. T*he forbs. *Fauria crista-galli* and *Geum calthifolium* are common associates. Ericaceous shrubs are usually also present, but provide little cover. This ecotype is only found below treeline, on hillslopes or occasionally flat benches (mean slope 15°). Soils are saturated throughout the growing season; pH is usually acidic (mean pH 5.4; range 4.0–7.1). There is a thick to very-thick organic mat (mean thickness 36 cm; maximum 76 cm) and the dominant texture is organic-rich or peaty. Fine mineral material is generally limited to a thin layer of grus or other residuum between the organic layer and the bedrock. Several plant associations were recorded in this ecotype; the most common include Tufted Bulrush, Deer Cabbage/Tufted Bulrush, and Tall Cottongrass-Tufted Bulrush. This ecotype is similar to Upland Rocky–Loamy–Organic Deer Cabbage Slope Fen, except that soils are more paludified, there is less vascular plant cover, and sedges are dominant. These two upland slope fen ecotypes were aggregated together and mapped as Upland Herbaceous Slope Fen.

Upland Rocky Black Cottonwood Forest





This early-successional forest ecotype has a limited distribution in KEFJ, but is extensive on post-Little Ice Age moraine and glacial outwash near the Resurrection River and Exit Glacier. It is floristically distinctive, and is the only upland forest ecotype in KEFJ that is dominated by deciduous trees. It was recorded on several post-glacial geomorphic units, including Older Moraine, Younger Till, and Glaciofluvial Esker Deposit. Vegetation is characterized by open- to closed stands of *Populus trichocarpa*. Conifers, mainly *Picea sitchensis*, are often present as saplings or pole-sized understory trees; mixed stands do occur, but are not common and few data are available. Tall alder shrubs are usually abundant in the understory. Several understory forb species, including *Pyrola asarifolia*, *Galium triflorum*, and *Platanthera obtusata* are common in this ecotype but are virtually absent elsewhere in KEFJ. Soils are moist, and acidic to circumneutral (pH range 4.5–6.3). A thin organic layer (mean thickness 9 cm) overlies gravelly or bouldery material. A typical soil profile is pictured at right and described in Table 20, below. Typic Cryorthent and Typic Cryofluvent were the soil subgroups identified in this ecotype. Vegetation corresponds to a single plant association, Black Cottonwood/Sitka Alder. Over time, this ecotype gives way to Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest as Picea sitchensis becomes dominant in the canopy. Upland Rocky Black Cottonwood Forest is similar to Riverine Black Cottonwood Forest, but it is rarely or never subject to overbank flooding.

Table 20. Typical soil stratigraphy for the ecotype Upland Rocky Black Cottonwood Forest, plot number KEFJ_Teg1_02_2013, Kenai Fjords National Park, 2013

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−4	--	--	--
2	Oe	4−10	--	--	--
3	CB	10−17	Gravelly	Sandy loam	--
4	Cd	17−42	Cobbly	Sandy clay loam	compacted till

Upland Rocky Sitka Spruce-Alder Forest





This forest ecotype is common at low elevations on post-glacial deposits and rocky hillslopes. It was recorded on numerous geomorphic units, including Glaciofluvial Outwash Abandoned-cover Deposit, Hillside Colluvium, Glaciofluvial Esker Deposit, and Abandoned Marine Beach. Vegetation is characterized by open stands of *Picea sitchensis.* Canopy gaps support dense shrub growth, primarily of *Alnus sinuata, Rubus spectabilis,* and *Oplopanax horridus.* Common herbs include *Dryopteris dilitata* and *Streptopus amplexifolius.* Feathermosses form a discontinuous carpet on the forest floor. This ecotype is generally found at low elevations (plot elevation range 2–110 m), usually on gentle slopes (mean slope angle 7°). Soils are moist and usually acidic (mean pH 4.9). Surface organics form a thin mat (mean thickness 5 cm) and usually overly fragmental substrates; however, this ecotype occasionally occurs on loamy soils. Numerous soil subgroups were identified in this ecotype, including Typic Cryorthent, Aquic Cryofluvent, and Fluventic Dystrocryept. Common plant associations include Sitka Spruce/Sitka Alder, Sitka Spruce/Salmonberry-Devil's Club, and Sitka Spruce/Devil's Club. This ecotype is distinguished from other upland coniferous forest ecotypes primarily by the dense, alder-dominated shrub understory, and by the relatively thin organic mat. It frequently occurs on fairly young glacial deposits (~75–100 years old). This ecotype could not be reliably distinguished from Upland Rocky Moist Acidic Sitka Spruce–Feathermoss Forest during mapping; these ecotypes were collectively mapped as Upland Sitka Spruce–Early Successional Forest.

Upland Rocky Sitka Spruce-Feathermoss Forest





This distinctive, early-successional forest ecotype is found at low elevation on fairly young glacial deposits and abandoned beach deposits. It was recorded on numerous geomorphic units, including Older Till, Older Moraine, Abandoned Marine Beach, and Glaciofluvial Kame Deposit. Vegetation is characterized by dense, even-aged stands of pole- to timber-sized *Picea sitchensis.* The trees form a dense canopy and most are suppressed by shade. The forest understory is very open and species-poor, and lacks substantial cover of shrubs and herbs. The orchid *Listera cordata* is usually present. Feathermosses, especially *Rhytidiadelphus loreus* and *Hylocomium splendens*, form a continuous carpet on the forest floor. This ecotype was recorded only at low elevation (plot elevation range 7–67 m) on flat beach ridges or gentle slopes near the coast (mean slope 6°). Soils are moist and acidic (mean pH 4.6). Surface organic accumulations tend to be thin (mean thickness 8 cm) and overlie fragmental material. A typical soil profile is pictured at right and described in Table 21, below. A number of soil subgroups were identified in this ecotype; most common were Typic Cryorthent and Typic Dystrocryept. Sitka Spruce/Splendid Feather Moss was by far the most common plant association. Over time, this ecotype likely transitions to Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest. Upland Rocky Sitka Spruce-Feathermoss Forest could not be reliably distinguished from Upland Rocky Moist Acidic Sitka Spruce–Alder Forest during mapping; these ecotypes were aggregated and for mapping as Upland Sitka Spruce–Early Successional Forest.

Table 21. Typical soil stratigraphy for the ecotype Upland Rocky Sitka Spruce-Feathermoss Forest, plot number KEFJ_Tjl_01_2013, Kenai Fjords National Park, 2013

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−4	--	--	--
2	Oe	4−10	--	--	--
3	BC	10−15	Gravelly	Sandy loam	with pockets of loamy coarse sand
4	C	15−37+	Gravelly	Sandy loam	--

Upland Rocky-Loamy Moist Lady Fern Meadow





This ecotype is very similar to Subalpine Rocky-Loamy-Organic Fern Meadow, but it occurs in forest gaps at low elevation and tends to be less species-rich, with most of the live cover dominated by a few large forb species. Upland Rocky-Loamy Moist Lady Fern Meadow was recorded on the geomorphic units Hillside Colluvium, Alluvial Fan Abandoned Deposit, and Ash-laden Loess. Vegetation is characterized by rank stands of large forbs, strongly dominated by the fern *Athyrium filix-fimina.* Other common forbs include *Streptopus amplexifolius*, *Trientalis europea*, and *Veratrum viride*; the grass *Calamagrostis canadensis* is also usually present. This plot was typically recorded on gentle slopes (range 8–25°) near sea level (mean elevation 44 m). Soils are moist, and acidic to circumneutral (pH range 4.9–6.9). Dominant soil textures are variable; this ecotype commonly occurs on relatively deep loams, but was also found on blocky and bouldery substrates. The surface organic horizon is very thin (measured range 1–5 cm), likely because the herbaceous litter is readily decomposed. A typical soil profile is pictured at right and described in Table 22, below. One soil subgroup was identified in this ecotype—Typic Haplocryod. Vegetation corresponded to a single plant association—Lady Fern. This ecotype tends to occur in small patches, frequently forming complex mosaics with Upland Rocky–Organic Alder Tall Shrub; we mapped these mosaics as Upland Tall Alder Shrub–Lady Fern Meadow Mosaic.

Table 22. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy Moist Lady Fern Meadow, plot number KEFJ_Tcb2_01_2013, Kenai Fjords National Park, 2013

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−2	--	--	--
2	Oe	2−5	--	--	--
3	AE	5−8	--	Silt loam	--
4	Bs	8−15	Cobbly	Silt loam	--
5	Eb	15−19	Cobbly	Silt loam	volcanic ash
6	Bsb	19−40+	Very cobbly	Silt loam	--

Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest



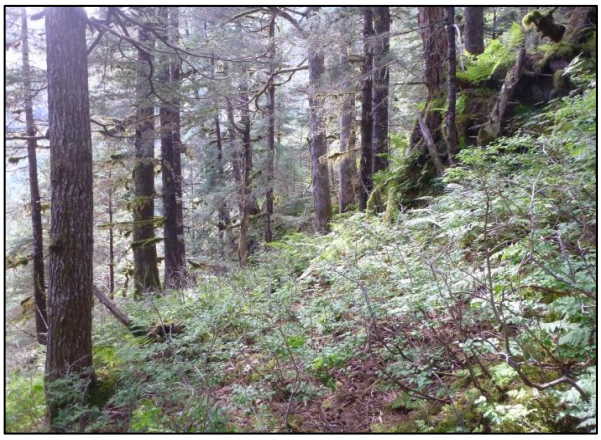


This forest ecotype is characteristic of the oldest landscapes of KEFJ—the long-deglaciated outer fjordlands (e.g, Aialik Peninsula). Many stands represent old-growth and except for local wind-throw, ecological disturbance is rare. Hillside Colluvium was by far the most common geomorphic unit, but many other geomorphic units were occasionally recorded including Upland Loess, Ash-laden Loess, and Bog. Vegetation is characterized by open or closed coniferous stands strongly dominated by *Tsuga mertensiana*. Low shrubs tend to be extensive in the understory, particularly *Vaccinium ovalifolium* and occasionally congeners *V. caespitosum* and *V. alaskensis. Cornus canadensis* and *Rubus pedatus* are characteristic forbs. Feathermosses, especially *Rhytidiadelphus loreus* and *Hylocomium splendens,* are abundant on the forest floor. This ecotype occurs from sea level to near treeline (plot elevation range 19–253 m) on gentle- to steep slopes (recorded range 0–43°). Soils are moist and acidic (mean pH 4.8). The dominant soil texture is variable and appears to depend on surficial geology (granitic or metasedimentary), local drainage conditions, and the time available for peat accumulation. Organic-rich and loamy textures are common, but this ecotype was also regularly found on fragmental and lithic substrates. A typical soil profile is pictured at right and described in Table 23, below. Three soil subgroups were recorded in this ecotype—Lithic Cryofolist, Vitandric Cryorthent, and Lithic Cryosaprist. The most common plant associations were Mountain Hemlock/Early Blueberry, Mountain Hemlock/Early Blueberry-Devil's Club, and Mountain Hemlock/Early Blueberry-Copperbush.

Table 23. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest, plot number KEFJ_Tagc2_03_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−0.5	--	--	--
2	Oe	0.5−2	--	--	--
3	Oa	2−4	--	--	--
4	Bw	4−16	--	Silt loam	volcanic ash
5	C1	16−20	Extremely bouldery	Silt loam	--
6	C2	20+	--	Boulders	--

Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest





This forest ecotype is widely distributed in older landscapes of KEFJ, primarily in areas that remained ice-free during the Little Ice Age. Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest was recorded primarily on Hillside Colluvium; other common geomorphic units include Bedrock, Upland Loess, and Abandoned Marine Beach. Floristically, this ecotype is very similar to Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest, but *Picea sitchensis* is co-dominant with *Tsuga mertensiana*. Over time, these mixed conifer stands are likely to become increasingly dominated by *Tsuga mertensiana* unless disturbance is renewed, as that species is more shade-tolerant than *Picea sitchensis*. This ecotype occurs from sea level to near treeline (measured range 2–343 m) on gentle- to steep hillslopes. Soils are moist and usually acidic (mean pH 4.5; range 3.3–7.0). As for the preceding ecotype, dominant soil texture is quite variable; organic-rich, sandy, and blocky soils are all common. The surface organic mat is well-developed, but tends to be somewhat thinner than for Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest (mean thickness 14 cm). A typical soil profile is pictured at right and described in Table 24, below. Folistic Dystrocryept was the most common soil subgroup; Typic Haplocryod and Andic Haplocryod were also recorded. Mountain Hemlock-Sitka Spruce/Early Blueberry was by far the most common plant association; others include Mountain Hemlock-Sitka Spruce/Early Blueberry/Wood Fern and Mountain Hemlock-Sitka Spruce/Early Blueberry-Salmonberry.

Table 24. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest, plot number KEFJ_Tqc_04_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−1	--	--	--
2	Oe	1−3	--	--	--
3	Oa	3−7	--	--	--
4	Bs	13−19	--	Silt loam	volcanic ash
5	E/Bs	19−34	Very stony	Silt loam	E material broken and discontinuous
6	Bs	34−50+	Very stony	Silt loam	--

Upland Rocky-Loamy-Organic Salmonberry Low Shrub





This shrubland ecotype is common on steep, rocky hillslopes from sea level to the subalpine zone, frequently in association with disturbed areas such as avalanche tracks and active colluvial slopes. It is characterized by dense thickets of *Rubus spectabilis*. Common associates include *Sambucus racemosa*, *Alnus sinuata*, and *Athyrium filix-fimina*. Species diversity is low. The shrub canopy is usually low (<1.5 m), but taller stands are common, especially at low elevation. Upland Rocky-Loamy-Organic Salmonberry Low Shrub was primarily recorded on Hillside Colluvium, Colluvial Fan Deposit, and Avalanche Deposit. This ecotype is found on all aspects of steep slopes (mean slope 34°). Soils are moist, and acidic to circumneutral (mean pH 5.1; range 4.2–7.0). Soil profiles are rather variable; the organic mat may be well-developed or absent altogether (measured range 0–16 cm). There is usually considerable microsite variability in organic accumulation among the uneven, blocky substrates on which this ecotype typically occurs. Some soils, however, were dominated by loam or organic material. A typical soil profile is pictured at right and described in Table 25, below. Soil subgroups associated with this ecotype include Folistic Dystrocryepts, Typic Dystrocryept, and Typic Cryorthent. Two plant associations were identified—Salmonberry and Salmonberry/Lady Fern. Upland Rocky-Loamy-Organic Salmonberry Low Shrub usually co-occurs with Upland Rocky-Organic Alder Tall Shrub, typically in belts that are more regularly disturbed by avalanche or rockslide. Because these two ecotypes are floristically similar and frequently co-occur within complex mosaics that are difficult to differentiate in available imagery, they were consolidated for mapping into a single class—Upland Alder-Salmonberry Tall Shrub.

Table 25. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Salmonberry Low Shrub, plot number KEFJ_Tsb1_03_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oe	0−4	--	--	--
2	Oa1	4−16	--	--	--
3	Oa2	16−30	Extremely bouldery	--	Many medium to coarse roots
4	C	30+	--	Boulders	--

Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest





The most extensive forest ecotype in KEFJ, Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest is widespread near sea level in older landscapes of KEFJ that did not become glaciated during the Little Ice Age. This ecotype is similar to the preceding two forest ecotypes, except that *Picea sitchensis* dominates the canopy and *Tsuga mertensiana* is scarce or absent. Understory vegetation is also similar, but *Vaccinium* spp. tend to be less abundant. Stand-age appears to be somewhat younger on most sites than in forests in which *Tsuga mertensiana* is prominent. This ecotype was usually recorded on Hillside Colluvium; it was also found on Upland Loess and Bedrock. Unlike the preceding ecotypes, Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest does not occur near treeline; it was only recorded below 73 m. Soils are moist and acidic (pH range 3.4–5.9). The surface organic mat is usually thick (mean thickness 19 cm; range 5–31 cm). The dominant soil texture is usually either organic-rich, or blocky. A typical soil profile is pictured at right and described in Table 26, below. Several soil subgroups were identified within this ecotype; Folistic Dystrocryepts were most common. Other subgroups include Typic Humicryod and Andic Haplocryod. Common plant associations include Sitka Spruce/Early Blueberry, Sitka Spruce/Early Blueberry-Wood Fern, and Sitka Spruce/Devil's Club.

Table 26. Typical soil stratigraphy for the ecotype Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest, plot number KEFJ_Tpb2_04_2013, Kenai Fjords National Park, 2013

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−2	--	--	--
2	Oe	2−4	--	--	--
3	Oa	4−5	--	--	--
4	C	5−8	--	Sand	--
5	Bw	8−16	--	Silt Loam	ferric mottles present
6	Bs	16−23		Silt Loam	ferric mottles present
7	Oa	23−24	--	--	
8	2C	24−41+	Extremely gravelly	Sandy Loam	glaciofluvial outwash

Upland Rocky-Organic Alder Tall Shrub

Upland Rocky-Organic Alder Tall Shrub is widespread and abundant in KEFJ, from sea level to treeline. It is characterized by tall stands (>1.5 m) of the thicket-forming shrub, *Alnus sinuata*. Species richness tends to be very low in closed alder stands, but may be high in open stands. The shrubs *Rubus spectabilis* and *Sambucus racemosa* are virtually ubiquitous associates, as are the ferns *Athyrium filix-fimina* and *Dryopteris dilitata.* The ground surface is usually covered by leaf litter and lacks extensive moss cover. This ecotype was found on numerous geomorphic units, primarily Hillslope Colluvium, Avalanche Deposit, and Colluvial Fan Deposit. Upland Rocky-Organic Alder Tall Shrub is similar to other alder-dominated ecotypes, especially Glacial Rocky Alder Tall Shrub, but soils usually have substantial accumulations of organic matter (mean thickness 8 cm; range 0–27 cm). Soils are moist, and usually acidic (mean pH 4.7; range 3.4–7.4). Soil texture is usually blocky, although organic-rich soils can occur. A typical soil profile is pictured at right and described in Table 27, below. Typic Cryorthent was the most common soil subgroup; a few plots corresponded to Folistic Dystrocryept. Sitka Alder-Salmonberry/Lady Fern and Sitka Alder-Salmonberry were by far the most common plant associations. For mapping, this ecotype was aggregated with the closely-related ecotype Upland Rocky-Loamy-Organic Salmonberry Low Shrub, and mapped as Upland Alder-Salmonberry Tall Shrub. This map ecotype frequently forms complex mosaics with Upland Rocky–Loamy Moist Acidic Lady Fern Meadow; we mapped mosaic landscapes as Upland Tall Alder Shrub–Lady Fern Meadow Mosaic.





Table 27. Typical soil stratigraphy for the ecotype Upland Rocky-Organic Alder Tall Shrub, plot number KEFJ_Tsb1_04_2013, Kenai Fjords National Park, 2013.

Horizon Number	Horizon	Depth Range (cm)	Texture modifier	Soil Texture	Horizon Notes
1	Oi	0−1	--	--	--
2	Oe	1−4	--	--	--
3	Bw	4−8	Very gravelly	Sandy clay loam	--
4	C	8−16	--	Stones	--
5	Oa	16−42	Extremely cobbly	--	--

Relationships Among Ecological Components

Landscape Relationships

Toposequences

The classification of ecotypes (local-scale ecosystems) was based on the survey of ecological components (topography, geomorphology, soil, hydrology, permafrost, and vegetation) along toposequences. The toposequences display two-dimensional views of the landscape-soil-vegetation relationships that were used as the basis for classifying and mapping ecotypes (Figures 5–8). Vegetation classes follow the AVC (Viereck et al. 1992). Four toposequences representing distinct ecosystems within the study area are described below and summarize ecological relationships across a coastal-riverine-upland toposquence at Quicksand Cove, an upland-subalpine toposequence at Agnes Cove, an upland-glacial toposequence at Exit Glacier, and an Alpine toposequence in the high mountains above the Resurrection River valley.

The Quicksand Cove toposequence is characteristics of the coastal to upland physiography transition in sandy coastal environments in areas of KEFJ unaffected by the LIA glaciation. At Quicksand Cove, the toposequence begins at the beach on Active Gravelly Marine Beach Deposits where vegetation is sparse to absent (Figure 5). The steep beach rises quickly to a sandy Coastal Levee deposit dominated by Beach Rye vegetation. Soils were sandy with few coarse fragments and a buried organic layer (Oe horizon), indicating recent sedimentation. Driftwood was common and suggests the site is subject to periodic storm surges. Behind the levee, the toposequence cuts across a Tidal Gut that extends into a lagoon periodically flooded by tide water during extreme high tide events and storm surges. At the time of sampling in late August, the lagoon was not flooded. Vegetation in the lagoon was Halophytic Sedge Wet Meadow, Brackish. Soils were wet, sandy, and electrical conductivity was 1580 microsiemens, indicating a brackish environment. The upper section of the soil profile featured many interbedded layers of sand, silt, and organic matter (C/Oa horizons) reflecting frequent sedimentation resulting from periodic flooding by tide waters. The toposequence transitions from coastal to riverine physiography at an Inactive Alluvial Fan deposited by a nearby river. Vegetation was Open Tall Alder-Willow. The fan forms a gentle toeslope that leads to a steep bedrock controlled mountain slope. Vegetation on the mountain slope was Closed Mixed Coastal Conifer dominated by *Picea sitchensis* and *Tsuga mertensiana*. Soils on the mountain slope were ash-laden loess over colluvium. The ash-laden loess was likely deposited by historic volcanic events associated with volcanoes on the Alaska Peninsula. Bear beds and trails were common on this mountain slope.

The Agnes Cove toposequence is characteristic of the coastal to upland physiography transition in rocky coastal environments in areas of KEFJ unaffected by the LIA glaciation. At Agnes Cove, the toposequence begins at a rocky shore at the base of a very steep bedrock-controlled mountain slope (Figure 6). A stand of Closed Mixed Coastal Conifer is present at the bottom of the slope. Soils were formed from hillside colluvium and featured a thick (30 cm) organic surface horizon (Oi) overlying granitic boulders (C). A horizon of highly decomposed organic matter (Oa) representing the historic soil surface lay beneath the boulders indicating that the boulders had moved downslope to their current position and buried the historic soil surface. Bedrock outcrops were commonly encountered

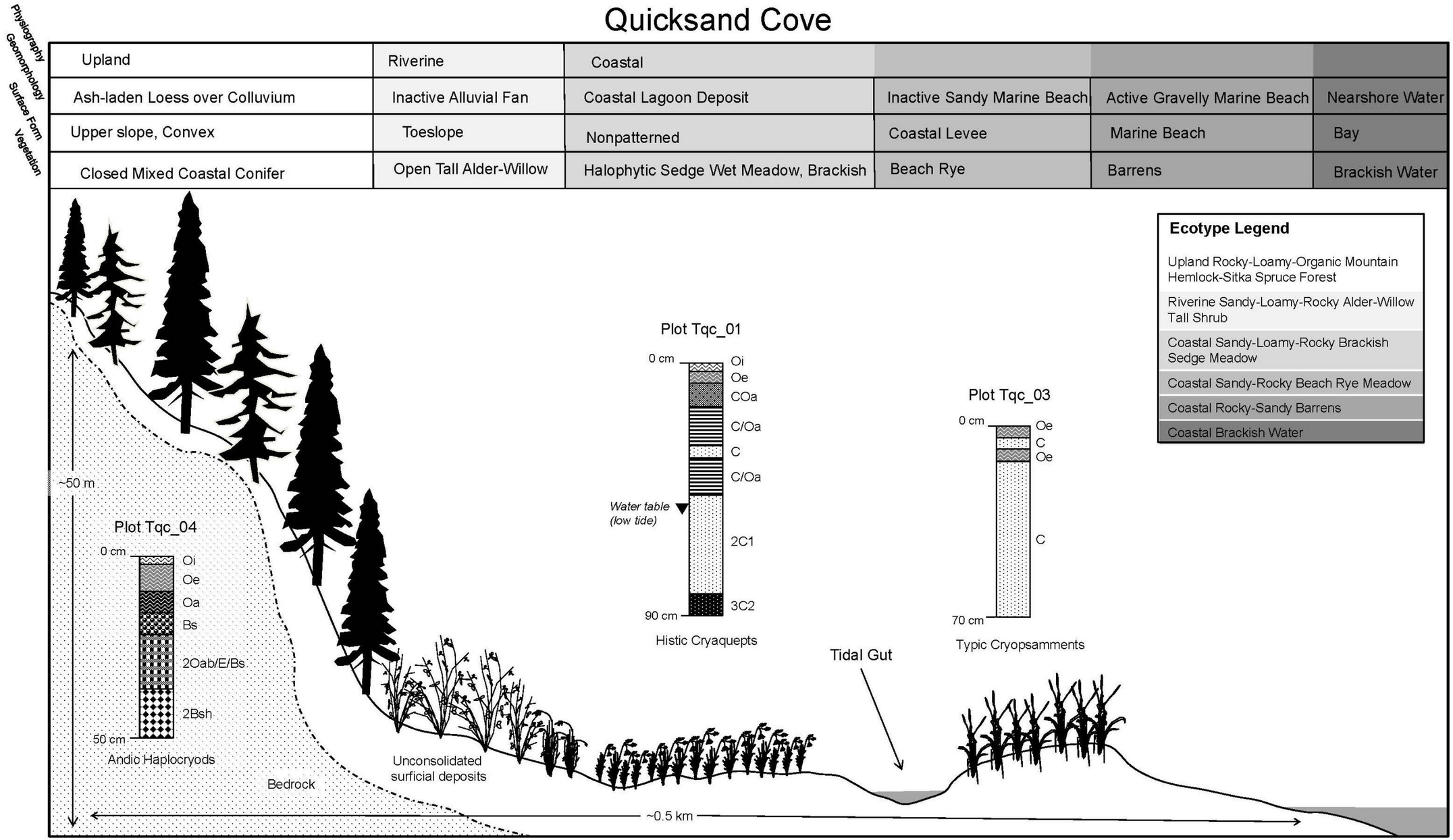


Figure 5. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Quicksand Cove, Kenai Fjords National Park, southcentral Alaska.

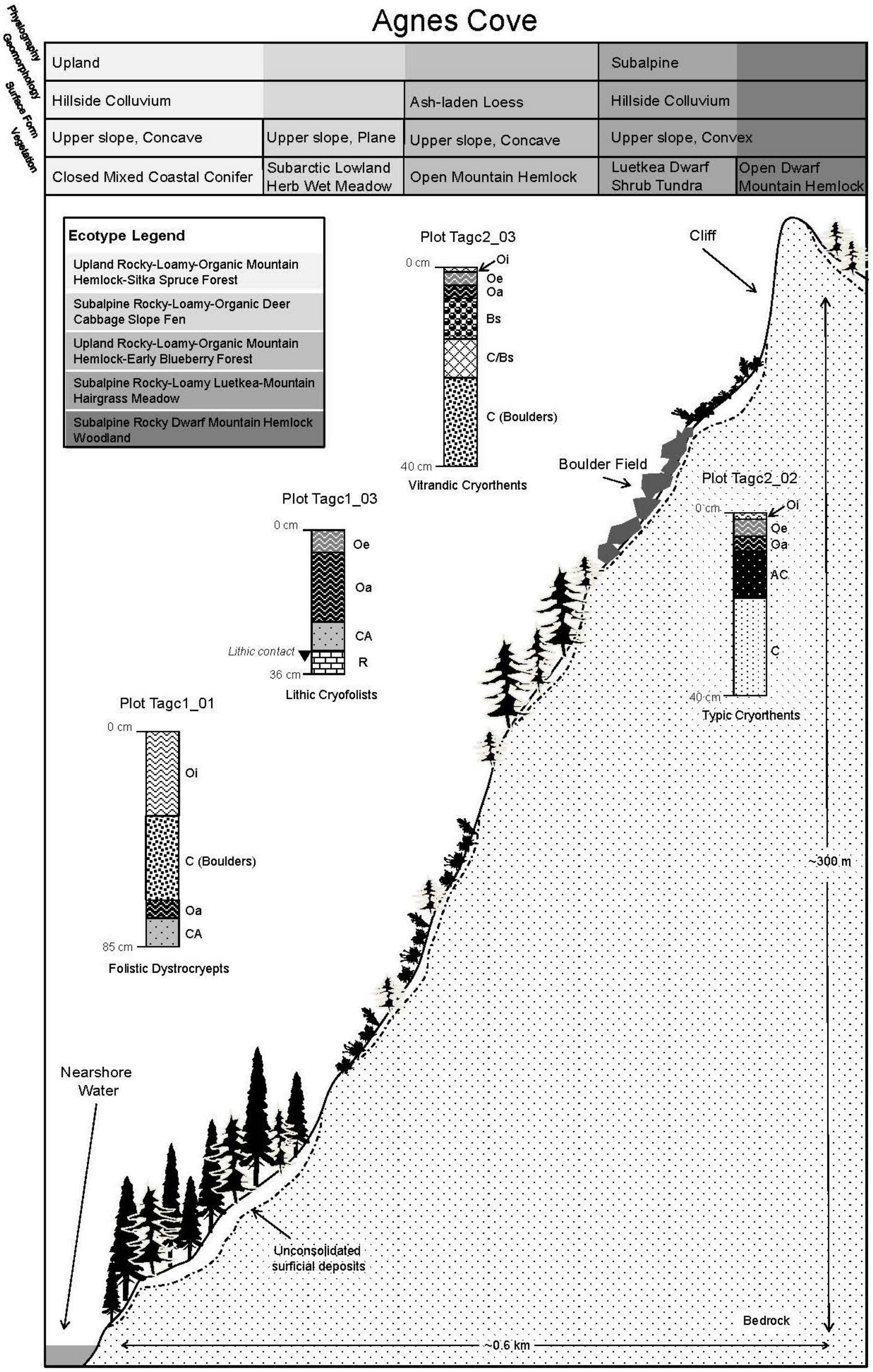


Figure 6. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Agnes Cover, Kenai Fjords National Park, southcentral Alaska.

Exit Glacier

Physiography					
Upland			Glacial		
Younger Till and Outwash		Younger Moraines	Younger Till	Bedrock	Glacier
Undulating		Undulating	Upper slope, convex	Shoulder and Crest	Undulating
Open Black Cottonwood Forest	Closed Tall Alder	Closed Black Cottonwood Forest	Open Tall Alder	Barrens	Ice

Geomorphology

Surface Form

Vegetation

*Call outs indicate the estimated year and location of the Exit Glacier terminus since 1917. Present day (2013) terminus is not depicted on this cross-section.

Ecotype Legend

- Upland Rocky Black Cottonwood Forest
- Upland Rocky-Organic Alder Tall Shrub
- Glacial Rocky Alder-Willow Tall Shrub
- Glacial Barrens and Partially Vegetated
- Glaciers and Permanent Snow Fields

Plot Teg1_07

0 cm — Oi

C

42 cm

Typic Cryorthents

Plot Teg1_06

0 cm — Oi

C

2Cd

42 cm

Typic Cryorthents

Plot Teg2_02

0 cm — Oi

Lithic contact — C

R

30 cm

Lithic Cryorthents

Exit Glacier

Glacial Erratics

Exit Glacier Nature Center

Plot Teg2_01

0 cm — C

Lithic contact

R

30 cm

Lithic Cryorthents

1917*

1926

1961

~75 m

Unconsolidated surficial deposits

Bedrock

~1.25 km

Figure 7. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils at Exit Glacier, Kenai Fjords National Park, southcentral Alaska.

Alaska Natural Heritage Program Transect 80





Landscape (left) and soil (right) photos for Alaska Natural Heritage Program Plot 80.3.





Landscape (right) and soil (left) photos for Alaska Natural Heritage Program Plot 80.2.





Landscape (left) and soil (right) photos for Alaska Natural Heritage Program Plot 80.4.

Alpine					
Bedrock, residual soil	Hillside Colluvium	Upland Loess	Talus	Bedrock, weathered	Snow field
Lower slope, plane	Upper slope, convex	Lower slope, plane	Upper slope, plane	Crest	Upper slope, concave
Crowberry Dwarf Shrub Tundra*	Cassiope Dwarf Shrub Tundra	Moist Sedge Meadow Tundra		Barrens	Snow

*Vegetation not depicted due to scale of illustration

Ecotype Legend

- Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub
- Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub
- Alpine Rocky Moist Sedge Meadow
- Alpine Rocky Barrens
- Glaciers and Permanent Snow Fields

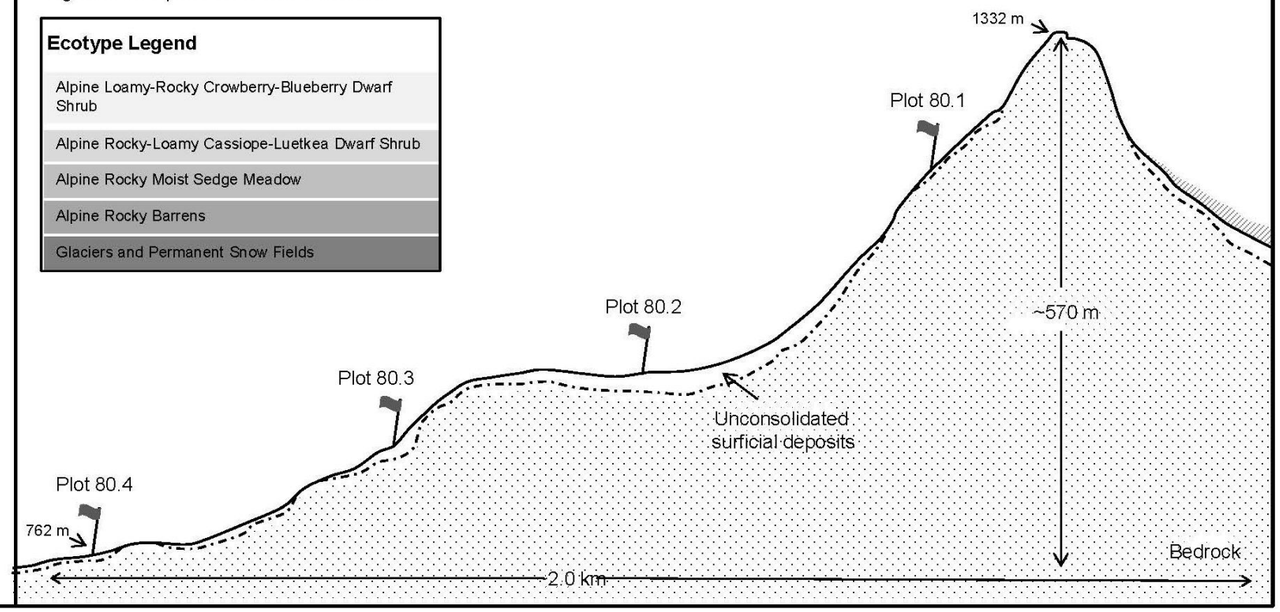


Figure 8. A generalized toposequence illustrating relationships among physiography, geomorphology, surface form, vegetation, and soils in Alpine physiography, Alaska Natural Heritage Program Transect 80, southwest of the Resurrection River, Kenai Fjords National Park, southcentral Alaska.

on this toposequence indicating shallow to moderately deep soils throughout. Many small patches of Subarctic Lowland Herb Wet Meadow dominated by *Fauria crista-galli* occurred upslope of the conifer forest as part of a mosaic that included dwarf hemlock, small stands of Closed Mixed Coastal Conifer, and rock outcrop. Soils in the meadow were wet, organic-rich, and shallow (≤50 cm) to granitic bedrock. Open stands of mountain hemlock and boulder fields were common throughout the middle portions of the mountain slope. In the hemlock stands, soils comprised ash-laden loess over colluvium and featured a thin surface organic layer above a thin, highly leached horizon with abundant volcanic ash (Bs) above boulders. In the boulder fields, abundant mosses and lichens, most notably *Rhytidiadelphus loreus, Diplophyllum albicans, Paraleucobryum enerve,* and *Stereocaulon botryosum* covered the boulders; soils were thin to non-existent. The toposequence transitioned to subalpine physiography near the boulder fields. Above the boulder fields and directly below cliffs near the top of the mountain slope, Luetkea Dwarf Shrub Tundra occurred on thick deposits of hillside colluvium. The vegetation was dominated by *Luetkea pectinata, Carex dioica* ssp. *gynocrates,* and *Vahlodea atropurpurea*. This assemblage of vegetation is indicative of late-lying snow banks, an important landscape process driving vegetation patterns in the subalpine. Open Dwarf Mountain Hemlock occupies exposed slope positions above cliffs on the opposing slope.

The Exit Glacier toposequence describes a recently deglaciated environment in KEFJ. The Exit Glacier toposequence is similar to other recently deglaciated environments in that at more recently deglaciated areas, the soils are in the very early stages of development, and tall shrub and barrens characterize the vegetation. However, the Exit Glacier toposequence is somewhat unique in KEFJ in the predominance of *Populus trichocarpa* forests on slightly older glacial deposits. At Exit Glacier, beginning at the Exit Glacier Nature Center, the toposequence starts in Open Black Cottonwood Forest in undulating terrain on younger till and outwash (Figure 7). The forests here are dominated by timber-sized (15 to 30 cm Diameter at Breast Height [DBH]) *Populus trichocarpa* with a dense understory of tall (>1.5 m) alder *(Alnus sinuata)*. The toposequence next crosses through a stand of Closed Tall Alder which features a dense thicket of *Alnus sinuata* and scattered *Populus trichocarpa*. The "1917" sign, indicating the estimated location of the Exit Glacier terminus in the year 1917, occurs along the Glacier Trail near this transition. The transition from a more mature, forested vegetation type to a less mature, shrub-dominated vegetation type may be related to a more recent outwash event in the alder stand that reset the vegetation succession in this area. The soils are indicative of a glacio-fluvial event; featuring a thin 6 cm surface organic horizon (Oi) over a thick layer of extremely gravelly sandy clay loam (C). The toposequence next crosses a series of Younger Moraines. The "1926" sign, indicating the estimated location of the Exit Glacier terminus in the year 1926, occurs along the Glacier Trail near this transition. The vegetation along this section of the transect is Closed Black Cottonwood Forest dominated by pole-sized (5 to 15 cm DBH) *Populus trichocarpa* that generally become smaller in size with decreasing distance from the glacier. Soils feature a thin 7 cm surface organic horizon (Oi) over very bouldery coarse sands (C), followed by a dense layer of compacted till (Cd). The toposequence transitions into Glacial physiography near the base of a metasedimentary (quartz-phyllite) bedrock-controlled rocky knob. The "1961" sign, indicating the estimated location of the Exit Glacier terminus in the year 1961, occurs along the Glacier Trail near this transition. The vegetation shifts to Open Tall Alder dominated by *A. sinuata* with occasional low willows, commonly *Salix sitchensis*. The understory, while depauperate of

vascular species, is rich in mosses and lichens, namely *Racomitrium ericoides*, *Stereocaulon grande*, and *Brachythecium reflexum*. Soils are shallow (≤50 cm) to bedrock and feature a thin (<14 cm) surface organic horizon (Oi) over extremely gravelly till, over bedrock. Near the middle of the rocky knob the toposequence transitions to Barrens. Soils are shallow (<25 cm) to bedrock or non-existent and glacial erratics are common. At the top of the bedrock knob the toposequence drops down to Exit Glacier, which fills the adjacent valley and extends up to the Harding Ice Field.

The Transect 80 toposequence is characteristic of alpine areas in KEFJ and describes the transition from lower alpine near treeline to the upper alpine. This alpine toposequence, Alaska Natural Heritage Program Transect 80, traverses up a bedrock-controlled mountain slope southwest of the Resurrection River, beginning at approximately 760 m above mean sea level in Crowberry Dwarf Shrub Tundra (Figure 8). The vegetation is characterized by *Empetrum nigrum*, *Salix rotundifolia*, *Dryas integrifolia*, and *Vaccinium uliginosum*. Soils are derived from bedrock and likely shallow to moderately deep. The toposequence next crosses a moderately steep upper slope characterized by Cassiope Dwarf Shrub Tundra vegetation. Dominant species include *Cassiope stelleriana* and *Luetkea pectinata*. Soils are derived from hillside colluvium and are likely moderately-deep to deep. The toposequence next transitions to a lower slope characterized by Moist Sedge Meadow Tundra vegetation. Dominant species include *Carex microchaeta*, *Racomitrium sudeticum*, and *Salix rotundifolia*. Soils are derived from a thin layer of Upland Loess over Hillside colluvium. Higher on the toposequence, the slope increases and the geomorpholgy transitions to Talus. As elevation increases, the vegetation type remains the same but vegetation cover becomes increasingly sparse. Unvegetated bedrock with shallow to non-existent soilsoccurs near the crest of the slope. . On the opposing slope, a permanent snow field fills this concave slope position.

Hierarchical Organization of Ecological Components

We developed hierarchical relationships among ecological components by successively grouping data from the 486 intensive plots by physiography, soil texture, geomorphology, slope position, surface form, drainage, soil chemistry, vegetation structure, and floristic class. Frequently, geomorphic units with similar textures or genesis were grouped (e.g., loamy and organic were grouped in some cases) to reduce the number of classes. Ecotypes then were derived from these tabular associations to differentiate sets of associated characteristics.

Analyzing the toposequences and cross-tabulation of the plot data revealed consistent associations among soil texture, geomorphic units that denote depositional environments, slope position, surface forms related to hydrology, and vegetation structure. The hierarchical organization of the ecological components reveals how tightly or loosely the components are linked. For example, some physiographic settings included several geomorphic units with similar soil textures. Similarly, a given vegetation type could occur on several geomorphic units, depending on surface form characteristics and hydrology. In contrast, some geomorphic units (e.g., tidal flats) were associated only with a few distinct vegetation types.

Results from this analysis were used in several ways. First, they were used to assess how ecosystems respond to an evolving landscape influenced by a variety of geomorphic processes within Alpine, Subalpine, Upland, Lowland, Lacustrine, Riverine, Glacial, and Coastal areas (see section on Factors

Affecting Landscape Evolution). Identifying the changing patterns in geomorphic units and vegetation, along with analysis of changes in soil properties helps identify processes (e.g., acidification, sedimentation) that influence the changing patterns. Second, the hierarchical relationships developed from the ground up were used to determine the rules for modeling and restricting the distribution of map classes from the top down (see Methods, GIS Modeling). Third, knowing the ecological relationships, we could recode the AKNHP land-cover map (Appendix E) and created maps that describe landscape characteristics, such as an ecotype map, soil landscape map, and disturbance regime map (see Results, Classification and Description of Soil Landscapes).

The contingency table analysis also can be used to evaluate how well these general relationships conform to the data set, and how reliably they can be used to extrapolate trends across the landscape. During development of the relationships, approximately 13% of the observations (62 plots) were excluded from the table because of inconsistencies among physiography, texture, geomorphology, drainage, soil chemistry, and vegetation. We excluded these points because our primary goal was to identify the most distinct and consistent trends, not necessarily to include every plot. We believe that there is an upper limit to our ability to describe landscape patterns; there will always be a proportion (in this case 13%) of sites that do not conform to the overall relationships among factors. These sites may be: (1) transitional (ecotones); (2) sites where vegetation and soils have been affected by historical factors (e.g., changes in water levels, disturbances) in ways that are not readily explainable based on current environmental conditions; (3) vegetation and soil types that are prevalent on the landscape but were inadequately sampled; or (4) rare and thus not mappable.

Environmental Characteristics

Single-factor Comparisons by Ecotype:

Four environmental parameters (elevation, slope gradient, surface organic thickness, pH) were summarized (mean and standard deviation) for comparing ecotypes (Table 5). We excluded ecotypes with insufficient data ($n < 3$). The thickness of the surface organic horizon showed large differences among ecotypes. Ecotypes where surface organic accumulations were thin to absent included areas with severe climate and soil conditions (e.g., Alpine Rocky Barrens and Subalpine Rocky Barrens); areas with frequent flooding and sediment deposition (e.g., Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat); and areas with insufficient time lapsed for vegetation and soil development (e.g., Glacial Rocky Barrens and Glacial Rocky Fireweed). The thickest surface organic accumulations were found in older, stable environments, including Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest, Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest, Upland Loamy-Organic Deer Cabbage Slope Fen, Upland Organic-rich Wet Sedge Slope Fen, and Lowland Organic-rich Wet Sedge Meadow.

The topography in KEFJ is generally very steep. In the fjordlands, steep mountain slopes plunge downward at a precipitous angle from ridgelines, often ending at a cliff before plunging straight into the ocean. Areas of gentle topography are relatively uncommon. Traditional concepts of lowland physiography as occurring at lower elevations relative to uplands and subalpine do not necessarily fit in all cases in KEFJ. Lowlands in KEFJ may occur at elevations coincident with upland and subalpine physiography on gentle (<3 degrees) slope gradients with perennially wet soils. Similarly,

upland physiography is typically restricted to areas with dry to moist soils, and with wet soils limited to lowland, lacustrine, or riverine physiography. This traditional concept of soil moisture in uplands does not always hold true in KEFJ. The wet climate in KEFJ maintains high soil moisture even on steep upland slopes; for instance, Upland Loamy-Organic Deer Cabbage Slope Fen is the eighth steepest ecotype but features wet soils throughout the growing season. Tidal flats and coastal meadows, floodplains, lake margins, and ridge tops are among the other environments and landscape positions with the gentlest slopes. Average slope gradient was steepest in subalpine Upland Rocky-Loamy-Organic Salmonberry Low Shrub, Subalpine Rocky-Loamy Sitka Spruce Woodland, and Subalpine Rocky Barrens. Average slope gradient was lowest in coastal and riverine ecotypes, namely Coastal Sandy-Rocky Beach Pea Meadow, Riverine Rocky-Sandy Willow Low and Tall Shrub, and Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow.

Soil pH in KEFJ was typically acidic (≤5.5) to circum-acidic (~5.5–6.6). However, soil pH values ranged widely, from 3.1–9.0 among physiography and ecotype. Ecotypes with the lowest (most acidic) pH values occurred in Subalpine and Upland alder shrub, and spruce and hemlock forest ecotypes (e.g., Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest, Subalpine Rocky Alder Tall Shrub). Nitrogen fixation from Alder and organic acids from spruce and hemlock lower the pH in these ecotypes. The forested ecotypes also occur in older, more stable environments in which much of the soil cations have been leached from the soil over long time periods. Ecotypes with the highest pH occurred in coastal environments with frequent flooding by saltwater (e.g., Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat), and in glacial environments with freshly exposed sediments high in base cations (e.g., Glacial Rocky Fireweed).

Elevation values in the dataset ranged from sea level along the Gulf of Alaska coast to just over 1,400 meters in the mountains. In general, elevation ranged broadly between ecotypes occurring in different physiography classes, and less so between ecotypes within each physiography. Alpine ecotypes had the highest average elevation, while coastal ecotypes had the lowest average elevation. Ecotypes with the highest average elevations include Alpine Rocky Barrens and Alpine Rocky Moist Sedge Meadow, ecotypes with the lowest elevations include Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat and Coastal Rocky-Sandy Seaside Sandplant Beach.

Rock Samples

Classifications for the 16 rock samples are provided in Appendix D. The majority of rock samples classified into the metasedimentary rock class; metasedimentary rocks were identified as phyllite, quartz-phyllite, meta-greywacke, and quartzite. These rock samples were collected primarily from areas mapped as Metasedimentary Rocks, Undivided by Wilson and Hults (2012). Four rock samples classified into the granitic rock class, these were identified as quartz-diorite, quartz-syenite, granodiorite, and biotite granite. These rock samples were collected from the distal portions of the outer peninsulas. A single sample collected at Quicksand Cove classified as gneiss, a metamorphic rock class. The granitic and metamorphic rocks were collected from areas mapped as Granitic Rocks of the Harding Icefield region by Wilson and Hults (2012). Several of the rock types (e.g., quartz-syenite) have not previously been described in Prince William Sound and surrounding areas, including KEFJ, based on work by Wilson and Hults (2012). There are several possible reasons why

the current geologic maps do not show all of the rocks types identified in this study. Most importantly, in some cases the rock samples collected may not be representative of the broader bedrock geology of the area within which they were collected. This may be particularly true for smaller-sized rock samples (e.g., one sample measured 2 x 3 x 2 cm), and rock samples collected from surface deposits rather than bedrock outcrops.

Vegetation Composition

Species Summary:

We classified a total of 54 ecotypes in KEFJ; these ecotypes correspond to 60 AVC vegetation classes at the plot level (Table 3). Some ecotypes correspond to multiple AVC classes, because the degree of canopy closure is represented in AVC classes pertaining to forests and low/tall shrublands (e.g., the ecotype Upland Alder-Salmonberry Tall Shrub includes the AVC classes open tall alder, and closed tall alder). Species-cover data collected by ABR and AKNHP at field plots correspond to a total of 87 plant associations of DeVelice et al. (1999) and Boggs et al. (2008); however some plots did not belong to any published association. The AVC vegetation classes identified in KEFJ include 12 forest classes (including 1 dwarf forest class), 6 tall shrub classes (≥1.5 m height), 7 low shrub classes (0.20–1.5 m), 6 dwarf shrub classes (≤0.20 m), 7 forb meadow classes, 17 graminoid meadow classes, and 2 aquatic emergent classes. ABR and AKNHP collectively recorded 398 vascular and 123 non-vascular species in KEFJ (Appendices 1 and 2). We caution, however, that these species totals should be considered an approximate minimum number of species in KEFJ, because our sampling methods were not designed to support a comprehensive floristic inventory such as was completed by Carlson et al. (2004) for KEFJ in 2003.

Ordination of Vegetation:

In addition to the single-factor comparisons of environmental variables by ecotype, non-metric multidimensional scaling (NMDS) (Shepard 1962a,b; Kruskal 1964a,b) was used to separate plots by species composition. The combined effects of physiography and various environmental variables were assessed by superimposing the ecotype class for each plot on the ordination. Because of the large number of species, ecotypes, and differing environmental gradients, the ordinations were completed separately by physiographic or vegetation structure groupings (Figures 9–14). Within each physiographic grouping, species occurring at trace cover were removed, prior to analysis. Each physiographic ordination was computed using a Bray/Curtis dissimilarity matrix calculated from the abundance data for each physiographic group (Bray and Curtis 1957). The combined effects of physiography and various environmental variables were assessed by superimposing the ecotype class for each plot on the ordination. The points in the ordination diagrams correspond to field plots, and each point was assigned a unique symbol based on the ecotype class assigned to each respective plot. The ordinations are displayed in the two-dimensions which best illustrated the distinctions between ecotypes based on visual review. Outliers were occasionally excluded to better differentiate highly central tendencies. The ordinations reveal which ecotypes had very similar species composition, those with distinct species assemblages, and the diversity of species composition within ecotypes.

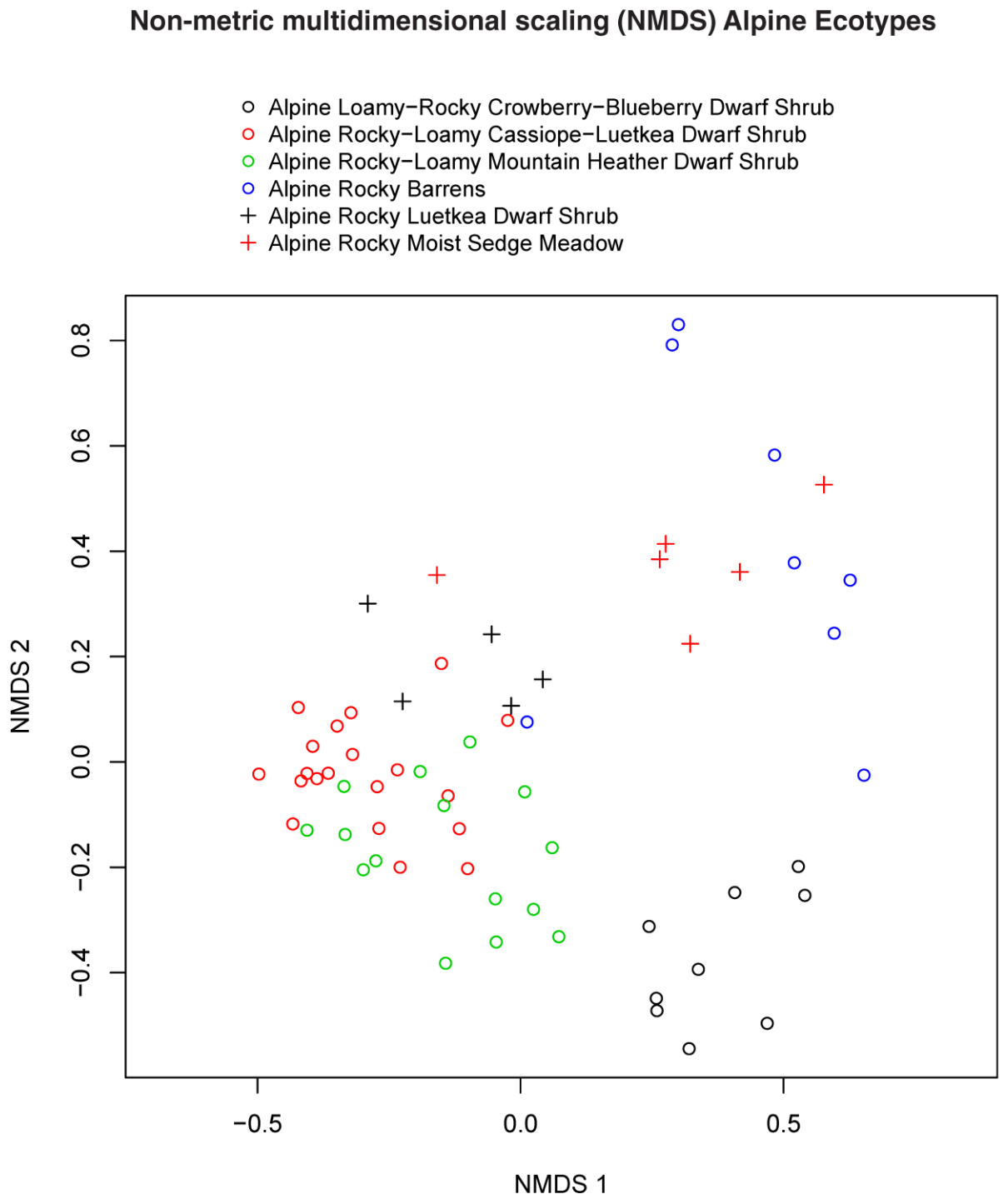


Figure 9. Non-metric multidimensional scaling of species composition for Alpine ecotypes in Kenai Fjords National Park, southcentral Alaska.

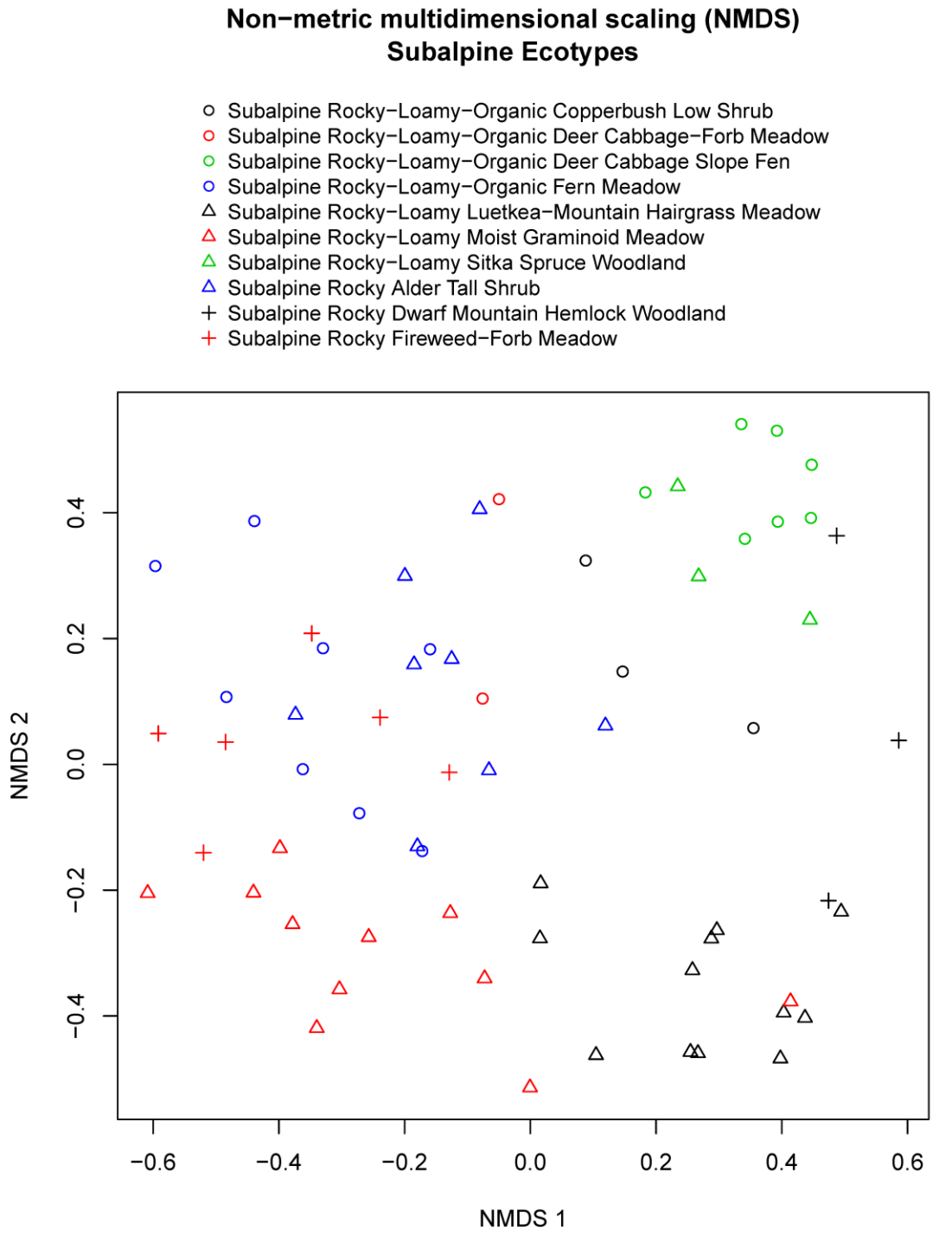


Figure 10. Non-metric multidimensional scaling of species composition for Subalpine ecotypes in Kenai Fjords National Park, southcentral Alaska.

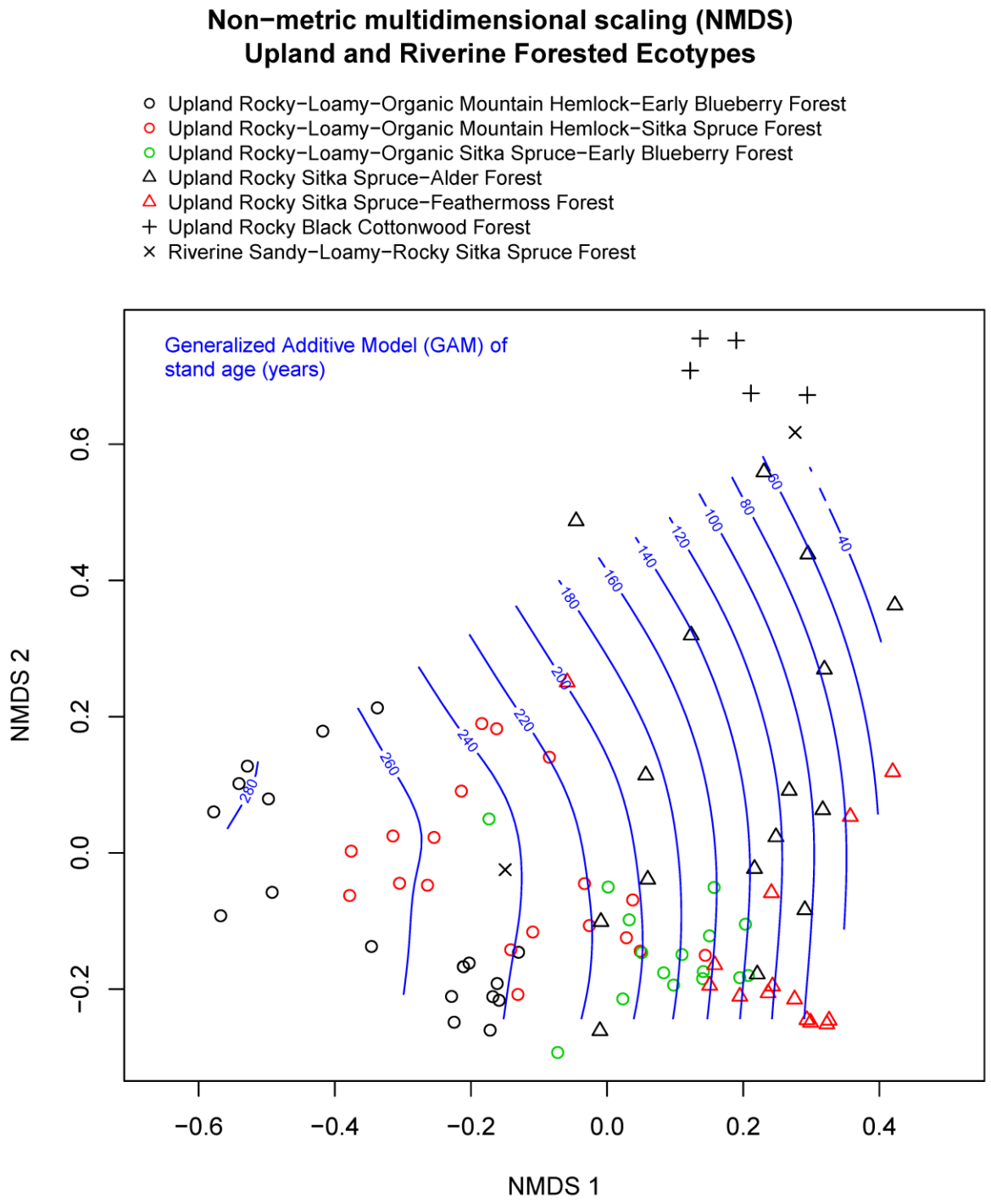


Figure 11. Non-metric multidimensional scaling of species composition for Upland and Riverine forested ecotypes in Kenai Fjords National Park, southcentral Alaska. The isolines indicate forest stand age increasing from the lower left to the upper right corner of the ordination.

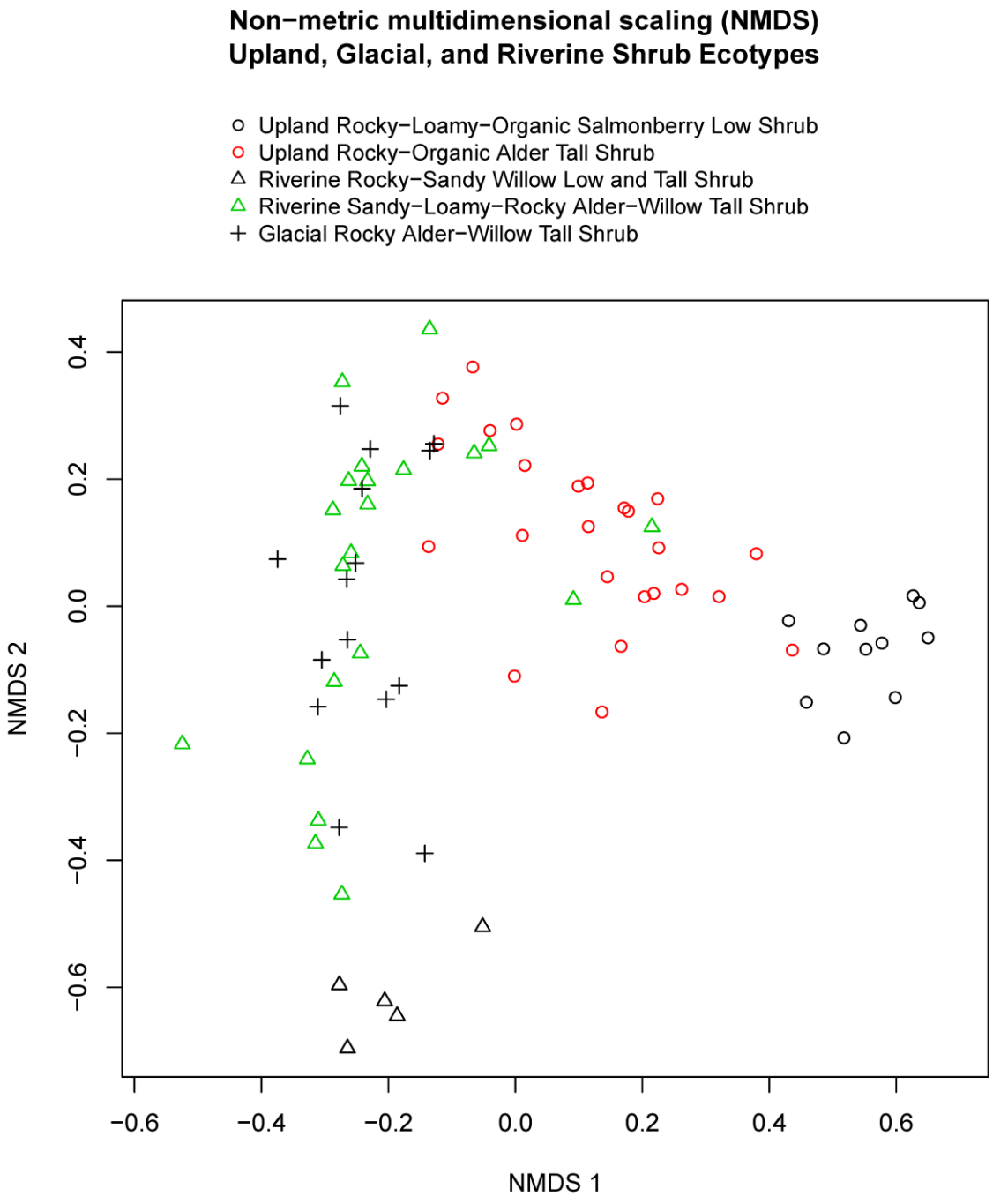


Figure 12. Non-metric multidimensional scaling of species composition for Upland, Glacial, and Riverine shrub ecotypes in Kenai Fjords National Park, southcentral Alaska.

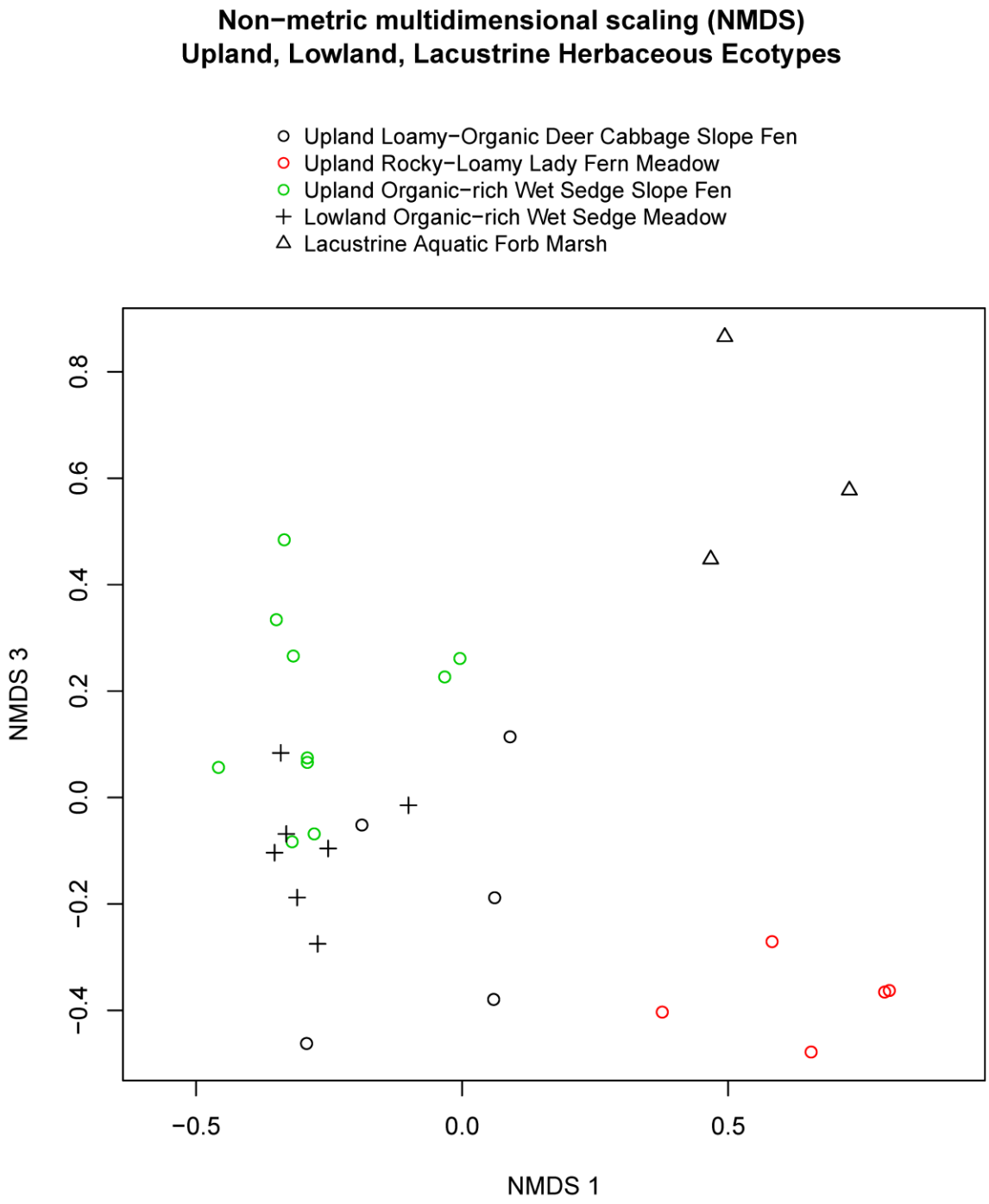


Figure 13. Non-metric multidimensional scaling of species composition for Upland, Lowland, and Lacustrine ecotypes in Kenai Fjords National Park, southcentral Alaska.

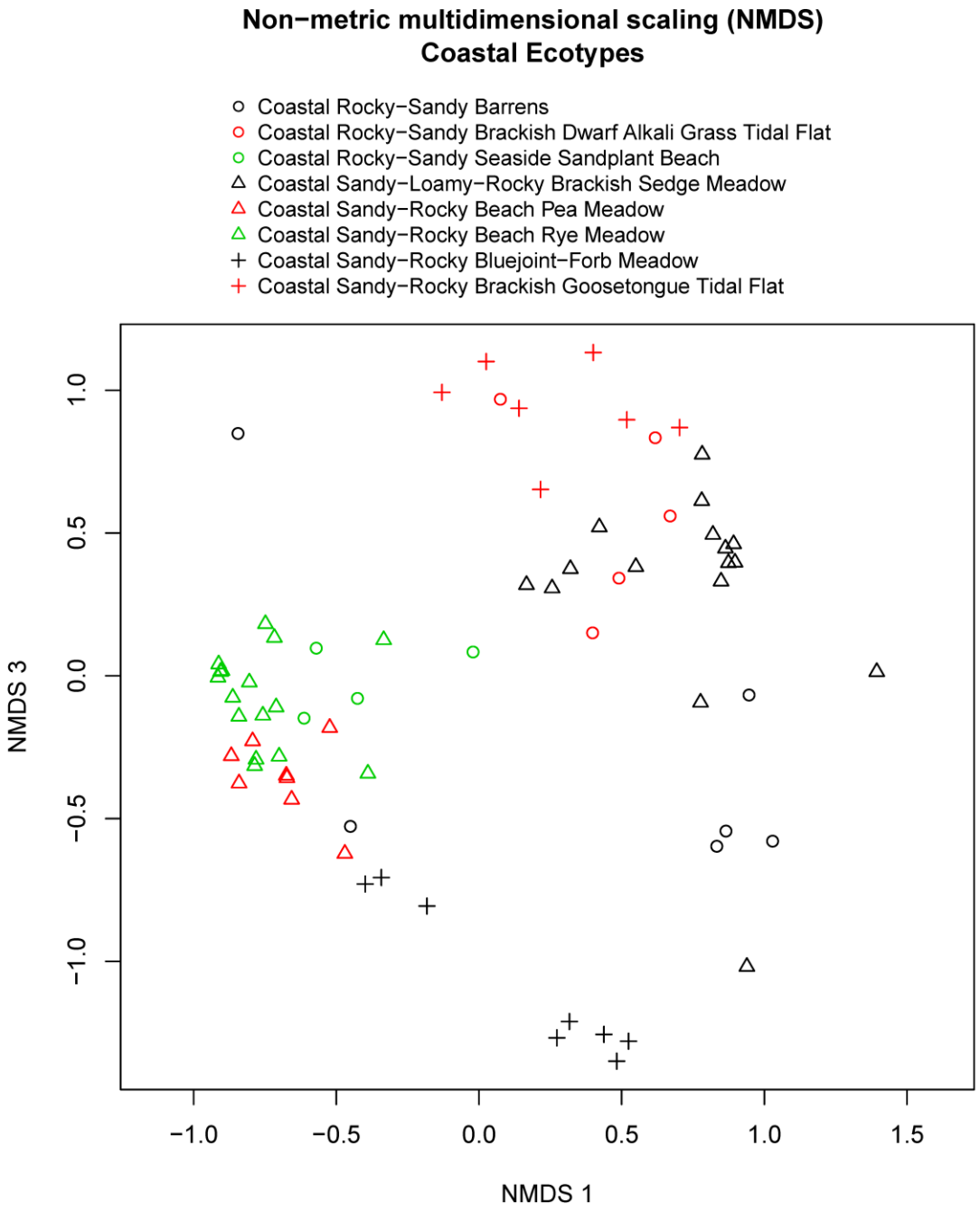


Figure 14. Non-metric multidimensional scaling of species composition for Coastal ecotypes in Kenai Fjords National Park, southcentral Alaska.

Alpine ecotypes had several distinct classes and a few classes with substantial overlap among ecotypes (Figure 9). The ordination reveals a soil moisture and elevation gradient, with soil moisture decreasing and elevation increasing from the lower left to the upper right corner. Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub had the most distinct vegetation assemblage with no overlap with points assigned to other ecotypes. Alpine Rocky Barrens and Alpine Rocky Moist Sedge Meadow overlap slightly in the upper right corner of the NMDS indicating some similarities in vegetation composition. However, the Alpine Rocky Barrens has higher within ecotype variability in species composition as indicated by the long narrow point cloud. Conversely, the relatively tight cluster of points assigned to Alpine Rocky Moist Sedge Meadow suggests a more homogenous species composition between plots in this ecotype. Alpine Rocky Luetkea Dwarf Shrub forms a fairly distinct cluster of points near the center of the ordination with minor overlap with points the Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub. This pattern suggests floristic similarities between the two ecotypes, namely a strong *Luetkea pectinata* component in both ecotypes, but that overall the two ecotypes are distinct floristically. The two ecotypes being set off from one another by the dominance of *Cassiope stelleriana* in Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub and the general absence of this species in Alpine Rocky Luetkea Dwarf Shrub. Lastly, significant overlap exists between Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub and Alpine Rocky-Loamy Mountain Heather Dwarf Shrub indicating high floristic similarity and environmental overlap. The two ecotypes are distinguished by an abundance of *Phyllodoce aleutica* in Alpine Rocky-Loamy Mountain Heather Dwarf Shrub and the absence or lower abundance (typically <25%) of this species in Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub.

Subalpine ecotypes had a number of classes with significant overlap and classes with high within ecotype variability in species composition as indicated by more diffuse point clouds (Figure 10). In the lower right corner of the NMDS diagram, the point corresponding to Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow have relatively little overlap with points assigned to other ecotypes and a moderately tight point cloud. This indicates that this ecotype is floristically distinct and that floristic similarity between plots in this ecotype is moderately high. Subalpine Rocky-Loamy Moist Graminoid Meadow occurs in the lower left hand corner of the NMDS diagram directly adjacent to Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow. The adjacency of these two ecotypes on the lower end of NMDS axis 2 suggests a high degree of environmental affinity, but the lack of overlap indicates that in general the two ecotypes are floristically distinct. Several ecotypes show a high degree of overlap in the middle to upper left of the NMDS diagram, including Subalpine Rocky-Loamy-Organic Fern Meadow, Subalpine Rocky Alder Tall Shrub, Subalpine Rocky Fireweed-Forb Meadow, and Subalpine Rocky Loamy-Organic Deer Cabbage-Forb Meadow. This indicates that these four ecotypes occur in similar environments and that there is a high degree of floristic similarity. These four ecotypes often co-occur as a mosaic of small patches of vegetation distinguished by the predominance of one or two species with an otherwise similar floristic assemblage. For instance, Subalpine Rocky Alder Tall Shrub is distinguished from the other three ecotypes by the dominance (>25%) of *Alnus sinuata*, while Subalpine Rocky-Loamy-Organic Fern Meadow is distinguished from the others by the absence of low abundance of *A. sinuata* and the dominance of *Athyrium filix-femina* ssp. *cyclosorum*. Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow is distinguished by the absence or low abundance of *A. sinuata* and *A. filix-*

femina ssp. *cyclosorum* and the dominance of *Fauria crista-galli*, while Subalpine Rocky Fireweed-Forb Meadow is distinguished by the absence or low abundance of all of the above 3 dominant species, and a forb-dominated community, including most notably *Epilobium angustifolium*, *Geranium erianthum*, *Heracleum lanatum*, and *Lupinus nootkatensis*. The ecotypes Subalpine Rocky-Loamy-Organic Copperbush Low Shrub, Subalpine Rocky-Loamy Sitka Spruce Woodland, and Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen occur in the upper right hand corner of the NMDS diagram all feature fairly distinct clusters of points with little overlap. This indicates that these three ecotypes occur in similar environments and are floristically distinct. The final ecotype, Subalpine Rocky Dwarf Mountain Hemlock Woodland spans across NMDS axis 2 suggesting that this ecotype is broadly defined and shows both floristic and environmental diversity. The commonality between the plots in this ecotype is the prevalence of dwarf *Tsuga mertensiana*; however the understory species composition is wide ranging, including in some cases, species assemblages typical of moist alpine communities and in other cases, species assemblages typical of wet upland and subalpine communities.

Upland and Riverine forested ecotypes had a number of classes with a moderate to high degree of overlap (Figure 11). The ordination reveals a forest stand age and soil development gradient, with older forested stands on well-developed soils in the lower left corner, and younger forested stands on poorly-developed soils. Upland Rocky Black Cottonwood Forest had the most distinct grouping of points, no overlap with other ecotypes, and a tight cluster of points all of which are evidence of high floristic similarity between plots in this ecotype. Upland Rocky Sitka Spruce-Alder Forest was the next most distinct, overlapping only slightly with Upland Rocky Sitka Spruce-Feathermoss Forest at the lower end of NMDS axis 2. Although distinct from other ecotypes, the within ecotype similarity between plots was low as indicated by the diffuse point cloud spanning across much of axis 2. The ecotypes Upland Rocky Sitka Spruce-Feathermoss Forest, Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest, Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest, and Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest all have a moderate to high degree of overlap. These ecotypes are related along a successional trajectory and correspond to unique successional stages. On the right side of the ordination are early successional ecotypes, including Upland Rocky Sitka Spruce-Feathermoss Forest and Upland Rocky Sitka Spruce-Alder Forest. Further to the left are later successional ecotypes, including Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest, Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest, and Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest. NMDS axis 1 represents a gradient in stand age as represented by the fitted surface of a Generalized Additive Model of stand age (model fit [deviance squared] = 0.50) overlaid on the NMDS in Figure 11. The oldest stands are predicted on the bottom of axis 2 and on the left of axis 1 corresponding with the Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest and Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest ecotypes. Stand age is predicted to decrease further right on axis 1 and towards the top of axis 2. The youngest stands are predicted on the far right side of axis 1 and towards the top of axis 2 corresponding to the Upland Rocky Sitka Spruce-Alder Forest and Upland Rocky Sitka Spruce-Feathermoss Forest ecotypes.

Upland, Glacial, and Riverine shrub ecotypes showed two distinct broad groupings, including 1) upland, and 2) glacial and riverine with little overlap between (Figure 12), indicating the upland shrub ecotypes are floristically distinct from riverine and glacial shrub ecotypes. The ordination reveals a physiography and elevation gradient along axis 1, from higher elevation uplands on the right side of the ordination to lower elevation upland in the center, to riverine and glacial physiography on the left side. The ecotype Upland Rocky-Loamy-Organic Salmonberry Low Shrub is one of the more floristically distinct and homogenous ecotypes as determined by the tight cluster of points on the far right of the upland group. Upland Rocky-Organic Alder Tall Shrub forms a broad cluster near the upper end of NMDS axis 2 and the middle of axis 1. The broad grouping of points indicates that within ecotype species composition is variable. Upland Rocky-Organic Alder Tall Shrub overlaps somewhat with Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub but in general is floristically distinct. Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub and Glacial Rocky Alder-Willow Tall Shrub are strongly overlapping and both ecotypes span across NMDS axis 2. This suggests considerable environmental and floristic similarities, and high within ecotype variability in species composition. Lastly, Riverine Rocky-Sandy Willow Low and Tall Shrub forms a tight cluster with little overlap in the lower left corner of the NMDS diagram indicating this ecotype is floristically distinct from other shrub ecotypes and has high floristic similarity between plots.

The Upland, Lowland, and Lacustrine ecotypes have several ecotypes with considerable overlap in species composition, but two ecotypes were distinct in this regard (Figure 13). The ordination reveals a gradient in elevation and soil moisture, with soil moisture decreasing and elevation increasing from top to bottom along axis 3. Upland Rocky-Loamy Lady Fern Meadow was distinct from other ecotypes but had high within ecotype similarity in species composition between plots; it is the driest ecotype in this group, occurring predominantly on hillside colluvium. In contrast, Lacustrine Aquatic Forb Marsh also was distinct from the other ecotypes in this group, but the within ecotype species composition between plots was variable. This is ecotype is the wettest ecotype in the group and occurs in standing water in shallow ponds and along lake margins with species typical of aquatic systems. Upland Loamy-Organic Deer Cabbage Slope Fen overlaps slightly with Lowland Organic-rich Wet Sedge Meadow but is otherwise floristically distinct; however it has the highest within ecotype variability in species composition of all ecotypes in this group. The final 2 ecotypes, Upland Organic-rich Wet Sedge Slope Fen and Lowland Organic-rich Wet Sedge Meadow have considerable overlap between their point clouds in the NMDS diagram suggesting these two types share some floristic similarities. Specifically, they both include wet sedge meadows dominated by *Eriophorum angustifolium*. These 2 ecotypes also have similar wet, organic-rich soils, but differ in the steepness of slope that they occur on. The Upland type occurs on steep slopes, while the Lowland type occurs on gentle slopes. These two ecotypes do not overlap completely, indicating there are some floristic differences, namely that only the Upland ecotype includes plots dominated by *Trichophorum caespitosum*. The Lowland ecotype also forms a tighter cluster than the Upland ecotype, suggesting it has a higher within ecotype similarity.

The Coastal ecotypes have a number of ecotypes with considerable overlap in the NMDS diagram (Figure 14). The ordination reveals a salinity gradient along axis 3, with decreasing salinity from top

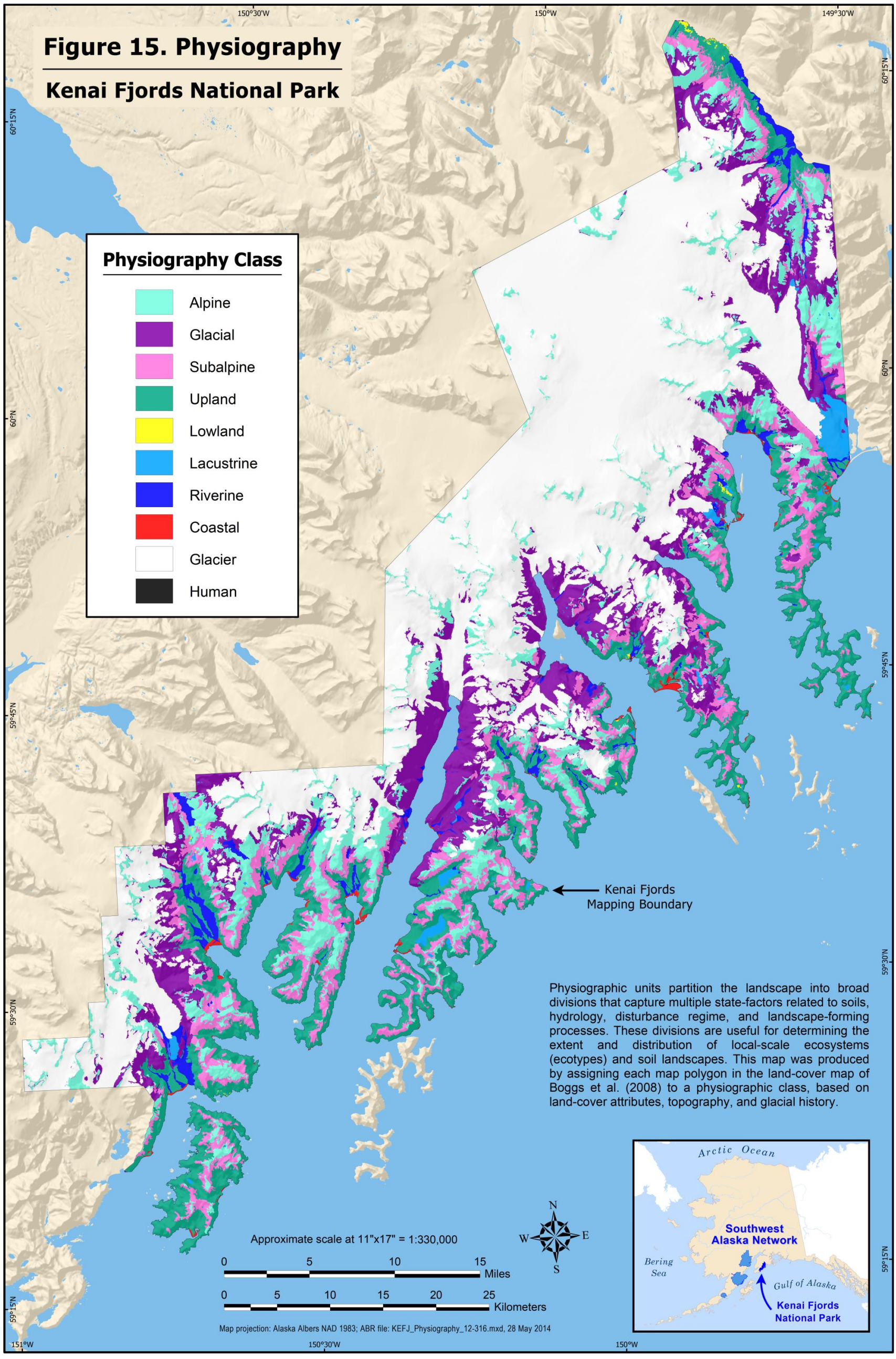


Figure 15. Physiography map for Kenai Fjords National Park, southcentral Alaska.

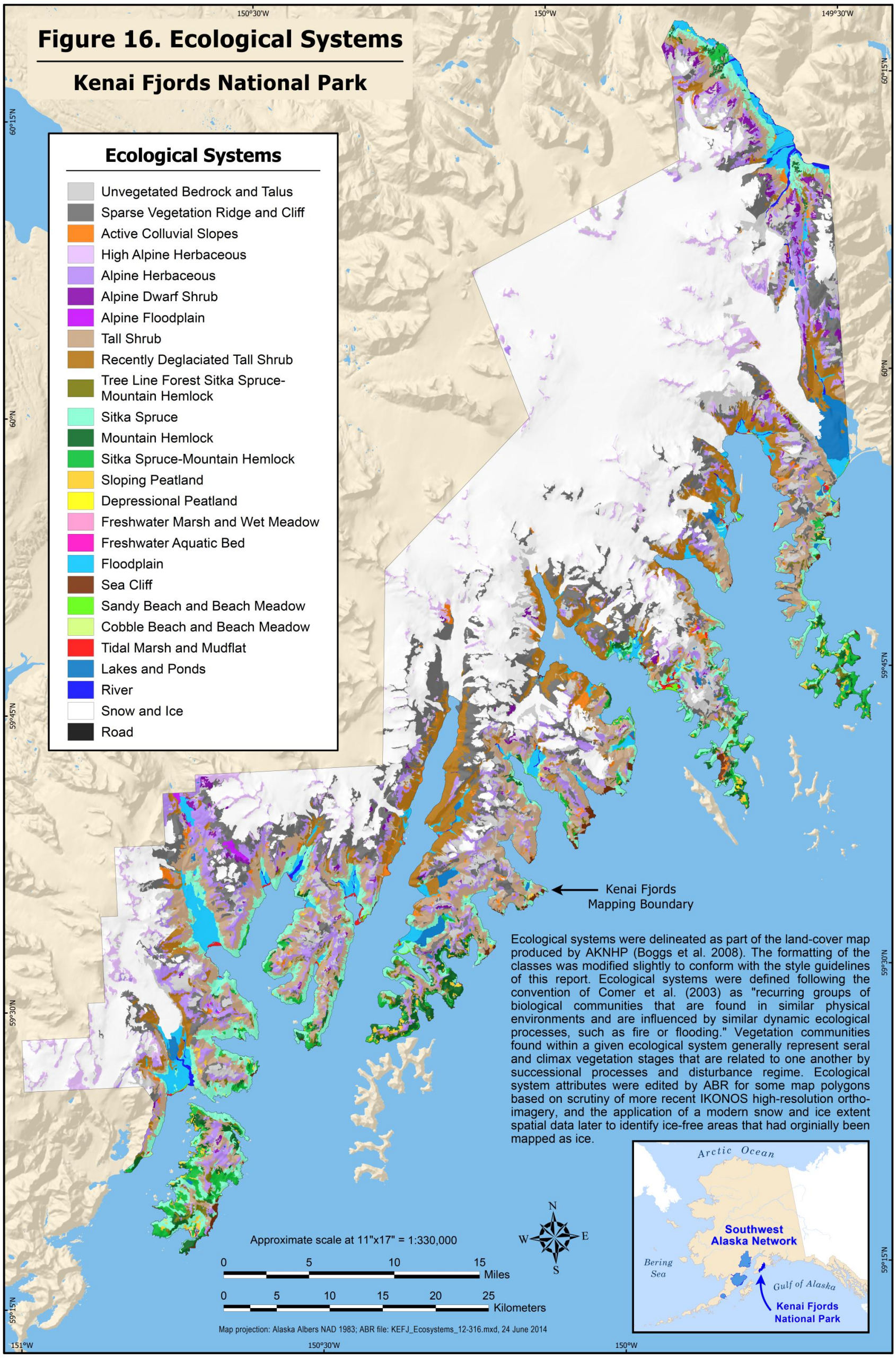


Figure 16. Ecological systems map for Kenai Fjords National Park, southcentral Alaska. Adapted from KEFJ land-cover map of Boggs et al. (2008).

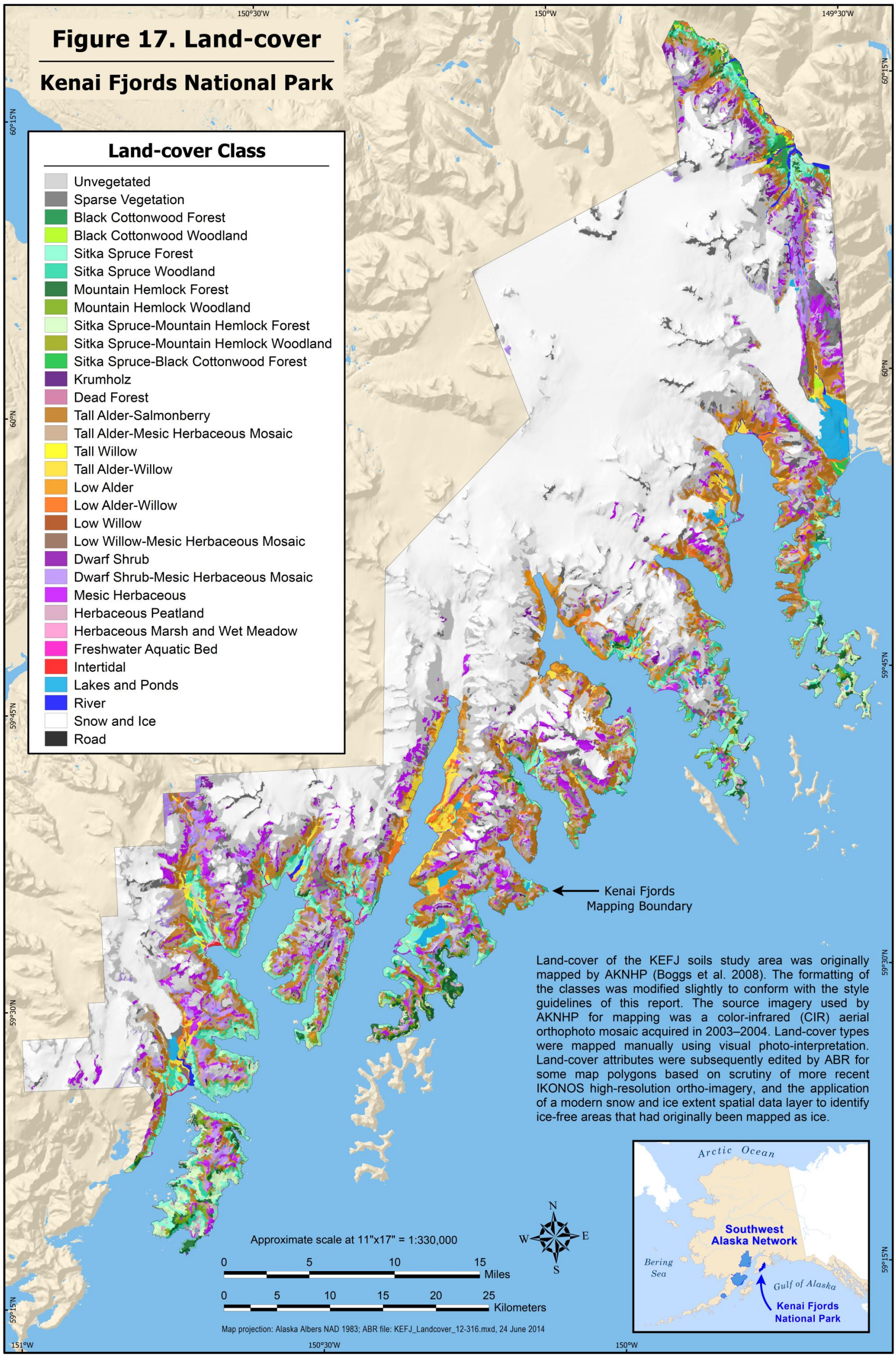


Figure 17. Land-cover map for Kenai Fjords National Park, southcentral Alaska. Adapted from KEFJ land-cover map of Boggs et al. (2008).

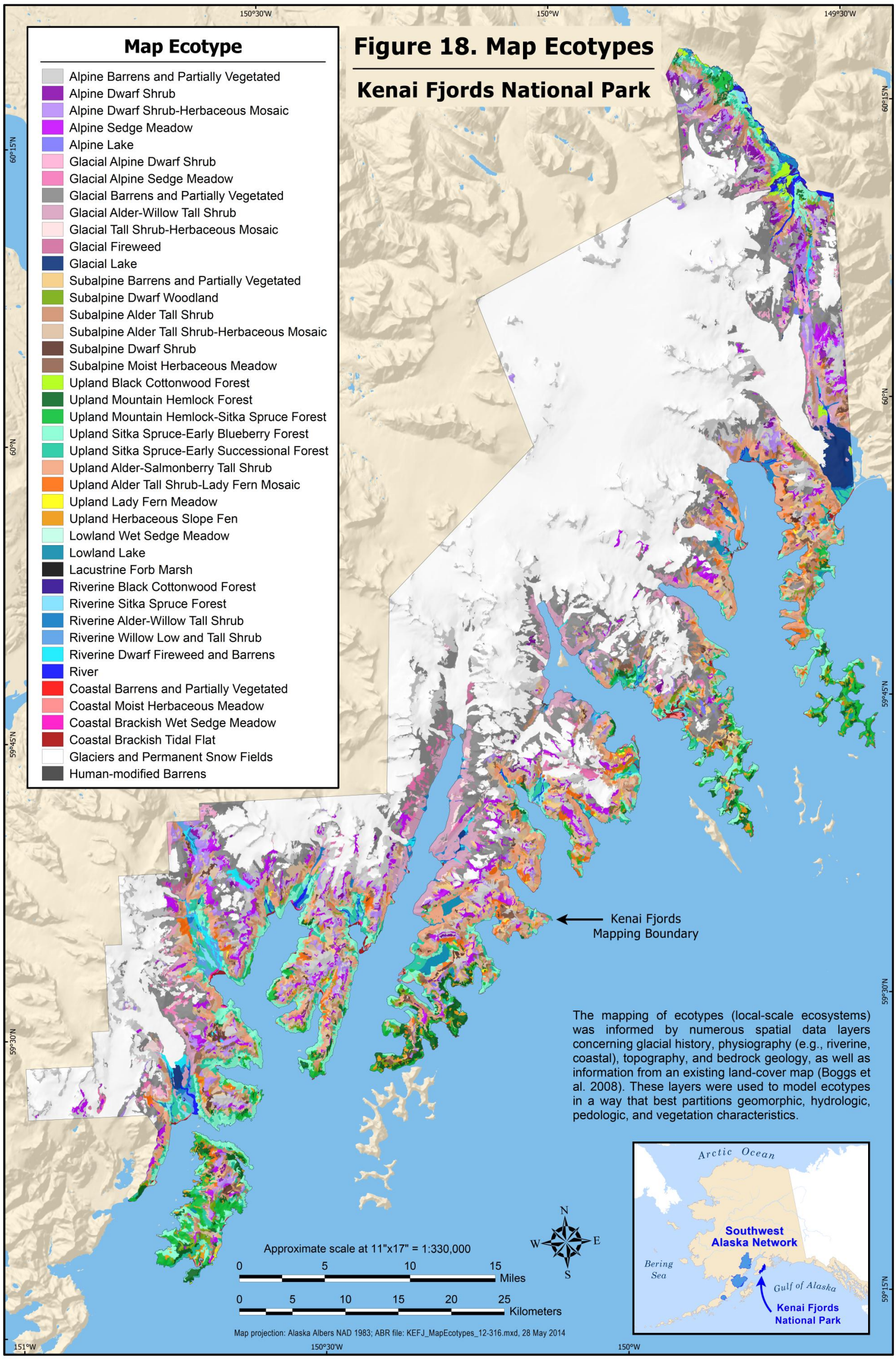


Figure 18. Map ecotypes for Kenai Fjords National Park, southcentral Alaska.

to bottom along axis 3. Additionally, a soil moisture gradient is revealed, with soil moisture increasing left to right along axis 1. On the far left side of the ordination the ecotypes Coastal Sandy-Rocky Beach Rye Meadow, Coastal Sandy-Rocky Beach Pea Meadow, and Coastal Rocky-Sandy Seaside Sandplant Beach occur in a tight group with considerable overlap between points. These 3 ecotypes occur in close proximity to one another at elevations near and above the normal high tide line. The relative proportions of *Leymus mollis*, *Lathyrus maritimus*, and *Honckenya peploides*, respectively, are what sets these 3 ecotypes apart from one another in species composition. At the center of the ordination at the upper end of NMDS axis 3 Coastal Sandy-Loamy-Rocky Brackish Sedge Meadow, Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat, and Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat occur in a broad grouping with considerable overlap. The 3 ecotypes occur in the middle to lower tidal zone and are differentiated from one another by the relative proportion of sedges, predominantly *Carex lyngbyaei*, *Puccinellia nutkaensi*s, and *Plantago maritima*, respectively. Coastal Sandy-Rocky Bluejoint-Forb Meadow occurs as 2 distinct clusters of points, the first in the middle of the ordination at the bottom of NMDS axis 3, the second as 3 points located up and left of the first next to the Coastal Sandy-Rocky Beach Rye Meadow, Coastal Sandy-Rocky Beach Pea Meadow, Coastal Rocky-Sandy Seaside Sandplant Beach group. Both clusters are very tight, indicating strong floristic affinities within each group. Overall, this ecotype is characterized by dominance of *Epilobium angustifolium* and/or *Calamagrostis canadensis*. The 3 points located up and left of the main group of 5 points represents plots with higher cover of *Leymus mollis* and *Lathyrus maritimus*, reflecting the variability in floristic composition of this ecotype. Lastly, Coastal Rocky-Sandy Barrens features a central grouping of points in the center of NMDS axis 1 and near the center of axis 3 and 2 points. This ecotype is distinct from the other ecotypes but it also has high variability in floristic composition as indicated by several points scattered across the ordination. This ecotype includes barrens and partially vegetated areas in coastal environments as well as a variety of landforms, including coastal cliff, sandy beaches, coastal dunes, and rocky inter-tidal areas. The species composition is as diverse as the wide range of coastal landforms associated with this ecotype.

Ecosystem Mapping

Physiography

We classified and mapped a total of 10 physiographic classes in KEFJ (Figure 15, Table 28). The most extensive physiographic class by far is Glacier, which encompasses nearly half of the park. Other common classes include Upland (14.0% of park), Glacial (13.5%), and Alpine (10.9%). The Lowland, Coastal, and Human-modified physiographic classes have an extremely limited distribution (<1%).

Ecological systems

AKNHP classified and mapped a total of 30 ecological system classes in KEFJ using CIR air-photo mosaics acquired 2003–2004 (Boggs et al. 2008) (Figure 16, Table 29). We reinterpreted some of the original map polygons using the higher-quality IKONOS 2005 base ortho-imagery, most commonly on steep slopes that were strongly shadowed or had excessive terrain distortion in the earlier air photos. We also used more recent mapping of contemporary snow and ice cover (Arendt et al. 2014)

to recode ice-free areas that had originally been mapped as snow and ice and used higher-quality IKONOS 2005 base ortho-imagery to reclassify areas previously shadowed (steep sloped) or that had excessive ice. As a result, the areal extents of ecological systems reported here differ from those reported by Boggs et al. (2008). The most common revised ecological systems were Snow and Ice (48.3% of park), Tall Shrub (9.3%), Sparse Vegetation Ridge and Cliff (8.2%), and Alpine Herbaceous (5.7%). The rarest ecological systems (<0.1%) were mostly associated with Lowland and Lacustrine physiographies, such as Depressional Peatland, Freshwater Aquatic Bed, Freshwater Marsh and Wet Meadow, and Pond.

Table 28. Area (km^2) of physiographic classes mapped in Kenai Fjords National Park, southcentral Alaska.

Physiographic class	Area (km^2)	% of park
Alpine	293.5	10.9
Glacial	364.7	13.5
Subalpine	265.3	9.9
Upland	377.5	14.0
Lowland	1.9	0.1
Lacustrine	27.9	1.0
Riverine	51.6	1.9
Coastal	9.6	0.4
Glacier	1,301.0	48.3
Human	0.1	<0.1

Land Cover

The AKNHP land-cover classification distinguished 55 land-cover classes in KEFJ (Figure 17, Table 30). We recoded the land-cover attributes of original map polygons in some cases, as described above for ecological systems. In contrast to the AKNHP classification approach, we did not distinguish polygons in the land-cover map that had been coded with both primary and secondary land-cover classes; we mapped those polygons using the primary land-cover class only. Snow and Ice was by far the most extensive land-cover class (48.3% of park). Additional common land-cover classes include Unvegetated (13.5%), Closed Alder-Mesic Herbaceous Mosaic (5.1%), Closed Tall Alder (4.4%), and Mesic Herbaceous. Forty-one of the remaining land-cover classes had very limited distributions (<1%). Grouping of land-cover classes with similar vegetation structure indicate that forest or woodland land-cover types encompass 9.8% of the park, low or tall shrublands 16.2%, dwarf shrublands 3.8%, and herbaceous meadows or marshes 4.9%. Barren or partially vegetated classes encompass 15.7% of the park.

Map Ecotypes

We mapped a total of 43 ecotypes in KEFJ (Figure 18, Tables 31 and 32). The most extensive, non-glaciated map ecotypes were Glacial Barrens and Partially Vegetated (8.9% of park), Alpine Barrens and Partially Vegetated (5.8%), Upland Alder-Salmonberry Tall Shrub (3.9%), and Subalpine Alder

Table 29. Area (km^2) of ecological systems mapped in Kenai Fjords National Park, southcentral Alaska. Ecological systems classification follows Boggs et al. (2008).*

Ecological system	Area (km^2)	% of park
Active Colluvial Slope	4.9	0.2
Alpine Active Colluvial Slope	3.1	0.1
Alpine Dwarf Shrub	20.5	0.8
Alpine Floodplain	2.5	0.1
Alpine Herbaceous	153.7	5.7
Cobble Beach and Beach Meadow	1.1	<0.1
Depressional Peatland	0.2	<0.1
Floodplain	65.3	2.4
Freshwater Aquatic Bed	<0.1	<0.1
Freshwater Marsh and Wet Meadow	1.3	<0.1
High Alpine Herbaceous	65.4	2.4
Lake	26.8	1.0
Mountain Hemlock	33.6	1.2
Pond	1.0	<0.1
Recently Deglaciated Tall Shrub	146.1	5.4
River	7.1	0.3
Road	0.1	<0.1
Sandy Beach and Beach Meadow	2.5	0.1
Sea Cliff	8.3	0.3
Sitka Spruce	136.5	5.1
Sitka Spruce-Mountain Hemlock	39.0	1.4
Sloping Peatland	11.8	0.4
Snow and Ice	1,301.0	48.3
Sparse Vegetation Ridge and Cliff	220.0	8.2
Tall Shrub	251.1	9.3
Talus Slopes and Colluvial Fans	9.9	0.4
Tidal Marsh and Mudflat	4.1	0.2
Tree Line Forest Sitka Spruce-Mountain Hemlock	16.2	0.6
Unvegetated Bedrock	81.2	3.0
Unvegetated Talus	78.6	2.9

* The formatting of the classes was modified slightly to conform with the style guidelines of this report.

Table 30. Area (km^2) of land-cover classes mapped in Kenai Fjords National Park, southcentral Alaska. Land-cover classification follows Boggs et al. (2008).*

Land-cover Class	Area (km2)	% of park
Closed Alder-Mesic Herbaceous Mosaic	137.3	5.1
Closed Alder-Salmonberry	74.3	2.8
Closed Black Cottonwood	2.2	0.1
Closed Low Alder	6.1	0.2
Closed Low Alder-Willow	8.7	0.3
Closed Low Salmonberry	0.3	<0.1
Closed Low Willow	0.6	0.0
Closed Mountain Hemlock	15.0	0.6
Closed Sitka Spruce	56.8	2.1
Closed Sitka Spruce-Black Cottonwood	0.5	<0.1
Closed Sitka Spruce-Mountain Hemlock	24.4	0.9
Closed Tall Alder	118.1	4.4
Closed Tall Alder-Willow	31.7	1.2
Closed Tall Salmonberry	0.4	<0.1
Closed Tall Willow	2.2	0.1
Dead Forest	0.4	<0.1
Dwarf Shrub	18.5	0.7
Dwarf Shrub-Mesic Herbaceous Mosaic	83.9	3.1
Freshwater Aquatic Bed	<0.1	<0.1
Herbaceous Marsh and Wet Meadow	4.3	0.2
Herbaceous Peatland	1.8	0.1
Intertidal Sparse Vegetation	1.3	<0.1
Krumholz	1.0	<0.1
Lake	26.8	1.0
Mesic Herbaceous	108.5	4.0
Moss-Lichen	17.6	0.7
Mountain Hemlock-Sitka Spruce Peatland	7.5	0.3
Open Black Cottonwood	2.3	0.1
Open Low Alder	20.4	0.8
Open Low Alder-Willow	10.6	0.4
Open Low Shrub	2.0	0.1
Open Low Shrub Peatland	2.5	0.1

Table 30. Continued.

Land-cover Class	Area (km2)	% of park
Open Low Willow	1.1	<0.1
Open Low Willow-Mesic Herbaceous	4.9	0.2
Open Mountain Hemlock	11.8	0.4
Open Sitka Spruce	52.4	1.9
Open Sitka Spruce-Mountain Hemlock	10.5	0.4
Open Sitka Spruce/Black Cottonwood	1.9	0.1
Open Tall Alder-Willow	6.4	0.2
Open Tall Willow	0.7	<0.1
Pond	1.0	<0.1
River	7.1	0.3
Road	0.1	<0.1
Snow and Ice	1,301.0	48.3
Sparse Vegetation	57.9	2.1
Unvegetated	362.6	13.5
Woodland Black Cottonwood	2.2	0.1
Woodland Mountain Hemlock	16.8	0.6
Woodland Sitka Spruce	4.1	0.2
Woodland Sitka Spruce-Alder	32.1	1.2
Woodland Sitka Spruce-Alder-Willow	10.6	0.4
Woodland Sitka Spruce-Herbaceous	5.7	0.2
Woodland Sitka Spruce-Mountain Hemlock	5.7	0.2
Woodland Sitka Spruce/Black Cottonwood	1.2	<0.1

* The formatting of the classes was modified slightly to conform with the style guidelines of this report.

Tall Shrub-Herbaceous Mosaic (3.6%). Twenty-nine map ecotypes had very limited distributions (<1%) in KEFJ.

Soil Landscapes

We classified and mapped a total of 18 soil landscapes in KEFJ (Figure 19, Table 33). The most extensive, non-glaciated soil landscapes were Glacial Rocky Barrens, Meadows and Shrublands (13.5% of park), Subalpine Rocky Barrens, Meadows and Shrublands (8.9%), Alpine Rocky Barrens and Sedge Meadows (8.1%), and Upland Rocky Meadows, Shrublands, and Forests (7.3%). Ten soil landscapes had very limited distributions (<1%) in KEFJ.

Disturbance Landscapes

A total of 12 disturbance landscape classes were mapped across KEFJ, the most common of which were Ablation/Surge (48.3% of park; associated with glaciers and ice sheets) and Mass Wasting and Landslide/Avalanche (38.6%; mainly associated with steep alpine slopes) (Figure 20, Table 34). The least common (<0.1%) disturbance landscapes were Drying/Paludification and Human.

Table 31. Crosswalk of map ecotypes with abbreviated ecotype names, soil landscapes, and disturbance landscapes identified in Kenai Fjords National Park, southcentral Alaska.

Map ecotype	Abbreviated ecotype name(s)	Soil landscape	Disturbance landscape
Alpine Barrens and Partially Vegetated	Alpine Rocky Barrens	Alpine Rocky Barrens and Sedge Meadows	Mass Wasting and Landslide, Avalanche
Alpine Dwarf Shrub	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub Alpine Rocky Luetkea Dwarf Shrub Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub Alpine Rocky-Loamy Mountain Heather Dwarf Shrub	Alpine Rocky-Loamy Dwarf Shrub	Mass Wasting and Landslide, Avalanche
Alpine Dwarf Shrub-Herbaceous Mosaic	Alpine Loamy-Rocky Crowberry-Blueberry Dwarf Shrub +[1] Alpine Rocky Leutkea Dwarf Shrub + Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub + Alpine Rocky-Loamy Mountain Heather Dwarf Shrub + Alpine Rocky Moist Sedge Meadow	Alpine Rocky-Loamy Dwarf Shrub	Mass Wasting and Landslide, Avalanche
Alpine Sedge Meadow	Alpine Rocky Moist Sedge Meadow	Alpine Rocky Barrens and Sedge Meadows	Mass Wasting and Landslide, Avalanche
Alpine Lake	Alpine Lake	Alpine Lake	Sedimentation, Paludification
Glacial Alpine Dwarf Shrub	Alpine Rocky-Loamy Cassiope-Luetkea Dwarf Shrub Alpine Rocky Luetkea Dwarf Shrub	Glacial Rocky Barrens, Meadows, and Shrublands	Mass Wasting and Landslide, Avalanche
Glacial Alpine Sedge Meadow	Alpine Rocky Moist Sedge Meadow	Glacial Rocky Barrens, Meadows, and Shrublands	Mass Wasting and Landslide, Avalanche
Glacial Barrens and Partially Vegetated	Glacial Rocky Barrens	Glacial Rocky Barrens, Meadows, and Shrublands	Mass Wasting and Landslide, Avalanche
Glacial Alder-Willow Tall Shrub	Glacial Rocky Alder-Willow Tall Shrub	Glacial Rocky Barrens, Meadows, and Shrublands	Mass Wasting and Landslide, Avalanche
Glacial Tall Shrub-Herbaceous Mosaic	Glacial Rocky Alder-Willow Tall Shrub + Glacial Rocky Fireweed +	Glacial Rocky Barrens, Meadows, and Shrublands	Mass Wasting and Landslide, Avalanche
Glacial Fireweed	Glacial Rocky Fireweed		
Glacial Lake	Glacial Lake	Glacial Lake	Catastrophic Drainage, Sedimentation
Subalpine Dwarf Woodland	Subalpine Rocky Dwarf Mountain Hemlock Woodland	Subalpine Rocky Barrens, Shrublands, and Woodlands	Mass Wasting and Landslide, Avalanche, Pests and Pathogens

Table 31. Continued.

Map ecotype	Abbreviated ecotype name(s)	Soil landscape	Disturbance landscape
Subalpine Alder Tall Shrub	Subalpine Rocky Alder Tall Shrub	Subalpine Rocky Barrens, Shrublands, and Woodlands	Mass Wasting and Landslide, Avalanche
Subalpine Alder Tall Shrub-Herbaceous Mosaic	Subalpine Rocky Alder Tall Shrub + Subalpine Rocky Fireweed-Forb Meadow + Subalpine Rocky-Loamy Moist Graminoid Meadow + Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow + Subalpine Rocky-Loamy-Organic Fern Meadow	Subalpine Rocky Barrens, Shrublands, and Woodlands	Mass Wasting and Landslide, Avalanche
Subalpine Dwarf Shrub	Subalpine Rocky-Loamy Luetkea-Mountain Hairgrass Meadow	Subalpine Rocky Barrens, Shrublands, and Woodlands	Mass Wasting and Landslide, Avalanche
Subalpine Moist Herbaceous Meadow	Subalpine Rocky Fireweed-Forb Meadow Subalpine Rocky-Loamy Moist Graminoid Meadow Subalpine Rocky-Loamy-Organic Copperbush Low Shrub Subalpine Rocky-Loamy-Organic Deer Cabbage-Forb Meadow Subalpine Rocky-Loamy-Organic Fern Meadow	Subalpine Rocky-Loamy-Organic Meadows and Shrublands	Mass Wasting and Landslide, Avalanche
Upland Black Cottonwood Forest	Upland Rocky Black Cottonwood Forest	Upland Rocky Meadows, Shrublands, and Forests	Windthrow, Pests and Pathogens
Upland Mountain Hemlock Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Early Blueberry Forest	Upland Rocky-Loamy-Organic Fens and Forests	Windthrow, Pests and Pathogens, Paludification
Upland Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Mountain Hemlock-Sitka Spruce Forest	Upland Rocky-Loamy-Organic Fens and Forests	Windthrow, Pests and Pathogens, Paludification
Upland Sitka Spruce-Early Blueberry Forest	Upland Rocky-Loamy-Organic Sitka Spruce-Early Blueberry Forest	Upland Rocky-Loamy-Organic Fens and Forests	Windthrow, Pests and Pathogens, Paludification
Upland Sitka Spruce-Early Successional Forest	Upland Rocky Sitka Spruce-Alder Forest Upland Rocky Sitka Spruce-Feathermoss Forest	Upland Rocky Meadows, Shrublands, and Forests	Windthrow, Pests and Pathogens
Upland Alder-Salmonberry Tall Shrub	Upland Rocky-Organic Alder Tall Shrub Upland Rocky-Loamy-Organic Salmonberry Low Shrub	Upland Rocky Meadows, Shrublands, and Forests	Mass Wasting and Landslide, Avalanche
Upland Alder Tall Shrub-Lady Fern Mosaic	Upland Rocky-Organic Alder Tall Shrub + Upland Rocky-Loamy-Organic Salmonberry Low Shrub + Upland Rocky-Loamy Lady Fern Meadow	Upland Rocky Meadows, Shrublands, and Forests	Mass Wasting and Landslide, Avalanche
Upland Lady Fern Meadow	Upland Rocky-Loamy Lady Fern Meadow	Upland Rocky Meadows, Shrublands, and Forests	Mass Wasting and Landslide, Avalanche

Table 31. Continued.

Map ecotype	Abbreviated ecotype name(s)	Soil landscape	Disturbance landscape
Upland Herbaceous Slope Fen	Upland Loamy-Organic Deer Cabbage Slope Fen Upland Organic-rich Wet Sedge Slope Fen Subalpine Rocky-Loamy-Organic Deer Cabbage Slope Fen	Upland Rocky-Loamy-Organic Fens and Forests	Avalanche, Paludification
Lowland Wet Sedge Meadow	Lowland Organic-rich Wet Sedge Meadow	Lowland Organic-rich Wet Meadows and Marshes	Drying, Paludification
Lowland Lake	Lowland Lake	Lowland Lake	Sedimentation, Paludification
Lacustrine Forb Marsh	Lacustrine Aquatic Forb Marsh	Lowland Organic-rich Wet Meadows and Marshes	Drying, Paludification
Riverine Black Cottonwood Forest	Riverine Sandy-Rocky Black Cottonwood Forest	Riverine Sandy-Loamy-Rocky Shrublands and Forests	Flooding, Sedimentation, Erosion
Riverine Sitka Spruce Forest	Riverine Sandy-Loamy-Rocky Sitka Spruce Forest	Riverine Sandy-Loamy-Rocky Shrublands and Forests	Flooding, Sedimentation, Erosion
Riverine Alder-Willow Tall Shrub	Riverine Sandy-Loamy-Rocky Alder-Willow Tall Shrub	Riverine Sandy-Loamy-Rocky Shrublands and Forests	Flooding, Sedimentation, Erosion
Riverine Willow Low and Tall Shrub	Riverine Rocky-Sandy Willow Low and Tall Shrub	Riverine Sandy-Loamy-Rocky Shrublands and Forests	Flooding, Sedimentation, Erosion
Riverine Dwarf Fireweed and Barrens	Riverine Rocky Dwarf Fireweed Riverine Rocky Dwarf Shrub Riverine Rocky Barrens	Riverine Rocky Barrens, Herbaceous, and Dwarf Shrub	Flooding, Sedimentation, Erosion
River	River	River	Flooding, Sedimentation, Erosion
Coastal Barrens and Partially Vegetated	Coastal Rocky-Sandy Barrens	Coastal Rocky-Sandy Moist Herbaceous Meadows	Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment
Coastal Moist Herbaceous Meadow	Coastal Rocky-Sandy Brackish Seaside Sandplant Beach Coastal Sandy-Rocky Beach Pea Meadow Coastal Sandy-Rocky Beach Rye Meadow Coastal Sandy-Rocky Bluejoint-Forb Meadow	Coastal Rocky-Sandy Moist Herbaceous Meadows	Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment
Coastal Brackish Wet Sedge Meadow	Coastal Sandy-Loamy-Rocky Wet Brackish Sedge Meadow	Coastal Sandy-Loamy-Rocky Brackish Tidal Flats and Wet Sedge Meadows	Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment
Coastal Brackish Tidal Flat	Coastal Rocky-Sandy Brackish Dwarf Alkali Grass Tidal Flat Coastal Sandy-Rocky Brackish Goosetongue Tidal Flat	Coastal Sandy-Loamy-Rocky Brackish Tidal Flats and Wet Sedge Meadows	Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment

Table 31. Continued.

Map ecotype	Abbreviated ecotype name(s)	Soil landscape	Disturbance landscape
Glaciers and Permanent Snowfields	Glacier	Glaciers and Permanent Snowfields	Ablation, Surge
Human-modified Barrens	Human-modified Barrens	Human-modified	Human
Nearshore Water	Coastal Brackish Water	Nearshore Water	Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment

[1] Plus signs (+) indicate mosaic map ecotypes.

Table 32. Area of map ecotypes in Kenai Fjords National Park, southcentral Alaska.

Map ecotype	Area (km^2)	% of park
Alpine Barrens and Partially Vegetated	156.2	5.8
Alpine Dwarf Shrub	16.2	0.6
Alpine Dwarf Shrub-Herbaceous Mosaic	59.9	2.2
Alpine Lake	2.3	0.1
Alpine Sedge Meadow	61.2	2.3
Coastal Barrens and Partially Vegetated	1.7	0.1
Coastal Brackish Tidal Flat	4.1	0.2
Coastal Brackish Wet Sedge Meadow	0.6	<0.1
Coastal Moist Herbaceous Meadow	3.1	0.1
Glacial Alder-Willow Tall Shrub	77.9	2.9
Glacial Alpine Dwarf Shrub	16.0	0.6
Glacial Alpine Sedge Meadow	14.7	0.6
Glacial Barrens and Partially Vegetated	238.7	8.9
Glacial Fireweed	4.3	0.2
Glacial Lake	15.9	0.6
Glacial Tall Shrub-Herbaceous Mosaic	12.2	0.5
Glaciers and Permanent Snow Fields	1,301.0	48.3
Human-modified Barrens	0.1	<0.01
Lacustrine Forb Marsh	<0.1	<0.01
Lowland Lake	9.7	0.4
Lowland Wet Sedge Meadow	1.1	<0.1
River	7.1	0.3
Riverine Alder-Willow Tall Shrub	18.4	0.7
Riverine Black Cottonwood Forest	2.5	0.1
Riverine Dwarf Fireweed and Barrens	9.7	0.4
Riverine Sitka Spruce Forest	5.0	0.2
Riverine Willow Low and Tall Shrub	9.7	0.4
Subalpine Alder Tall Shrub	83.2	3.1
Subalpine Alder Tall Shrub-Herbaceous Mosaic	97.8	3.6
Subalpine Barrens and Partially Vegetated	32.4	1.2
Subalpine Dwarf Shrub	9.9	0.4
Subalpine Dwarf Woodland	17.3	0.6
Subalpine Moist Herbaceous Meadow	23.8	0.9
Upland Alder Tall Shrub-Lady Fern Mosaic	27.3	1.0
Upland Alder-Salmonberry Tall Shrub	105.0	3.9
Upland Black Cottonwood Forest	5.2	0.2
Upland Herbaceous Slope Fen	12.2	0.5
Upland Lady Fern Meadow	2.4	0.1
Upland Mountain Hemlock Forest	33.4	1.2

Table 32. Continued.

Map ecotype	Area (km2)	% of park
Upland Mountain Hemlock-Sitka Spruce Forest	38.8	1.4
Upland Sitka Spruce-Early Blueberry Forest	97.2	3.6
Upland Sitka Spruce-Early Successional Forest	57.8	2.2

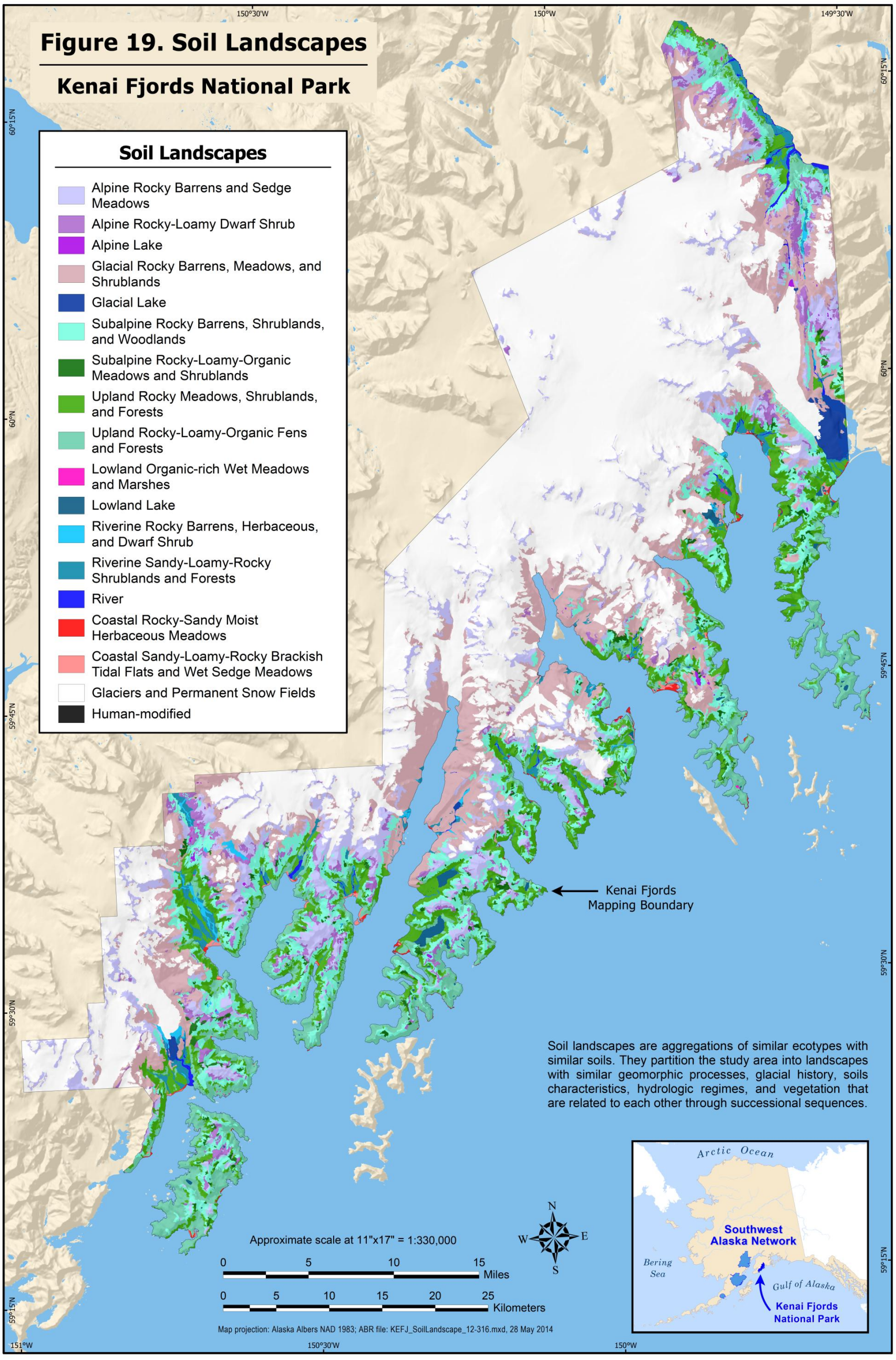


Figure 19. Soil Landscapes map for Kenai Fjords National Park, southcentral Alaska.

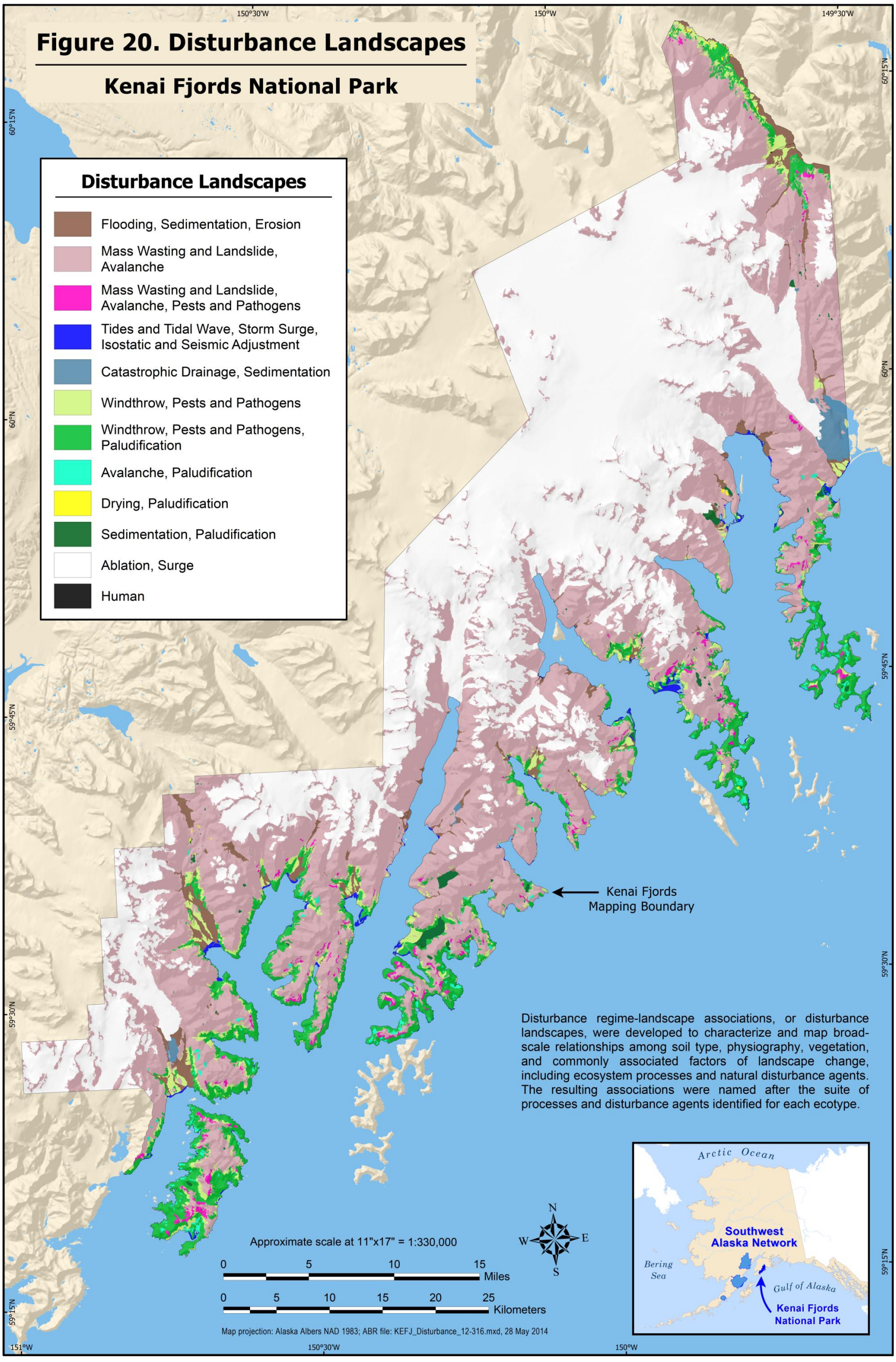


Figure 20. Disturbance Landscapes map for Kenai Fjords National Park, southcentral Alaska.

Table 33. Area (km^2) of soil landscape classes mapped in Kenai Fjords National Park, southcentral Alaska.

Soil landscape	Area (km^2)	% of park
Alpine Lake	2.3	0.1
Alpine Rocky Barrens and Sedge Meadows	217.5	8.1
Alpine Rocky-Loamy Dwarf Shrub	76.1	2.8
Coastal Rocky-Sandy Moist Herbaceous Meadows	4.8	0.2
Coastal Sandy-Loamy-Rocky Brackish Tidal Flats and Wet Sedge Meadows	4.7	0.2
Glacial Lake	15.9	0.6
Glacial Rocky Barrens, Meadows, and Shrublands	363.8	13.5
Glaciers and Permanent Snow Fields	1,301.0	48.3
Human-modified	0.1	<0.1
Lowland Lake	9.7	0.4
Lowland Organic-rich Wet Meadows and Marshes	1.1	<0.1
River	7.1	0.3
Riverine Rocky Barrens, Herbaceous, and Dwarf Shrub	9.7	0.4
Riverine Sandy-Loamy-Rocky Shrublands and Forests	35.7	1.3
Subalpine Rocky Barrens, Shrublands, and Woodlands	240.5	8.9
Subalpine Rocky-Loamy-Organic Meadows and Shrublands	23.8	0.9
Upland Rocky Meadows, Shrublands, and Forests	197.7	7.3
Upland Rocky-Loamy-Organic Fens and Forests	181.6	6.7

Table 34. Area (km^2) of disturbance landscape classes mapped in Kenai Fjords National Park, southcentral Alaska.

Disturbance landscape	Area (km^2)	% of park
Flooding, Sedimentation, Erosion	52.4	1.9
Mass Wasting and Landslide, Avalanche	1,039.2	38.6
Mass Wasting and Landslide, Avalanche, Pests and Pathogens	17.3	0.6
Tides and Tidal Wave, Storm Surge, Isostatic and Seismic Adjustment	9.6	0.4
Catastrophic Drainage, Sedimentation	15.9	0.6
Windthrow, Pests and Pathogens	63.0	2.3
Windthrow, Pests and Pathogens, Paludification	169.4	6.3
Avalanche, Paludification	12.2	0.5
Drying, Paludification	1.1	<0.1
Sedimentation, Paludification	12.0	0.4
Ablation, Surge	1,301.0	48.3
Human	0.1	<0.1

Soil Landscapes

Summary of Soil Characteristics

Soil Classification

Of the 486 plots included in the ecotype analysis, soils data sufficient for classifying soil subgroups was available for 101 plots. Soils from 4 orders of soil taxonomy were encountered during field sampling: Entisols, Histosols, Inceptisols, and Spodosols (Table 35). Twenty-four soil subgroups were identified during field sampling, although a majority of the subgroups (14) were rare (<3 observations).

Entisols included 9 observed subgroups and comprised 62% of observations. Entisols are undeveloped soils having little to no horizon development or translocation and accumulation of materials lower in the soil profile. Surface organic (O-horizons) and A-horizons if present are typically thin (<14 cm). Entisols are soils that have not had sufficient time for soil development to occur, often due to their location in a dynamic environment (e.g., floodplain, alluvial fan, recently deglaciated area) or sometimes due to intensive land use management practices. Entisols occur across all physiography types with the exception of lowlands. In Coastal areas, Entisols were most commonly sampled on Active Gravelly Marine Beach and Inactive Sandy Marine Beach deposits. In Glacial environments, Entisols were most commonly associated with Younger Till and Bedrock-undifferentiated. In Riverine environments, Entisols were most commonly sampled on Glaciofluvial Outwash Active and Inactive-cover Deposits. In Subalpine environments, Entisols were most commonly sampled on Avalanche Deposits, Hillside Colluvium, and Landslide Deposits. Lastly, in Upland environments, Entisols were associated with Hillside Colluvium, Younger Moraine, and sometimes Older Moraine and Glaciofluvial Outwash Abandoned-cover Deposit. Insufficient data were available for Lacustrine and Alpine physiography, but we expect that Entisols occur in these environments too, including recently drained lake bottoms in Lacustrine settings and on unstable, or recently deglaciated landforms in the Alpine.

Inceptisols accounted for 28% of observations and included 7 observed subgroups. Inceptisols are soils that are moderately developed and do not meet the requirements for any other soil order. They are characterized by distinct horizon development and mild weathering and translocation of materials to lower in the soil profile. Inceptisols were sampled most commonly in Upland and Subalpine physiographies. In Upland environments, Inceptisols were most commonly sampled on Hillside Colluvium and Older Till. In subalpine environments, they were most commonly sampled on Upland Loess and Ash-laden Loess. Sample size was too low in other physiography classes to summarize common landforms, but Inceptisols are expected to occur in Alpine areas that were not glaciated during the Little Ice Age (LIA) and in Riverine environments on abandoned glacio-fluvial deposits. Inceptisols are expected to be rare to absent in Lowland, Glacial, and Coastal environments.

Table 35. Description of soil subgroups found in Kenai Fjords National Park, Alaska, 2013. Soil classes are ordered hierarchically from soil order (broadest grouping of soil taxonomy, far left, all caps), through suborder (center left, bold), great group (center right, underlined), and soil subgroup (finest grouping of soil taxonomy, far right). Descriptions have been generalized in many cases for readability. For official criteria for each soil subgroup, please refer to Soil Survey Staff (1999) and USDA NRCS (2010). See glossary for definitions of technical terms.

Soil Taxonomic Class	Description
ENTISOLS	Undeveloped soils having little to no horizon development or translocation and accumulation of materials lower in the soil profile. Surface organic (O-horizons) and A-horizons if present are typically thin (<5 cm). Entisols are soils that have not had sufficient time for soil development to occur often due to their location in a dynamic environment (e.g., floodplain, alluvial fan) or sometimes due to intensive land use management practices.
AQUENTS	Entisols that are saturated with water and have reducing, anaerobic soil conditions within the soil profile throughout the growing season.
Cryaquents	Aquents that occur in a cryic soil temperature regime.
Typic Cryaquents	Cryaquents that are typical for this great group.
FLUVENTS	Entisols that have buried soil horizon(s) with an appreciation of organic carbon with increasing depth that is typically a result of periodic flooding.
Cryofluvents	Fluvents that have formed in a cryic soil temperature regime.
Aquic Cryofluvents	Cryofluvents that have within 50 cm of the soil surface redox depletions or a reduced matrix resulting from saturated anaerobic soil conditions throughout the growing season.
Oxyaquic Cryofluvents	Cryofluvents that experience periodic saturation within 100 cm of the mineral soil and do not remain saturated throughout the growing season.
Typic Cryofluvents	Cryofluvents that are typical for this great group.
ORTHENTS	Entisols that do not meet the taxonomic requirements for any other suborder of Entisols.
Cryorthents	Orthents that occur in a cryic soil temperature regime.
Lithic Cryorthents	Cryorthents that have bedrock within 50 cm of the mineral soil surface.
Oxyaquic Cryorthents	Cryorthents that experience periodic saturation within 100 cm of the mineral soil and do not remain saturated throughout the growing season.
Typic Cryorthents	Cryorthents that are typical for this great group.
Vitrandic Cryorthents	Cryorthents that have thick (≥18 cm) deposits of coarse unweathered volcanic ejecta such as pumice or coarse volcanic cinders, or an abundance (5% of soil volume) volcanic glass and accumulations of aluminum and iron in the soil subsurface.

Table 35. (continued)

Soil Taxonomic Class	Description
Cryopsamments	Psamments that occur in a cryic soil temperature regime.
Typic Cryopsamments	Cryopsamments that are typical for this great group.
HISTOSOLS	Soils that are saturated throughout the growing season and are comprised primarily of thick accumulations (typically >40 cm) of organic matter.
FIBRISTS	Histosols that are comprised of fibric soil materials more than any other kind of organic soil materials within a general depth of 0 to 120 cm.
Cryofibrists	Fibrists that have formed in a cryic soil temperature regime.
Sphagnic Cryofibrists	Cryofibrists that have three-fourths or more of the fibric soil materials composed of *Sphagnum* within the depth of 0 to 60 cm.
FOLISTS	Histosols that are saturated with water for less than 30 cumulative days during normal years (and are not artificially drained).
Ustifolists	Folists that have formed in an ustic soil moisture regime.
Lithic Ustifolists	Ustifolists that have bedrock contact within 50 cm of the soil surface.
SAPRISTS	Histosols that have more thickness of sapric soil materials than any other kind of organic soil material within a general depth of 0 to 120 cm.
Cryosaprists	Saprists that have formed in a cryic soil temperature regime.
Lithic Cryosaprists	Saprists that have bedrock contact within 50cm of the soil surface.
INCEPTISOLS	Soils that are moderately developed and include soils that do not meet the requirements for other soil orders. Inceptisols are characterized by distinct horizon development and mild weathering and translocation of materials to lower in the soil profile. Inceptisols also include soils with thick (15–40 cm) surficial organic deposits that do not meet the requirements for Histosols. Surface organic horizons that are not saturated for 30 more cumulative days (i.e., folistic epipedons) must be ≥15 cm thick. Surface organic horizons that are saturated for 30 or more cumulative days (i.e., histic epipedons) must be ≥20 cm thick.
AQUEPTS	Inceptisols that are saturated with water and have reducing, anaerobic soil conditions within the soil profile throughout the growing season.
Cryaquepts	Aquepts that occur in a cryic soil temperature regime.
Histic Cryaquepts	Cryaquepts that have organic soil materials at the surface that are 21–40 cm thick and remain saturated with water for 30 days or more cumulative in a normal year and do not meet the requirements for Histosols.
CRYEPTS	Inceptisols that occur in a cryic soil temperature regime.
Dystrocryepts	Cryepts that typically have a lower soil pH (<5.5 and do not have thick (>18 cm) accumulations of dark organic-carbon rich soil material at, or near, the soil surface.
Andic Dystrocrypets	Dystrocryepts that have formed in weathered volcanic ejecta or volcaniclastic materials and do not meet the requirements for Andisols.

Table 35. (continued)

Soil Taxonomic Class	Description
Fluventic Dystrocryepts	*Dystrocrypets that have buried organic (O-) horizon(s) at depth. These buried soil horizons are typically a result of flooding.*
Folistic Dystrocryepts	Dystrocryepts that have a thick organic surface horizon (15–40 cm) and are not saturated for more than 30 days cumulative in normal years.
Lithic Dystrocryepts	Dystrocryepts that have bedrock contact within 50 cm of the soil surface.
Typic Dystrocryepts	Dystrocryepts that are typical for this great group.
Haplocryepts	Cryepts that predominantly have higher pH values (>5.5) and do not have thick (>18 cm) accumulations of dark organic-carbon rich soil material at, or near, the soil surface.
Oxyaquic Haplocryepts	Haplocryepts that do not remain saturated, but experience periods of saturation within 100 cm of the mineral soil surface in normal years for 20 or more consecutive days, or 30 or more cumulative days.
SPODOSOLS	Soils that have thick accumulations of translocated humus and aluminum and/or iron in the mineral subsurface.
CRYODS	Spodosols that occur in a cryic soil temperature regime.
Haplocryods	Spodosols that do not have cemented horizons and do not have 6% organic carbon or more throughout a layer 10 cm or more thick within the spodic horizon.
Andic Haplocryods	Haplocryods forming in weathered volcanic eject or volcaniclastic materials.
Typic Haplocryods	Haplocryods that are considered typical for this great group.
Humicryods	Cryods that have significant accumulations (>6%) of organic carbon within the horizon of translocated aluminum and/or iron.
Typic Humicryods	Humicryods that are typical for this great group.

Spodosols accounted for 6% of observations and included 3 observed subgroups. Spodosols are soils that have accumulations of translocated humus and aluminum and/or iron in the mineral subsurface. Spodosols occurred most commonly in Uplands on older, stable geomorphic landscapes such as *Picea sitchensis* and *Tsuga mertensiana* forest along the outer fjords and southern tips of the peninsulas in KEFJ. Spodosols were often associated with thin (5–10 cm thick) layer of volcanic ash characterized by an abundance of volcanic glass and a low bulk density (i.e., a given volume of soil feels lighter than it appears). The thickness of the volcanic ash deposits were insufficient to classify these soils into the Andisols soil order, and at times insufficient to classify them into Andic Subgroups. The forces of wind and water have redistributed ash sediments in KEFJ downslope over time. Accumulations thick enough to meet Andic subgroup requirements (~18–25 cm) most often occurred at footslope positions on mountain slopes in the Upland, or on leeward sheltered benches in the Subalpine. Spodosols were not sampled in other physiography classes. Weakly-developed Spodosols or spodic intergrades of Inceptisols may occur on stable landforms in older Subalpine landscapes. Spodosols are expected to be absent in other physiography classes.

Histosols (thick peats) accounted for 4% of observations and included 3 subgroups. Histosols were sampled primarily in sloping fens and wet meadows in Upland, Subalpine, and Lowland environments, particularly in older, granite-dominated landscapes of the outer fjordlands. Histosols in KEFJ often form directly on top of bedrock and classify as Lithic subgroups when bedrock is less than 50 cm below the soil surface.

Single-factor Comparisons by Subgroup

The soil classification was effective at partitioning the variability of numerous soil properties because the classification is based largely on soil moisture, depth to water table, organic horizon thickness, and base saturation as inferred from pH (Table 35). For example, soils with measurable water table depths within 40 cm of the surface were associated with the soil suborders Aquents (Entisols) and Aquepts (Inceptisols) and Aquic subgroups (e.g., Aquic Cryofluvents). Average soil pH values ≤5.0 were associated with well-developed soils that have experienced a higher degree of weathering and leaching of base cations, including the Dystrocryepts and Haplocryods Great Groups of the Inceptisols and Spodosols soil orders. Lower soil pH was also associated with the Histosols (e.g., Lithic Cryofolists) soil order, the result of the accumulation of organic acids from decomposing organic matter. Average soil pH values >5.0 were associated with soils with regular sedimentation and flooding, including the Cryofluvents and Cryaquents Great Groups of the Entisols soil order, and the Cryaquepts Great Group of the Inceptisols soil order. Soils with higher pH also include young soils with little weathering in which base cations have not yet leached out of the upper soil solum. Average surface organic thicknesses ≥15 cm were associated with Histic and Folistic subgroups of Inceptisols (e.g., Folistic Dystrocryepts), and Lithic Subgroups of Histosols.

Classification and Description of Soil Landscapes

The following section provides a description of each of the soil landscape classes, including the map ecotypes aggregated within each soil landscape; a brief description of the soils, environment, and vegetation; and the spatial extent of each soil landscape class as a percentage of the study area. Table 33 also provides a summary of areal extent of each soil landscape class.

Alpine Lake

This soil landscape encompasses one map ecotype, Alpine Lake. This soil landscape includes waterbodies in alpine areas (~ >500 m) and typically does not support soil development. This soil landscape class is rare, encompassing 0.1% of the study area.

Alpine Rocky Barrens and Sedge Meadows

This soil landscape encompasses 2 map ecotypes: Alpine Barrens and Partially Vegetated and Alpine Sedge Meadow. It is found in mountainous areas above treeline with shallow soils (≤50 cm). The parent material is a mantle of rocky colluvium or glacial till over bedrock. Bedrock outcrops and exposures are common. The soils and vegetation of this soil landscape class are similar to Glacial Rocky Barrens, Meadows, and Shrublands except that these soils were either unglaciated during the last glacial maximum, or have been ice-free since 1950. There was insufficient soil data to classify the soils. However, common soil subgroups are likely to include Lithic Cryorthents and Typic Cryorthents. This soil landscape class is the fourth most common soil landscape class, encompassing 8.1% of the study area.

Alpine Rocky-Loamy Dwarf Shrub

This soil landscape encompasses 2 map ecotypes: Alpine Dwarf Shrub and Alpine Dwarf Shrub-Herbaceous Mosaic. It is a spatially extensive soil landscape that extends from the southwest to the northeast border of the park in mountainous areas above treeline and at the transition zone with the Subalpine. Soils tend to be acidic to circum-acidic with mixed rocky and loamy soils over bedrock. Soils most commonly form in colluvium or glacial till deposited prior to 1950 and are often shallow (≤50 cm) to bedrock. Dwarf ericaceous shrubs and alpine herbs characterize the vegetation. There was insufficient soil data to classify the soils, however common soil subgroups are likely to include Lithic Cryorthents and Typic Cryorthents. This soil landscape class encompasses 2.8% of the study area.

Coastal Rocky-Sandy Moist Herbaceous Meadows

This soil landscape encompasses 2 map ecotypes: Coastal Barrens and Partially Vegetated and Coastal Moist Herbaceous Meadow. Coastal Rocky-Sandy Moist Herbaceous Meadows are extensive along the KEFJ coastline where beaches or sand dunes are still subject to flooding, either tidally or by storm surge activity. This soil landscape includes coastal soils that have formed primarily in sandy and rocky soils. The soil chemistry ranges widely, from circum-acidic to alkaline and brackish. High variability in soil pH and electrical conductivity (EC) is related to the regularity of coastal flooding (i.e., higher pH and higher EC for active beaches) and the somewhat excessively drained property of sandy and rocky soils. The dominant species for vegetated sites is *Leymus mollis*. Common soil subgroups include Psammentic Cryorthents, Typic Cryorthents, Oxyaquic Cryorthents, and Oxyaquic Cryofluvents. This soil landscape class is rare, encompassing 0.2% of the study area.

Coastal Sandy-Loamy-Rocky Brackish Tidal Flats and Wet Sedge Meadows

This soil landscape encompasses 2 map ecotypes: Coastal Brackish Tidal Flat and Coastal Brackish Wet Sedge Meadow. Coastal Sandy-Loamy-Rocky Brackish Tidal Flats and Wet Sedge Meadows occur primarily on tidal flats at the mouth of glacier-fed rivers and creeks, and secondarily near lagoons and estuaries. Soils are typically sandy and gravelly with an alkaline and brackish chemistry due to the regular fluctuations of the water table caused by tides. This soil landscape characterizes wet meadows with halophytic vegetation. Common soil subgroups include Typic Cryaquents, Aquic Cryorthents and Oxyaquic Cryorthents. This soil landscape class is rare, encompassing 0.2% of the study area.

Glacial Lake

This soil landscape includes a single ecotype, Glacial Lake, consisting of proglacial lakes in recently-deglaciated terrain. These waterbodies are vulnerable to rapid shoreline and depth change and may drain or form episodically. This soil landscape typically does not support soil development. This soil landscape class is somewhat rare, encompassing 0.6% of the study area.

Glacial Rocky Barrens, Meadows and Shrublands

This soil landscape encompasses 6 map ecotypes: Glacial Alder-Willow Tall Shrub, Glacial Alpine Dwarf Shrub, Glacial Alpine Sedge Meadow, Glacial Barrens and Partially Vegetated, and Glacial Fireweed. Glacial Rocky Barrens, Meadows and Shrublands represent early-successional landscapes that range from rocky barrens to tall shrub communities. It is most extensive in inner fjordlands that

have experienced substantial ice retreat since 1950. The parent material for this soil landscape includes young glacial till, glaciofluvial deposits, ice-cored moraines that support vegetation, and exposed bedrock. Soils are typically rocky and/or shallow to bedrock, and have a broad pH range from acidic to circum-neutral. Early-successional species dominate this soil landscape, including *Alnus sinuata*, *Epilobium latifolium*, and *Salix* spp. Common soil subgroups include Lithic Cryorthents and Typic Cryorthents. This soil landscape class is the second most common soil landscape class, encompassing 13.5% of the study area.

Glaciers and Permanent Snowfields

This soil landscape includes the single map ecotype, Glaciers and Permanent Snowfields, wihch covers approximately 51% of the park. Most of this soil landscape is associated with the Harding Icefield, the largest icefield solely contained within the United States (Truffer 2014). Ice thickness of the Harding Icefield and its outlet glaciers can exceed 650 m. Repeat-photography studies (e.g., USGS 2014) document that many of KEFJ's glaciers have retreated dramatically in the last 100 years (e.g., Northwestern and McCarty Glaciers), although some have been fairly stable (e.g., Aialik Glacier). Nearly 40 glaciers flow from the Harding Icefield, and additional glaciers flow from the Kenai Mountains in the southwestern portion of the park. This soil landscape class is by far the most common soil landscape class, encompassing 48.3% of the study area.

Human-modified

This soil landscape includes the map ecotype, Human-modified barrens. This soil landscape class is extremely rare, encompassing <0.1% of the study area.

Lowland Lake

This soil landscape includes the single ecotype, Lowland Lake. It is of limited spatial extent and includes waterbodies in low-elevation mountain valleys and small kettle lakes and ponds. This soil landscape typically does not support soil development, however, limited areas may support soils along lake margins or within shallow lakes that have experienced considerable paludification. Soils are typically circum-neutral and permanently flooded, and may include a water horizon, which is a layer of liquid water between two layers of soil material. Insufficient data were available to classify the soils, but common soil subgroups are likely to include Typic Cryaquents and Hydric Cryofibrists. This soil landscape class is rare, encompassing 0.4% of the study area.

Lowland Organic-rich Wet Meadows and Marshes

This soil landscape consists of the 2 map ecotypes, Lacustrine Forb Marsh and Lowland Wet Sedge Meadow. This soil landscape includes flat to gently sloping areas (0–3°) with saturated soils that have formed in lacustrine or alluvial parent material. Soils in the wet meadows and marshes differ in surface organic mat thickness. Soils in wet meadows are typically characterized by thick organic surface horizons (≥20 cm) and acidic site chemistry. Conversely, soils in marshes have very thin surface organic horizons (≤5 cm) and circum-alkaline site chemistry. Vegetation is dominated by *Sphagnum* sp. and *Eriophorum angustifolium* in wet meadows and by *Equisetum fluviatile* in marshes. Insufficient soil data were available to classify the soils, but common soil subgroups likely to be present include Sphagnic Cryofibrists and Histic Cryaquepts in meadows, and Typic

Cryaquents and Aquic Cryofluvents in marshes. This soil landscape class is extremely rare, encompassing <0.1% of the study area.

Nearshore Water
This soil landscape includes the ecotype, Nearshore Water, and represents the estuarine waters of the fjords and the marine waters of the northern Gulf of Alaska.

Riverine Rocky Barrens, Herbaceous and Dwarf Shrub
This soil landscape includes the single map ecotype, Riverine Dwarf Fireweed and Barrens. Riverine Rocky Barrens, Herbaceous and Dwarf Shrub occur on active- and inactive glaciofluvial channel deposits along braided rivers and meandering creeks. Soils are rocky, circum-acidic, and poorly developed. Early-successional vegetation consists primarily of *Alnus sinuata* and *Salix* spp. shrublands. Insufficient data were available to classify the soils, but common soil subgroups are likely to include Typic Cryofluvents, Oxyaquic Cryofluvents, and Typic Cryorthents. This soil landscape class is rare, encompassing 0.4% of the study area.

Riverine Sandy-Loamy-Rocky Shrublands and Forests
This soil landscape includes 4 map ecotypes: Riverine Alder-Willow Tall Shrub, Riverine Black Cottonwood Forest, Riverine Sitka Spruce Forest, and Riverine Willow Low and Tall Shrub. The ecotypes in this soil landscape represent a successional sequence from shrublands dominated by *Alnus sinuata* and *Salix* spp. on active and inactive fluvial surfaces, to mature stands of *Picea sitchensis* on abandoned fluvial surfaces or terraces. In general, soils in low and tall shrublands dominated by willow are sandy and rocky, with a circum-neutral site chemistry. Conversely, soils in tall shrublands dominated by alder are sandy and rocky with an acidic to circum-acidic site chemistry. Soils are typically moist and transition from sandy and rocky soils in early successional stages on active fluvial surfaces, to interbedded sands and silts with occasional buried organic horizons on inactive or abandoned fluvial surfaces. Common soil subgroups include Typic Cryorthents, Typic Cryofluvents, Oxyaquic Cryofluvents, and Fluventic Dystrocryepts. This soil landscape class encompasses 1.3% of the study area.

Subalpine Rocky Barrens, Shrublands and Woodlands
This soil landscape includes 5 map ecotypes: Subalpine Alder Tall Shrub, Subalpine Alder Tall Shrub-Herbaceous Mosaic, Subalpine Barrens and Partially Vegetated, Subalpine Dwarf Shrub, and Subalpine Dwarf Woodland. This soil landscape captures the elevation transition zone from a forested to a dwarf shrub (Subalpine) community (~ ≥250 m). Occasionally plots within this soil landscape may occur below 250 m, however, they are on regularly disturbed landforms such as avalanche and colluvial fans with similar soils and vegetation to the Subalpine zone. The vegetation in the Subalpine Dwarf Shrub map ecotype is early successional and is associated with colluvial and avalanche fans, which in many cases extend well below the majority of the subalpine belt. The tall shrublands that are extensive throughout this soil landscape are dominated by *Alnus sinuata.* Where present, *Picea sitchensis* and *Tsuga mertensiana* are usually stunted and form dwarf woodland stands. Soils are typically deep (≥100 cm) and acidic and form in rocky colluvium on steep mountain slopes. They also are well drained and generally develop Entisols with a thin (<15 cm) surface organic mat. An exception to this are older, more stable stands of tall alder that may have weakly

developed Inceptisols with a thick (≥15 cm) surface organic mat. Common soil subgroups for this soil landscape include Typic Cryorthents, Folistic Dystrocrypets, and less commonly, Lithic Cryorthents. This soil landscape class is the third most common soil landscape class, encompassing 8.9% of the study area.

Subalpine Rocky-Loamy-Organic Meadows and Shrublands

This soil landscape includes the single map ecotype, Subalpine Moist Herbaceous Meadow. This soil landscape most commonly occurs above 250 m in elevation in the subalpine zone, but occasionally occurs lower on regularly disturbed landforms, such as avalanche and colluvial fans, that havesoils and vegetation similar to the subalpine zone. Vegetation in this soil landscape is dominated by perennial herbaceous plants (forbs and graminoids), such as *Athyrium filix-fimina*, *Sanguisorba stipulata*, and *Calamagrostis canadensis*. Soils form primarily on deep (≥100 cm) rocky and loamy colluvium on steep mountain slopes. Soils range from acidic to circum-acidic, and tend to form weakly-developed Inceptisols with a thick surface organic mat (15–39 cm) over time. This soil landscape differs from the Subalpine Rocky Barrens, Shrublands, and Woodlands in that the soils are generally thicker, loamier, and in a more advanced stage of development. Common soil subgroups include Typic Dystrocryepts, Histic Cryaquepts, Folistic Dystrocryepts, Andic Dystrocryepts, and less commonly Typic Croyorthents, Lithic Cryorthents, and Entic Haplocryods. This soil landscape class encompasses 0.9% of the study area.

Upland Rocky Meadows, Shrublands and Forests

This soil landscape includes 5 map ecotypes: Upland Alder-Salmonberry Tall Shrub, Upland Alder Tall Shrub-Lady Fern Mosaic, Upland Black Cottonwood Forest, Upland Lady Fern Meadow, and Upland Sitka Spruce-Early Successional Forest. Soils and vegetation in this soil landscape capture vegetation succession and soil development associated with mid-successional shrublands, including the recruitment of conifers and, in some areas, development of black cottonwood forests. Shrub communities, dominated by *Alnus sinuata* and *Rubus spectabilis*, occur on younger glacio-fluvial or till deposits, as well as on colluvium on mountain slopes more prone to disturbance. The Upland Lady Fern Meadow ecotype, dominated by forbs *Athyrium filix-fimina cyclosorum* and *Veratrum viride eschscholtzii*, occurs in mosaics with shrublands and forests in valley bottoms on moist, rocky glaciofluvial deposits. Younger forests dominated by *Picea sitchensis* and, in the northernmost part of the park, *Populus trichocarpa*, occur on older glacial till and abandoned glaciofluvial deposits. Soils are rocky and range in chemistry from circum-acidic to acidic. Barring disturbance, soils will accumulate a thick (≥15 cm), unsaturated organic mat at the surface. From tall shrublands to conifer forests, common soil subgroups typically evolve from poorly developed Typic Cryorthents or Typic Cryofluvents to moderately developed Folistic Dystrocryepts or Fluventic Dystrocryepts. Insufficient soil data were available to classify all of the soils in Lady Fern Meadows, but common soil subgroups likely include Fluventic Dystrocryepts, Entic Haplocryods and Typic Haplocryods. This soil landscape class is the fifth most common soil landscape class, encompassing 7.3% of the study area.

Upland Rocky-Loamy-Organic Fens and Forests

This soil landscape comprises 4 map ecotypes: Upland Herbaceous Slope Fen, Upland Mountain Hemlock Forest, Upland Mountain Hemlock-Sitka Spruce Forest, and Upland Sitka Spruce-Early Blueberry Forest. In addition to its unique soil and vegetation properties, the Upland Herbaceous Slope Fen differs from the 3 forested map ecotypes in that it can extend up into the subalpine zone. Upland Herbaceous Slope Fen often occurs in a mosaic with upland forests in this soil landscape. The vegetation in the Upland Herbaceous Slope Fen is dominated by *Fauria crista-galli* and often occurs in conjunction with bedrock-controlled (lithic contact ≤50 cm) soils. Soils typically have little mineral soil material and primarily form in acidic organic material over bedrock. The bedrock prevents infiltration of the abundant rainfall, and allows for the development of Histic subgroups of Inceptisols and Lithic subgroups of Histosols on very steep slopes in a maritime climate regime. Common soil subgroups for Upland Herbaceous Slope Fen include Lithic Cryofolists, Histic Lithic Cryaquepts, Histic Cryaquepts, Lithic Dystrocryepts, and Lithic Cryorthents. The forested map ecotypes in this soil landscape represent late-successional stands of mountain hemlock and/or Sitka spruce. Soils are typically acidic and have formed in old glacial till or undisturbed colluvial deposits that have developed moderately- to well-developed soils. The oldest and most stable sites record a history of volcanic activity southwest of KEFJ along the Alaska Peninsula, in the form of very thin (0.5–1.5 cm), stratified horizons of ash in the soil profile. Forests with Sitka spruce typically form a thick (≥15 cm), unsaturated surface organic mat and have moderately-developed mineral soils. Common soil subgroups for Upland Mountain Hemlock-Sitka Spruce Forest and Upland Sitka Spruce-Early Blueberry Forest include Folistic Dystrocryepts, Typic Haplocryods, and Andic Haplocryods. Forests dominated by mountain hemlock tend to be older, and are unique in that they can form either in shallow (≤50 cm) organic soils over bedrock, or deep (≥100 cm) mineral soils with a thick (≥15 cm) surface organic mat. Insufficient data were available to classify the Upland Mountain Hemlock Forest soils, but common soil subgroups are likely to include Andic Dystrocryepts, Folistic Dystrocryepts, Spodic Dystrocrypets, Histic Lithic Cryaquepts, Lithic Cryofolists, and Lithic Cryosaprists. This soil landscape class is the sixth most common soil landscape class, encompassing 6.7% of the study area.

Soil Landscapes Mapping

The map of soil landscapes was developed by aggregating and recoding the 42 map ecotypes into a reduced set of 18 soil landscapes (Figure 18, 19; Tables 32, 33). The soil landscapes are named by their physiography, generalized texture, and dominant vegetation structure(s). The most common soil landscape classes included Glaciers and Permanent Snowfields (48.3%); Glacial Rocky, Barrens, Meadows and Shrublands (13.5%); Subalpine Rocky Barrens, Shrublands, and Woodlands (8.9%); Alpine Rocky Barrens and Sedge Meadows (8.1%); Upland Rocky Meadows, Shrublands, and Forests (7.3%); and Upland Rocky-Loamy-Organic Fens and Forests (6.7%) (Figure 19, Table 33). The rare (all <0.1%) soil landscape classes were Human-modified and Lowland Organic-rich Wet Meadows and Marshes. Appendix F presents the relationship between 12 terrestrial Soil Landscapes that express soil development and the common soil orders and great groups that are associated with each Soil Landscape.

Factors Affecting Landscape Evolution and Ecosystem Development

The structure and function of ecosystems are regulated largely along gradients of energy, moisture, nutrients, and disturbance. These gradients are affected by climate, tectonic effects on physiography, and parent material as controlled by bedrock geology and geomorphology (Swanson et al. 1988, ECOMAP 1993, Bailey 1996). Thus, these large-scale ecosystem components can be viewed as state factors that affect ecological organization (Jenny 1941, Van Cleve et al. 1990, Vitousek 1994, Bailey 1996). Information on how these landscape components have affected ecosystem patterns and processes in KEFJ is synthesized below, based on our results and a review of the relevant literature.

Climate

KEFJ experiences a temperate maritime climate regime characterized by cool summers and relatively mild winters, with frequent cloud-cover and abundant precipitation throughout the year. The marine waters of the north Pacific Ocean moderate diurnal and seasonal changes in air temperature, and provide a ready source of moisture for storms. This climate regime, coupled with KEFJ's active tectonic setting and resultant rugged terrain, has resulted in the development of the Harding Icefield and its many outlet glaciers. Glacial dynamics resulting from long-term climate changes have had a dominant influence on ecosystem development in KEFJ and are described in a separate section below. The focus of this section is the direct effects of climate on ecosystem development.

We summarized the climate of KEFJ using the long-term climate record (1908–present) of the town of Seward, which is at an elevation of 9 m and approximately 5 km beyond the northeastern boundary of the park. The mean summer temperature (June–August) is 12.5°C, the mean winter temperature (December-February) is -2.3°C, and the mean annual temperature is 4.6°C (1981–2010 base period) (NCDC 2014). Mean annual precipitation is 180.2 cm, most of which falls as rain; however, total precipitation (especially snowfall) is much greater at higher elevations, nourishing the Harding Icefield and its outlet glaciers. Although there are no distinct, regional-scale climate gradients within KEFJ, strong elevational climate gradients are virtually ubiquitous at the landscape scale due to the rugged terrain. For example, the highest point in the park—an unnamed peak with a summit elevation of 1,996 m—is only approximately 7 km away from the shoreline of McCarty Fjord. The dramatic topographic relief has profound effects on temperature and precipitation regimes. After encountering mountainous terrain, moisture-laden air from the Gulf of Alaska is forced upward and undergoes adiabatic cooling, which lowers the moisture-holding capacity of the air and results in abundant precipitation at high elevations. For example, total precipitation over the Harding Icefield is typically three- to fourfold greater than that received at sea-level (Spencer and Irvine 2004).

The elevational climate gradients described above have a strong influence on geomorphic- and soil-development processes that result in recurring, predictable patterns of soil landscape distribution, especially in long-deglaciated areas. For example, in cold alpine environments, soil development is very slow due to the low rates of organic input and microbial decomposition. Alpine areas tend to be dominated by weakly-developed soil orders, such as Entisols and Inceptisols, even in areas that have remained ice-free for long periods of time (e.g., nunataks). In contrast, forest soils at low elevation

usually exhibit much stronger soil development, such as Spodosols, which are strongly leached and have high concentrations of weathered iron and aluminum.

KEFJ's location at high latitude also results in strong local-scale differences in microclimate, due to differences in insolation as a function of slope and aspect. North-facing slopes are strongly shaded and therefore tend to have lower soil temperatures, lower evapotranspiration rates, fewer frost-free days, more persistent snow-cover, and higher available soil water during the growing season, compared to south-facing slopes (Barry and Van Wie 1974). The influence of aspect on local climate is often manifested in the distribution of ecotypes, particularly in the Subalpine zone. On colder, north-facing slopes, the uppermost stands of trees and tall shrublands tend to occur at lower elevation than on south-facing slopes. Additionally, redistribution of snow by wind results in sharp, local-scale contrasts in snowpack depth and persistence, which affect physical and chemical weathering processes. For example, nivation hollows are a geomorphic feature frequently associated with snowbed microsites. Here, repetitive cycles of freeze-thaw at the base of the snowpack tend to promote frost-shattering. Additionally, infiltration of abundant snowmelt leaches cations from the soil and promotes acidic soil chemistry.

Due to the rugged terrain of KEFJ and the high snowfall, local-scale differences in the depth and persistence of the snowpack lead to strong contrasts in vegetation composition and structure, particularly in Alpine and Subalpine physiographies. Differences in snow regime are largely the result of the redistribution of snow by wind (Johnson and Billings 1962). Convex slope positions are the most exposed to wind, and are areas of net snow loss during the winter. Exposed slopes therefore are less protected from winter desiccation and removal of fine-textured material, and usually have lower available water. Vegetation is often sparse and discontinuous, and soils tend to be rocky and poorly developed (e.g., Alpine Rocky Barrens ecotype). Concave slope positions develop much thicker, persistent snowpacks. These slope positions usually have moister soils, and the snow protects vegetation from winter desiccation and abrasion by spindrift. Additionally, these sites are more likely to retain fine-textured material that is deposited by wind, or weathered *in situ*. As a result, soils in these areas tend to be finer in texture and support greater vegetation cover. Several subalpine ecotypes, such as Subalpine Rocky-Loamy-Organic Fern Meadow, are often associated with deep, loamy soils.

Tectonic Setting and Physiography

KEFJ encompasses two major geologic units of Jurassic and Cretaceous age, which serve as the parent material for soils across the landscape. The most widespread geologic unit consists of an assortment of highly-metamorphosed, sedimentary (metasedimentary) deposits, which make up the mountains underlying the Harding Icefield, as well as most of the inner fjordlands. These metasedimentary deposits have heterogeneous lithologies, which can be roughly divided into two rock types: quartzites, derived from sandstone; and phyllites, derived from slate. Metasedimentary quartzites are primarily composed of highly-resistant quartz crystals (>90% by volume), which weather to sand-sized particles. In contrast, metasedimentary phyllites have little quartz, but are rich in mica; mica-rich parent materials are much more susceptible to physical and chemical weathering, and readily break down to silt and clay-sized particles. The distribution of these materials is complex;

they frequently co-occur and no map layers exist by which to characterize their distribution. Our local observations of soils, however, and identification of rock samples collected at 16 field plots (pers. comm., R. J. Newberry) suggest that the occurrence of loamy soils in the metasedimentary zone is often linked to exposures of phyllite-dominated bedrock.

Granitic deposits in KEFJ are widespread on the distal portions of the outer peninsulas of McCarty, Harris and Aialak. Although these deposits have been deglaciated for longer periods of time than the metasedimentary rocks further inland, granitic rocks are highly resistant and do not readily weather to fine-textured mineral soil. Many soil pits excavated in the oldest landscapes of the outer peninsulas revealed minimal weathering of the underlying granitic rock, with organic material overlying bedrock, in some cases with a very thin intermediate layer of residual grus (i.e., gravel-size quartz particles).

In addition to the composition and distribution of geologic parent materials, landscape development within KEFJ is strongly affected by its highly-active tectonic setting. KEFJ is situated adjacent to an active zone of subduction at the boundary of the North American continental plate, and the relatively dense North Pacific oceanic plate. This highly active tectonic setting, coupled with intense glacial activity since the early Pleistocene, has produced the park's extremely rugged terrain and its eponymous fjords. Twelve earthquakes of magnitude ≥6.0 have occurred over the last 100 years alone (Haeusser and Plafker 1995). The active tectonic environment of KEFJ has resulted in complex faulting of the landscape, which is conspicuous from the air and in satellite imagery of the park. Episodes of intense seismic activity (magnitude ≥8.0), such as the Great Alaska Earthquake of March 27, 1964, were particularly important in shaping park landscapes and initiating persistent changes in soils and vegetation. KEFJ lies just north of the northeast-southwest trending "hinge line" which separates zones of seismic uplift to the southeast (e.g., Montague Island in Prince William Sound) from zones of subsidence to the northwest. During the 1964 earthquake, KEFJ experienced subsidence of 2–6 feet, with the most intense subsidence occurring in the upper fjordlands (Plafker 1969). The most conspicuous effects of this subsidence include numerous, dead stands of large Sitka spruce trees near the coast, which were killed due to saltwater intrusion and a persistent shift to saline soil conditions. Additional impacts include local-scale landslides both above and below sea level, as well as tsunamis and associated physical disturbance of soils and vegetation (Spencer and Irvine 2004). The 1964 earthquake is by no means the first intense seismic event to affect the KEFJ area; an earthquake of similar magnitude occurred ~750 YBP (Mann and Crowell 1996). Such episodes of subsidence are, however, superimposed over a long-term trend of regional uplift, with an uplift rate of approximately 10.4 mm yr^{-1} recorded in 2000 at Seward (Larsen et al. 2003). The net effect of tectonic movement and eustatic sea-level rise since the late Pleistocene has been the submergence or "drowning" of the ridges and cirques of the outer fjordlands of the park, such as Aialik Peninsula. These forces have also countered the isostatic rebound that might have otherwise accompanied the loss of ice cover during the Holocene.

Volcanism

To the west of the Kenai Peninsula and Cook Inlet is the Alaska Peninsula, which comprises the northernmost part of the Pacific "Ring of Fire" (Gaul 2007), a highly active subduction zone that

extends along the eastern Aleutian Arc north to Cook Inlet. Over 40 historically active volcanoes exist within the Aleutian Arc. The location of KEFJ east of these volcanic centers (in the direction of prevailing winds) has important implications for soil development, specifically the presence of volcanic ash in the upper mantle of soils in older, more stable landscapes, such as the Upland Rocky-Loamy-Organic Fens and Forests soil landscape. Soil cores of glacio-lacustrine sediments at Skilak Lake, located on the Kenai Peninsula west of KEFJ, show evidence of ash falls every 10–35 years in the twentieth century, and at least once every 50–100 years over the past 500 years (Beget et al. 1994). Many of these events have contributed tephra to soils in parts of KEFJ. Soil lab data on volcanic glass content for 10 soils revealed very thin (0.5–1.5 cm), stratified ash-rich layers in 5 soil horizons, ranging from 40% to 90% volcanic glass content (Appendix C). The thickness of volcanic ash in the soils sampled in KEFJ, however, was insufficient to meet the requirements to classify as Andisols, the soil order pertaining to soils developed from volcanic ash. Instead, some of these soils were classified as Andic intergrades of Inceptisols and Spodosols. Depending on the origin and makeup of eruption products, soils that form in volcanic ash can have distinctive chemical and physical properties, such as 1) high concentrations of phosphorus and other nutrients; 2) a high proportion of volcanic glass or iron- and aluminum-rich minerals with weak crystalline structure that makes them highly susceptible to weathering; 3) low bulk density (i.e., a high ratio of pore space to soil particles) lending to a light, fluffy texture, high water holding capacity, and erosion resistance; 4) accumulation of soil organic matter (Ugolini and Dahlgren 2002); 5) progressive development of highly acidic pH and aluminum toxicity during weathering; and 6) a very high phosphorus-binding-capacity that can lead to severe phosphorus limitations over time (Nanzyo 2002).

In KEFJ, volcanism has played a local role in soil development in areas that remained ice-free during the LIA, and where local topography and vegetation promote the capture of ash deposits and their incorporation into the soil profile (e.g., well-vegetated, leeward benches or concavities). Although ash layers observed at field plots were fairly thin, this material represents exogeneous inputs of fine-textured mineral material and nutrients in a landscape that is largely dominated by very young, rocky soils. Eruption events of the last several decades, such as at Cleveland Volcano, Mt. Augustine and Mt. Redoubt, have not contributed significant ash deposits at KEFJ. However, historic eruptions have had lasting, local-scale effects in some soil landscapes of KEFJ, indicating the potential for future eruption events to influence soil development within the park.

Glaciations

The effects of past and ongoing glacial activity are striking and ubiquitous throughout the landscapes of KEFJ, from sea level to the alpine. Nearly half of the park remains covered by ice, including the vast Harding Icefield, its many outlet glaciers, and a multitude of isolated alpine glaciers. The widespread glacial landforms of KEFJ trace their origins to glacial dynamics over the past ~2.6 million years. The Quaternary period, which includes the Pleistocene (~2.6 Ma–12 Ka) and Holocene (12 Ka–present) epochs, has been characterized by a series of broad-scale climatic warming and cooling events, and associated intervals of glacial advance (glacials) and retreat (interglacials) with far-reaching effects in mid- to high-latitude regions of the world. Most of the present-day landscape of KEFJ reflects glacial dynamics since the late Pleistocene, because glacial landforms and deposits of earlier glacial intervals are destroyed by the erosive effects that accompany subsequent episodes.

In the late Pleistocene, four major episodes of glacial advance occurred in southcentral Alaska (Reger and Pinney 1996). The maximum extent of these advances covered virtually all of KEFJ in ice, with the exception of a handful of nunataks that protruded above the Harding Icefield. Late Pleistocene glaciations extended onto the continental shelf, some 50 miles beyond the present-day coastline of the Gulf of Alaska (Molnia 1986). During the Holocene, several smaller "neoglacial" advances have occurred, the most recent of which—the LIA—ended in the late nineteenth century (Figure 3). The LIA maximum extent has resulted in conspicuous changes to KEFJ landscapes within a human lifetime, and represents a critical step-change in vegetation and soil properties across short distances within KEFJ (Figure 21). Truffer (2014) reports that between the mid-1950s and mid-1990s the Harding Icefield has lost an average of 0.47 m/yr of elevation, a rate that increased by a factor of about 1.5 in the years between 1995 and 1999. The effects of glacial retreat since the LIA are most obvious in the McCarty and Northwestern Fjords, as well as the Exit Glacier near Seward, where early-successional vegetation and minimally-developed soils abruptly give way to more mature plant communities and soil landscapes beyond LIA Maximum terminal moraines.

Glacial dynamics are accompanied by powerful erosional and depositional processes, the effects of which are highly persistent on the landscape and typically lead to a great deal of heterogeneity in landforms at a range of spatial scales (see Geomorphology and Soils section, below). Post-glacial geomorphic features, such as moraines and glacial outwash plains, typically support a high degree of microtopographic variation at meter- to patch-scales. These patterns are reflected in contrasts in the pace and trajectory of soil and vegetation development. For example, on convex, exposed surfaces, wind and water remove finer soil materials and soils tend to be dry, rocky and poorly developed. In contrast, adjacent concave positions retain fine-textured material and tend to be moist to wet with more productive vegetation.

Coastal Processes

Coastal processes play a large role in the evolution of park landscapes. KEFJ comprises a relatively small proportion (<10%; 2,693 km²) of the total land area of the SWAN network of national parklands (38,040 km²), but it includes a large proportion of the total SWAN shoreline extent. This is due to the highly complex configuration of fjords and embayments that have developed from interactions of glacial processes, tectonic subsidence, and eustatic sea level rise. The coastal environments of KEFJ can be divided into three broad categories: (1) coastal cliffs, headlands, and rocky shores of the outer coast that are exposed to the North Pacific and associated high-energy wave action related to ocean swells and storm surges; (2) protected rocky shores in upper fjords and embayments, which are generally subject to local, wind-driven wave action; and (3) tidal flats and lagoons in the vicinity of the outlets of larger rivers and streams.

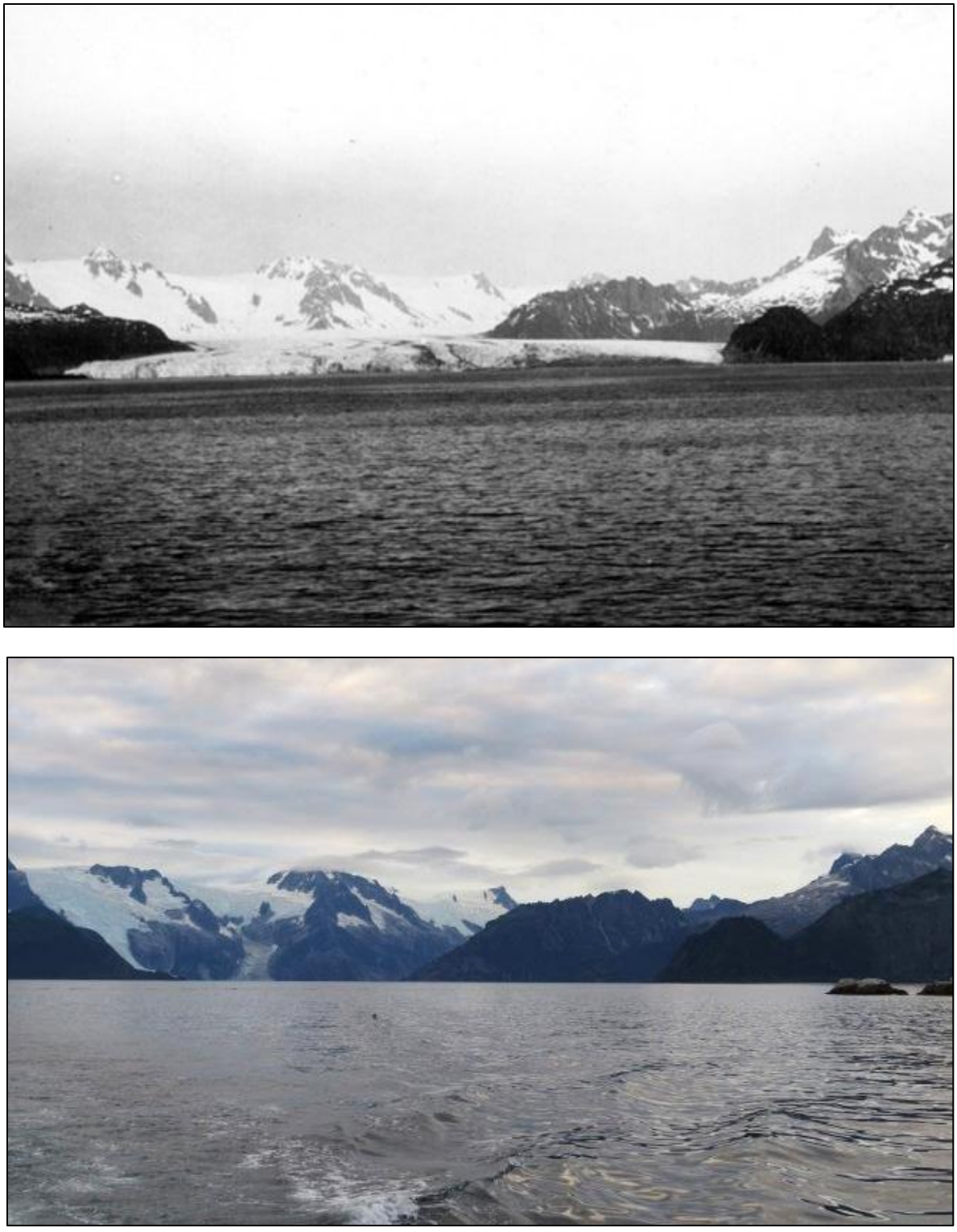


Figure 21. Northwestern Fjord seen from Harris Bay in 1909 (U. Grant) and 2013 (G. Frost), Kenai Fjords National Park, southcentral Alaska. Glacial retreat has been the dominant landscape-change mechanism in KEFJ since the end of the Little Ice Age (circa 1850). 1909 photo from Grant and Higgins (1913).

The outermost fjordlands consist of narrow, convoluted peninsulas that represent partially submerged mountain ridges and glacial cirques. These rugged, steeply-sloping landscapes trace their origins to glacial erosion and their coastlines are dominated by bedrock and talus. Vegetation is sparse or absent on exposed surfaces, which are subject to the full force of long-period swells, storm surges, and wind-driven salt spray. Bedrock-dominated surfaces are very resistant to physical weathering, and bedrock coasts are often armored by colluvial talus deposits. Nonetheless, bedrock cliffs and slopes can become undermined over time by high-energy wave action, which promotes slope failure and the maintenance of a sparsely-vegetated, bedrock- and talus-dominated coastline.

Coastlines of the inner fjordlands are similar in many respects to the outer fjordlands, but they are more protected from high-energy wave action associated with ocean swell. Instead, erosive processes are primarily driven by short-period wave action from local winds. As a result, the effects of salt spray do not extend as far upslope, and forest vegetation can develop closer to the high-tide line. Because most of the coastline is dominated by bedrock and talus, the coast is generally very resistant to erosion. Most watersheds are small and do not provide substantial input of terrestrial sediment; consequently, the intertidal zone is dominated primarily by bedrock and talus. Coarse sand and gravel beaches occur in protected coves near the outlets of small creeks, as well as glacial outwash fans such as at Dinglestadt Glacier. Historical photos we repeated during the 2013 field survey revealed minor changes over a 104-year time period at Three Hole Point along Aialik Peninsula. The photo comparisons indicated that changes to bedrock coasts are episodic in nature and typically occur at very local scales (Figure 22). The highly-active tectonic setting of KEFJ, however, combined with the constricted bathymetry of the fjords, increases the potential for high-intensity, earthquake-induced tsunami events to affect coastal landforms and lower slope positions on centennial to millennial timescales. Additionally, tsunamis can be induced by local-scale landslide events.

The coastal salt marshes and lagoons near the outlets of larger watersheds of the inner fjordlands comprise high-value habitats for black bears, fishes, and other wildlife. The watersheds supply glacial and terrestrial sediments, which provide the material by which salt marshes, beaches, and coastal dunes are formed and maintained. Tides represent the most conspicuous coastal process influencing soils and vegetation. Two approximately 12-hour lunar tide cycles (one low and one high tide) occur each day, with an average amplitude of about 3 m at locations such as Aialik Sill and Beauty Bay. Slight changes in elevation in tidal marshes, on the order of several centimeters to one meter, can have disproportionate effects on vegetation composition and soils. Salt marsh species are adapted to specific hydro-periods and salt tolerances and thus occur in distinct zones along an elevation gradient from mean sea level to the high tide line. Soils in lower elevations in salt marshes are flooded for longer periods, sometimes permanently, resulting in the development of anaerobic soil conditions and the production of abundant hydrogen sulfide, making these soils strongly acidic (Jorgenson et al. 2010). Vegetation in these lower salt marshes is commonly barrens, or sparse meadows of extremely salt-tolerant species such as *Puccinellia nutkaensis* and *Plantago maritima*. In upper tidal flats, the duration of flooding by salt water is shorter and soils are typically better drained. The continual action of waves creates gravelly beach ridges that are often positioned between the

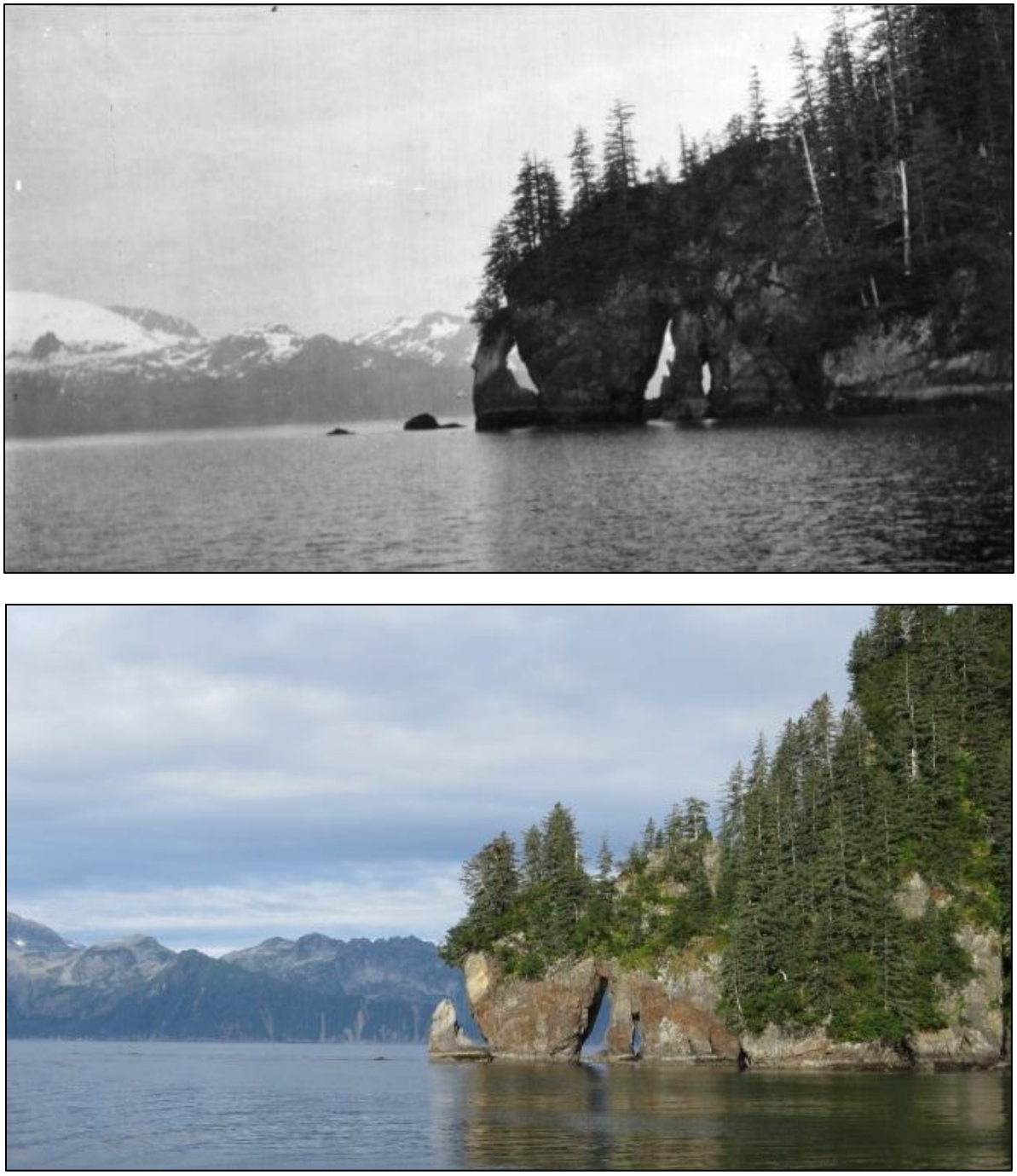


Figure 22. Three Hole Point on western side of Aialik Peninsula seen in 1909 (U. Grant) and 2013 (G. Frost), Kenai Fjords National Park, southcentral Alaska. Changes to the bedrock coastline are minor and very local in scale. Mountain hemlock and Sitka spruce forest vegetation above the cliff is little-changed.

ocean and the tidal marshes, thus protecting them from storm surges. Although dunes are not extensive along the KEFJ coast, the supply of sand is adequate to promote dune development over the beach ridges in locations such as Harris Bay, east of the LIA terminal moraine of Northwestern Glacier. Beach ridges and dunes occur at elevations well above high tide, and are not directly influenced by tides or storm surges. The gravelly-sandy soils are well drained and typically include Typic Cryorthents. Early vegetation succession begins with *Leymus mollis*. Beach ridges and dunes may eventually become disjunct from the active wave front (i.e., abandoned) due to a combination of processes, including tectonic uplift, and beach accretion. Vegetation succession parallels beach ridge and dune abandonment, shifting from herbaceous meadows to alder or willow shrublands and eventually to *P. sitchensis* forests. In the recent past, however, episodes of subsidence (e.g., Great Alaska Earthquake)have resulted in local forest mortality and the re-establishment of halophytic vegetation. Tidal rivers carry salt water into the upper reaches of salt marshes and provide pathways for nutrients and travel for mammals and fish. Salmon return each year to spawn in the upper freshwater reaches of the tidal rivers, and their decomposed carcasses contribute marine-derived nutrients to adjacent floodplains (Naiman et al. 2002). These coastal marshes and tidal rivers also are important for black bears that frequent these tidal marshes to graze on salt marsh vegetation and fish for salmon.

Geomorphology and Soils

At the landscape scale (hundreds to thousands of hectares to hundreds to thousands of square kilometers), soil formation in KEFJ is strongly influenced by time since last glaciation, slope, elevation, and the temperate maritime climate along the coast. Of a total area of 2,693 km^2, just over 48% of the park is locked in ice. The glacially scoured fjords and steep headwalls of KEFJ comprise a young landscape that is in the early stages of soil formation. The historical and enduring impact that glaciation has had on this landscape cannot be overemphasized. Glacial processes scour and erode the landscape, while simultaneously redistributing and depositing materials elsewhere, producing a wide range of geomorphic landforms.

A generalized continuum of soil development from the least developed to the highest degree of soil formation can be correlated to the different physiography breaks in the park, which in large part relate to time since last glaciation and elevation. Poorly developed soils, or Entisols, are most prevalent in the most recently deglaciated Glacial and Alpine physiographies. Soils in the Subalpine zone range from poorly developed Entisols on less stable landforms like colluvial and avalanche fans, to moderately developed Inceptisols on stable slopes. Spodosols were not described in the Subalpine zone due to limited data, but we surmise they may occur on stable landforms that were not glaciated during the LIA. Soils in the Upland physiography encompass the highest degree of soil formation in the park. At elevations <250 m, the soil climate is warmer and rates of organic matter accumulation and decomposition are higher. The warmer soil temperature promotes the chemical transformation in the soil profile known as the podzolization process. This is a chemical process whereby organic acids contribute to the weathering of aluminum, and occasionally iron, where it can be translocated and precipitate out lower in the soil profile (Lundstrum et. al. 2000). Soils in the Lowland and Lacustrine physiographies range from Entisols on both freshly exposed Lacustrine sediments and saturated Lowland marshes, to well-developed organic Histosols in Lowland

meadows. The Riverine physiography captures young stratified glaciofluvial deposits that are regularly (annually) to semiregularly flooded (during high water events) to form poorly developed Entisols. The factor of time since disturbance influencing soil development still holds true in the Coastal physiography except it is less a function of glaciation and elevation, and more a function of time since tectonic rebound, subsidence, or coastal flooding and erosion.

The glacial erosion process of plucking has had extensive influence on the geomorphological features present in KEFJ. Glacial plucking occurs when portions of bedrock become frozen in the overlying glacier. As the glacier advances, large blocks of bedrock can be plucked out and carried away in the ice (Dale 2014). The plucking process has left behind many surfaces with a "stair step" morphology and benches in the Alpine and Subalpine zones. Over time, ledges or benches in the Subalpine zone have accumulated surface organics, along with thin layers of ash and loess, and now host somewhat developed Inceptisols and Histosols. Glacial abrasion, an erosive process that leaves behind a smooth bedrock surface, are most noticeable in KEFJ as cirques, aretes, and roche moutonnees in the alpine and subalpine zones. Less apparent to the naked eye, but still extensive, are smooth bedrock surfaces on steep mountain slopes that become colonized by mosses, liverworts, and vascular plants. The bedrock prevents the infiltration of rainfall, promoting the accumulation of organic matter over time, which retains moisture and promotes the development of hydrophytic, slope-fen vegetation. These slope-fens form Histosols on bedrock, mostly in Upland physiography, although they can extend into the Subalpine zone.

Glacial landforms that were sampled in KEFJ included moraines, kettle and proglacial lakes, eskers, kame deposits, and glaciofluvial outwash and till plains. Glacial till deposited during the LIA, approximately 160 years ago, was considered young till for this survey. Soil formation in young till deposits or on young moraines was virtually non-existent; rocky Entisols prevailed. The areas of the park that were unaffected by the LIA have glacial till deposits that were recognized in this survey as old till deposits or old moraines. Older till deposits show some sign of soil development, usually in the form of a weakly weathered illuvial horizon (e.g., Bw), or the development of a folistic epipedon (≥15 cm unsaturated organic mat). Soils on older till deposits are typically moderately developed Inceptisols, but may still classify as Entisols if they have not undergone enough pedogenesis to meet the diagnostic criteria for Inceptisols.

Glaciofluvial processes are a unique combination of glacial processes (i.e., glacial meltwater surge) and riverine processes (i.e., channel migration and flooding) that combine to form riverine landforms. Large volumes of glaciofluvial sediment flow out from a glacier and become stored in terraces, fans, outwash plains, floodplains, and active channels. Soil development on active and inactive glaciofluvial deposits are similar in that they form highly stratified mineral soils that may include thin horizons of buried organic material at depth. These soils are poorly developed Entisols on account of regular flood water disturbance. Once glaciofluvial deposits are outside of the high water and 100 year flood zone, they progress in soil formation with the accumulation of surface organic materials and the weathering of subsurface mineral horizons (i.e., Bw and Bs horizons). Many of these deposits will go on to form moderately developed Inceptisols and occasionally Spodosols on eskers, kames and abandoned outwash plain deposits.

Proglacial lakes have formed at the terminus of some retreating glaciers (i.e., Bear Glacier) and are often open systems that are subject to tide water influence. Proglacial lakes can be dammed by moraine debris or by meltwater trapped above glacial ice (Schoeneberger and Wysocki 2002). In recent years, an outburst flood has drained an unnamed proglacial lake on Bear Glacier every year or two in late summer or fall (NPS 2014, Wilcox et al. 2014). These events have led to downstream flooding of Bear Lake and presumably, an atypical thick deposit of glaciolacustrine sediments. Glaciolacustrine deposits are unique in that the sedimentation type and thickness is influenced by season throughout the course of one year. Clayey sediments that form during the non-meltwater season (winter) are stratified between thicker deposits of sandy and silty material from the meltwater season. These seasonally dependant stratified lacustrine deposits are known as glacial varves (Schoeneberger and Wysocki 2002). Freshly exposed drained lake sediments are poorly developed soils forming in saturated anaerobic soil conditions. Organic soils, or Histosols, may form over time along lake shore margins, or in association with older, drained lake sediments.

When the maximum extent of the LIA (~160 ya) was reached, glacially excavated valleys with rivers of ice were left in its wake. As the ice began to retreat, long fjords with steep mountain walls were revealed. The seaward end of the fjords, or outer granitic peninsulas, were the first ice-free landscapes to become available for vegetation colonization and soil development. Today, these Upland areas support old-growth spruce and hemlock forests on the most developed soils in the park. These older colluvial soils typically form a slope-stabilizing organic mat that serves as the source of organic acids for the podzolization process. The podzolization process is necessary for spodic development in the B-horizon of a soil profile. Spodic horizon development accounts for the formation of Spodosols and spodic intergrades of Inceptisols in Upland areas of the park. Moderately developed Spodosols and Inceptisols, with thin horizons of volcanic ash, are the result.

Regardless of time since last glaciation, soils that are prone to disturbance will be less developed than similarly aged sediments. Slope severity on steep (>30°) mountain slopes can retard soil development due to mass wasting, landslides, and avalanches that reset the soil formation clock. Flat, or gently sloping surfaces, that would otherwise promote soil development, are commonly found on regularly disturbed landforms such as floodplains and coastal beaches. Despite the low slope angle in glacial valleys and along the coast, poorly developed Entisols or weakly developed Inceptisols prevail in these landscapes. Small glacial benches of very limited spatial extent were sampled during the 2013 field survey, where moderately- to well-developed organic Histosols prevailed.

At local scales (thousands of square meters to tens and hundreds of hectares), the thickness and physical properties of ash-laden loess is widely variable depending on topographic position, slope and aspect, time since last disturbance event, source material, and distance from source. Landscape positions that are stable (flat and lower slopes, concavities) and those on the leeward side of prevailing winds are subject to the thickest accumulations of volcanic ash, a pattern related to the nature of volcanic ash deposition. During an eruption, airborne ash will be carried in the direction of the prevailing winds. The forces of wind and water quickly erode and redistribute the fine, unconsolidated ash from steeper, upper slope positions to lower slope positions and areas of sediment accumulation (pers. comm., J. Beget). For instance, soils on alluvial fans or footslope positions at the

base of mountain slopes, may have thicker deposits of reworked ash from different aged eruptions and likely from different source volcanoes. Soils across a river valley tend to differ significantly in ash thickness related to age of a given landform in relation to the timing of regional volcanic activity and flooding frequency. Older river terraces may have relatively thick accumulations of ash deposited from adjacent side slopes as well as ancient rivers inundated with ashy material shortly after historic eruptive events. Younger terraces and active floodplains may have thin inclusions or be completely devoid of ash, a pattern related to the ash being deposited prior to recent flooding and erosion events (pers. comm. J. Beget).

Unlike LACL, which is roughly 100 km to the northwest of KEFJ, coarse-grained ash deposits with vitric properties were lacking. That is because heavier coarse ash (0.062–2 mm) falls out of suspension in the air before fine ash (<0.062 mm) does. This process typically restricts coarse-ash deposition to within close proximity of the source. Vitric properties, or low water holding capacity, is a unique soil subgroup because ash deposits characteristically have a high water holding capacity. One plot (Tagc2_03) was classified as a Vitrandic Cryorthents not because it had a low water holding capacity(<15% at 1500 kPa), but rather due to the *Keys to Soil Taxonomy* not differentiating between Vitrandic and Andic subgroups at the early soil formation stage of the Cryorthents great group. Soil samples suspected of containing mixed colluvium and ash deposits were collected from mountain slopes to analyze for volcanic glass content. The lab results for some of these soils showed andic soil properties, but they lacked the minimum requirement for volcanic glass (≥5%) to be classified as andic subgroups (Appendix C). Andic soil properties are explained in the Volcanism section of this report. According to the *Keys to Soil Taxonomy*, "Soils that are in cool, humid climates and have abundant organic carbon, may develop andic soil properties without the presence of glass." Since volcanic minerals are relatively soluble and undergo fairly rapid transformation when soils are moist, we assumed that two of our upland mountain slope plots (KEFJ_Tqc_04_2013 and KEFJ_Ttb1_04_2013) were Andic Haplocryods.

Soil microbes play a role in soil formation at local scales. Soil microbes play a particularly important role in the podzolization process by increasing the decomposition rates of organic material and the production of organic acids necessary for spodic horizon development in Spodosols and Andic subgroups. These organic acids can also be produced from plants, such as alder and spruce. Plants and microorganisms work in tandem and impact soil fertility and nutrient availability as vegetation provides the addition of litter to the soil where soil microorganisms and fauna break it down into humus (Ping et al. 2006).

At the landscape scale, climate also plays a role in podzolization. For instance, soils forming in the temperate maritime climate experience faster rates of podzolization related to warmer temperatures and higher rates of precipitation. At lower elevations (<250 m), the climate of KEFJ promotes rapid vegetation colonization on disturbed sites and in recently deglaciated areas. It also allows for histic epipedons, or thick (≥20 cm) saturated organic mats to uncharacteristically form on very steep (>30°) slopes.

Landscape Change

While some of the major landscape-forming processes in KEFJ are linked to tectonic and seismic processes that are inherently unpredictable, others are directly or indirectly related to climate regime and climate changes:

- Temperature changes: state-shifts in vegetation, treeline, shrubline
- Snow regime changes, especially for snow-controlled subalpine communities
- Precipitation changes and implications for glacier mass balance and terminus dynamics
- Species dispersal and range shifts
- Eustatic sea level rise

During the 2013 field survey, we opportunistically acquired oblique photographs from favorable vantage points to document and monitor three focal landscape features in KEFJ: Dinglestadt Glacier in McCarty Fjord, Northwestern Fjord, and Aialik Bay. We also acquired repeat photographs at two historical photo points in Northwestern Fjord (Figure 21) and at Three Hole Point (Figure 22). At all of these locations, we recorded spatial coordinates and other metadata to facilitate repeat photography. These vantage points, coupled with previously re-photographed vantage points presented in Molnia (1986) and additional historical photo locations in Grant and Higgins (1913) and Jorgenson et al. (2006), make up a network of monitoring points for documenting and interpreting recent landscape changes and to monitor future landscape changes in the dynamic landscapes of KEFJ.

Summary and Conclusions

This study employed an ecological land survey (ELS) to inventory and classify soils and vegetation within the ecosystems of Kenai Fjords National Park (KEFJ). The classifications identified by the ELS were then mapped across the park, using an archive of Geographic Information System (GIS) and Remote Sensing (RS) datasets pertaining to land-cover, topography, and glacial history. The description and mapping of the landform-vegetation-soil relationships identified by the ELS offers tools to support the design and implementation of future field- and RS-based studies; facilitates further analysis and contextualization of existing data, and informs natural resource management decisions.

We collected information on the geomorphic, topographic, hydrologic, pedologic, and vegetation characteristics of ecosystems within a network of 486 field plots, of which 105 were sampled by us in 2013, and 381 were sampled by the Alaska Natural Heritage Program (AKNHP) and NPS in 2004–2005. The plot network encompassed all of the major environmental gradients and landscape histories present in KEFJ. Individual state-factors (e.g., soil pH, slope-aspect) and other ecosystem components (e.g., geomorphic unit, vegetation species-cover data) were measured, or categorized using standard classification schemes developed for Alaska. We described and analyzed the hierarchical relationships among the ecosystem components to classify 54 ecotypes (local-scale ecosystems) that best partition the variation in soils, vegetation, and disturbance properties observed at field plots. From the 54 ecotypes, we developed classifications of soil landscapes and disturbance landscapes that could be mapped across the park.

Detailed soil descriptions at 101 of the field plots pertained to 4 soil orders: Entisols (62% of plots), Inceptisols (28%), Spodosols (6%), and Histosols (4%). Within these 4 soil orders, field plots corresponded to a total of 24 soil subgroups, the most common of which were Typic Cryorthents (35% of plots), Folisitic Dystrocryepts (14%), Typic Cryofluvents (8%), and Lithic Cryorthents (6%). The soil classification was effective at partitioning the variability of numerous soil properties, including organic-layer thickness, depth to rock (coarse fragments), depth to bedrock, texture, ash/loess thickness, and pH. Soil-landscape associations, or soil landscapes, were classified by cross-tabulating soil types with the ecotypes assigned for each plot. These groupings were used to identify and map 18 soil landscape classes across KEFJ. Many physical and chemical properties of the soil environment (state-factors) were consistently linked to specific ecotypes and their vegetation characteristics. Mean surface organic-horizon thickness, an indicator of the time since deglaciation and local regimes of disturbance and hydrology, ranged from 0 cm in Glacial Rocky Barrens to >30 cm in upland slope fens and Lowland Organic-rich Wet Sedge Meadow. Soil texture, an indicator of glacial history, site stability, and parent materials, is composed of coarse fragments (gravel-sized particles or larger) in most ecotypes, but sandy- or loamy soils were regularly found in ecotypes pertaining to late-successional forests, subalpine meadows, and coastal flats. Additionally, organic-rich soils are fairly common in late-successional forest and slope fen ecotypes. Mean pH, which affects nutrient availability and ion exchange, ranged from strongly acidic (<5.0) in well-vegetated, generally late-successional forest and slope fen ecotypes, to circumneutral or slightly alkaline (>5.6), primarily in glacial, riverine, and coastal ecotypes.

The spatial distribution of ecotypes and soil landscapes in KEFJ is primarily linked to two factors, local elevation and the time since deglaciation. Although the entirety of KEFJ experiences a maritime climate regime and there are no distinct regional-scale divisions in climate, strong elevational climate gradients are ubiquitous across the rugged landscapes of the park. This results in conspicuous zonation of vegetation, albeit within an extremely compressed elevational range. In many areas, old-growth forests of large conifers near sea level give way to alpine barrens and glaciers over an elevation gradient of only ~1,000 m. The dynamics of the Harding Icefield and its many outlet glaciers have sculpted landscapes across the entire park. Other landscape processes important at patch and landscape scales, such as mass wasting, landslides, floodplain development, and paludification, are superimposed over the long-lasting, initial conditions established by glacial processes. The oldest landscapes of the park are on the granitic outer fjordlands; these peninsulas represent partially-submerged ridges and cirques shaped by glacial action during the Pleistocene. Several of large valley glaciers draining Harding Icefield, such as Northwestern, McCarty, and Bear Glaciers, have retreated dramatically since the end of the Little Ice Age (late nineteenth century), initiating primary succession on a variety of post-glacial surfaces including moraine, till, glaciofluvial outwash, and ice-scoured bedrock. The pace and trajectory of vegetation and soils development in post-glacial landscapes varies widely depending on elevation, substrate, and microtopography. Shrubland development occurs very quickly at lower elevations, and forest development can occur within a century on favorable sites (typically non-bedrock Entisols). As forests mature, organic inputs and *in situ* weathering promote the evolution of young, post-glacial Entisols into Inceptisols. Successional processes and soil development are much slower at high elevation, particularly on exposed bedrock, as seen in the upper sections of McCarty and Northwestern Fjords. Substantial soil development at high elevations is only found in well-vegetated, alpine "refugia" that have escaped glaciation in recent centuries. Old-growth coniferous forests dominate the much older, low-elevation landscapes of the outer fjordlands, and well-developed soils (Spodosols) are locally common in areas that are not regularly affected by disturbance associated with hillslope processes. The prevalence of highly resistant, granite bedrock prevents infiltration of the abundant rainfall, creating a perched water table that promotes paludification and local development of Histosols, even on steep mountain slopes. Across KEFJ, soils with substantial loamy texture are restricted to long-deglaciated, stable landscape positions that allow the retention of wind-deposited ash or loess and material weathered *in situ*; such environments include old-growth forests and subalpine snowbeds.

The field data, the classifications of ecotypes and soil landscapes, a pre-existing land-cover map developed by AKNHP, and ancillary GIS and RS data were used to produce a series of ecosystem maps for KEFJ. Nine physiographic units capturing broad-scale divisions in landscape position, microclimate, and other state-factors were mapped using a combination of land-cover attributes in the AKNHP map, and rule-based modeling related to topography and glacial history. The ecotypes classified using field data were aggregated into a reduced set of map ecotypes that could be mapped across the study domain; aggregation was based on similarities in vegetation structure, general soil texture, and successional processes. The map ecotypes were further organized into 18 soil landscape and 12 disturbance landscape classes. The most widespread, non-glaciated soil landscapes include Glacial Rocky Barrens, Meadows, and Shrublands (13.5% of park), Subalpine Rocky Barrens,

Shrublands, and Woodlands (8.9%), and Alpine Rocky Barrens and Sedge Meadows (8.1%). The disturbance landscapes were derived from map ecotypes with broadly similar disturbance regimes. The most common disturbance landscape in non-glaciated areas was Mass Wasting and Landslide/Avalanche (38.6%). This disturbance landscape is associated with steep mountainsides that are virtually ubiquitous across the park, which are commonly affected by active hillslope processes. The second most common Disturbance Landscape was Windthrow/Pests and Pathogens/Paludification (6.3%); this disturbance landscape is associated with forests, where disturbance is infrequent and usually very localized.

The ELS approach employed in this study to understand landscape processes, their influence on ecosystem functions, and the environments in which they operate provides several benefits. First, landscapes were analyzed as ecological systems with functionally-related parts, recognizing the importance of geomorphic and hydrologic processes to disturbance regimes, the flow of energy and material, and ecosystem development. This hierarchical approach, which incorporates numerous ecosystem components into ecotypes with co-varying properties, allows users to partition the variability of a wide range of ecological characteristics. Additionally, the linkage of the land-cover map to climatic, physiographic, topographic, and glacial history variables to develop ecosystem maps improves our ability to predict the susceptibility and response of KEFJ ecosystems to a range of human impacts and natural forcings. It also facilitates the production of a variety of thematic maps for resource management applications and analyses.

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Appendix A. List of vascular species encountered by ABR in Kenai Fjords National Park, southcentral Alaska, 2013.

Araliaceae
- *Oplopanax horridus (Smith) Miquel*

Aspidiaceae (Dryopteridaceae)
- *Dryopteris dilatata (Hoffm.) A.Gray ssp. americana (Fisch.) Hult.*
- *Gymnocarpium dryopteris (L.) Newm.*

Athyriaceae
- *Athyrium distentifolium americanum*
- *Athyrium filix-femina (L.) Roth*
- *Cystopteris fragilis (L.) Bernh.*

Betulaceae
- *Alnus tenuifolia Nutt.*
- *Alnus sinuata (Regel) Rydb.*

Blechnaceae
- *Blechnum spicant (L.)*

Campanulaceae
- *Campanula rotundifolia L.*

Caprifoliaceae
- *Linnaea borealis L.*
- *Sambucus racemosa L*
- *Viburnum edule (Michx.) Raf.*

Caryophyllaceae
- *Stellaria humifusa Rottb.*
- *Stellaria sitchana Steud var. sitchana*
- *Stellaria monantha Hult.*
- *Stellaria crispa Cham. & Schlecht.*
- *Stellaria calycantha (Ledeb.) Bong.*
- *Honckenya peploides (L.) Ehrh.*
- *Stellaria borealis Bigelow*

Compositae (Asteraceae)
- *Erigeron peregrinus (Pursh) Greene*
- *Artemisia arctica Less. ssp. arctica*
- *Senecio triangularis Hook.*
- *Prenanthes alata (Hook.) Dietr.*
- *Petasites hyperboreus Rydb.*
- *Petasites frigidus (L.) Franchet*
- *Artemisia tilesii Ledeb.*
- *Achillea borealis Bong*
- *Artemisia arctica Less.*
- *Arnica frigida C.A. Mey.*
- *Anaphalis margaritacea*
- *Aster subspicatus Nees*

Cornaceae
- *Cornus canadensis L.*
- *Cornus suecica L.*

Crassulaceae
- *Sedum rosea (L.) Scop. ssp. integrifolium (Raf.) Hult.*

Cruciferae (Brassicaceae)
- *Cardamine umbellata Greene*
- *Draba hyperborea (L.) Desv.*
- *Cakile edentula Bigel. Hook*
- *Arabis lyrata L. ssp. kamchatica (Fisch.) Hult.*

Cryptogrammaceae (Pteridaceae)
- *Cryptogramma crispa (L.) R. Br. var. acrostichoides (R. Br.) Clarke*
- *Cryptogramma crispa (L.) R. Br. var. sitchensis (Rupr.) Christens.*
- *Cryptogramma crispa (L.) R. Br.*

Cyperaceae
- *Carex microchaeta Holm.*
- *Carex mertensii Prescott*
- *Trichophorum caespitosum (L.) Hartm.*
- *Eriophorum viridicarinatum (Englem.) Fern., Rhodora*
- *Eriophorum angustifolium Honck. ssp. subarcticum (V. Vassiljev) Hult.*
- *Eleocharis palustris (L.) Roem. & Schult.*
- *Carex spectabilis Dewey*
- *Carex ramenskii Kom.*
- *Carex anthoxanthea Presl*
- *Carex macloviana d'Urv. ssp. pachystachya (Cham.) Hult.*
- *Carex nigricans C.A. Meyer*
- *Carex mackenziei V. Krecz.*
- *Carex lyngbyaei Hornem.*
- *Carex laeviculmis Meinsh.*
- *Carex kelloggii W. Boott*
- *Carex glareosa Wahlenb. ssp. glareosa*
- *Carex dioica ssp. gynocrates (Wormsk.) Hult.*
- *Carex macrochaeta C.A. Mey.*

Droseraceae
- *Drosera rotundifolia L.*

Empetraceae
- *Empetrum nigrum L.*

Equisetaceae
- *Equisetum arvense L.*
- *Equisetum fluviatile L. ampl. Ehrh.*
- *Equisetum palustre L.*

Ericaceae
- *Vaccinium vitis-idaea L.*
- *Andromeda polifolia L.*
- *Cassiope lycopodioides (Pall.) D. Don*
- *Cassiope stelleriana(Pall.) DC.*
- *Cladothamnus pyrolaeflorus Bong.*
- *Loiseleuria procumbens (L.) Desv.*
- *Menziesia ferruginea Sm.*
- *Phyllodoce aleutica (Spreng.) A. A. Heller*
- *Vaccinium alaskensis Howell*
- *Vaccinium caespitosum Michx.*
- *Vaccinium ovalifolium Sm.*
- *Vaccinium uliginosum L.*

Gentianaceae
- *Gentiana douglasiana Bong.*
- *Gentiana platypetala Griseb.*

Geraniaceae
- *Geranium erianthum DC.*

Gramineae (Poaceae)
- *Elymus arenarius L. ssp. mollis (Trin.) Hult.*
- *Puccinellia grandis Swallen*
- *Poa palustris L.*
- *Poa macrocalyx Trautv. & Mey.*
- *Poa eminens Presl*
- *Poa arctica R. Br.*
- *Poa alpina L.*
- *Phleum commutatum Gaudin var. americanum (Fourn.) Hult.*
- *Hordeum brachyantherum Nevski*
- *Hierchloe alpina (Sw.) Roem. & Schult.*
- *Festuca rubra L.*
- *Festuca richardsonii Hook.*
- *Elymus trachycaulis SL*
- *Deschampsia caespitosa (L.) P. Beauv.*
- *Deschampsia beringensis Hultén*
- *Cinna latifolia (Trev. ex Goepp.) Griseb.*
- *Calamagrostis nutkaensis (C. Presl) Steudel*
- *Calamagrostis canadensis (Michx.) Beauv.*
- *Agrostis thurberiana A. S. Hitchc.*
- *Agrostis borealis Hartm.*
- *Agrostis alaskana Hult.*
- *Agropyron violaceum (Hornem.) Lange ssp. violaceum*
- *Poa stenantha Trin.*
- *Festuca brachyphylla Schult.*
- *Puccinellia nutkaensis (Presl) Fern. & Weath.*
- *Trisetum spicatum (L.) Richter ssp. spicatum*
- *Vahlodea atropurpurea (Wahlenb.) E. Fries*
- *Poa pratensis L.*

Juncaceae
- *Juncus arcticus Willd. ssp. alaskanus Hult.*
- *Juncus biglumis L.*
- *Juncus drummondii E. M*
- *Luzula parviflora (Ehrh.) Desv.*
- *Luzula wahlenbergii Rupr. ssp. wahlenbergii*

Juncaginaceae
- *Triglochin maritimum L.*
- *Leguminosae (Fabaceae)*
- *Lupinus nootkatensis Donn*
- *Oxytropis deflexa (Pall.) DC.*
- *Lathyrus maritimus L. ssp. maritimus*

Lentibulariaceae
- *Pinguicula vulgaris L.*

<u>*Liliaceae*</u>
- *Maianthemum dilatatum (How.) A. Nels. & J.F. Macbr.*
- *Streptopus amplexifolius (L.) DC.*
- *Veratrum viride Ait. ssp. Eschscholtzii (Gray) Love & Love*

Lycopodiaceae
- *Lycopodium alpinum L.*
- *Lycopodium annotinum L.*
- *Lycopodium clavatum L.*
- *Lycopodium selago L.*
- *Menyanthaceae*
- *Fauria crista-galli (Menzies) Makino*

Onagraceae
- *Epilobium hornemannii Reichb. ssp. Hornemannii*
- *Epilobium latifolium L.*
- *Epilobium angustifolium L.*
- *Circaea alpina L.*

Orchidaceae
- *Listera cordata (L.) R. Br.*
- *Platanthera dilatata Pursh*
- *Platanthera obtusata (Pursh) Lindl.*
- *Amerorchis rotundifolia (Banks) Hult.*

Pinaceae
- *Picea sitchensis (Bong.) Carr.*

Tsuga heterophylla (Raf.) Sarg.
Tsuga mertensiana (Bong.) Sarg.

Plantaginaceae
Plantago maritima L. ssp. juncoides (Lam.) Hult.

Polemoniaceae
Polemonium acutiflorum Willd.
Polemonium pulcherrimum Hook.

Polygonaceae
Oxyria digyna (L.) Hill
Rumex fenestratus Greene

Polypodiaceae
Polypodium vulgare L. ssp. occidentale (Hook.) Hultén

Portulacaceae
Claytonia sibirica L.

Primulaceae
Dodecatheon jeffreyi Van Houtte
Glaux maritima L.
Trientalis europaea L.
Pteridaceae
Adiantum pedatum L.

Pyrolaceae
Moneses uniflora (L.) Gray
Pyrola asarifolia Michx.
Pyrola secunda L.
Pyrola secunda L. ssp. secunda

Ranunculaceae
Aquilegia formosa Fisch.
Coptis asplenifolia Salisb.
Coptis trifolia (L.) Salisb.
Actaea rubra (Ait.) Willd.
Aconitum delphinifolium DC.
Anemone narcissiflora L.

Rosaceae
Sibbaldia procumbens L.
Sorbus sitchensis Roem.
Sanguisorba stipulata Raf.
Rubus spectabilis Pursh
Rubus pedatus Sm.
Rubus arcticus L. ssp. arcticus
Potentilla villosa Pall.
Potentilla egedii Wormsk. ssp. grandis (Torr. & Gray) Hult.
Luetkea pectinata (Pursh) Ktze.
Geum macrophyllum Willd. ssp. macrophyllum
Aruncus sylvester Kostel.
Geum calthifolium Menzies
Rubus arcticus L.
Spiraea beauverdiana Schneid.

Rubiaceae
Galium trifidum L. ssp. trifidum
Galium triflorum Michx.

Salicaceae
Populus balsamifera L. ssp. trichocarpa (Torr. & Gray) Brayshaw
Salix scouleriana Barratt
Salix planifolia Pursch. ssp.pulchra (Cham.) Argus
Salix brachycarpa Nutt. ssp. niphoclada (Rydb.) Argus
Salix alaxensis (Anderss.) Cov.
Salix sitchensis Sanson
Salix barclayi Anderss.

Saxifragaceae
Saxifraga mertensiana Bong.
Tellima grandiflora (Pursh) Dougl.
Tiarella trifoliata L.
Saxifraga tricuspidata Rottb.
Saxifraga punctata L.
Saxifraga nivalis L.
Saxifraga bronchialis L.
Ribes triste Pall.
Ribes glandulosum Grauer
Ribes bracteosum Dougl.
Heuchera glabra Willd.
Mitella pentandra Hook.
Saxifraga ferruginea Graham

Scrophulariaceae
Lagotis glauca Gaertn. ssp. glauca
Castilleja caudata (Pennell) Rebr.
Castilleja unalaschcensis (Cham. & Schlecht.) Malte

Thelypteridaceae
Thelypteris limbosperma (All.) Fuchs
Thelypteris phegopteris (L.) Slosson

Umbelliferae (Apiaceae)
Angelica lucida L.
Conioselinum chinense L. BSP.
Heracleum lanatum Michx.
Ligusticum scoticum L. ssp. hultenii (Fern.) Cald. & Tayl.
Osmorhiza purpurea (Coult. &Rose) Suksd.

Urticaceae
Urtica lyallii S. Wats.

Valerianaceae

Valeriana sitchensis Bong.

Violaceae

Viola langsdorffii Fisch.

Viola epipsila Ledeb. ssp. repens (Turcz.) Becker

Appendix B. List of non-vascular species encountered by ABR in Kenai Fjords National Park, southcentral Alaska, 2013.

Amblystegiaceae
- *Calliergon stramineum (Brid.) Kindb.*
- *Drepanocladus polycarpus (Bland. ex Voit) Warnst.*
- *Sanionia uncinata (Hedw.) Loeske*
- *Warnstorfia exannulata (Guemb. in B.S.G.) Loeske*

Anastrophyllaceae
- *Barbilophozia lycopodioides (Wallr.) Loeske*
- *Gymnocolea inflata (Huds.) Dumort.*

Antheliaceae
- *Anthelia julacea (L.) Dum.*

Bartramiaceae
- *Plagiopus oederianus (Sw.) H.A. Crum & L.E. Anderson*
- *Philonotis fontana (Hedw.) Brid.*

Brachytheciaceae
- *Brachythecium salebrosum (Web. et Mohr) B.S.G.*
- *Brachythecium reflexum (Starke in Web.et Mohr) Schimp.*
- *Brachythecium campestre (Müll. Hal.) Schimp.*
- *Brachythecium oedipodium (Mitt.) A. Jaeger*

Bryaceae
- *Bryum pseudotriquetrum (Hedw.) Gaertn. et al.*

Cephaloziaceae
- *Pleurocladula albescens (Hook.) Grolle*

Cladoniaceae
- *Cladonia chlorophaea (Flörke ex Sommerf.)*
- *Cladonia uncialis (L.) F. H. Wigg.*
- *Cladonia subfurcata (Nyl.) Arnold*
- *Cladonia squamosa Hoffm.*
- *Cladonia cornuta (L.) Hoffm. Ssp. Groenlandica*
- *Cladonia bellidiflora (Ach.) Schaerer*
- *Cladina stellaris (Opiz) Brodo*
- *Cladina mitis (Sandst.) Hustich*
- *Cladonia verruculosa (Vainio) Ahti*
- *Cladina arbuscula (Wallr.) Hale & Culb.*

Dicranaceae
- *Dicranum majus Sm.*
- *Paraleucobryum enerve (Thed.) Loeske*
- *Kiaeria falcata (Hedw.) I. Hagen*
- *Dicranum scoparium Hedw.*
- *Dicranum polysetum SW.*
- *Dicranum fuscescens Turner.*
- *Dicranum bonjeanii De Not*
- *Dicranum angustum Lindb.*
- *Dicranoweisia crispula (Hedw.) Lindb. ex Milde*
- *Dicranum laevidens Williams*

Ditrichaceae
- *Ceratodon purpureus (Hedw.) Brid.*
- *Ditrichum flexicaule (Schwaegr.) Hampe*

Grimmiaceae
- *Racomitrium lanuginosum (Hedw.) Brid*
- *Racomitrium panschii (C. Müll.) Kindb.*
- *Racomitrium heterostichum (Hedw.) Brid.*
- *Racomitrium ericoides (Web. ex Brid.) Brid.*
- *Racomitrium canescens (Hedw.) Brid.*

Gymnomitriaceae
- *Gymnomitrion pacificum Grolle*

Haplomitriaceae
- *Haplomitrium hookeri (Sm.) Nees*

Hylocomiaceae
- *Hylocomiastrum pyrenaicum (Spruce) Fleisch.*
- *Hylocomium splendens (Hedw.) B.S.G.*
- *Pleurozium schreberi (Brid.) Mitt.*
- *Rhytidiadelphus loreus (Hedw.) Warnst.*

Hypnaceae
- *Ptilium crista-castrensis (Hedw.) De Not.*
- *Herzogiella turfacea (Lindb.) Z. Iwats.*
- *Hypnum dieckei Renauld & Cardot*
- *Hypnum revolutum (Mitt.) Lindb.*
- *Stereodon callichrous (Brid.) Braithw.*

Jungermanniaceae
- *Lophozia pacifica Bakalin*
- *Lophozia sudetica (Nees ex Huebener) Grolle*
- *Mylia taylorii (Hook.) A. Gray*
- *Anastrophyllum assimile (Hook.) Stephani*

Leskeaceae
- *Lescuraea atricha (Kindb.) E. Lawton*
- *Lescuraea saxicola (Schimp.) Milde*
- *Pseudoleskea patens (Lindb.) Kindb.*

Leucodontaceae
- *Antitrichia curtipendula (Hedw.) Brid.*

Lobariaceae
- *Lobaria linita (Ach.) Rabenh.*
- *Lobaria pulmonaria (L.) Hoffm*

Mniaceae

Plagiomnium medium (Bruch & Schimp. in B.S.G.) T. Kop.

Rhizomnium nudum (Britt. & Williams) T. Kop.

Rhizomnium punctatum (Hedw.) T. Kop.

Nephromataceae

Nephroma parile (Ach.) Ach.

Orthotrichaceae

Amphidium mougeotii (Bruch & Schimp.) Schimp.

Parmeliaceae

Hypogymnia apinnata Goward & McCune

Platismatia glauca (L.) W. L. Culb.. & C. F. Culb

Peltigeraceae

Peltigera aphthosa (L.) Willd.

Peltigera britannica (Gyel.) Holt.-Hartw. & Tonsb.

Peltigera canina (L.) Willd.

Peltigera kristinssonii Vitik.

Plagiotheciaceae

Plagiothecium cavifolium (Brid.) Iwats.

Plagiothecium denticulatum (Hedw.) B.S.G.

Plagiothecium nemorale (Mitt.) A. Jaeger

Plagiothecium undulatum (Hedw.) Schimp. in B.S.G.

Pleuroziopsaceae

Pleuroziopsis ruthenica (Weinm.) Kindb. ex E. Britton

Polytrichaceae

Polytrichastrum alpinum (Hedw.) G.L.Sm.

Polytrichum juniperinum Hedw.

Polytrichum commune Hedw.

Oligotrichum hercynicum (Hedw.) Lam. & DC.

Pogonatum alpinum (Hedw.) Röhl.

Pogonatum contortum (Brid.) Lesq.

Pogonatum urnigerum (Hedw.) P. Beauv.

Pottiaceae

Syntrichia norvegica Web.

Ptilidiaceae

Ptilidium ciliare (L.) Hampe

Scapaniaceae

Macrodiplophyllum imbricatum (M. Howe) Perss.

Scapania paludosa (Müll. Frib.) Müll. Frib.

Macrodiplophyllum plicatum (Lindb.) Perss.

Diplophyllum taxifolium (Wahlenb.) Dumort.

Diplophyllum albicans (L.) Dumort.

Scapania bolanderi Austin

Sphaerophoraceae

Sphaerophorus globosus (Hudson) Vainio

Sphagnaceae

Sphagnum russowii Warnst.

Sphagnum subsecundum Nees ex Sturm

Sphagnum teres (Schimp.) Ångstr. in Hartm.

Sphagnum squarrosum Crome

Sphagnum papillosum Lindb.

Sphagnum girgensohnii Russ.

Sphagnum compactum DC. in Lam. et DC.

Sphagnum angustifolium (Russ. ex Russ.) C.Jens

Sphagnum capillifolium (Ehrh.) Hedw.

Splachnaceae

Splachnum luteum

Stereocaulaceae

Stereocaulon botryosum Ach.

Stereocaulon grande (H. Magn.) H. Magn.

Zosteraceae

Zostera marina L.

Appendix C. Chemical and physical laboratory data for 38 soil samples across 34 plots, Kenai Fjords National Park, southcentral Alaska, 2013.

		100 C Oven Dry							Air Dry					
	Depth	Total C	Total N	Sand	Silt	Clay	Organic C	BS[1]	Fe	Al	Si	PO_4[2]	15 Bar[3]	Glass[4]
Unique ID	cm	%	%	%	%	%	%	%	%	%	%	%	%	%
KEFJ_Tagc1_01_2013	73-79	4.76	0.27	42.00	42.40	15.60	4.76	3.67	0.23	0.37	0.01	51.35	17.1	0
KEFJ_Tagc1_03_2013	26-36	4.74	0.32	56.00	29.40	14.60	4.74	3.32	NA	NA	NA	NA	NA	NA
KEFJ_Tagc2_01_2013	11-28	26.20	1.54	65.00	21.40	13.60	26.19	0.66	NA	NA	NA	NA	NA	NA
KEFJ_Tagc2_02_2013	5-41	2.32	0.18	60.60	26.80	12.60	2.32	2.82	NA	NA	NA	NA	NA	NA
KEFJ_Tagc2_03_2013	4-16	9.31	0.70	27.35	64.90	7.76	9.30	2.81	1.20	0.87	0.07	91.66	29.6	70
KEFJ_Tcb1_04_2013	20-40	14.98	0.75	47.80	34.60	17.60	14.98	1.02	NA	NA	NA	NA	NA	NA
KEFJ_Tcb2_01_2013	8-19	4.74	0.31	19.60	66.80	13.60	4.73	3.40	NA	NA	NA	NA	NA	NA
KEFJ_Tcb2_02_2013	10-40	6.31	0.45	23.60	60.80	15.60	6.30	1.57	1.88	0.96	0.21	95.38	19.7	0
KEFJ_Tcb2_04_2013	3-44	2.11	0.16	30.20	50.20	19.60	2.11	6.27	NA	NA	NA	NA	NA	NA
KEFJ_Tdg_02_2013	2-42	1.23	0.10	73.20	13.20	13.60	1.23	71.68	NA	NA	NA	NA	NA	NA
KEFJ_Tdl_03_2013	13-42	0.92	0.09	56.80	25.60	17.60	0.91	9.11	NA	NA	NA	NA	NA	NA
KEFJ_Tdl_04_2013	15-27	0.77	0.03	63.20	29.20	7.60	0.76	17.97	NA	NA	NA	NA	NA	NA
KEFJ_Teg1_02_2013	10-42	0.63	0.06	49.20	21.20	29.60	0.63	34.66	NA	NA	NA	NA	NA	NA
KEFJ_Tnwl3_01_2013	11-34	1.47	0.10	61.20	21.20	17.60	1.47	16.27	NA	NA	NA	NA	NA	NA
KEFJ_Tnwl3_04_2013	3-40	0.95	0.06	64.80	20.60	14.60	0.95	23.88	NA	NA	NA	NA	NA	NA
KEFJ_Tnwl4_02_2013	8-45	0.20	0.00	72.80	19.60	7.60	0.20	25.38	NA	NA	NA	NA	NA	NA
KEFJ_Tpac_01_2013	30-45	2.04	0.14	46.80	35.60	17.60	2.04	7.14	0.48	0.23	0.03	29.84	9.3	0
KEFJ_Tpac_02_2013	11-33	10.97	0.39	47.80	34.60	17.60	10.96	2.87	1.45	0.63	0.04	79.18	30.7	0
KEFJ_Tpac_03_2013	5-32	11.81	0.82	42.80	49.60	7.60	11.80	2.71	0.67	0.88	0.09	88.34	30.5	40
KEFJ_Tpac_03_2013	15-17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	70
KEFJ_Tpb1_01_2013	20-31	10.86	0.83	28.80	62.60	8.60	10.83	1.43	0.77	2.23	0.23	99.32	29.9	90
KEFJ_Tpb1_01_2013	30-31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	40
KEFJ_Tpb2_02_2013	0-27	1.35	0.13	78.80	11.60	9.60	1.34	100.00	NA	NA	NA	NA	NA	NA

Appendix C. Continued.

	100 C Oven Dry										Air Dry			
	Depth	Total C	Total N	Sand	Silt	Clay	Organic C	BS[1]	Fe	Al	Si	PO_4[2]	15 Bar[3]	Glass[4]
Unique ID	cm	%	%	%	%	%	%	%	%	%	%	%	%	%
KEFJ_Tpb2_06_2013	13-32	6.88	0.31	57.56	31.78	10.67	6.87	1.39	NA	NA	NA	NA	NA	NA
KEFJ_Tpl_05_2013	8-22	7.40	0.43	48.00	35.40	16.60	7.39	2.95	NA	NA	NA	NA	NA	NA
KEFJ_Tqc_04_2013	7-19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
KEFJ_Tqc_04_2013	7-34	10.29	0.62	42.27	52.37	5.36	10.27	1.70	2.50	1.08	0.11	92.11	20.7	NA
KEFJ_Tsb1_01_2013	18-32	4.38	0.29	34.00	58.80	7.20	4.38	12.22	NA	NA	NA	NA	NA	NA
KEFJ_Tsb1_02_2013	0-24	1.43	0.09	63.60	20.80	15.60	1.43	52.28	NA	NA	NA	NA	NA	NA
KEFJ_Ttb1_01_2013	4-52	8.84	0.71	42.60	50.80	6.60	8.84	9.53	NA	NA	NA	NA	NA	NA
KEFJ_Ttb1_03_2013	6-31	2.82	0.17	57.20	28.20	14.60	2.81	4.90	NA	NA	NA	NA	NA	NA
KEFJ_Ttb1_04_2013	16-41	5.01	0.14	34.60	55.80	9.60	4.99	4.28	3.49	0.90	0.18	86.53	15.7	0
KEFJ_Ttb1_04_2013	24-41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0
KEFJ_Ttb2_01_2013	27-50	6.51	0.44	48.00	45.40	6.60	6.49	10.07	NA	NA	NA	NA	NA	NA
KEFJ_Ttb2_02_2013	0-20	6.36	0.53	29.60	62.80	7.60	6.36	6.44	NA	NA	NA	NA	NA	NA
KEFJ_Ttb2_05_2013	17-40	4.19	0.23	43.20	47.20	9.60	4.18	9.76	NA	NA	NA	NA	NA	NA

[1] Percent Base Saturation

[2] Percent Phosphate Retention

[3] Percent 15 Bar Water Retention

[4] Percent Volcanic Glass Estimate

Appendix D. Identification of rock types from 15 plots, Kenai Fjords National Park, southcentral Alaska, 2013.

Rock Class	Rock Type	Rock Weathering Potential	Unique ID
granitic	quartz-monzonite	moderate	KEFJ_Tmc_03_2013
granitic	quartz-syenite	moderate	KEFJ_Tagc2_02_2013
granitic	quartz-syenite	moderate	KEFJ_Tpac_01_2013
metamorphic	gneiss	moderate	KEFJ_Tqc_04_2013
metamorphic & granitic	quartzite and quartz-syenite	low to moderate	KEFJ_Tnwl4_01_2013
metasedimentary	meta-greywacke	moderate	KEFJ_Ttb1_03_2013
metasedimentary	meta-greywacke and quartz-phyllite	moderate	KEFJ_Ttb2_03_2013
metasedimentary	phyllite	high	KEFJ_Tcb2_02_2013
metasedimentary	phyllite	high	KEFJ_Tcb2_04_2013
metasedimentary	phyllite	high	KEFJ_Tjl_02_2013
metasedimentary	quartzite	low	KEFJ_Tmb_01_2013
metasedimentary	quartz-phyllite	moderate	KEFJ_Teg2_01_2013
metasedimentary	quartz-phyllite	moderate	KEFJ_Tnwl3_05_2013
metasedimentary	quartz-phyllite	moderate	KEFJ_Ttb2_02_2013

Appendix E. Crosswalk between map ecotypes and the ecosystem and land-cover classes of Boggs et al. (2008), and the total area (km^2) of each unique combination of ecotypes and classes, Kenai Fjords National Park, southcentral Alaska, 2013.

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
Alpine Barrens and Partially Vegetated	Alpine Active Colluvial Slope	Moss - Lichen	0.03
		Sparse Vegetation	0.41
		Unvegetated	0.03
	Alpine Dwarf Shrub	Sparse Vegetation	0.58
	Alpine Herbaceous	Sparse Vegetation	2.74
		Unvegetated	0.94
	High Alpine Herbaceous	Moss - Lichen	11.39
		Sparse Vegetation	0.87
		Unvegetated	31.76
	Recently Deglaciated Tall Shrub	Sparse Vegetation	<0.01
	Sparse Vegetation Ridge and Cliff	Moss - Lichen	1.69
		Sparse Vegetation	21.49
		Unvegetated	35.82
	Talus Slopes and Colluvial Fans	Sparse Vegetation	0.57
		Unvegetated	0.88
	Unvegetated Bedrock	Unvegetated	20.87
	Unvegetated Talus	Sparse Vegetation	2.15
		Unvegetated	23.35
Alpine Barrens and Partially Vegetated Total			155.56
Alpine Dwarf Shrub	Alpine Dwarf Shrub	Dwarf Shrub	15.86
	Sparse Vegetation Ridge and Cliff	Dwarf Shrub	0.36
Alpine Dwarf Shrub Total			16.21

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
Alpine Dwarf Shrub-Herbaceous Mosaic	Alpine Active Colluvial Slope	Dwarf Shrub - Mesic Herbaceous Mosaic	0.15
	Alpine Dwarf Shrub	Dwarf Shrub - Mesic Herbaceous Mosaic	1.50
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.11
	Alpine Herbaceous	Dwarf Shrub - Mesic Herbaceous Mosaic	56.88
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.04
	Sparse Vegetation Ridge and Cliff	Dwarf Shrub - Mesic Herbaceous Mosaic	1.10
	Talus Slopes and Colluvial Fans	Dwarf Shrub - Mesic Herbaceous Mosaic	0.09
Alpine Dwarf Shrub-Herbaceous Mosaic Total			59.86
Alpine Lake	Lake	Lake	1.79
	Pond	Pond	0.46
Alpine Lake Total			2.25
Alpine Sedge Meadow	Alpine Active Colluvial Slope	Mesic Herbaceous	1.21
	Alpine Herbaceous	Mesic Herbaceous	49.34
	High Alpine Herbaceous	Mesic Herbaceous	3.81
	Recently Deglaciated Tall Shrub	Mesic Herbaceous	0.11
	Sparse Vegetation Ridge and Cliff	Mesic Herbaceous	5.49
	Talus Slopes and Colluvial Fans	Mesic Herbaceous	1.29
Alpine Sedge Meadow Total			61.25
Coastal Barrens and Partially Vegetated	Cobble Beach and Beach Meadow	Intertidal Sparse Vegetation	0.01
		Sparse Vegetation	0.02
		Unvegetated	0.39
	Floodplain	Unvegetated	0.08
	Sandy Beach and Beach Meadow	Intertidal Sparse Vegetation	0.09
		Sparse Vegetation	0.01
		Unvegetated	0.28
	Sea Cliff	Sparse Vegetation	0.08
		Unvegetated	0.74
Coastal Barrens and Partially Vegetated Total			1.71

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
Coastal Brackish Tidal Flat	Tidal Marsh and Mudflat	Herbaceous Marsh and Wet Meadow	2.36
		Intertidal Sparse Vegetation	1.18
		Sparse Vegetation	0.35
		Unvegetated	0.25
Coastal Brackish Tidal Flat Total			4.14
Coastal Brackish Wet Sedge Meadow	Floodplain	Herbaceous Marsh and Wet Meadow	0.52
	Sandy Beach and Beach Meadow	Herbaceous Marsh and Wet Meadow	0.08
	Tidal Marsh and Mudflat	Herbaceous Marsh and Wet Meadow	<0.01
Coastal Brackish Wet Sedge Meadow Total			0.60
Coastal Moist Herbaceous Meadow	Cobble Beach and Beach Meadow	Mesic Herbaceous	0.69
	Floodplain	Mesic Herbaceous	0.26
		Open Low Willow - Mesic Herbaceous	0.13
	Sandy Beach and Beach Meadow	Mesic Herbaceous	1.97
		Open Low Willow - Mesic Herbaceous	0.06
Coastal Moist Herbaceous Meadow Total			3.11
Glacial Tall Shrub-Herbaceous Mosaic	Active Colluvial Slope	Closed Alder - Mesic Herbaceous Mosaic	0.02
	Recently Deglaciated Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	11.85
		Open Low Willow - Mesic Herbaceous	0.01
	Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	0.23
		Open Low Willow - Mesic Herbaceous	0.13
Glacial Tall Shrub-Herbaceous Mosaic Total			12.25
Glacial Alder-Willow Tall Shrub	Active Colluvial Slope	Closed Low Alder - Willow	0.14
		Closed Tall Alder	0.14
		Open Tall Alder - Willow	0.04
	Alpine Active Colluvial Slope	Open Low Alder - Willow	0.11
Glacial Alder-Willow Tall Shrub (continued)	Recently Deglaciated Tall Shrub	Closed Alder - Salmonberry	2.95
		Closed Low Alder	4.26
		Closed Low Alder - Willow	3.50

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Closed Tall Alder	28.12
		Closed Tall Alder - Willow	17.13
		Closed Tall Willow	0.25
		Open Low Alder	8.73
		Open Low Alder - Willow	4.47
		Open Low Shrub	0.27
		Open Low Willow	0.05
		Open Tall Alder	4.59
		Open Tall Alder - Willow	1.55
	Tall Shrub	Closed Tall Alder	1.51
		Open Low Alder	0.06
	Talus Slopes and Colluvial Fans	Open Low Alder	0.04
Glacial Alder-Willow Tall Shrub Total			77.92
Glacial Alpine Dwarf Shrub	Alpine Dwarf Shrub	Dwarf Shrub	1.92
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.11
	Alpine Herbaceous	Dwarf Shrub - Mesic Herbaceous Mosaic	13.53
	Sparse Vegetation Ridge and Cliff	Dwarf Shrub - Mesic Herbaceous Mosaic	0.38
	Talus Slopes and Colluvial Fans	Dwarf Shrub - Mesic Herbaceous Mosaic	0.09
Glacial Alpine Dwarf Shrub Total			16.04
Glacial Alpine Sedge Meadow	Alpine Herbaceous	Mesic Herbaceous	11.59
	High Alpine Herbaceous	Mesic Herbaceous	2.99
	Talus Slopes and Colluvial Fans	Mesic Herbaceous	0.13
Glacial Alpine Sedge Meadow Total			14.71
Glacial Barrens and Partially Vegetated	Active Colluvial Slope	Sparse Vegetation	0.07
		Unvegetated	0.09
	Alpine Active Colluvial Slope	Sparse Vegetation	0.82
		Unvegetated	0.30

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Alpine Herbaceous	Sparse Vegetation	0.96
		Unvegetated	2.35
	High Alpine Herbaceous	Moss - Lichen	3.96
		Sparse Vegetation	0.22
		Unvegetated	10.33
	Recently Deglaciated Tall Shrub	Sparse Vegetation	2.27
		Unvegetated	1.89
	Sparse Vegetation Ridge and Cliff	Moss - Lichen	0.46
		Sparse Vegetation	11.00
		Unvegetated	110.09
	Talus Slopes and Colluvial Fans	Sparse Vegetation	0.16
		Unvegetated	1.99
	Unvegetated Bedrock	Unvegetated	57.86
	Unvegetated Talus	Sparse Vegetation	0.50
		Unvegetated	34.03
Glacial Barrens and Partially Vegetated Total			239.34
Glacial Fireweed	Alpine Active Colluvial Slope	Mesic Herbaceous	0.01
	Recently Deglaciated Tall Shrub	Mesic Herbaceous	1.95
	Sparse Vegetation Ridge and Cliff	Mesic Herbaceous	2.29
Glacial Fireweed Total			4.25
Glacial Lake	Lake	Lake	15.90
Glaciers and Permanent Snow Fields	Snow and Ice	Snow and Ice	1,300.99
Human-modified Barrens	Road	Road	0.06
Lacustrine Forb Marsh	Freshwater Aquatic Bed	Freshwater Aquatic Bed	0.02
	Freshwater Marsh and Wet Meadow	Freshwater Aquatic Bed	<0.01
		Herbaceous Marsh and Wet Meadow	0.02
Lacustrine Forb Marsh Total			0.04
Lowland Lake	Lake	Lake	9.15

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Pond	Pond	0.57
Lowland Lake Total			9.73
Lowland Wet Sedge Meadow	Depressional Peatland	Herbaceous Peatland	0.11
		Herbaceous Peatland	0.07
	Freshwater Marsh and Wet Meadow	Herbaceous Marsh and Wet Meadow	0.86
		Herbaceous Marsh and Wet Meadow	0.01
Lowland Wet Sedge Meadow Total			1.05
River	River	River	7.06
Riverine Alder-Willow Tall Shrub	Active Colluvial Slope	Closed Low Alder - Willow	0.06
		Closed Tall Alder	0.11
		Closed Tall Alder - Willow	0.23
		Open Low Alder - Willow	0.01
		Open Tall Alder - Willow	0.12
	Floodplain	Closed Low Alder - Willow	4.03
		Closed Tall Alder	1.56
		Closed Tall Alder - Willow	6.07
		Open Low Alder	0.74
		Open Low Alder - Willow	2.89
		Open Low Alder - Willow	0.18
		Open Tall Alder	0.19
		Open Tall Alder - Willow	1.46
Riverine Alder-Willow Tall Shrub (continued)	Recently Deglaciated Tall Shrub	Closed Alder - Salmonberry	0.10
		Closed Tall Alder	0.33
		Closed Tall Alder - Willow	0.02
		Open Low Alder - Willow	0.07
		Open Tall Alder - Willow	0.03
	Tall Shrub	Closed Tall Alder	0.05
		Closed Tall Alder - Willow	0.04

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Talus Slopes and Colluvial Fans	Open Tall Alder - Willow	0.12
Riverine Alder-Willow Tall Shrub Total			18.42
Riverine Black Cottonwood Forest	Floodplain	Closed Black Cottonwood	0.60
		Open Black Cottonwood	1.29
		Woodland Black Cottonwood	0.65
Riverine Black Cottonwood Forest Total			2.54
Riverine Dwarf Fireweed and Barrens	Active Colluvial Slope	Sparse Vegetation	0.05
		Unvegetated	0.17
	Alpine Floodplain	Dwarf Shrub	0.02
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.20
		Mesic Herbaceous	0.28
		Sparse Vegetation	0.14
		Unvegetated	1.00
	Floodplain	Dwarf Shrub	0.11
		Mesic Herbaceous	0.48
		Sparse Vegetation	2.44
		Unvegetated	4.82
Riverine Dwarf Fireweed and Barrens Total			9.69
Riverine Sitka Spruce Forest	Active Colluvial Slope	Woodland Sitka Spruce - Alder	0.06
	Floodplain	Closed Sitka Spruce	0.34
Riverine Sitka Spruce Forest (continued)		Closed Sitka Spruce - Black Cottonwood	0.31
		Open Sitka Spruce	0.78
		Open Sitka Spruce / Black Cottonwood	0.37
		Woodland Sitka Spruce	0.28
		Woodland Sitka Spruce - Alder	1.01
		Woodland Sitka Spruce - Alder-Willow	1.35
		Woodland Sitka Spruce - Herbaceous	0.18
		Woodland Sitka Spruce / Black Cottonwood	0.30

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Sitka Spruce	Open Sitka Spruce	0.03
		Woodland Sitka Spruce	0.04
Riverine Sitka Spruce Forest Total			5.05
Riverine Willow Low and Tall Shrub	Active Colluvial Slope	Closed Low Willow	0.16
		Open Low Willow - Mesic Herbaceous	0.05
	Alpine Floodplain	Open Low Alder - Willow	0.22
		Open Low Willow	0.03
		Open Low Willow - Mesic Herbaceous	0.67
	Floodplain	Closed Low Willow	0.37
		Closed Tall Willow	1.99
		Dead Forest	0.43
		Open Low Shrub	0.07
		Open Low Willow	0.98
		Open Low Willow - Mesic Herbaceous	3.84
		Open Tall Willow	0.72
	Recently Deglaciated Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	0.02
		Closed Low Willow	0.04
		Open Low Shrub	0.04
		Open Low Willow - Mesic Herbaceous	0.02
	Tall Shrub	Open Low Willow - Mesic Herbaceous	0.01
Riverine Willow Low and Tall Shrub Total			9.65
Subalpine Alder Tall Shrub	Active Colluvial Slope	Closed Low Alder - Willow	0.01
	Alpine Active Colluvial Slope	Open Low Alder	0.03
	Recently Deglaciated Tall Shrub	Closed Alder - Salmonberry	5.36
		Closed Low Alder	0.31
		Closed Low Alder - Willow	0.39
		Closed Low Salmonberry	0.11
		Closed Tall Alder	4.89

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Closed Tall Alder - Willow	1.83
		Closed Tall Salmonberry	0.10
		Open Low Alder	2.50
		Open Low Alder - Willow	0.24
		Open Tall Alder	0.55
		Open Tall Alder - Willow	0.34
	Sparse Vegetation Ridge and Cliff	Closed Alder - Salmonberry	1.12
		Closed Low Alder	0.69
		Closed Tall Alder	1.13
		Closed Tall Alder - Willow	0.27
		Open Low Alder	2.46
		Open Low Alder - Willow	0.09
		Open Tall Alder	0.56
		Open Tall Alder - Willow	0.20
	Tall Shrub	Closed Alder - Salmonberry	23.26
		Closed Low Alder	0.10
		Closed Low Salmonberry	0.16
		Closed Tall Alder	29.76
		Closed Tall Alder - Willow	0.73
		Closed Tall Salmonberry	0.28
Subalpine Alder Tall Shrub (continued)		Open Low Alder	3.94
		Open Low Alder - Willow	0.11
		Open Tall Alder	0.64
	Talus Slopes and Colluvial Fans	Closed Tall Alder	0.51
		Open Low Alder	0.31
		Open Low Alder - Willow	0.19
Subalpine Alder Tall Shrub Total			83.16
Subalpine Alder Tall Shrub-Herbaceous Mosaic	Active Colluvial Slope	Closed Alder - Mesic Herbaceous Mosaic	0.06

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Recently Deglaciated Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	11.85
	Sparse Vegetation Ridge and Cliff	Closed Alder - Mesic Herbaceous Mosaic	5.74
	Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	79.91
	Talus Slopes and Colluvial Fans	Closed Alder - Mesic Herbaceous Mosaic	0.26
Subalpine Alder Tall Shrub-Herbaceous Mosaic Total			97.82
Subalpine Barrens and Partially Vegetated	Active Colluvial Slope	Sparse Vegetation	0.21
		Unvegetated	0.27
	Alpine Active Colluvial Slope	Unvegetated	0.06
	Alpine Dwarf Shrub	Sparse Vegetation	0.10
	Alpine Herbaceous	Sparse Vegetation	0.01
	Recently Deglaciated Tall Shrub	Sparse Vegetation	0.10
		Unvegetated	0.49
	Sea Cliff	Sparse Vegetation	0.36
		Unvegetated	1.18
	Sparse Vegetation Ridge and Cliff	Moss - Lichen	0.09
		Sparse Vegetation	6.45
		Unvegetated	0.55
	Talus Slopes and Colluvial Fans	Sparse Vegetation	0.67
		Unvegetated	0.78
Subalpine Barrens and Partially Vegetated (continued)	Unvegetated Bedrock	Unvegetated	2.48
	Unvegetated Talus	Sparse Vegetation	0.52
		Unvegetated	18.06
Subalpine Barrens and Partially Vegetated Total			32.38
Subalpine Dwarf Shrub	Active Colluvial Slope	Dwarf Shrub	0.02
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.05
	Alpine Dwarf Shrub	Dwarf Shrub	0.08

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Dwarf Shrub - Mesic Herbaceous Mosaic	0.22
	Alpine Herbaceous	Dwarf Shrub - Mesic Herbaceous Mosaic	7.38
	Sparse Vegetation Ridge and Cliff	Dwarf Shrub	0.14
		Dwarf Shrub - Mesic Herbaceous Mosaic	1.91
	Talus Slopes and Colluvial Fans	Dwarf Shrub - Mesic Herbaceous Mosaic	0.12
Subalpine Dwarf Shrub Total			9.92
Subalpine Dwarf Woodland	Mountain Hemlock	Open Mountain Hemlock	0.24
		Woodland Mountain Hemlock	0.16
	Sitka Spruce - Mountain Hemlock	Woodland Mountain Hemlock	0.04
		Woodland Sitka Spruce - Mountain Hemlock	0.37
	Sparse Vegetation Ridge and Cliff	Krumholz	0.08
		Open Sitka Spruce - Mountain Hemlock	0.06
		Woodland Mountain Hemlock	0.06
	Tree Line Forest Sitka Spruce - Mountain Hemlock	Closed Mountain Hemlock	0.45
		Krumholz	0.96
		Open Mountain Hemlock	0.74
		Open Sitka Spruce	0.22
		Open Sitka Spruce - Mountain Hemlock	0.03
		Woodland Mountain Hemlock	8.59
Subalpine Dwarf Woodland (continued)		Woodland Sitka Spruce	0.30
		Woodland Sitka Spruce - Alder	1.49
		Woodland Sitka Spruce - Herbaceous	2.19
		Woodland Sitka Spruce - Mountain Hemlock	1.30
Subalpine Dwarf Woodland Total			17.27
Subalpine Moist Herbaceous Meadow	Active Colluvial Slope	Mesic Herbaceous	0.09
	Alpine Herbaceous	Mesic Herbaceous	7.95
	Recently Deglaciated Tall Shrub	Mesic Herbaceous	0.61

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Open Low Shrub	0.37
	Sparse Vegetation Ridge and Cliff	Mesic Herbaceous	5.14
		Open Low Shrub	1.12
	Tall Shrub	Mesic Herbaceous	7.47
		Open Low Shrub	0.08
	Talus Slopes and Colluvial Fans	Mesic Herbaceous	0.98
Subalpine Moist Herbaceous Meadow Total			23.81
Upland Alder Tall Shrub-Lady Fern Mosaic	Active Colluvial Slope	Closed Alder - Mesic Herbaceous Mosaic	0.35
	Floodplain	Closed Alder - Mesic Herbaceous Mosaic	0.10
	Recently Deglaciated Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	2.81
	Sea Cliff	Closed Alder - Mesic Herbaceous Mosaic	0.44
	Sparse Vegetation Ridge and Cliff	Closed Alder - Mesic Herbaceous Mosaic	0.64
	Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	22.84
	Talus Slopes and Colluvial Fans	Closed Alder - Mesic Herbaceous Mosaic	0.11
Upland Alder Tall Shrub-Lady Fern Mosaic Total			27.29
Upland Alder-Salmonberry Tall Shrub	Active Colluvial Slope	Closed Alder - Salmonberry	0.04
		Closed Low Alder	0.04
		Closed Low Salmonberry	0.03
		Closed Tall Alder	0.67
Upland Alder-Salmonberry Tall Shrub (continued)		Closed Tall Alder - Willow	0.65
		Open Low Alder - Willow	0.05
		Open Tall Alder	0.03
	Floodplain	Closed Alder - Salmonberry	0.46
		Closed Low Alder - Willow	0.27
		Closed Tall Alder	0.48
		Closed Tall Alder - Willow	1.50
		Open Low Alder - Willow	0.57
		Open Tall Alder - Willow	0.11

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Open Tall Alder - Willow	0.03
	Recently Deglaciated Tall Shrub	Closed Alder - Mesic Herbaceous Mosaic	0.05
		Closed Alder - Salmonberry	4.22
		Closed Low Alder	0.53
		Closed Tall Alder	7.93
		Closed Tall Alder - Willow	1.63
		Open Low Alder	0.33
		Open Low Alder - Willow	0.77
		Open Low Shrub	0.02
		Open Tall Alder	0.23
		Open Tall Alder - Willow	1.96
		Open Tall Alder - Willow	0.11
	Sea Cliff	Closed Tall Alder	2.13
		Closed Tall Alder - Willow	0.02
		Open Low Alder	0.22
		Open Tall Alder	0.04
		Open Tall Alder - Willow	0.03
	Sparse Vegetation Ridge and Cliff	Closed Alder - Salmonberry	0.42
		Closed Low Alder	0.11
Upland Alder-Salmonberry Tall Shrub (continued)		Closed Tall Alder	0.15
		Open Low Alder	0.17
		Open Tall Alder	0.21
	Tall Shrub	Closed Alder - Salmonberry	36.14
		Closed Low Alder	0.06
		Closed Low Alder - Willow	0.33
		Closed Low Salmonberry	0.02
		Closed Tall Alder	38.46
		Closed Tall Alder - Willow	1.42

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Closed Tall Salmonberry	0.05
		Open Low Alder	0.84
		Open Low Alder - Willow	0.63
		Open Tall Alder	0.12
		Open Tall Alder - Willow	0.29
	Talus Slopes and Colluvial Fans	Closed Alder - Salmonberry	0.21
		Closed Tall Alder	0.14
		Closed Tall Alder - Willow	0.13
Upland Alder-Salmonberry Tall Shrub Total			105.05
Upland Black Cottonwood Forest	Floodplain	Closed Black Cottonwood	1.62
		Closed Sitka Spruce - Black Cottonwood	0.15
		Open Black Cottonwood	1.06
		Woodland Black Cottonwood	0.76
		Woodland Sitka Spruce / Black Cottonwood	0.78
	Recently Deglaciated Tall Shrub	Woodland Black Cottonwood	0.81
Upland Black Cottonwood Forest Total			5.17
Upland Herbaceous Slope Fen	Freshwater Marsh and Wet Meadow	Herbaceous Marsh and Wet Meadow	0.44
	Sloping Peatland	Herbaceous Peatland	1.65
		Mountain Hemlock - Sitka Spruce Peatland	7.47
Upland Herbaceous Slope Fen (continued)		Mountain Hemlock - Sitka Spruce Peatland	0.04
		Open Low Shrub Peatland	2.49
		Woodland Sitka Spruce - Mountain Hemlock	0.11
Upland Herbaceous Slope Fen Total			12.20
Upland Lady Fern Meadow	Active Colluvial Slope	Mesic Herbaceous	0.03
	Recently Deglaciated Tall Shrub	Mesic Herbaceous	0.03
	Sea Cliff	Mesic Herbaceous	0.48
	Sparse Vegetation Ridge and Cliff	Mesic Herbaceous	0.26
	Tall Shrub	Mesic Herbaceous	1.45

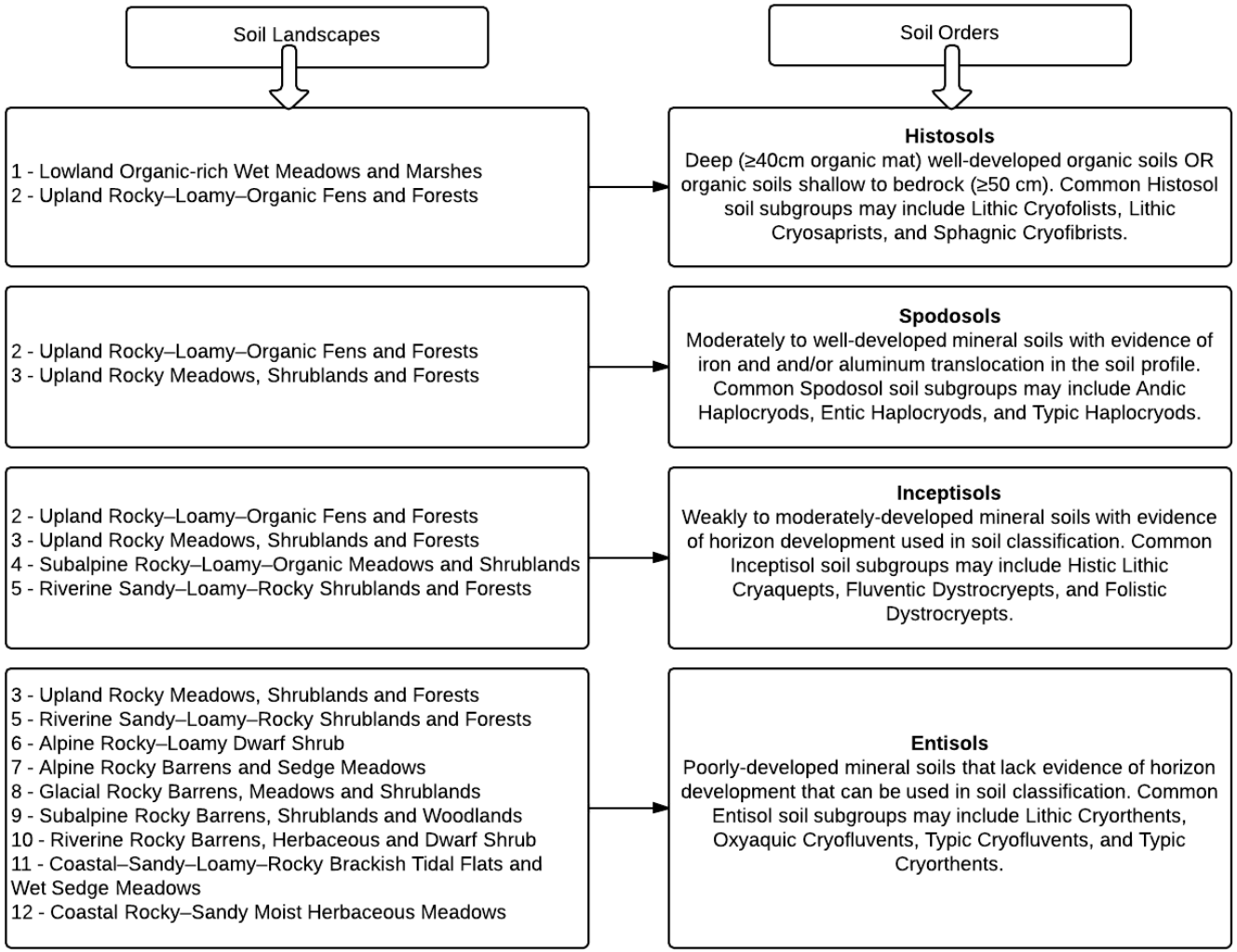
Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
	Talus Slopes and Colluvial Fans	Mesic Herbaceous	0.09
Upland Lady Fern Meadow Total			2.35
Upland Mountain Hemlock Forest	Mountain Hemlock	Closed Mountain Hemlock	14.51
		Open Mountain Hemlock	10.85
		Woodland Mountain Hemlock	7.89
	Sea Cliff	Closed Mountain Hemlock	0.08
		Woodland Mountain Hemlock	0.11
Upland Mountain Hemlock Forest Total			33.43
Upland Mountain Hemlock-Sitka Spruce Forest	Sea Cliff	Closed Sitka Spruce - Mountain Hemlock	0.10
		Woodland Sitka Spruce - Mountain Hemlock	0.03
	Sitka Spruce - Mountain Hemlock	Closed Sitka Spruce - Mountain Hemlock	24.30
		Open Sitka Spruce - Mountain Hemlock	10.43
		Woodland Sitka Spruce - Mountain Hemlock	3.90
Upland Mountain Hemlock-Sitka Spruce Forest Total			38.76
Upland Sitka Spruce-Early Blueberry Forest	Sitka Spruce	Closed Sitka Spruce	51.81
		Open Sitka Spruce	45.35
Upland Sitka Spruce-Early Blueberry Forest Total			97.16
Upland Sitka Spruce-Early Successional Forest	Active Colluvial Slope	Closed Sitka Spruce	0.06
		Open Sitka Spruce	0.17
		Woodland Sitka Spruce - Alder	0.43
		Woodland Sitka Spruce - Alder-Willow	0.07
	Floodplain	Closed Sitka Spruce	4.56
		Open Sitka Spruce	5.32
		Open Sitka Spruce / Black Cottonwood	1.47
		Woodland Sitka Spruce	0.28
		Woodland Sitka Spruce - Alder	0.79

Appendix E. (continued)

Map ecotype	Ecosystem	Land-cover class	Area (km^2)
		Woodland Sitka Spruce - Alder-Willow	3.19
	Sea Cliff	Open Sitka Spruce	0.55
		Woodland Sitka Spruce - Alder	1.08
		Woodland Sitka Spruce - Herbaceous	0.61
	Sitka Spruce	Open Sitka Spruce / Black Cottonwood	0.05
		Woodland Sitka Spruce	3.21
		Woodland Sitka Spruce - Alder	27.27
		Woodland Sitka Spruce - Alder-Willow	5.97
		Woodland Sitka Spruce - Herbaceous	2.69
		Woodland Sitka Spruce / Black Cottonwood	0.08
Upland Sitka Spruce-Early Successional Forest Total			57.84

Appendix F. Relationship between soil landscape classes and soil order.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
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