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Sincerely,

Matt Bowser

--
Matt Bowser, Entomologist
Kenai National Wildlife Refuge
PO Box 2139
Soldotna, Alaska 99669
60.4647°N, 151.0735°W
(907) 260-2812

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Dear Matthew Austin,

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Matt
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LANDSAT-FACILITATED VEGETATION CLASSIFICATION OF THE KENAI NATIONAL WILDLIFE REFUGE AND ADJACENT AREAS, ALASKA

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ABSTRACT

A Landsat-based vegetation map was prepared for Kenai National Wildlife Refuge and adjacent lands, 2 million and 2.5 million acres respectively. The refuge lies within the middle boreal subzone of south central Alaska. Seven major classes and sixteen subclasses were recognized: forest (closed needleleaf, needleleaf woodland, mixed); deciduous scrub (lowland and montane, subalpine); dwarf scrub (dwarf shrub tundra, lichen tundra, dwarf shrub and lichen tundra, dwarf shrub peatland, string bog/wetlands); herbaceous (graminoid meadows and marshes); scarcely vegetated areas; water (clear, moderately turbid, highly turbid); and glaciers.

The methodology employed a cluster-block technique. Sample areas were described based on a combination of helicopter-ground survey, aerial photo interpretation, and digital Landsat data. Major steps in the Landsat analysis involved: preprocessing (geometric correction), spectral class labeling of sample areas, derivation of statistical parameters for spectral classes, preliminary classification of the entire study area using a maximum-likelihood algorithm, and final classification through ancillary information such as digital elevation data.

The vegetation map (scale 1:250,000) was a pioneering effort since there were no intermediate-scale maps of the area. Representative of distinctive regional patterns, the map was suitable for use in comprehensive conservation planning and wildlife management.

INTRODUCTION

The Alaska National Interest Land Act of 1980 required the U.S. Fish and Wildlife Service to identify and describe wildlife habitats as part of developing refuge comprehensive conservation plans for nine new national wildlife refuges in Alaska. Vegetation maps were necessary to examine these habitats since habitat is essentially a vegetational phenomenon (Egler 1977).

Kenai National Wildlife Refuge (NWR) was selected as the first refuge for analysis. During the literature review it was apparent a paucity of vegetation data suitable for conservation or management plans existed.

Published vegetation maps that included the refuge such as Kuchler (1966; scale 1:7,500,000) were too broad to convey much information appropriate for planning. It was therefore suggested new 1:250,000 scale vegetation maps be prepared, and a Landsat-derived map was selected as the most practical approach. The reasons included: 1) short completion time 2) remoteness and large refuge size 3) ease of data base registration to the Landsat-facilitated map.

This paper: 1) presents a Landsat-derived classification and 2) describes the variation in the physiognomy and composition of the vegetation in relation to broad ecological factors. The classification is a first approximation preparing the way for more detailed quantitative methods.

GEOGRAPHICAL SETTING

The study area is Kenai NWR (2 million acres) and adjacent lands (2.5 million acres) that encompass most of the Kenai Peninsula. The refuge lies within two diverse land resource areas: Cook Inlet-Susitna Lowland and South Central Alaska Mountains (Reiger et al. 1979).

Soil development occurs on a variety of surficial deposits: slope, moraine, glacio-lacustrine, glacio-fluvial, and modern floodplain (Karlstrom et al. 1964). Three soil orders are represented--Spodosols, Histosols, and Inceptisols. The most widespread soil subgroups are Typic Cryorthods, Sphagnic Borofibrists, and Dystric Cryandepts (Reiger et al. 1979). The Kenai Mountains are classed as rough mountainous land.

The study area is situated within the middle boreal subzone (Hamet-Ahti 1976). The climate of the eastern half of the Kenai Peninsula is maritime while the western section is transitional between maritime and continental (Joint Federal-State Land Use Planning Commission for Alaska 1973). The average annual temperature and total precipitation for Anchorage (20 miles north of the peninsula) are 35.8 F and 14.7 in, and for Homer (on the southern peninsula), 36.5 F and 23.0 in, respectively.

Vegetation maps of Alaska published by Kuchler (1966; 1:7,500,000) and the Joint Federal-State Land Use Planning Commission for Alaska 1973; scale 1:2,500,000) are relatively similar. Classes recognized by Kuchler (1966) are: 1) hemlock-spruce forest (Tsuga-Picea) 2) spruce-birch forest (Picea-Betula) 3) black spruce forest (Picea) 4) muskeg (Eriophorum-Sphagnum-Betula) 5) cottonsedge tundra (Eriophorum) and 6) dryas meadows and barren (Dryas-Carex-Betula).

METHODS

The vegetation map was developed in a stepwise procedure as follows:

Inventory

Two Landsat scenes (#22043-20390 and -20393; 26 August 1980) covering the entire study area were acquired prior to initiating the field investigation. Twelve sampling areas (9x9 mi) or training blocks were selected from the scene within the refuge using the cluster block technique of Flemming (1975). Criteria for block placement involved visually interpreting the Landsat image and locating the blocks in areas which represented the totality of spectral variation within the refuge. Other criteria included differences in landforms, soils, surficial geology, and spatial distribution. Color infrared aerial photographs (scale 1:60,000) were obtained for each training block. The photographs were visually interpreted using stereo triplets and delineated into spectrally homogeneous units or polygons.

Following a fixed-wing aerial reconnaissance of the study area, a combined helicopter-ground survey was conducted. In this survey vegetation description was accomplished at two levels: general and detailed. At the general level, the physiognomy and dominant woody species were recorded for each polygon. All polygons were classified using a combination of the UNESCO (1967) and Ellenberg and Mueller-Dombois (1967) systems. Sampling intensity ranged from approximately ten to twenty polygons per training block. At the detailed level, quantitative descriptions were recorded of the floristic composition, structure, and major site features of 30 stands selected to represent the spectrum of major environmental and vegetational variation.

To be acceptable for sampling a stand had to be homogeneous and representative of the community from which it was sampled. Stand descriptions were from single plots employing a 30x30 ft quadrat for non-forest vegetation and a 70x70 ft quadrat for forest vegetation. Cover values were estimated for each species using nine cover-abundance classes (Westhoff and Maarel 1973).

Preprocessing

The 1980 Landsat scenes were obtained in computer compatible format. All digital processing was conducted at the U.S. Geological Survey's EROS Field Office, Anchorage on the Interactive Digital Image Manipulation System (IDIMS, ESL Incorporated 1981).

Geometric correction of the Landsat scenes to a Universal Transverse Mercator (UTM) projection was performed to allow for registration of other related data sets (e.g., terrain information, refuge and watershed boundaries, Landsat winter data and fire history maps) to the classified image. For scene registration, three points were located on each USGS topographic map (scale 1:63,360) and corresponding points on the scene by viewing the image on a color display. The 75 points covering each scene were used to define two second-order, least-squares polynomial transformations relating UTM northing and easting values on the map to row and column position for each of the Landsat scenes. The coefficients in the polynomial equations were used to correct the scenes to a UTM projection with individual pixels $50m^2$. Examination of mean residual errors associated with the second-order transformation equation indicated a registration accuracy of +1 pixel. Following registration, the two scenes were mosaiced together to produce one data set which provided complete coverage for the study area. All subsequent processing addressed the registered scenes as a single data set.

<u>Development of Training Classes and Associated Statistics</u>

A cluster block approach (Flemming 1975) was used to develop training classes. The 12 blocks visited in the field were grouped into three sets of four blocks each. A clustering algorithm (ISOCLASS) was used to define discrete groups of pixels on the basis of their reflectance in the four Landsat spectral bands. Each of the four block data sets were clustered independently to produce three discrete statistical files. It was arbitrarily specified that 50 discrete clusters be produced for each data set. The algorithm classified pixels of similar reflectance values, maximized statistical distance between classes of dissimilar pixels, and provided statistical estimates (mean vector and convarience matrix) for the individual classes. Thus, from clustering the Kenai study blocks, three statistical files with 50 classes each were generated.

Generating three sets of statistics provided three independent estimates of the spectral characteristics of the scenes being classified. Following statistical tests for cluster separability, the three files were merged into one final statistical file. Mean spectral reflectance values for clusters which were redundant or where significant cluster overlap occurred were either combined into one cluster or one of the redundant files was deleted. After completing the pooled file, analysis of the field data and aerial photographs was begun.

Spectral Class Labeling

The process of assigning spectral classes to individual land cover classes was accomplished by using field reference data, true color, and high altitude color infrared aerial photography. The individual study blocks that had been used in the development of the spectral classes were displayed on the IDIMS system. Each pixel had been classified into one of the 48 classes present in the final pooled statistics file by using a maximum-likelihood classification algorithm. Individual classes of displayed pixels were evaluated for their relationship to the field data and aerial photographs and notes were made on their apparent composition in terms of the vegetation types which they were found to contain. Problem classes were noted for later refinement in the post-classification phases.

Several classes were found to be comprised of more than one land cover category. Most frequently these cases occurred where variations in slope and aspect caused one vegetation type to have inconsistent reflectance properties based on topographic position and/or different cover types to have similiar reflectance properties due to the influence of terrain.

Another factor serving to greatly alter the reflectance characteristics of any one vegetation type was the amount of water present in association with the vegetation. Wet herbaceous meadows, wet graminoid peatlands and string bogs were consistently confused with open and closed conifer forests which have low reflectance in the infrared. A solution not involving the use of terrain data was required to deal with the problem in post classification refinement

Classification

The training class statistical file developed within the study blocks was applied to the entire two-scene mosaic using a maximum-likelihood classification algorithm. The algorithm compared each pixel's reflectance value to the mean and covariance matrix values obtained for each training class and assigned it to a class with maximum probability. Thus, every pixel in the two scene study area was assigned to a spectral class developed and labeled in the previous phases resulting in a preliminary classification.

Post Classification Refinement

A visual evaluation of spectral class integrity of the preliminary map was performed to see how classes developed within the study blocks correlated with classes outside the study blocks. The most significant problems related to those spectral classes containing more than one vegetation class due to the influence of terrain and/or water on the spectral reflectance values. To reduce these problems, two ancillary data types--Digital Elevation Model (DEM) and winter Landsat MSS data--were registered and intergrated into the data base.

DEM data, produced by digitizing elevation contours from USGS topographical maps (scale 1:250,000), was registered to the same 50 meter UTM grid as the Landsat MSS data. Algorithms in the IDIMS system were subsequently used to derive slope and aspect information from the elevation data to provide a total of three terrain-related sets to complement the Landsat data. The relationship of vegetation types to terrain variables was documented by field observation. Aerial photo interpretation was then used to correct classification errors such as: 1) slope and aspect to distinguish mountain shadows from the water classes 2) elevation data to separate lowland cover classes from subalpine and alpine cover types 3) elevation and aspect data to label spectral classes on north and northwest aspects which were shadowed due to their position on the terrain.

Winter Landsat MSS data was used to overcome problems relating to the relative amounts of water found in association with particular vegetation types. Because there is less reflectance by water in the infrared, wetland communities which commonly have open standing water associated with them tend to have much lower mean reflectance values when the vegetation and water reflectance is averaged over the pixel. This resulted in wetland communities such as string bogs having a spectral signature almost identical to coniferous forest. To resolve this problem, winter Landsat MSS data (Band 7) was registered and analyzed. Because low growing wetland communities are normally frozen and covered with an even layer of snow in winter, their reflectance is much greater than taller communities such as conifer forests. Accordingly, a density slice was performed on the winter data and a mask was generated which contained all areas having a brightness value greater than what was determined to be associated with areas of forest or scrub. This mask was then applied to the classified summer data to stratify out the misclassified wetland communites which were being classified as forest.

RESULTS

The vegetation map documents the spatial dimensions and recurrent patterns of the vegetation throughout the Kenai study area as seven vegetation classes and sixteen subclasses.* A representative portion (Kenai Quadrangle; scale 1:785,000) is shown in Figure 1. Types recognized are:

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* The map is available in color for the entire study area (scale 1:250,000) from the second author at the cost of reproduction.

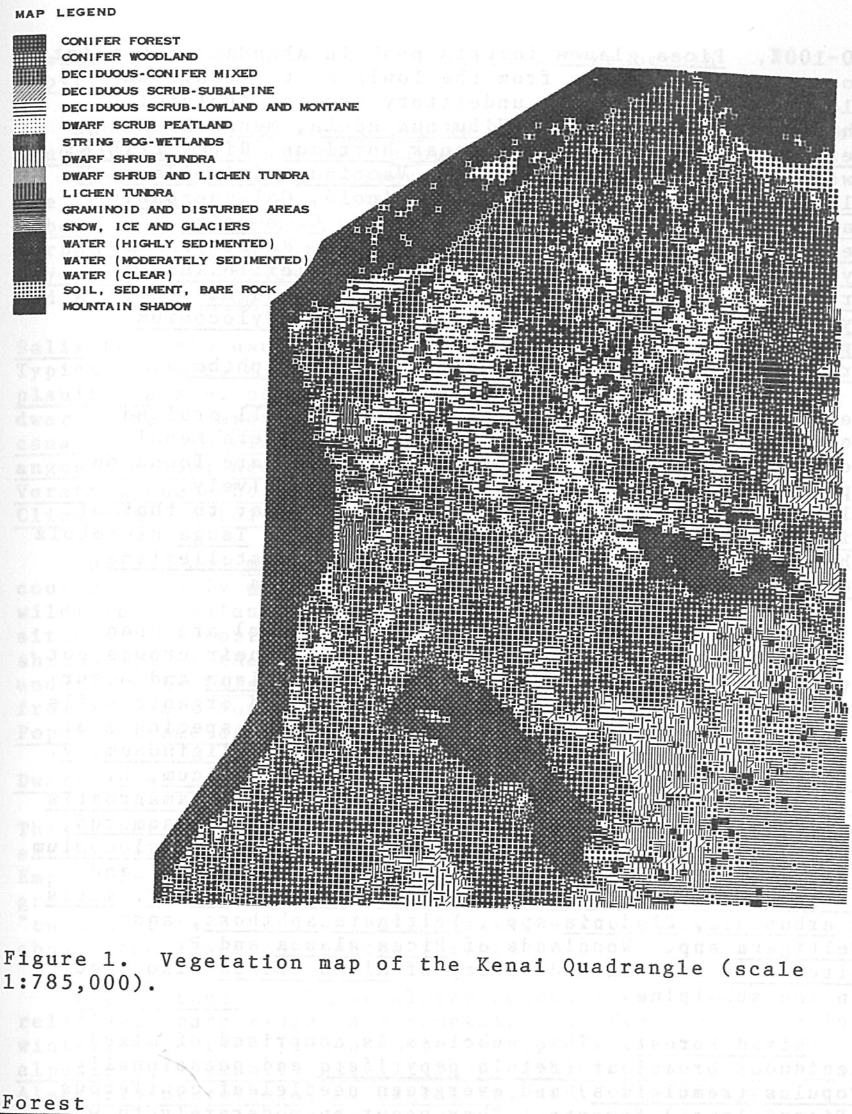

Figure 1. Vegetation map of the Kenai Quadrangle (scale 1:785,000).

Forest

Forests are formed of tree species 16 ft tall. Included within the concept of forest is secondary tree growth temporarily less than 16 ft in height, i.e., intermediate successional stages. The forest class is the most widespread vegetation type covering 37% of the refuge. The major forest subclasses are: closed needleleaf forest, needleleaf woodland, and mixed forest.

Closed needleleaf forest. This subclass is dominated by forests of *Picea glauca*, *P. sitchensis*, and *Tsuga mertensiana*. In closed forests tree cover ranges from

60-100%. Picea glauca forests peak in abundance on moist to well drained sites from the lowlands to subalpine slopes. Characteristic understory species include: shrubs, Rosa acicularis, Viburnum edule, Menziesia ferruginea, Salix spp. Oplopanax horridus, Ribes triste; dwarf shrubs, Linnaea borealis, Vaccinum vitis-idaea, V. uliginosum, Empetrum nigrum; graminoid, Calamagrostis canadensis; forbs, Cornus canadensis, C. suecica, Geocaulon lividum, Trientalis europaea, Rubus pedatus, Gymnocarpium dryopteris, Streptopus amplexifolius, Dryopteris austriaca, Actaea rubra, Lycopodium spp., Pyrola spp., and Equisetum spp.; mosses, Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis; and lichen, Peltigera aphthosa.

Dense Picea sitchensis forests occur on well drained coastal montane areas chiefly in the southern Kenai. Forest and krummholz of Tsuga mertensiana are found on upper montane and subalpine sites, respectively. Floristic understory composition is similiar to that of Picea glauca forests with the exception of Tsuga krummholz characterized by the presence of Cassiope stelleriana, Luetkea pectinata, and Spiraea beauverdiana

Needleleaf woodlands (10-60% tree cover) are open stands of trees at least 16 ft tall with their crowns not touching. They are dominated by Picea mariana and occur on moderately to poorly drained mineral and organic soils of the lowlands and lower montane. Typical species are: dwarf shrubs, Betula glandulosa, Vaccinium uliginosum, V. vitis-idaea, Empetrum nigrum, Ledum groenlandicum, L. decumbens, Andromeda polifolia; graminoids, Calamagrostis canadensis; forbs, Geocaulon lividum, Rubus chamaemorus, Pedicularis spp;, mosses, Pleurozium schreberi, Hylocomium splendens, Polytrichum strictum, Sphagnum fuscum; and lichens, Nephroma arcticum, Cladina rangiferina, C. mitis x arbuscula, Cladonia spp., Peltigera aphthosa, and Peltigera spp. Woodlands of Picea glauca and P. sitchensis with an understory of Alnus crispa also occur in the subalpine.

Mixed Forest. This subclass is comprised of mixed deciduous broadleaf (Betula papyrifera and occasionally Populus tremuloides) and evergreen needleleaf coniferous (Picea glauca) forests. They occur on moderately to well drained sites in the lowlands and montane. Understory composition is similiar to closed needleleaf forest.

Deciduous Scrub

This vegetation class is predominantly composed of woody plants ranging between 1.5 and 16 ft in height that shed their foilage simultaneously in connection with winter. Within the class concept are included multiple-stemmed woody plants such as Salix and Alnus as well as immature stands of single-stemmed tree species like Betula papyrifera.

Subalpine deciduous scrub is found above timberline as Alnus or Salix thickets. Alnus crispa scrub predominates on steep, well-drained sites. Characteristic associates are the shrubs, Sorbus sitchensis, Sambucus racemosa, Ribes triste; graminoid, Calamagrostis canadensis, and forbs, Trientalis europaea, Streptopus amplexifolius, Dryopteris austriaca, and the mosses, Plagiothecium spp. and Brachythecium spp.

Salix thickets usually occur on relatively gentle slopes. Typical species are the shrubs, Salix barclayi, S. planifolia ssp. puchra, S. glauca, Betula glandulosa; dwarf shrub, Empetrum nigrum; graminoids, Calamagrostis canadensis, Luzula parviflora; forbs, Epilobium angustifolium; Aconitum delphinifolium, Rubus arcticus, Veratrum eschscholtzii, Equisetum spp.; and mosses, Climacium dendroides, Mnium magnifolium.

Lowland and montane deciduous scrub occurs along water courses, poorly drained sites, areas regenerating from wildfires, avalanche sites, and on sandy, wind-exposed sites on the northernmost Kenai Peninsula. Principal shrubs are of the genera Alnus and Salix and are usually underlain by Calamagrostis canadensis. Areas regenerating from fire are dominated by immature Betula papyrifera and Populus tremuloides.

Dwarf Scrub and Related Types

This vegetation class is composed of slow growing dwarf shrubs less than 1.5 ft composed chiefly of Ericaceae and Empetraceae. There are an abundance of mosses and lichens growing admidst the dwarf shrubs. As used below the term "tundra" refers to low growing dwarf scrub communities above the limit continuous forests in the mountains.

Lichen tundra. These alpine communities grow on relatively bare ridges and mountaintops often snow free in winter. The rich lichen cover is represented by Cladina alpestris, Thamnolia subuliformis, Sphaerophorus globosus, Alectoria ochroleuca, A. nigricans, and Cetraria spp. Creeping dwarf shrubs form a significant component, Dryas octopetala, Loiseleuria procumbens, Arctostaphylos alpina, Empetrum nigrum, Vaccinium vitis-idaea, V. uliginosum, and Diapensia lapponica. Characteristic forbs include Arenaria macrocarpa, Campanula lasiocarpa, and Oxytropis nigrescens.

Dwarf shrub tundra. Elevationally, this alpine subclass occurs below lichen tundra. It is dominated by erect and prostrate dwarf shrubs such as Betula glandulosa, Empetrum nigrum, Ledum decumbens, Vaccinium uliginosum, and V. vitis-idea Mosses and lichens are abundant in the understory: Pleurozium schreberi, Hylocomium splendens, Ptilidium ciliare, Peltigera aphthosa, Lobaria pulmonaria, Cladina spp., Thamnolia subuliformis, and Cetraria spp.

Dwarf scrub and lichen tundra. This subclass forms a mozaic of the two tundra types discussed above.

String bog/wetlands. On water impermeable material with flat or nearly imperceptible slopes, a type of organic terrain develops termed string bog. These are open bogs either devoid of trees or with a few trees (Picea mariana) of low vigor. The bogs have a patterned microrelief of raised strings covered by dwarf schrubs--Betula glandulosa, Vaccinium uliginosum, Potetilla fruticosa, and Andromeda polifolia--and rich in sphagnum peat mosses. Wetter depressions, flarks, occur between the strings and are usually dominated by graminoids, Eriophorum russeolum, E. angustifolium, Carex livida, C. rotundata and C. pluriflora.

Dwarf shrub peatland is formed mainly by sphagnum or other mosses that cover the land surface as organic terrain. Soils are poorly to very poorly drained. Dwarf shrubs such as Ledum decumbens, Betula glandulosa, Vaccinium uliginosum, Andromeda polifolia, Myrica gale, Empetrum nigrum are concentrated on the relatively drier portions of the peatland or are loosely scattered. Graminoids like Carex aquatilis, C. limosa, C. livida, C. chordorrhiza, C. rotundata, C. plurifora, Scirpus caespitosus, Eriophorum angustifolium, and forbs, Menyanthes trifoliata and Potentilla palustris may dominate locally. Slow growing trees, Picea mariana, or shrubs, Salix spp., are often found and grow as isolated individuals, in groups, or in woodlands that are marginal to the dwarf shrub peatlands.

Herbaceous Vegetation

Herbaceous plants--graminoids and forbs--are without significant woody tissue. They die back to the ground surface each year.

Graminoid marsh and meadows. This subclass includes sedge marshes (Carex rostrata); cultural grasslands such as hayfields (Phleum commutatum) and lawns (Poa); lowland and subalpine meadows (Calamagrostis canadensis); and areas regenerating from wildfires.

Scarcely Vegetated Areas

Plants are scattered or absent in this class and bare mineral substrate or rock determines the overall appearance of the landscape. Major examples and their characteristic species are tidal mud flats (Triglochin maritima, Puccinellia grandis, Scirpus paludosus, Carex lyngbyei, C. ramenskii), coastal sandy cliffs and beaches (Elymus arenarius, Artemisia tilesii), and talus (Umbilicaria, Grimmia maritima, Andreaea rupestris).

Water

The water class includes lakes, rivers, and marine waters. Subclasses are distinguished based on water clarity from clear to highly turbid.

Clear water. Contains little particulate matter.

Moderately turbid water. Water with some visible sediment.

Highly turbid water. Considerable particulate matter and appears opaque or milky.

Glaciers

This class identifies glaciers and late-melt snowbeds.

DISCUSSION

There are no intermediate-scale vegetation maps published for the Kenai Peninsula. This vegetation map is a pioneering effort and the first attempt to map the vegetation in a quantitative and systematic manner. Information on vegetation composition extends knowledge of the North America boreal zone.

A Landsat study of Tetlin NWR (Talbot et al. 1984) from the northern boreal subzone of interior Alaska distinguished seven major vegetation classes and nineteen subclasses. In conjunction with the present study these indicate what is possible with Landsat at intermediate mapping scales in different areas of Alaska.

The use of ancillary data such as elevation facilitated our ability to extend the vegetation classification and assisted in establishing ecologically meaningful units. Winter MSS data was helpful in reducing misclassification between treeless wetlands and coniferous forests. Accuracy of future Landsat studies in the boreal forest may also be enhanced by applying the mask procedure to the winter MSS data.

One of the major reasons for selecting Landsat-facilitated mapping was the relatively short time period that was available for study completion. The final map was produced within four months meeting our objectives. As a baseline vegetation study for the comprehensive planning effort the map was successfully used to derive wildlife-habitat relationships (Bailey 1984).

ACKNOWLEDGMENTS

We are grateful to the following taxonomists who identified or confirmed voucher specimens: bryophytes (W.C. Steere), *Sphagnum* (R.E. Andrus), Gramineae (W.W. Mitchell), *Salix* (G.W. Argus), Cyperaceae (J.H. Hudson).

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