Project Status Report, ADF&G/DWC/PSR-2011-1-R3

Habitat Evaluation Techniques for Moose Management in Interior Alaska

Federal Aid in Wildlife Restoration Project 5.20

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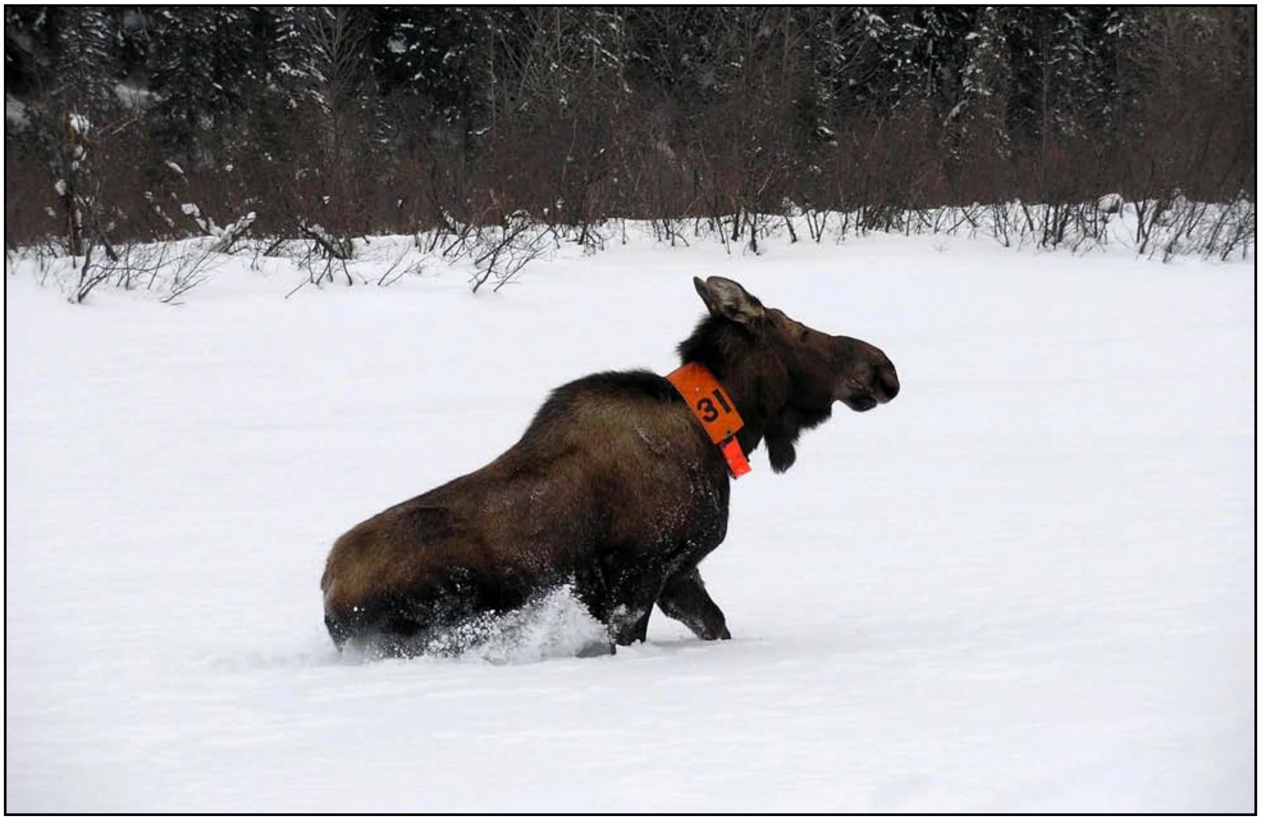

February 2011

Alaska Department of Fish and Game Division of Wildlife Conservation

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This report covers the period of research from 1 July 2007–30 June 2010.

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Much of the research and preparation of this report were supported by funds from Federal Aid in Wildlife Restoration, Grants W-33-6, W-33-7, and W-33-8. A Capital Improvement Project from the Alaska State Legislature funded part of the prescribed burn and browse surveys. The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition and archery equipment. The Federal Aid program allots funds back to states through a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum 5% of revenues collected each year. The Alaska Department of Fish and Game uses federal aid funds to help restore, conserve and manage wild birds and mammals to benefit the public. These funds are also used to educate hunters to develop the skills, knowledge and attitudes for responsible hunting. Seventy-five percent of the funds for this report are from Federal Aid.

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This Project Status Report was approved for publication by Scott Brainerd, Regional Research Coordinator in Region III for the Division of Wildlife Conservation.

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Please reference this report as:

Paragi, T. F., and K. A. Kellie. 2011. Habitat evaluation techniques for moose management in Interior Alaska. Alaska Department of Fish and Game. Project Status Report, period 1 July 2007–30 June 2010. Project 5.20. ADF&G/DWC/PSR-2011-1-R3. Juneau, Alaska.

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Cover Photo: A moose struggles in deep snow in the Berners Bay area of Southeast Alaska. ©2007 ADF&G. Photo by Kevin White.

Summary

We calculated from recent LANDFIRE classification the percentage of vegetated cover (potential summer range) and the percentage of cover types potentially containing preferred browse species (potential winter range) for 17 game management units (Unit) that had a positive determination for intensive management of moose (*Alces alces*) in Interior Alaska. LANDFIRE distinguishes nonvegetated areas to depict potential summer range but presently should not be used to infer whether winter range is a restricted portion of units until further validation of class types occurs.

We obtained, formatted, and created a database for snow depth data collected by the National Resource Conservation Service (NRCS) and the National Weather Service (NWS) from 1960 through 2007 for Interior Alaska. We used this information to identify areas of Interior Alaska where snow depth is more likely to influence moose populations. To evaluate scalar properties of snow depth as an influence on moose ecology, we measured snow depth along a longitudinal gradient across the Interior in early April 2009 at set distances (0.018–60 mi [0.03–100 km]) from preselected points. We found that there was negligible correlation among snow depths that were >0.6 mi [1 km] apart. Thus, an infeasible number of snow gauges would be necessary to model a high-resolution surface of snow depths across the Interior. However, snow depths from the same unit were more similar than snow depths from different units. This information may be useful in developing low-resolution monitoring plans where snow information from a few gauges could be summarized by unit.

A telemetry study of adult (>1 year old) female moose and moose calf survival during a predation control experiment in Unit 19D documented lower overwinter calf survival when snow depth exceeded 32 inches (80 cm) by March in winter 2004–2005. We have partitioned habitat use by adult females between 3 winters of shallow snow (<28 in [70 cm]) and the one winter of deep snow for hierarchical modeling of the effect of snow depth on habitat selection.

In late winter 2009 and 2010, we conducted browse surveys to estimate proportional biomass removal of current annual growth by moose in Units 19D, 20A, 20B, 20D, and 26A. We additionally conducted a preliminary analysis of browse data from Units 20A (collected in 2007) and 21D (collected in 2006).

In eastern Unit 19D, proportional browse removal prior to 6 years of wolf (*Canis lupus*) control and 2 years of bear (brown/grizzly [*Ursus arctos*] and black bears [*Ursus americanus*]) translocation was 15.9% (95% CI: 11.2–19.5%) in 2001 and 17.0% (14.4–22.2%) in 2003. In 2009, we documented significantly higher removal of browse biomass (40.5%, 33.2–47.1%) compared with either previous survey ($Z \geq 6.23$, $P < 0.0005$, 1-tailed tests) coincident with a doubling of moose density in the study area.

In southwest Unit 20D, browse removal in 2007 was 25.3% (19.1–32.3%) prior to 2 years of liberal antlerless hunts to slow population growth given evidence of declining nutritional condition. By 2010 browse removal was 15.3% (14.0–16.6%), which was lower than 2007 ($Z \geq 3.66$, $P < 0.0005$, 1-tailed test) and coincident with an apparent 40% lower density of moose. In Units 24A and 24B, we documented a mean twinning rate of 51% (range: 34–60%) during 2008–2010; in 2007 browse biomass removal in Unit 24B was the lowest recorded to date in the

Interior (5.4% [95% CI: 2.3–7.9%]). The 2009 browse survey in Unit 20A served as pretreatment data to evaluate the potential for prescribed fire to enhance browse production on subalpine winter range.

Key words: Alaska, aspen, birch, browse, habitat, moose, prescribed fire, snow, willow.

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Background

Intensive management of moose (*Alces alces*) populations to produce a high yield for consumptive use was defined and mandated in a 1994 Alaska Statute (AS 16.05.255(e)). The statute listed predator control, habitat enhancement, and harvest management as methods for intensive management. The statute also required establishment of population objectives by game management unit and sustainable yield calculated from those objectives. In March 1998 the Alaska Board of Game determined which units were subject to intensive management and discussed harvest and population objectives. Moose population and harvest objectives for most of Region III were established in November 2000 (Alaska Administrative Code 5 AAC 92.108). The Division of Wildlife Conservation (DWC) provided approximations for the amount of moose habitat in a few units, but differences in the quality of moose habitat within and among units was not addressed. Consequently, population objectives were often based on extrapolations of moose density from surveyed areas to larger areas that were not surveyed, without consideration of differences in habitat capability. The National Research Council (1997:185) recommended better information on the role of ungulate habitat in managing predator-prey systems. Our project evaluates the utility of selected habitat parameters for objectively defining the appropriate size and location of intensive management areas for moose in the Interior and how environmental factors may influence the response of moose populations to intensive management. The goal is to define habitat parameters that are feasible to inventory and monitor in large remote areas of Interior Alaska.

Land cover classifications in Alaska have historically been performed on specific ownership parcels using Landsat imagery (30-m resolution) in the public domain and class criteria often unique to area-specific research or management objectives (e.g., wetlands, timber). Merging different classifications for inference on moose habitat in game management units often meant gaps where no classification existed, incongruous cover types, and imagery from different time periods. Dissimilar time periods complicates classification of disturbed areas in burns or active river floodplains, which are important as moose habitat. The National Land Cover Database (NCLD) for Alaska that was released to the public domain in early 2008 by the U.S. Geological Survey as the first “seamless” classification across the state using Landsat imagery from 2001 (last year before a sensor malfunctioned on Landsat 7). The National Land Cover Database maintained the national classification scheme, which poorly fit boreal forest types because of their relative rarity in the conterminous 48 states. The LANDFIRE project (www.landfire.gov) is an attempt to use the 2001 Landsat data for characterizing fuel types to infer fire risk, forecast fire behavior, and prioritize mitigation strategies involving fuel reduction or modification treatments. Alaska was a separate region for LANDFIRE and involved regional experts in vegetation to derive multiple classification levels. The first statewide release of LANDFIRE occurred in late summer 2009, but classification accuracy had not yet been directly validated for the entire state.

Estimating habitat capability to support moose is difficult because of variation in the environment and in the seasonal energy requirements of the ungulate. We must begin by spatially defining quantity of winter browse potentially available to moose. Quantity of browse production within reach of moose in winter is a parameter that may be enhanced by vegetative management (Haggstrom and Kelleyhouse 1996; Collins and Schwartz 1998; Paragi et al. 2009:job 1e). A consistent definition will provide a context for relating habitat to moose reproduction and survival and potential population size under management. We can quantify browse production and removal by vegetative cover type, but we must also include snow characteristics to gauge winter forage availability for moose; thus, snow depth must also be a recognized component of habitat capability. Snow density interacts with depth to impede movements by moose (Coady 1974), but we will focus on snow depth because it is a characteristic that is practical to sample on a large geographic scale. Snow depth may be particularly important in the western Interior, where it commonly exceeds 90 cm by April (National Weather Service data, 1975–2005). Whereas aerial surveys are commonly done during postrut congregations in early winter to permit composition estimates from antlered moose, information on moose distribution relative to vegetation type at different snow depths requires sampling at periods of low, moderate, and deep snow throughout the winter to understand how moose interact with habitat. We recognize that browse quality (e.g., nutrient content or digestibility) also influences habitat potential to support moose. Nutritional quality of browse may be improved above baseline for 1–2 growing seasons following fire (DeByle et al. 1989) or mechanical treatments (Bowyer et al. 2001; Rea and Gillingham 2001, 2007). This frequency of disturbance may be feasible for game ranching on relatively confined ranges, but managing browse quality for wild populations over extensive areas where spatial use is unpredictable is infeasible.

Prior research on moose indicated that snow depth >16 inches (40 cm) begins to impede movement, depth >28 inches (70 cm) influences habitat selection, and depth >36 inches (90 cm) restricts movements and greatly increases energy consumption (Coady 1974). Initial evaluation of snow depth data assembled by the National Resource Conservation Service (NRCS) from 1975 to 2005 indicated a relatively high frequency of depth >28 inches in the southwestern Interior and southern slopes of the Brooks Range (Paragi et al. 2009:job 1j). Distribution of snow measurement sites in the NRCS data illustrated large areas of the Interior lacking historic or contemporary snow measurements where depth is likely to affect habitat use or potentially winter survival of young moose. Improving the ability to gauge or predict snow depth over spatial scales appropriate to moose range use and population dynamics would improve ability of managers to incorporate winter conditions into management recommendations.

Decisions on intensive management of moose ideally include an assessment of whether nutritional status is limiting the potential for population growth. Boertje et al. (2007) discussed the use of proportional browse removal (Seaton 2002), 10-month calf weights, twinning rate, and other indices of nutritional status in moose for gauging population level relative to habitat capability in Alaska. The Seaton (2002) technique is designed to estimate moose forage removal where moose utilize vegetation in Interior Alaska, but its sampling intensity is inadequate to estimate production for modeling carrying capacity at the landscape level. Recent data (Paragi et al. 2008) described how proportional removal of browse production was inversely related to twinning rate in 8 Alaska study areas where intensive management is underway or proposed. Estimating browse removal can allow managers to assess the nutritional condition of moose in areas where intensive management is being considered. Future evaluation of the browse removal technique should examine its sensitivity to changes in moose density and/or other nutritional indicators in a study population over time. We also need to understand how factors influencing forage accessibility (e.g., snow depth) or current annual growth (e.g., drought or insect defoliation) of twigs (diameter and shape) may affect estimates of browse biomass removal.

Habitat enhancement to increase production of browse for moose requires targeting treatment sites on known winter range. The high density of moose in Unit 20A had reduced population productivity for over a decade (Boertje et al. 2007). The Division of Wildlife Conservation has had a prescribed burn plan approved since 1995 to enhance winter range on the western Tanana Flats, which requires burning in midsummer to rejuvenate hardwoods and shrubs in spruce-dominated forest. This prescription requirement is problematic because of the risk of smoke entering urban areas or disrupting air traffic. With continued high density of moose on subalpine winter range in the Alaska Range foothills and lack of burn conditions or firefighter availability for the Tanana Flats burn, experimentation with aerial ignition to conduct a spring burn in subalpine habitats is warranted. Although vegetation response to fire in boreal forest is well documented, the potential to increase browse production in subalpine habitat with prescribed fire is unknown.

Although moose abundance and herd composition have been estimated using aerial surveys in defined geographic areas for decades, those attributes have not been linked directly to habitat capability. Similarly, harvest reports for moose and their predators (wolves [*Canis lupus*] and brown bears [*Ursus arctos*] regionwide, black bears [*Ursus americanus*] in some areas) are also coded to geographic areas based on drainages (Uniform Coding Unit). Creating databases of historical moose abundance and composition and wildlife harvest that can be spatially linked to habitat information and factors of social and economic systems (e.g., distance to communities or methods of access) will improve understanding of spatial relationships and potentially the effectiveness of wildlife management strategies.

Study Objectives and Jobs

OBJECTIVE 1: Develop a spatial model of winter habitat occupancy by moose to quantify the area to which density estimates should be extrapolated when setting population objectives for intensive management.

Job/Activity a: Define the proportion of each unit in Region III that contains vegetated cover for year-round moose habitat, and define the proportion of each unit that contains browse-producing species for winter range.

Job/Activity b: Conduct sampling of snow accumulation at the landscape scale to predict snow depth.

Job/Activity c: Estimate winter habitat use by moose with respect to snow depth.

Job/Activity d: Construct a spatial model of winter range use by moose.

OBJECTIVE 2: Improve understanding of the relationship between proportional removal of browse production and moose twinning rate in the boreal forest of Interior Alaska to gauge the utility of browse removal as an alternative index to when nutritional condition of moose hinders productivity.

Job/Activity a: Estimate browse production (kg/ha) and proportional removal.

Job/Activity b: Conduct moose twinning surveys in browse surveys areas.

OBJECTIVE 3: Create an archive of moose survey and harvest information to permit spatial analysis of population and harvest trends.

Job/Activity a: Collate historic moose survey and harvest/sealing records for moose, bears, and wolves as attributes of an associated spatial extent for electronic storage, analysis, and display.

OBJECTIVE 4: Write annual progress reports, a research interim technical report in FY10, and a final technical report. Give presentations at scientific forums, particularly in Alaska. Publish results in peer-reviewed journals for jobs where results have utility outside Region III.

OBJECTIVE 5: Evaluate the potential to increase browse production with prescribed fire in subalpine habitat and the subsequent response in browse removal by moose.

Job/Activity a: Conduct an experimental burn by aerial ignition of fine fuels in spring to evaluate the vegetative response in current annual growth.

Study Areas

JOB 1A: Vegetative composition from LANDFIRE classification

The LANDFIRE calculations for moose range cover the game management units administered from the Fairbanks regional office of the Alaska Department of Fish and Game (ADF&G) that include Interior Alaska and the northeastern Arctic. Interior Alaska is defined as between the Brooks Range in the north and Alaska Range in the south, between the Yukon-Kuskokwim Delta on the west (Unit 18) and the Yukon Territory border on the east. The calculations were done only for units where a positive determination exists for intensive management of moose. A focused comparison area of LANDFIRE relative to an earlier classification in Unit 19A is described in the methods.

JOB 1B: Snow depth at landscape scale

Sampling and analysis of external data sets occurred for Interior Alaska.

JOB 1C: Habitat use by female moose

Telemetry data were obtained for female moose in eastern Unit 19D in the upper Kuskokwim River drainage as part of federal aid projects 1.58 (Keech 2005) and 1.62 (Keech 2009).

JOB 2A: Browse surveys

Unit 19D (2009) — We sampled browse in the 1118-mi^2 survey area for moose near McGrath. This study area corresponded in part to earlier browse surveys (Paragi et al. 2008:Appendix A) in the large eastern Unit 19D (2001) and in the 528-mi^2 experimental micro-management area (2003) prior to implementation of wolf control in eastern Unit 19D (fall 2003–present) and a 2-year bear translocation from the experimental micro-management area (spring 2003–2004) in an attempt to increase moose abundance (Keech 2005, 2009).

Unit 20A (2007) — Browse data were collected over approximately 1800 mi^2 in the central Tanana Flats south of Fairbanks and adjacent foothills on the north side of the Alaska Range. Moose density in Unit 20A was 2.7/mi^2 in fall 1999 (Young 2010:Table 1) just prior to the late winter 2000 browse survey (Seaton 2002; Paragi et al. 2008). The population continued to grow in subsequent years, and 3 years of liberal antlerless hunts (2004–2006) were undertaken to slow population growth and improve nutritional condition. The population was estimated to be 3.1/mi^2 in fall 2006, just prior to the 2007 browse survey, and 2.5/mi^2 in fall 2008 (Young 2010:Table 1), just prior to the 2009 foothills survey as pretreatment data for the prescribed burn (job 5a).

Unit 20B (2010) — We sampled browse on the 913 mi^2 Minto Flats Management Area about 40 miles west of Fairbanks. The study area defined a sampling boundary for the proportion of parturient females with twin calves in spring and for weights of 10-month-old calves in project 1.67 (Kellie 2009) and defines a regulatory boundary for harvest management. Moose density in the study area was estimated at 3.1/mi^2 in fall 2008 (Seaton 2010:Table 1).

Unit 20D (2010) — We sampled browse in the 1777-mi^2 survey area that corresponded closely to a 2007 browse survey in southwestern Unit 20D (Paragi et al. 2008:Appendix A). Moose density in the study area was estimated at 6.0/mi^2 in November 2006, and after 2 years of liberal antlerless hunts to improve nutritional condition was estimated at 3.6/mi^2 in November 2009 (S. DuBois, Wildlife Biologist, ADF&G, Delta, unpublished data).

Unit 21D (2006) — Browse data were collected over approximately 2000 mi^2 in the Koyukuk River valley north of Galena and Kaiyuh Flats south of Galena in the middle Yukon River basin. Moose density was estimated to be 1.3/mi^2 in 2004 (Stout 2008:Fig. 1).

Unit 26A (2009) — We assisted Region V staff with their survey and inventory project for moose habitat on the North Slope. We sampled riparian habitat ≤1 km from the main channel of the Colville River and its major tributaries that defined the vast majority of available browse during winter in the vicinity of Umiat. This survey area duplicated the trend count area that has been used since 1991 to monitor the moose population within the highest density portions of the Colville drainage (L. Parrett, Wildlife Biologist, ADF&G, Fairbanks, personal communication).

JOB 2B: Moose twinning surveys

Surveys occurred in eastern Unit 19D (Keech 2005, 2009), southwestern Unit 20D (DuBois 2008), and Units 24A and 24B (this project).

JOB 5A: Subalpine prescribed burn

The project area is in the northern foothills of the Alaska Range in Unit 20A at an elevation of 2700–4400 feet and historically has among the highest density of moose on winter range in this unit. Upland vegetation communities include mixed coniferous-deciduous forest with white spruce and quaking aspen on drier sites; black spruce, Alaska paper birch, and balsam poplar on more moist sites; and shrub communities of willows, alder, and resin birch. Narrow riparian floodplains and adjacent uplands are dominated by alder and willow in seral communities maintained by periodic flooding in moderate-high gradient streams, some of which have glacial origin. Summer access is by aircraft. Treatment site (burn unit) 1 contains short black spruce and shrubs on moderate slopes with a general northeast aspect. Site 2 has shrub-dominated drainages and adjacent hillsides with steep northwest to moderate southeast aspects. Site 3 contains black or white spruce forest grading into mixed forest and shrubs on steep east to southeast slopes. Fire is relatively rare at subalpine elevations in Alaska, so vegetation is often climax in upland sites, except near active river floodplains. The cooperative burn plan between DWC and the Alaska Department of Natural Resources, Division of Forestry (approved 22 May 2009) defines the burn prescription (weather conditions, emergency contingencies, etc.) for the attempt to top kill all conifers, willows, and hardwoods in each of 3 treatments sites and has the following research objectives:

- Conduct browse surveys in late winter to estimate current annual production and removal by moose in the treatments sites and adjacent control sites before and after the burns.
- Use aerial photography early in the growing season following the burns to document proportion of conifers, willows, and hardwoods that burned.
- Document fire severity and initial vegetative growth during a site visit late in the same growing season following the burns.

Methods

JOB 1A: Vegetative composition from LANDFIRE classification

We downloaded the preliminary release of the LANDFIRE classification and clipped the raster data by unit in a Geographic Information System (GIS) to calculate the proportion of each unit devoid of vegetation (rock, ice, snow, bare ground) and the proportion with vegetation. We compared correspondence of the LANDFIRE classification focused on upland vegetation using 2001 Landsat imagery to a classification focused on wetlands (Ducks Unlimited 2000) of the Stony Military Operations Area (MOA) using 1989 Landsat imagery near McGrath (validated at 90% overall accuracy) for the northeast portion of Unit 19A (Fig. 1), which contains the variety of upland land cover types typical of the Interior. We extracted points on a uniform 1-km grid across this comparison area and condensed type classes to broad vegetation types as defined by Viereck et al. (1992) (tall shrub: >25% canopy cover; open forest: 25–60% canopy cover; closed forest: 60–100% canopy cover) that typically contain browse species eaten by moose (Paragi et al. 2008:Appendix C). We calculated the proportion of these broad types from each classification and compared their differences in a correlation matrix.

JOB 1B: Snow depth at landscape scale

For this job we investigated various options for modeling snow depth to determine whether the spatial correlation is adequate to allow fine-scale prediction of snow depth germane to moose ecology from sparse snow gauges. First, in 2006 and 2007 (Paragi et al. 2009:job 1j), snow depth information was obtained, formatted, and entered into a common Microsoft® Access™ database for 243 NRCS and NWS gauges throughout Interior Alaska during 1960–2006. We subsampled daily depths from the NWS dataset to a single depth on the first and fifteenth of each month from November through May so that data were similar to those collected at the NRCS snow stakes. We limited analyses to depths starting in 1977 because of a major climate shift that occurred in 1976 (Hartmann and Wendler 2005). For each snow gauge where >3 years of data were available, we calculated average snow depth based on the observation taken around the first of the month. Subsequently we conducted a spatial krige (2-dimentional averaging) between average snow depths in early April for snow gauges in Interior Alaska. We used the ordinary kriging method in the Geostatistical Analyst extension for ArcGIS 3.2 (ESRI, Redland, CA) to generate our kriged prediction and standard error surfaces.

We used the map of spatial uncertainty generated with the kriged model of snow depth to identify large spatial gaps in snow information (Figs. 2 and 3). In summer 2007 we used a helicopter to deploy 10 vertical gauges visible from fixed-wing aircraft to measure snow depth on moose winter range in Units 19A and 19D. We prioritized gaps in the southwest section of the study area because of existing and proposed intensive management programs for moose in that area. This project funded reading of snow depth on these gauges at the start of the month during November 2007–April 2008. In subsequent winters, 8 snow gauges (2 began leaning and now require maintenance) were observed under separate funding as part of the management program in the McGrath area office. All depth information is reported to the NRCS and incorporated into their monthly and annual watershed reports.

We also attempted to predict snow depth at the landscape level using a multivariate regression model. This model used a cubic function to explain the increase in snow depth from east to west and was trained using spatial information (e.g., latitude, longitude, and elevation) from a portion of the gauge sites. The model was then validated using the remaining sites. We then applied the multivariate equation using the grid calculator functions in Spatial Analyst extension for ArcGIS 3.2 to generate a predicted snow depth every 98 feet (30 m) based on the centerpoint elevation and coordinates.

In January 2009 we organized a one-day multi-agency workshop on snow measurement to discuss issues of sampling scale and frequency and demonstrate field techniques for measuring snow characteristics. Following discussions at the workshop, we evaluated an existing snow depth product generated for North America by the North American Regional Reanalysis (NARR) project. We worked with M. Sturm to obtain raw, unformatted snow depth data. These data were model-derived estimates based on a reanalysis of historical observations modeled at a 32-km grid scale. We converted and projected the information in ArcGIS 3.2 and plotted the data to evaluate the usefulness of this dataset for landscape-level snow modeling relative to moose habitat and population dynamics.

Finally, we reviewed literature on sampling and spatial analysis of snow data at multiple scales and discussed sampling design with 2 biometricians and 2 specialists in snow measurement. We determined that it was necessary to measure the spatial correlation of snow depth at multiple scales before proceeding with additional snow modeling and gauge deployment. In early April 2008 we sampled snow depth at several locations in 4 game management units east to west across Interior Alaska. We summarized the depth data by unit to observe patterns in snow depth at the landscape scale. Because of the strong east-west trend in the depth data, we binned data by unit and fitted separate variograms to each of the 4 units to examine the spatial correlation of snow depth at multiple scales.

JOB 1C: Habitat use by female moose

We reviewed literature on how snow influences habitat use by moose. To better understand sampling issues for habitat use by moose in late winter, we assisted with a moose survey in the Holitna and Hoholitna drainages of eastern Unit 19A during 12–14 March 2008 to observe moose distribution on the landscape and track patterns among vegetation types in conditions of relatively deep snow. Unit 19A was included in the snow depth sampling 3 weeks later (job 1b).

We began assembling historic data on moose locations in winter to understand the degree to which habitat use is influenced by snow depth. Global Positioning System (GPS) locations for individual moose were obtained during recent late winter surveys in Units 19A and 21E, but the data sheets were destroyed when the McGrath office burned in 2006. We obtained duplicate copies for surveys in February 2000 and 2005 (Unit 21E) and February 2001 and 2005 (Unit 19A) from the ADF&G regional office in Fairbanks and from the U.S. Bureau of Land Management (BLM) field office in Anchorage. Winter telemetry data were available for moose in eastern Unit 19D during 2001–2008 as part of ongoing predator-prey research near McGrath (Keech 2005, 2009), so we outlined a protocol with the principal investigator (M. Keech, ADF&G, Fairbanks) who collected those data to evaluate whether change in habitat selection occurred during deep snow winters.

A deep snow winter occurred in 2004–2005, and associated calf mortality was observed (M. Keech, M. Lindberg, R. Boertje, P. Valkenburg, B. Taras, T. Boudreau, and K. Beckmen, ADF&G, Fairbanks, unpublished manuscript), so in 2009 we prepared the location data for an analysis of habitat selection during severe winters. We created an Access database and entered over 11,000 locations for 600 moose. We used the winter location data from this database to derive several habitat characteristics at these locations (e.g., elevation, distance to nearest river, dominant vegetation within 4.4 miles [7 km]) in the Spatial Analyst extension for ArcGIS 3.2. We used the 30-m resolution National Land Cover Database (NLCD; http://landcover.usgs.gov/natllandcover.php) for vegetation variables.

JOB 2D: Spatial model of winter range use by moose

We reviewed the literature related to habitat selection. We found that for our needs, a hierarchical model that employed habitat selection and spatial and temporal aspects of the data would be most useful for deriving the changes in moose habitat selection during a deep snow winter.

JOB 2A: Browse surveys

Except where noted differently, we randomly chose geospatial population estimator (GSPE) cells in a study area stratified by moose density from recent fall surveys on a 3 high to 2 low basis, consistent with rationale on variability between low and high density strata for estimating moose abundance (Kellie and DeLong 2006:21). We accessed browse plots by flying to the southeast corner of a randomly chosen GSPE cell and then flying northwest until a suitable landing spot was found. The objective was to sample 40 plots per geographic stratum in a study area, so we chose extras because of past experience with no browse species at some landing sites or inability to land along some transects (e.g., forested). The plot center was chosen at a random distance and azimuth from a landing spot (Paragi et al. 2008). Procedures for randomized sampling of plants and twigs within plots were described in Seaton (2002). Except where noted differently, we used mass-diameter data from prior surveys in the same general study area (Paragi et al. 2008) for estimating biomass dry weight based on twig diameter in calculating production and removal (Seaton 2002).

Data from Unit 20A in 2007 were collected by researchers with the University of Alaska Fairbanks (UAF), Alaska Cooperative Fish and Wildlife Research Unit and ADF&G staff. Data from Unit 21D in 2006 were collected by UAF researchers and U.S. Fish and Wildlife Service staff (L. Parrett, personal communication). An electronic file was discovered at the Fairbanks ADF&G office in January 2009 with these unanalyzed survey data (Unit 20A was lacking the corresponding field data sheets). Data from both Units 20A and 21D were collected as part of a S. Szepanski's graduate project; her unfortunate passing in 2008 led to an interruption in the analysis of this data. Further analyses of these data are presumably being conducted by staff with the Alaska Cooperative Fish and Wildlife Research Unit at UAF. Analyses in this report for Unit 20A (2007) and Unit 21D (2006) were cursory for the purpose of aiding plans for future browse sampling by agency staff in the respective study areas. Detailed questions on data screening or analysis should be directed to the lead author of this report. Further inquiry on these surveys should be directed to L. Parrett, who participated in study design and data collection and has archived the plot and spatial data.

For all browse surveys we report proportional removal of browse at the plant mean level (based on samples of plants only) to minimize small sample bias, in contrast to the species total level (extrapolated from samples to plot composition) that is more inclusive to landscape variability for characterizing browse production at the study area scale (Paragi et al. 2008:73). We present estimates of plant mean removal as both deterministic calculations for comparison to earlier results (Seaton 2002) and based on bootstrapping 1000 samples with replacement from the number of plots in a survey to allow asymmetric confidence intervals (Paragi et al. 2008). When comparing results against earlier estimates for the same study area or between sections within a study area, we tested for difference between proportions of browse biomass removed (plant as sample unit) with a *Z*-test (Zar 1984:396). We interpreted *P*-values from a *t*-distribution using the smaller of *n* plants in the comparison for *v* degrees of freedom (Zar 1999:Table B-3).

Browse surveys in 2010 were done in collaboration with project 1.67 (Kellie 2009). One survey consisted of 60 permanent 1-m belt plots in a 2001 burn near Fairbanks (Unit 20A) for measuring browse production and removal at subsequent time periods during postfire succession. Plots locations were stratified among burn severity classes. Plot ends were marked with metal rebar for detection beneath snow by magnetic sensors. The plots were established at variable lengths to achieve 100 diameter measurements of current annual growth. These data are not reported here.

Unit 19D (2009) — Only 27 of the 40 random plots had browse species above the snow within the 98 foot (30 m) diameter plot, and only 1 plot was willow habitat in active floodplain, which historically tends to have high browse production and removal. Thus, the 2 field crews of 2 each also systematically chose another 15 plots every 6.25 miles (10 km; straight line by helicopter) along the active floodplain of the Takotna and Kuskokwim rivers.

Unit 20A (2007) — GPS location for plot center was predetermined by stratified random sampling by study area (flats or foothills, Seaton 2002), moose density, and a combination of 2 Landsat cover classifications (BLM-Alaska 2002a and Minto Flats GVEA Earth Cover Project [unpublished]). Plots were selected by study area (50% flats:50% foothills), and moose density strata (60 high:40 low), based on the most recent stratification for GSPE moose surveys, then selected within those strata based on remotely sensed vegetation community. After this initial stratification, plots were first visited by fixed-wing aircraft to verify presence of browse prior to sampling, similar to Seaton (2002). During these initial plot visits, an additional 15 sites were opportunistically selected to represent a rare but important habitat feature consisting of thick patches of *S. pulchra* in the upland areas, often in incised drainages. A total of 6 of these nonrandom sites were visited and sampled. During ground sampling, an alternate list of plots was available; if a site selected for a ground visit did not have browse above the snow, or was not suitable for helicopter landing, crews were instructed to visit the nearest alternate site. Ground-based sampling was conducted during 16–21 March. After proofing for errors, a condensed file was created that excluded alder (*Alnus* spp.; *n* = 108 plants), dwarf or resin birch (*Betula nana* or *B. glandulosa*; *n* = 3), and bog blueberry (*Vaccinium uliginosum*; *n* = 3). We lacked a mass-diameter relationship for these species. Browsing by moose was recorded on 48 (4.7%) of 1030 alder twigs measured but none of 30 resin/dwarf birch twigs or 23 blueberry twigs, similar to earlier experience in other browse surveys in the Interior (Seaton 2002; Paragi et al. 2008:4–5).

Unit 20A (2009) — This browse survey (see job 5a) was conducted by helicopter in proposed burn sites during 25 March–10 April 2009. Plots were uniformly located across the 3 proposed treatment sites in a GIS, but after visiting several without shrub species, we flew from preselected points over areas lacking browse above the snow to the nearest shrub patch to establish the plots because we expect immediate postfire succession to occur primarily through sprouting. Because fire is historically rare in this community, we obtained cross sections from a representative size class of larger shrub diameters to infer approximate stand age by counting annual growth rings.

Unit 20B (2010) — We randomly selected 75 GSPE cells spread across the study area and sampled by helicopter during 23–25 March.

Unit 20D (2010) — We randomly selected 75 GSPE cells spread across forested or agricultural lowlands and subalpine uplands and sampled mostly by helicopter during 5–8 April. Sites close to the road system were accessed by driving a truck to the nearest point perpendicular to the GPS location of the GSPE cell corner and walking a randomly chosen 49–328 feet (15–100 m) perpendicular toward the cell corner to establish the plot center, similar to previous surveys on the road system (Paragi et al. 2008).

Unit 21D (2006) — Plot locations were selected in a GIS using a stratified random design. Plots were selected by study area (Kaiyuh Flats and Koyukuk basin, the latter described as “West Galena”) and by moose density strata (60:40, high:low) based on the most recent stratification for GSPE moose surveys, then selected within those strata based on remotely sensed vegetation community. After this initial stratification, plots were first visited by fixed-wing aircraft to verify presence of browse prior to sampling, similar to Seaton (2002). Strata for browse sampling were based on an earth cover classification by the Ducks Unlimited, Inc. (2000) and the U.S. Bureau of Land Management (BLM-Alaska 2002b). The classification was done from Landsat Thematic Mapper images (98 foot [30 m] pixels) acquired 2 July 1999 and had overall classification accuracy of 87%. An area of 5 acres (roughly a block of 5 pixels) was considered the minimum size useful to stratify habitat for actually finding a specific cover type on the ground (D. Fehringer, Ducks Unlimited, Rancho Cordova, California, personal communication). Plots were subsequently sampled by helicopter during 16–27 March. During a period when the helicopter was unavailable, an additional 18 plots were opportunistically sampled by snowmachine in the Yukon River floodplain between Galena and the Koyukuk River confluence to examine browse production and removal across a gradient of stand ages on floodplain terraces of increasing elevation perpendicular to the Yukon River. Cross sections were taken from representative woody specimens at each plot to estimate age of vegetation cohort, but the samples decayed before counts of annuli were done. These systematic plots were appended to the 84 stratified random plots for a separate analysis of biomass removal. Diameter-mass relationships of most browse species in this survey were estimated from samples collected on or near plots and measured in the lab by the UAF researchers. We additionally used diameter-mass data from ADF&G browse surveys to analyze results for red osier dogwood (*Cornus stolonifera*) (data from Unit 21E), for Richardson's willow (*Salix richardsonii*) (Unit 20D), and for quaking aspen (*Populus tremuloides*) (Unit 20A).

Unit 26A (2009) — L. Parrett chose 100 stratified random points from 6 type classes in the floodplain habitat as defined by Muller et al. (1999) Landsat MSS cover types. Of the 100 points, 50 were of the "Moist Low-shrub Tundra and Other Shrublands" class and 50 were a random assortment of the remaining cover types, including "Dry Prostrate-shrub Tundra and Barrens," "Moist Graminoid, Prostrate-shrub Tundra (nonacidic)," "Moist Dwarf-shrub, Tussock-graminoid Tundra (typical tussock tundra)," "Wet Graminoid Tundra," and "Water."

Only 25 random plots we visited by helicopter had browse species above the snow within the 30-m diameter plot, so the 3 field crews of 2 also systematically chose another 22 plots. Along the active floodplain of the Colville River (CO), these systematic plots were selected by flying to the nearest location containing browse every 5 km (straight line by helicopter) from Umiat airfield, both upstream (U) and downstream (D) within the study area. Along the active floodplain of the Anaktuvuk (AN) and Chandler (CH) rivers, after 3 consecutive visits to random plots that contained no new browse plots, new plots (labeled with "A" suffix or as CTS) were chosen by flying toward the main river channel and stopping at the nearest location containing browse (Appendix A). For all plots (GPS location assigned in office or suitable site chosen in the field), the plot center was chosen using a random compass direction and distance within 100 m of the closest helicopter landing site. Diameter-mass relationships were developed for feltleaf willow (*S. alaxensis*, *n* = 204) and littletree willow (*S. arbusculoides*; *n* = 68) using twigs collected in the study area, and we substituted data for 3 other less common species from the nearest study areas: *n* = 190 pairs for diamondleaf willow (*S. pulchra*) from Units 24B and 24C; 174 for grayleaf willow (*S. glauca*) from Unit 20D; and 32 for *S. richardsonii* from Unit 20D.

JOB 2B: Moose twinning surveys

An interagency radiotelemetry study (ADF&G, BLM, National Park Service, and U.S. Fish and Wildlife Service) has maintained 40–60 marked female moose annually in recent years (number varied based on mortality and deployment of additional collars) in Units 24A and 24B. The

Galena assistant area biologist (T. Hollis, Wildlife Biologist, ADF&G, Fairbanks) conducted surveys of radiomarked females in addition to random (unmarked) females to estimate the proportion of parturient cow moose with twin calves in Units 24A and 24B in late May or early June during 2008–2010. Based on the recommendation of 50 parturient cows for estimating twinning rate (Boertje et al. 2007), we combined the results from both units because some animals moved between the adjacent study areas where they were captured (T. Hollis, personal communication).

We additionally obtained data from colleagues in Units 19D (M. Keech) and 20D (S. DuBois) to document twinning rate along with browse biomass removal for populations that have substantially increased or decreased during a study period, respectively. We address only the Unit 24 twinning data in this report.

JOB 3A: <u>Archive historic data</u>

We first assembled electronic records at the resolution of sampling cells or count areas to identify remaining data sets still in paper format (data sheets or maps). A regional biologist who formerly maintained the data for most moose surveys in the Interior (D. Haggstrom) retrieved data from older electronic media and converted them to Microsoft Excel® spreadsheet format. We contacted area biologists to obtain electronic or paper media for surveys not found in the regional office. We secured a section of warm storage with shelving at the regional office for a physical archive to organize paper media. A postdoctoral researcher (J. Schmidt) reviewed paper media and worked with student interns on electronic entry from data sheets (survey conditions and moose observations) into spreadsheets and on digitizing boundaries of survey maps to create GIS shapefiles.

JOB 5A: <u>Subalpine prescribed burn</u>

See job 2a for a description of the browse survey methods. Site visits by helicopter occurred on 14 May 2009 and 17 May 2010 to measure fuel moisture in preparation for planning aerial ignition. In 2009 we established 8 permanent markers across the 3 burn sites with metal stakes for acquiring repeated images of vegetation success over time. Photo stakes were often located in draws with adequate steepness to allow upslope fire movement for adequate fire intensity to ensure top kill. Preburn images were taken in the 4 cardinal directions at photo stakes.

Results and Discussion

JOB 1A: <u>Vegetative composition from LANDFIRE classification</u>

Our comparison of the LANDFIRE classification to the earlier Ducks Unlimited classification for the northeast portion of Unit 19A (based on 16,190 extracted points; Table 1A) indicated poor agreement along the diagonal of the correlation matrix within broad type classes potentially containing browse species, with the correlation matrix indicating only 3% of tall shrub and closed forest classes being of similar broad type in the sample points (Table 1B). Change matrices indicating how given broad types change from one classification to another (in both directions) illustrates how differences were distributed. For example, only 10% of extracted points classified as tall shrub in LANDFIRE were classified as tall shrub in Ducks Unlimited, whereas 36% of points classified as tall shrub in Ducks Unlimited were classified as tall shrub in LANDFIRE (Tables 1C and 1D).

An independent validation at several sites across the state of the initially released LANDFIRE classification found “significant errors in all the widely distributed EVT [Existing Vegetation Type] classes” (Boucher et al. 2009:3), including low and tall shrub being confused with dwarf shrub and coniferous forest being mapped as shrub. Overall accuracy assessment is calculated from the columns and rows of an error matrix that show the number of sample units assigned to a particular map class (classification data) relative to the actual number of sample units that belong to the map class (reference data in the validation process). A validation using 166 independent vegetation plots in a portion of Unit 20C (north side of Denali National Park) estimated an overall accuracy including all type classes (no collapsing or merging of types into broader groups) of only 17.4% that was improved to 30.5% by merging 4 pairs of similar types (Boucher et al. 2009:7–8). No other quantitative assessment of LANDFIRE was done for Interior Alaska.

Despite poor accuracy among for vegetation types in the initial LANDFIRE release, scientists involved in the Alaska accuracy assessment agreed[1] that LANDFIRE accurately portrays nonvegetated surfaces (water, rock, ice, snow, soil, etc.), from which vegetative area can be inversely derived. Thus, the present classification allows an estimate of the total vegetated area that potentially contains summer forage plants (semi-aquatic, forbs, grasses, woody stems and leaves, etc.) among game management units in the Interior (Table 2). Many tall shrub classes contain little or no moose browse (e.g., dominated by dwarf/resin birch or alder), so further inference from LANDFIRE for winter range is presently not warranted until a revised classification is validated relative to cover types known to contain browse species.

JOB 1B: Snow depth at landscape scale

Our plot of average snow depth in early April illustrated areas of deep snow but also the uneven distribution of snow courses across the Interior (Fig. 2). The kriged model of snow depth predictions for early April was cropped to the maximum latitude and longitude among all the snow gauges, thus did not cover the full extent of the study area (Fig. 3). Snow depth prediction was inaccurate in much of the Interior for purposes of inferring the effect of snow on moose ecology. For example, known areas of deep snow along the south side of the Brooks Range and the southwest corner of the study area were not well predicted.

The multivariate model of snow depth in early April performed better than the kriged model (Fig. 4). However, it still failed to depict known areas of deep snow in the southwest corner of the study area. From these early models, we concluded that fine-scale snow modeling could not be performed for deep snow areas where no empirical data were available.

The NARR models for average snow depth during 1979–2008 were unsuitable for predictions relative to habitat ecology of moose (Fig. 5). For example, known areas of deep snow in Units 19 and 21 were not captured. In addition, the NARR model failed to predict snow depth of ecological importance to moose (>16 in [40 cm]) for major portions of Interior Alaska.

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[1] During a 1 February 2010 teleconference attended by the lead author.

Snow depths for modeling spatial correlation were measured across Interior Alaska from 31 March through 4 April 2008. We acquired 580 snow depth measurements at 56 sites by fixed-wing aircraft north and east of Fairbanks and 106 sites by helicopter south and west of Fairbanks (Fig. 6). Depths were collected in Units 19, 20, 21, and 25. The original sampling design was based on juxtaposition of existing snow stakes rather than game management units, and sample sizes within game management units vary substantially. We summarized the data by unit because moose population objectives for intensive management were summarized in a similar manner. When plotted by unit (Fig. 7), only mean snow depth in Unit 19 was higher than the depth known to limit moose movement. When the data were broken down by unit (Fig. 8), Unit 19B had the highest snow loads, with Units 19A, 19D, and 25A also accumulating snow depths that may have restricted moose movements.

The fitted variograms for the snow depths binned separately by unit indicated poor spatial correlation of snow depth (high variation) between measurements >0.6 miles [1 km] apart (Fig. 9) but comparatively similar variation for measurements made at 0.6–30 miles (1–50 km) away from a known snow depth. In units where snow depths were more variable, the prediction was also more variable. Thus, we concluded that a fine-scale model of snow depth was not feasible for Interior Alaska because it would require an extremely fine network of snow gauges to be accurate. Based on this work, we decided that the best low-effort, long-term option for incorporating snow into moose management is to monitor a series of gauges within each game management unit where deep snow frequency is a concern and obtain an index from these of winter severity relative to moose ecology, similar to the methods used in Gasaway et al. (1983).

JOB 1C: Habitat use by female moose

We have prepared a dataset that includes location information and habitat variables from moose that were located bimonthly during project 1.62 (Keech 2009). There were 1882 locations from 167 moose located over 6 winters available for analysis. We will be working with biometricians to analyze winter habitat selection, comparing selection during the deep snow winter of 2004–2005 (*n* = 345) with the other 5 winters (*n* = 1537) included in the study that occurred during 2001–2007.

JOB 2A: Browse surveys

The Seaton (2002) technique is an index to moose forage removal from a minute sample of a large and complex landscape, not a robust estimate of total production or total removal at the landscape scale or even within vegetation strata (Paragi et al. 2008:12). The following preliminary results for surveys in 2009 and 2010 may be revised as further analysis of the browse data occurs.

Winter 2009–2010 was a near record for low snow depths in much of the Interior (0.3–0.5 m in plots across the study areas we sampled). Strong winds before and during the surveys served to scour open sites. Moose browsing was evident on exposed vegetation below the lower end of the sampling range (0.5 m) in the Seaton (2002) technique. A colleague (C. Gardner, Wildlife Biologist, ADF&G, Fairbanks) noted moose browsing on *Vaccinium* spp. shrubs that are typically covered with snow at this time of year, and we observed apparent moose utilization of exposed emergent aquatic plants, such as *Equisetum* (concentrated tracks in wetlands visible from aircraft). Moose also appeared to be dispersed across the study areas during browse sampling, rather than concentrating use in areas of high browse production or lower snow depth. These factors could have biased our estimate of biomass removal lower than expected for the late winter 2010 density of moose on ranges we sampled compared with what might be sampled during comparable periods with more typical snow depths.

Unit 19D (2009) — The 2 field crews of 2 each visited 42 plots and measuring 2746 twigs on 278 plants. The deterministic estimate of browse biomass removal was 40.6% ± 5.6% (95% CL: 36.8–44.4%), and the bootstrap estimate was 40.5% (33.2–47.1%). The 2009 removal estimate was higher than either previous survey ($Z \geq 6.23$, $P < 0.0005$, 1-tailed tests), coincident with a doubling of moose density in the study area (M. Keech, B. Taras, and K. Kellie, ADF&G, unpublished memo dated 28 January 2009, Fairbanks). Winter 2008–2009 produced relatively deep snow for McGrath.

Unit 20A (2007) — Proportional biomass removal was estimated from 100 plots (570 plants) that we subsequently stratified (postsurvey) using spatial criteria applied by an earlier analysis (Seaton 2002) into flats ($n = 56$ plots and 355 plants) and foothills ($n = 34$ plots and 189 plants) for the 90 plots with GPS locations (Appendix B). Species sampled were Alaska birch (*Betula neoalaskana*), *Populus balsamifera*, *P. tremuloides*, *Salix alaxensis*, *S. arbusculoides*, Bebb willow (*S. bebbiana*), *S. glauca*, *S. richardsonii*, and *S. pulchra*. Mean biomass removal for the study area was 20.2% (95% CI: 17.6–22.8%) using deterministic calculations and 20.0% (16.6–23.0%) using bootstrap methods. The difference in mean removal (bootstrap estimates) between the flats (20.1%, 14.5–24.3%) and foothills (19.4%, 14.5–23.1%) was not significant ($Z = 0.19$, $P > 0.5$, 2-tailed test). We did not directly compare this with the earlier survey because not all information from the 2007 survey was available, and several assumptions were made in screening electronic data entry without the benefit of data sheets.

Unit 20A (2009) — In this subalpine browse survey that serves as pretreatment for a prescribed fire (see job 5a), the 2 field crews of 2 each visited 37 plots and measured 2284 twigs on 230 plants. The deterministic estimate of browse biomass removal was 36.9% ± 5.6% (95% CL: 31.3–42.5%), and the bootstrap estimate was 41.9% (31.3–42.4%). The proportional removal in this minute study area was comparable to that of the broader foothills area in the 2000 survey (43.3%, 39.4–46.2%; Paragi et al. 2008:Table 4).

Unit 20B (2010) — The 2 field crews of 2 each visited 48 plots and sampled vegetation on the 40 that contained browse plants, measuring 2681 twigs on 279 plants. The deterministic estimate of browse biomass removal was 29.5% (95% CL: 27.0–32.0%), and the bootstrap estimate was 29.3% (24.7–32.9%).

Unit 20D (2010) — Three field crews of 2 visited a total of 71 plots and sampled vegetation on the 57 that contained browse plants, measuring 4108 twigs on 431 plants. The deterministic estimate of browse biomass removal was 15.3% (95% CL: 14.0–16.6%), and the bootstrap estimate was 15.3% (10.6–19.9%). The 2010 bootstrap removal estimate was lower ($Z \geq 3.66$, $P < 0.0005$, 1-tailed test) than the 2007 browse removal estimate (25.3%, 95% CI: 19.1–32.3%), coincident with an apparently lower moose density in the study area in 2010. We subsequently stratified (postsurvey) the 2010 data based on topography similar to the 2007 survey (Paragi et al. 2008) in flats (36 plots, 300 plants, 2760 twigs) and foothills (21 plots, 131 plants, 1348 twigs). The difference in mean removal (bootstrap estimates) in 2010 between the flats (10.7%, 5.2–15.4%) and foothills (22.7%, 14.9–30.2%) was significant ($Z = 3.27$, $0.001 < P < 0.002$, 2-tailed test), whereas it was not in 2007 ($P > 0.5$; Paragi et al. 2008:9).

Unit 21D (2006) — Proportional biomass removal was estimated from 112 plots (618 plants) that we subsequently stratified (postsurvey) based on moose survey boundaries (Stout 2008) into Kaiyuh Flats and Yukon River floodplain ($n = 61$ plots and 375 plants) and Koyukuk River ($n = 51$ plots and 243 plants) (Appendix C). Species sampled were Alaska paper birch (*Betula neoalaskana*), *Cornus stolonifera, Populus balsamifera, P. tremuloides, Salix alaxensis, S. arbusculoides*, Bebb willow (*S. bebbiana*), *S. glauca*, sandbar willow (*S. interior*), *S. richardsonii*, and *S. pulchra*. Mean biomass removal for the study area was 21.0% (95% CI: 18.5–23.5%) using deterministic calculations and 17.2% (14.2–21.4%) using bootstrap methods. The difference in mean removal (bootstrap estimates) between the Kaiyuh Flats and Yukon River floodplain (16.5%, 12.9–21.1%) and Koyukuk River (20.4%, 16.8–23.3%) was not significant ($Z = 1.23$, $0.5 < P < 0.2$, 2-tailed test).

Unit 26A (2009) — We measured 247 plants and 2192 twigs on the 47 plots from 5 willow species: *Salix alaxensis, S. arbusculoides, S. pulchra, S. glauca*, and *S. richardsonii*. Snow depth measurement averaged 0.66 m and ranged 0.15 to 1.20 m (Appendix A). Diameter-mass relationships were developed for *S. alaxensis* ($n = 204$ pairs) and *S. arbusculoides* ($n = 68$) using twigs collected in the study area in April 2008, and we substituted data for 3 other less common species from the nearest study areas ($n = 190$ *S. pulchra* and 174 *S. glauca* from Units 24B and 24C and 32 *S. richardsonii* from Unit 20D). Mean biomass removal for the study area was 10.0% (95% CI: 7.9–12.1%) based on deterministic calculations and 12.7% (5.9–23.9%) based on bootstrapping methods.

JOB 2B: Moose twinning surveys

The proportion of parturient cow moose with twins was similar between Units 24A and 24B in 2 of 3 years, and the combined data set was similar in the latest 2 years (Table 3). Confidence limits on twinning rates have not been estimated.

JOB 3A: Archive historic data

We advised UAF postdoctoral student J. Schmidt and master's student C. Carroll on archiving of historic data on trend counts (age and sex composition in large polygons) and counts in sampling cells used for population estimates (Gasaway-method polygons and rectangular GSPE cells) for moose in the Interior. Various types of information dating back to 1954, not necessarily complete for any given survey type or unit, was located for all game management units in the Interior: 12, 19A, 19B, 19C, 19D, 20A, 20B, 20C, 20D, 20E, 20F, 21A, 21B, 21C, 21D, 24A, 24B, 24C, 24D, 25A, 25B, 25C, and 25D. A few maps for Unit 26C in northeast Alaska were found. Both Units 26B and 26C are north of the Brooks Range and are administered by DWC Region III. In spring 2010 J. Schmidt provided an electronic archive in DVD format of moose survey data, associated survey attributes (search intensity, weather conditions, etc.), and GIS shapefiles of survey polygons or cells.

OBJECTIVE 4: Reporting

We prepared progress reports, budget requests, and work plans each year. In 2007 Kellie produced a memo outlining the methods for deploying 10 snow stakes, and in 2008 Kellie produced a memo on the scalar snow survey. Paragi helped as second author with preparation of manuscript (now in peer-review process) describing application of the Seaton (2002) technique and the relationship of browse biomass removal to twinning rate among 8 Interior moose populations (Paragi et al. 2008).

JOB 5A: Subalpine prescribed burn

We did an aerial reconnaissance of potential burn sites in the upper Little Delta River in September 2008 and assisted with writing a burn plan that was approved by the Alaska Division of Forestry in May 2009. We conducted a pretreatment browse survey in late March and early April 2009 (job 2a) and visited the proposed burn sites in May 2009 and 2010 with a fire specialist (R. Schmoll). The burn prescription (required weather conditions and fuel moisture to ignite the fire for given objectives) was met periodically during 15 May to 15 June 2009, but the burn did not occur because fire specialists or equipment were not available on some dates (tasked to wildland fire suppression), military airspace was restricted other dates, or another research prescribed burn of higher priority occurred. A similar situation occurred in 2010, when the burn did not occur because fire specialists or equipment were not available during feasible weather conditions.

Preliminary Conclusions and Recommendations

OBJECTIVE 1: Winter habitat occupancy by moose

Until the LANDFIRE classification is modified to improve accuracy for woody vegetation, it will not be useful for evaluating habitat capability with respect to winter forage of moose or population objectives for intensive management in specified areas. When a better type classification is available, further effort should be put into validating presence of browse species and browse production to better index potential value as winter range for moose.

Our preliminary assessment from the scalar survey of snow depth across the Interior is that high variability at the scale, likely pertinent to habitat use by moose (<30 m), would make sampling intensity infeasible for predictive purposes. A biometrician will critique our analysis and interpretation. The frequency of winters with a critical snow depth that reduces calf survival (e.g., 80 cm in Unit 19D during winter 2004–2005) may be a more useful parameter to managers than measuring the snow depth distribution at a broader landscape scale. We will now focus on improving the snow gauge system for Units 19A, 19D, and 21E, which have been identified as deep snow areas for Interior Alaska. On the basis of our data on winter moose distribution from job 1c and concurrent project 1.69 (Paragi and Kellie 2010), we will establish snow depth monitoring sites in Unit 21E during summer 2011. We will also examine the practicality of sonic transducers for automated recording of snow depth in remote locations on a set time schedule (e.g., once daily). Data retrieval from transducers may be by direct download (e.g., during annual maintenance visit) or by satellite telemetry. We will also discuss with the McGrath area management staff the potential for including residents of remote areas as cooperators to obtain snow depth in Units 19A, 19D, and 21E. When snow stakes become established in Unit 21E, we recommend that the last flight of the winter to read snow measurement stakes should include a search of the wintering area for parturient cows to determine level of winter mortality in calves. This effort may be aided by VHF telemetry of radiomarked cows in the wintering area (Paragi and Kellie 2010).

Modeling the physiological effects of deep snow on moose is complex because of high environmental variability and individual maternal status of females (calf presence) that influence nutritional condition (e.g., twinning rate). Attempting to link environmental factors to fitness in a model would be a tradeoff of requiring site-specific information in a cohort study to validate relationships for a study area over a range of winter snow depths. Understanding the functional response to snow at a defined depth threshold (e.g., when calf mortality increases significantly) and how frequently this depth occurs in different areas may be more practical for widespread application to moose management in a broad geographic region, such as Interior Alaska. The recent study conducted in Unit 19D provides us with a functional measurement of the effects of a deep snow winter on a moose population (Keech et al., ADF&G unpublished manuscript). We hope to combine this information with a demonstrated change in habitat selection during the same winter to provide a link between snow depth, habitat selection, and associated mortality.

Depending on results of the habitat selection analysis in Unit 19D, we may examine its application to predict moose location relative to habitat type and snow depth in a larger landscape. We have GPS locations of unmarked moose obtained during February 2000 and 2005 surveys in both Units 19A and 21E that could be used for this purpose.

OBJECTIVE 2: Relationship between browse removal and moose twinning rate

Browse data collected in 2010 from permanent plots established in a recent Unit 20A burn will be analyzed. A data entry screen for the permanent plot format will be created in Microsoft Access and modifications of the R software (R Development Core Team 2008) done to calculate browse production and removal for the data collected in the 2001 burn in Unit 20A. The permanent plot method will be further evaluated near Fairbanks for efficiency and power to detect change in biomass before further deployment by helicopter in 2011 for another recent burn in Unit 20A. Browse surveys are being considered for 2011 in the Fairbanks Management Area of Unit 20B to monitor habitat change in an area with a relatively high moose density near an urban center and in Unit 20C to evaluate habitat condition for the first time in an area being proposed for intensive management with moose at relatively low density.

The interagency telemetry project on moose in Units 24A and 24B was slated to end in March 2011, but the study has been extended at least 2 years and battery life may persist 3 years. With the difficulty of finding an adequate random sample of unmarked parturient cows to estimate twinning rate in the low-density moose population in Unit 24B, we will continue twinning surveys aided by telemetry in this remote area for the duration of project 5.20. This survey is a priority because in late winter 2007 we had estimated a browse biomass removal of 5.4% (95% CI: 2.3–7.9%) in Unit 24B, the lowest recorded to date in the Interior (Paragi et al. 2008:Table 4). An attempt in spring 2007 to conduct a twinning survey in Unit 24B using only randomly observed parturient cows was unsuccessful because of low sample size (unpublished).

OBJECTIVE 3: Spatial data archive

The postdoctoral student (Dr. J. Schmidt, UAF) has completed her project, so we will draft a short document explaining the organization of the existing archive. The archive is a defined starting point for identifying which data from the region are missing. Information from area offices can be incorporated more fully into the archive to reduce risk of historic data loss from fire, flood, or other accident.

OBJECTIVE 4: Reporting

We anticipate submitting manuscripts to peer-reviewed journals on the scalar analysis of snow depth (job 1b), winter habitat selection of moose relative to snow depth (job 1c), and changes in browse removal rate with change in moose density (job 2a). We anticipate revising Table 1 if LANDFIRE classification is revised and validated (job 1a) and drafting technical reports on long-term monitoring of snow depth (job 1b), the moose data archive (job 3a), and potentially the vegetative response to the prescribed burn if it occurs (job 5a).

OBJECTIVE 5: Prescribed fire enhancement of subalpine moose browse

The prescribed burn will be attempted in spring 2011. Depending on vegetative response in the first growing season, this may allow a postfire browse survey in March 2012. If the fire does not occur in spring 2011, this job will be discontinued as project 5.20 and is scheduled to end in June 2012.

Additional Federal Aid-funded Work Not Described Above

T. Paragi worked on other studies or projects associated with job 2a. In March and April 2009 Paragi and T. Seaton (Wildlife Biologist, ADF&G, Fairbanks) advised students in the UAF Student Chapter of *The Wildlife Society* who conducted a pilot browse survey in the Fairbanks Management Area of Unit 20B (incomplete due to low sample size). In April 2009 Paragi assisted with a moose browse survey in Unit 26A (Region V; operations funded by a Capital Improvement Project from the Alaska State Legislature), which is described earlier in this report. He also conducted a preliminary analysis of browse data collected during 2006 and 2007 in which ADF&G was a cooperator through a former employee (S. Szepanski, deceased) whose doctoral dissertation on moose nutritional condition was never completed. In May 2010 as part of fieldwork in job 5a, Paragi gathered samples from the proposed subalpine burn sites for a UAF graduate student studying the role of fungal mycorrhizae on shrub and tree roots in postfire reestablishment of woody vegetation near treeline.

K. Kellie collaborated with J. Schmidt on projects associated with job 3a. They conducted a spatial analysis of moose harvest as a function of moose density, fire history, and distance from community and transportation corridor (e.g., road or river), and a manuscript is being finalized for submission to a peer-reviewed journal. Kellie and Schmidt also collaborated on an analysis of trends in the field transportation used to hunt moose statewide over time and space among different types of hunts and hunters, and a manuscript is in preparation.

Acknowledgments

Much of this work was supported by funds from Federal Aid in Wildlife Restoration. A Capital Improvement Project from the Alaska State Legislature funded part of the prescribed burn and browse surveys. Cooperators on the project include Jennifer Schmidt (University of Alaska Fairbanks) and Matthew Stum (U.S. Army, Cold Regions Research and Engineering Laboratory). We thank several ADF&G employees and volunteers for help, particularly M. Keech for sharing moose and habitat data from Unit 19D, T. Seaton for collaboration in browse surveys, and L. Parrett for collaboration on browse surveys and his description of sampling in the earlier UAF browse surveys based on his participation in those surveys. T. Cambier of Chena River Aviation and C. Maurer and M. Terwilliger of Quicksilver Aviation safely and efficiently piloted helicopters. D. Haggstrom of ADF&G compiled historic electronic records of moose surveys, wrote much of the subalpine burn plan, and obtained burn permits. R. Schmoll of the Division of Forestry wrote the burn prescription and conducted preparatory field operations with the prescribed burn. B. Taras (ADF&G) and J. Ver Hoef (National Marine Fisheries Service) provided statistical advice on modeling habitat selection. R. McClure (NRCS, Anchorage) provided snow course data and design specifications for building snow gauges. G. Liston (Colorado State University) and A. Wagner (U.S. Army, Cold Regions Research and Engineering Laboratory, Fairbanks) provided help in accessing the North American Regional Reanalysis snow data.

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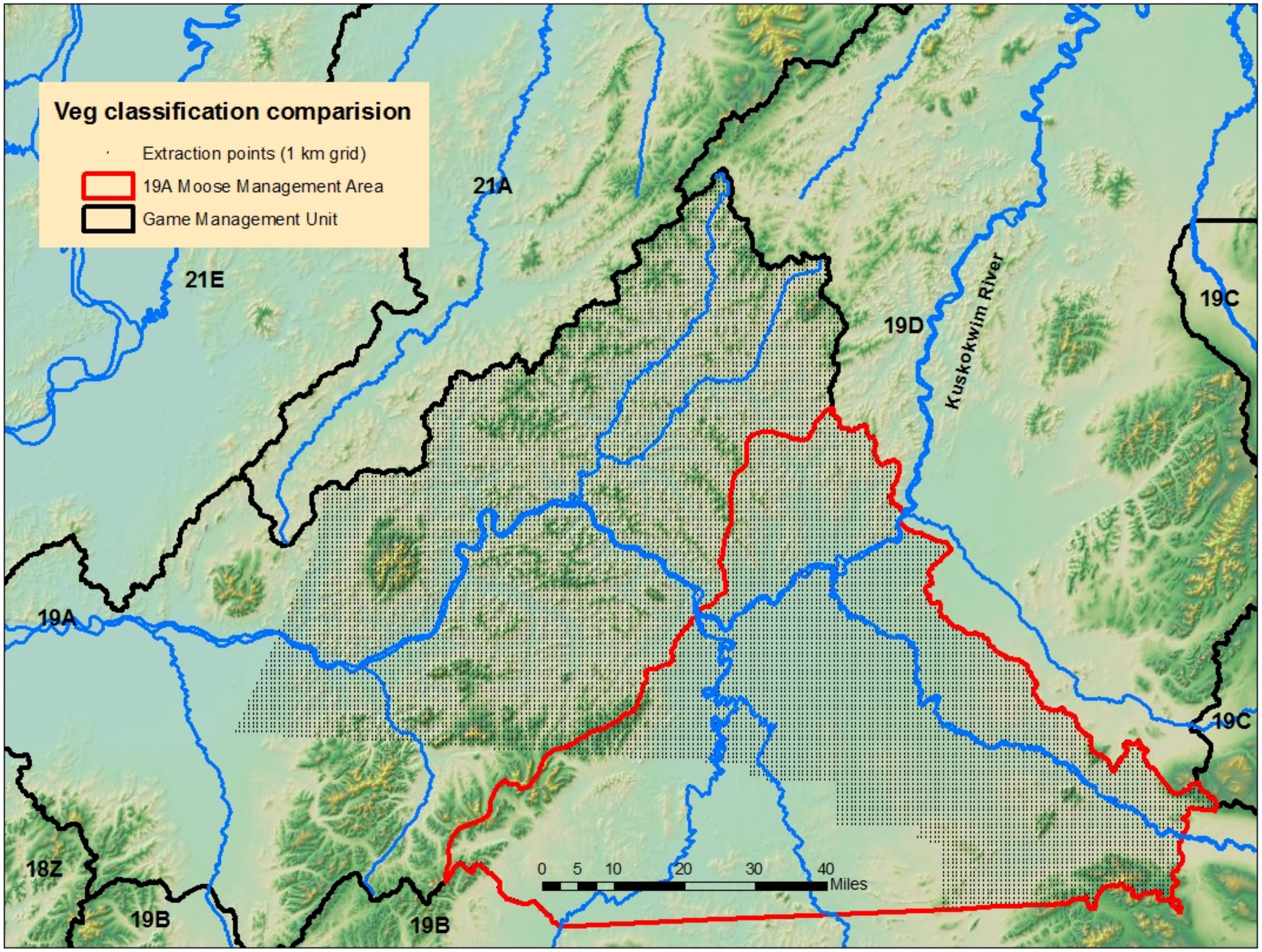


Figure 1. Location of extraction points in the area of overlap between LANDFIRE and Ducks Unlimited cover classifications for comparison of potential browse cover types in Game Management Unit 19A, western Interior Alaska.

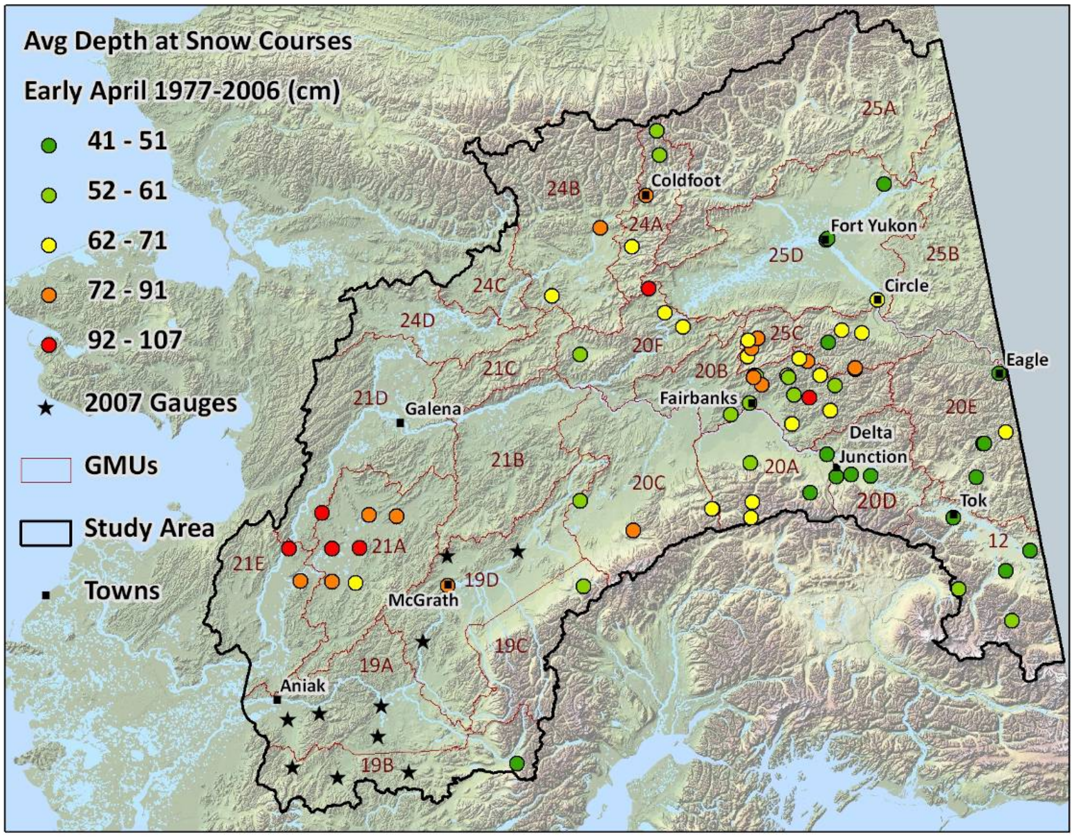


Figure 2. Average early April snow depth across Interior Alaska during 1977–2006 for the National Resource Conservation Service and National Weather Service snow courses where at least 3 years of data were available. Game management units (GMU) are shown for reference. Stars indicate the location of 10 snow stakes deployed in southwestern Interior by the Alaska Department of Fish and Game in summer 2007 for reading snow depth by fixed-wing aircraft.

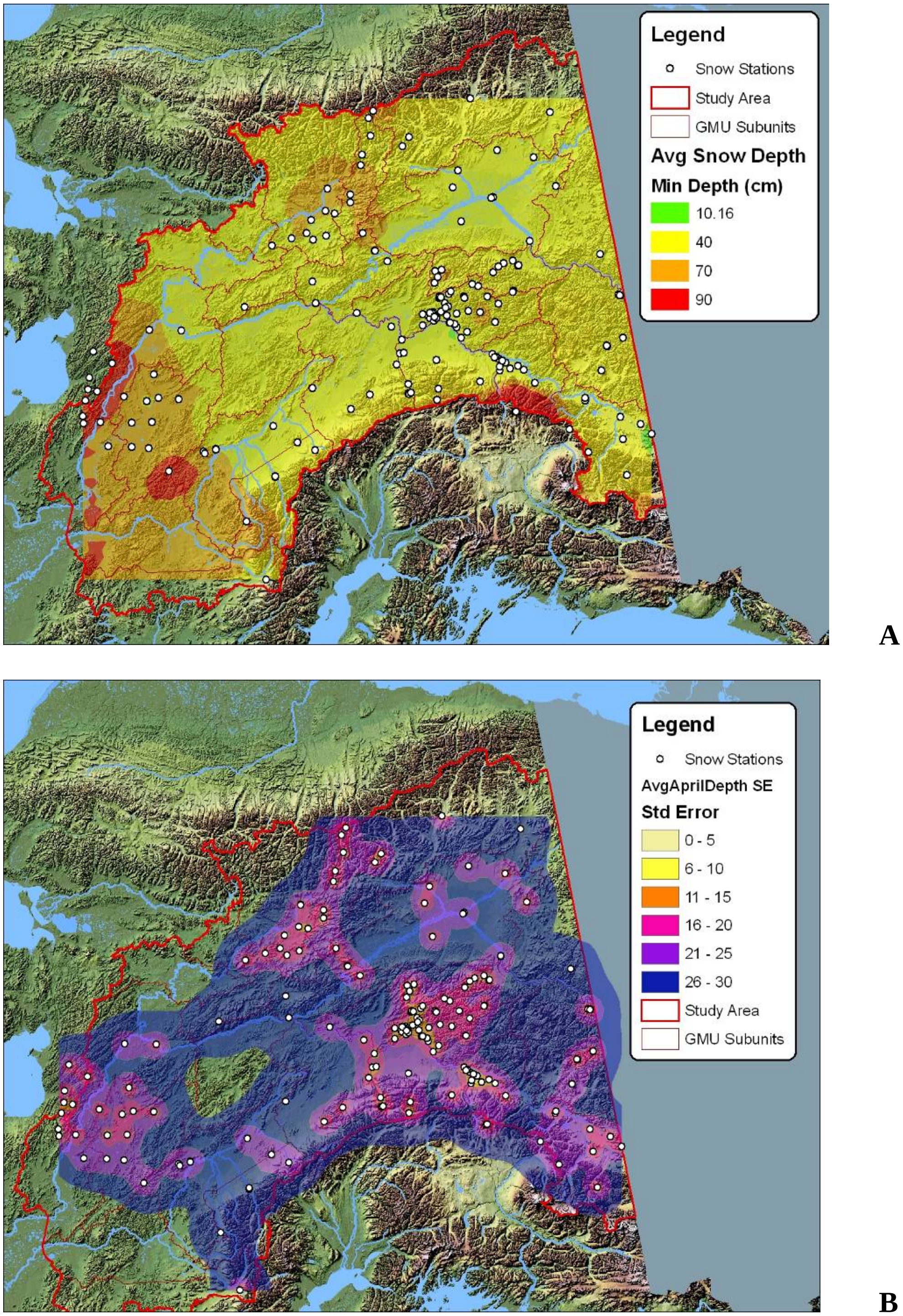


Figure 3. Kriged model of snow depth (A) and the standard error associated with the kriged surface (B) for average snow depth in early April across Interior Alaska during 1977–2006 for National Resource Conservation Service and National Weather Service snow courses where at least 3 years of data were available. Note that many areas have a large standard error, indicating a high level of uncertainty in prediction, and that deep snow levels known to occur along the south side of the Brooks Range were not well predicted.

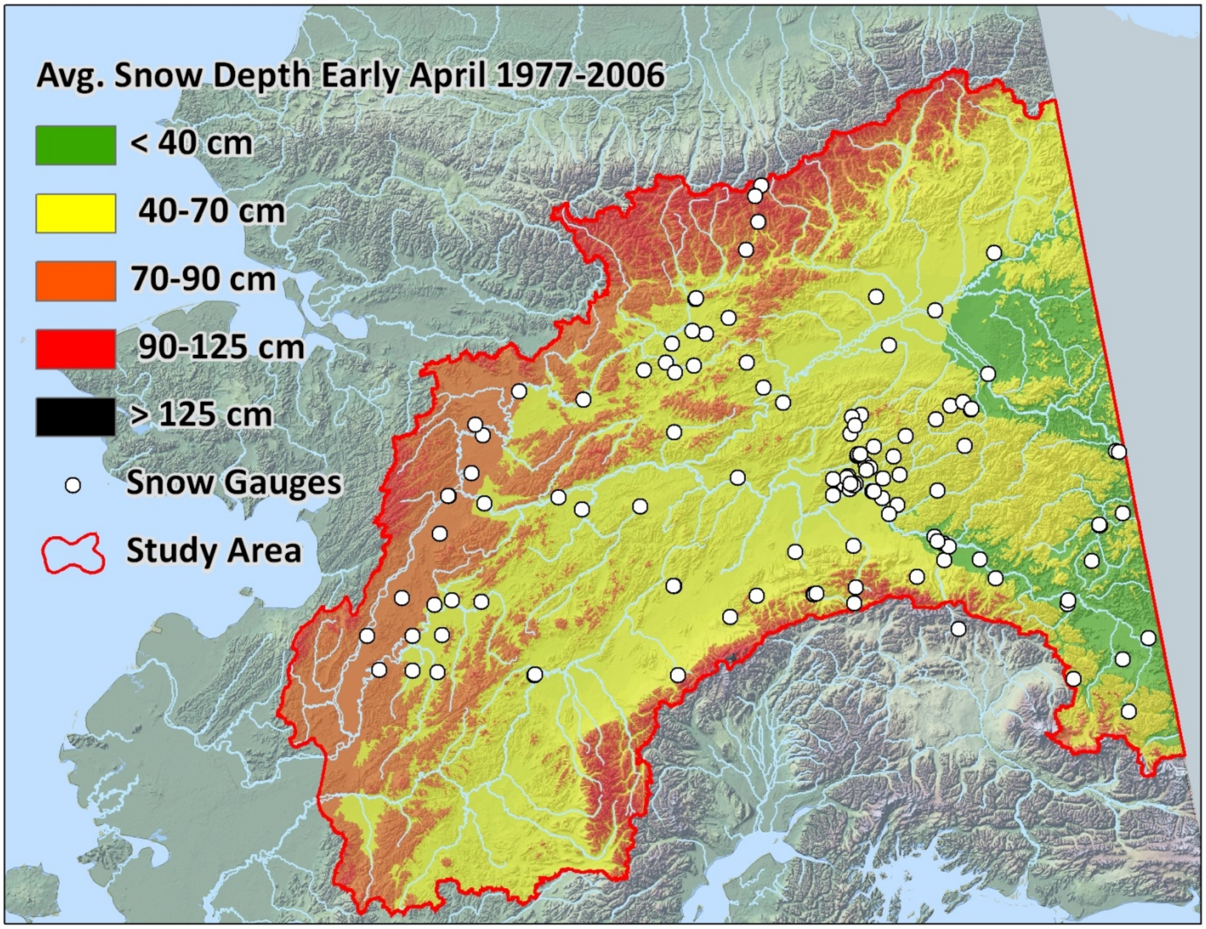


Figure 4. Multivariate regression model of average snow depth in early April during 1977–2006 across the study area. Areas of deep snow in the southwest portion of the study area were poorly predicted compared with empirical data.

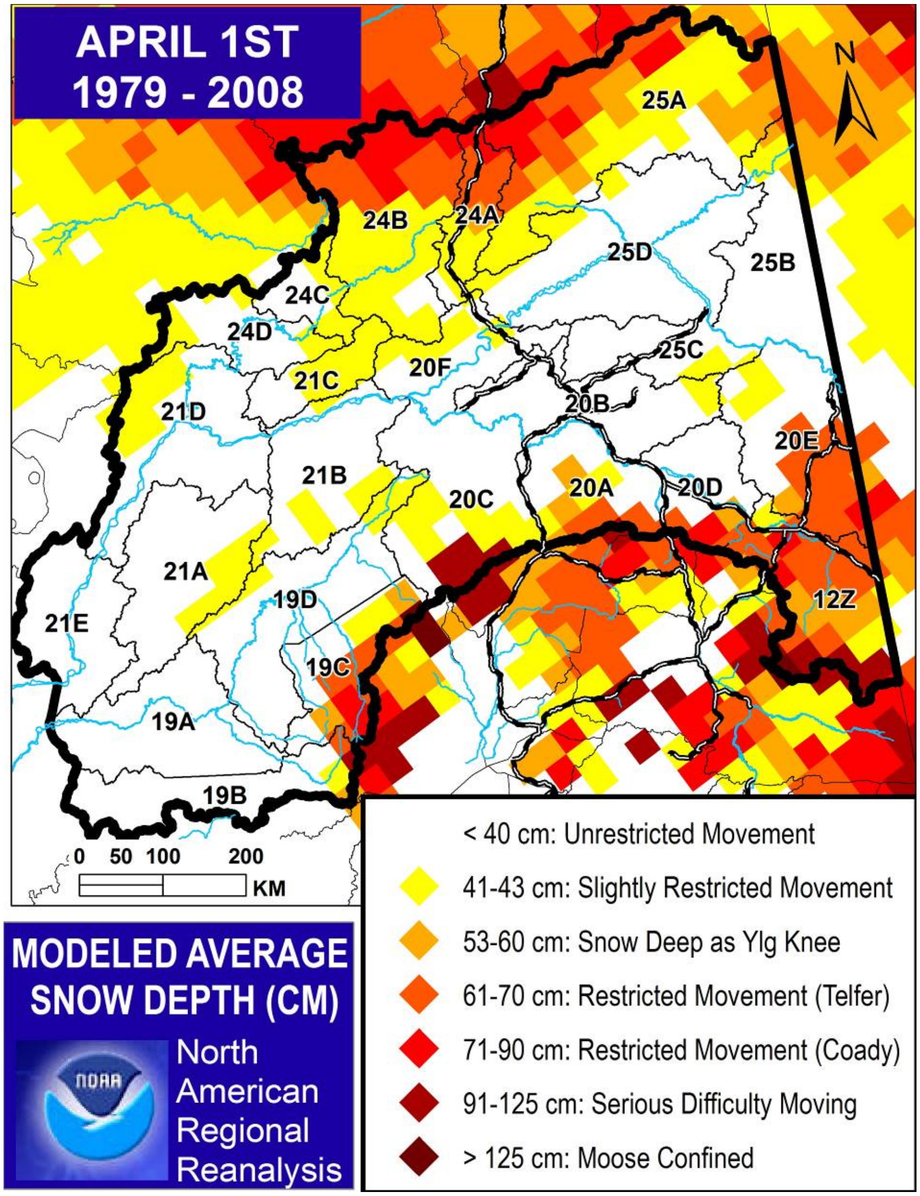


Figure 5. The North American Regional Reanalysis modeled average snow depth for Interior Alaska in early April during 1979–2008, predicted on a 32-km grid. Boundaries of game management units are shown for reference. This model failed to predict snowfall depth of ecological importance to moose (>16 in [40 cm]) throughout much of the Interior.

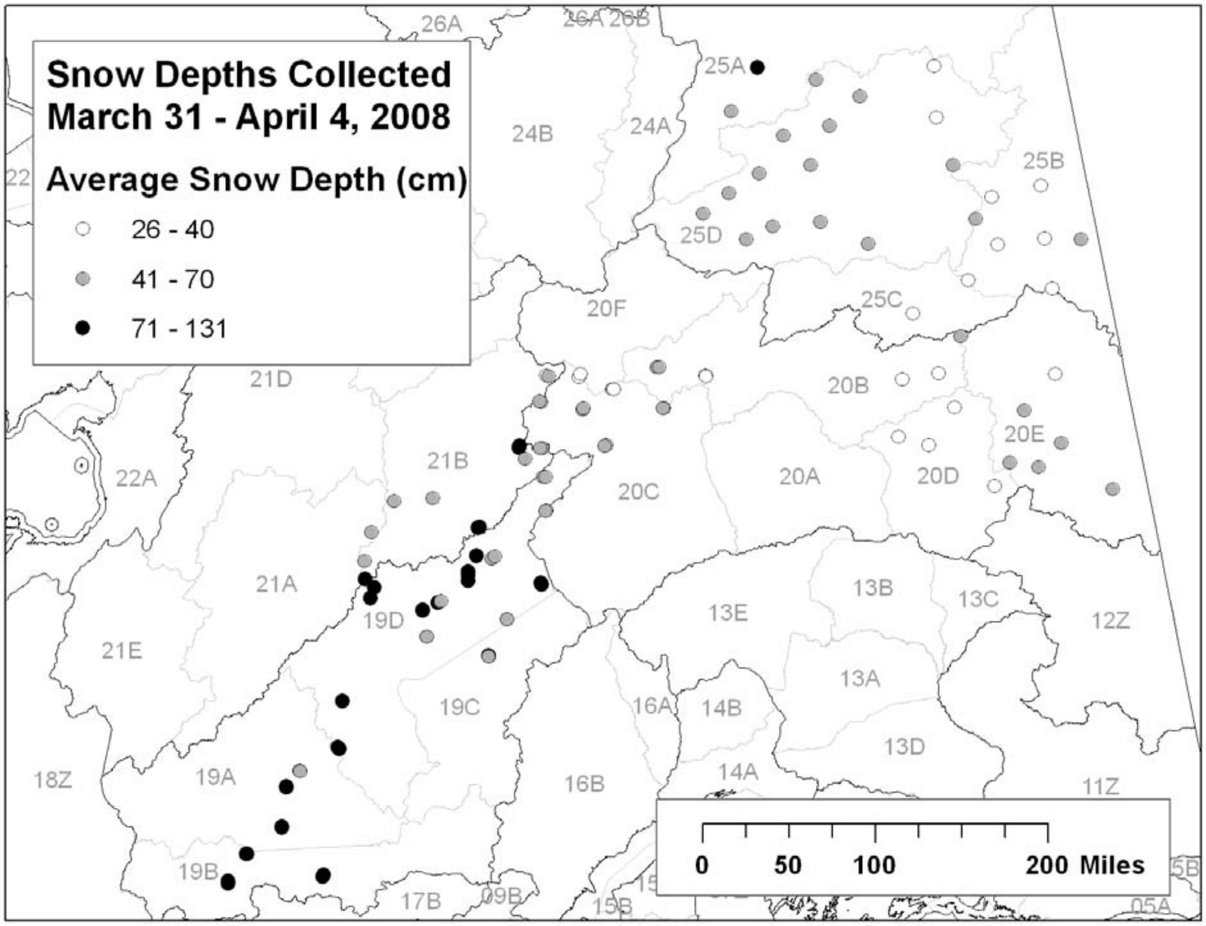


Figure 6. Sites and snow depths recorded during scalar sampling work in early April 2008. Some sites are hidden because the presentation scale results in spatial overlap. Boundaries of game management units are shown for reference.

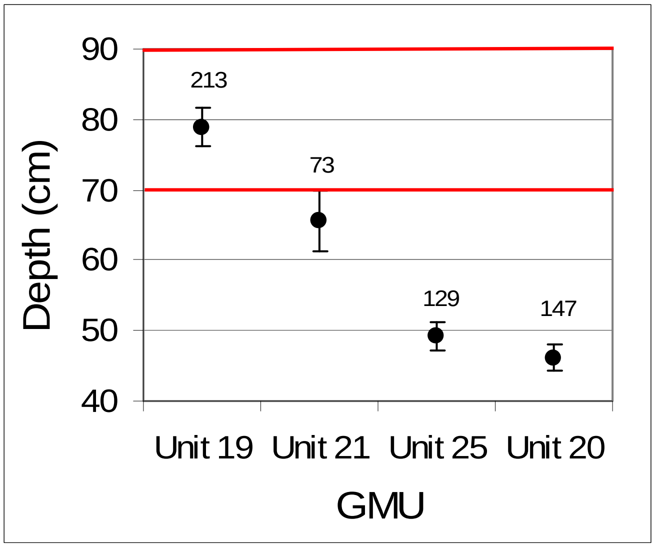


Figure 7. Mean snow depth and 95% CI by game management unit (GMU) sampled in early April 2008. Sample sizes are listed above confidence intervals. Depths are indicated in red where moose movements are limited and severely restricted (70 and 90 cm, respectively; Coady 1974). This is a preliminary plot; no correction has been included for correlation among depths from the same microsite, site, or paired sample.

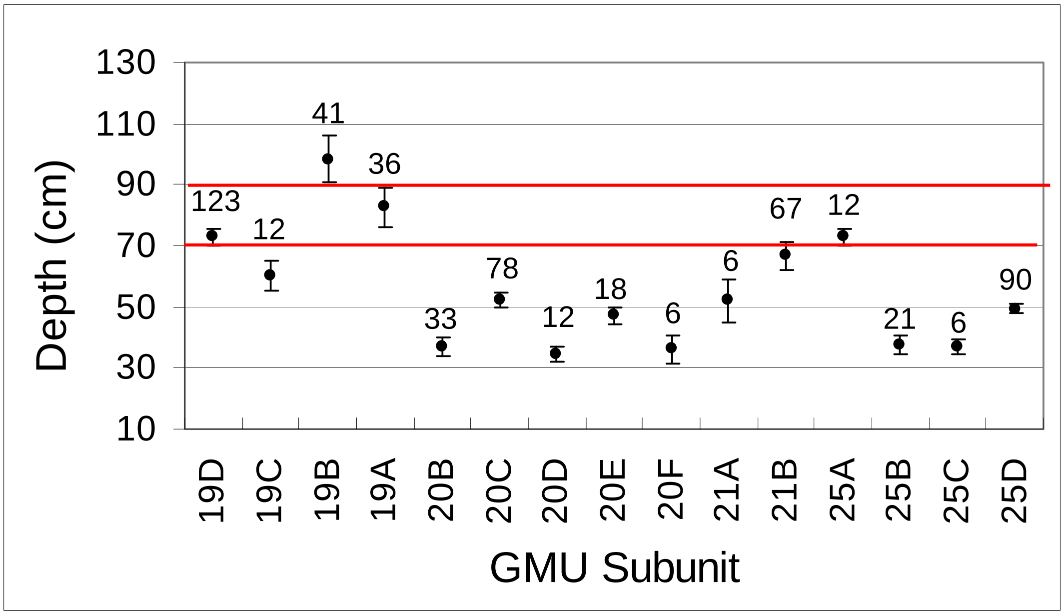


Figure 8. Mean snow depth and 95% CI for 15 game management units (GMU) sampled in early April 2008. Sample sizes are listed above data points. Subunits 19C, 20D, 20F, 21A, 25A and 25C are represented by only 1–2 landing spots. Depths are indicated in red where moose movement is limited and severely restricted (28 in [70 cm] and 36 in [90 cm], respectively; Coady 1974).

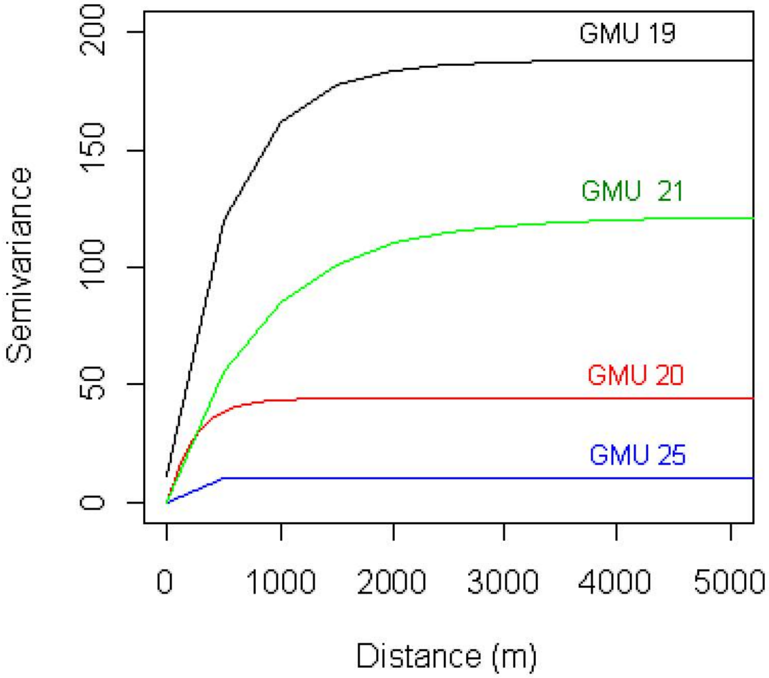


Figure 9. Fitted variograms showing spatial correlation of snow depth in April 2008 at multiple scales, binned separately by game management unit (GMU) across Interior Alaska.

Table 1. Correspondence between LANDFIRE (LF) and Ducks Unlimited (DU) classifications for broad type classes of tall shrub (TS), open forest (OP), and closed forest (CL) that potentially contain woody browse species used for winter range by moose in Unit 19A, western Interior Alaska. The correlation matrix shows the proportion of sample points where class types correspond between the classifications. Matrices of change within type class from one classification to another illustrate how points in one broad type are represented in the other classification. See text for details.

A) Extracted samples on 1-km spacing (*n*)

Ducks	LANDFIRE				
Unlimited	TS	OP	CL	Other	Total
TS	409	194	170	292	1,065
OP	2,096	3,891	1,597	1,769	9,353
CL	223	485	439	143	1,290
Other	1,477	1,120	519	1,366	4,482
Total	4,205	5,690	2,725	3,570	16,190

B) Correlation matrix 1 km samples (proportions)

Ducks	LANDFIRE				
Unlimited	TS	OP	CL	Other	Total
TS	0.03	0.01	0.01	0.02	0.07
OP	0.13	0.24	0.10	0.11	0.58
CL	0.01	0.03	0.03	0.01	0.08
Other	0.09	0.07	0.03	0.08	0.28
Total	0.26	0.35	0.17	0.22	1.00

C) "change" matrix (LF to DU) 1 km samples (probability)

Ducks	LANDFIRE			
Unlimited	TS	OP	CL	Other
TS	0.10	0.03	0.06	0.08
OP	0.50	0.69	0.58	0.50
CL	0.05	0.09	0.16	0.04
Other	0.35	0.20	0.19	0.38

D) "change" matrix (DU to LF) 1 km samples (probability)

Ducks	LANDFIRE			
Unlimited	TS	OP	CL	Other
TS	0.36	0.17	0.15	0.26
OP	0.22	0.41	0.17	0.19
CL	0.17	0.37	0.34	0.11
Other	0.33	0.25	0.11	0.30

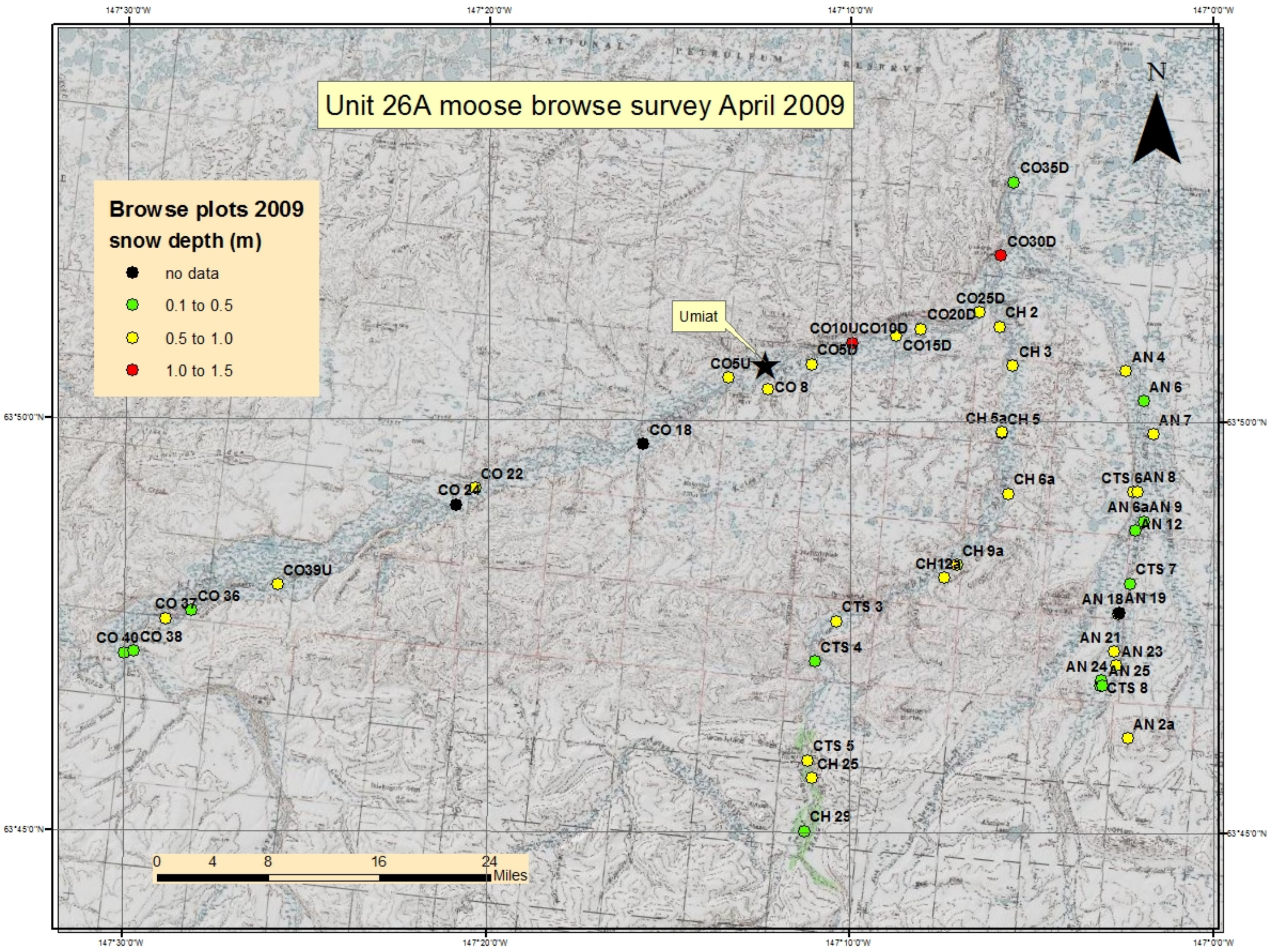
Table 2. Distribution of cover types for game management units with a positive determination for moose under intensive management in Interior Alaska. Types are national vegetation system classes in LANDFIRE (2009 release) created by supervised classification based on 2001 Landsat TM imagery without direct validation. Winter range is types potentially containing deciduous woody browse species >0.5 m tall, although snow depth may limit availability to moose in some areas. Summer range is winter range plus all other vegetated types, whereas total game management unit size includes summer range plus nonvegetated area. As of summer 2010, vegetated cover types have not been validated for accuracy for the entire LANDFIRE classification, thus only represent potential winter or summer range. No further inference on habitat quality or suitability of vegetation is presently warranted.

	Percentage of area in unit							Area (mi^2)		
Unit	Closed forest	Open forest	Tall shrub	Winter range	Other vegetated	Summer range	Non-vegetated	Winter range	Summer range	Total unit
12	25.4	18.1	8.4	51.9	13.1	65.0	35.0	5,250	6,572	10,107
19A	24.2	29.9	23.2	77.2	18.2	95.4	4.6	7,848	9,697	10,160
19B	16.2	25.7	29.0	70.9	15.3	86.3	13.7	5,533	6,730	7,801
19D	29.8	46.7	12.5	89.0	8.3	97.3	2.7	10,880	11,892	12,221
20A	20.3	29.6	13.4	63.3	15.8	79.1	20.9	4,353	5,441	6,878
20B	52.4	24.9	7.0	84.2	11.6	95.8	4.2	7,754	8,821	9,206
20C	25.5	33.0	11.1	69.6	18.8	88.4	11.6	8,408	10,676	12,078
20D	28.3	21.3	17.5	67.2	15.1	82.2	17.8	3,833	4,694	5,708
20E	42.0	23.2	17.8	83.0	12.9	95.8	4.2	8,938	10,323	10,771
21B	37.7	43.9	7.7	89.2	7.4	96.7	3.3	8,407	9,107	9,421
21D	38.3	32.5	15.6	86.5	9.4	95.9	4.1	10,582	11,736	12,238
21E	34.4	20.6	20.6	75.6	19.9	95.5	4.5	6,113	7,725	8,088
24A	23.1	12.4	18.7	54.2	35.2	89.4	10.6	2,275	3,751	4,195
24B	27.9	18.2	14.4	60.6	27.7	88.3	11.7	8,285	12,075	13,681
24C	45.2	29.3	13.7	88.3	9.0	97.2	2.8	2,723	3,000	3,085
24D	29.6	26.2	26.6	82.4	12.3	94.6	5.4	4,458	5,123	5,413
25D	54.5	15.6	10.3	80.3	14.3	94.7	5.3	14,353	16,911	17,864

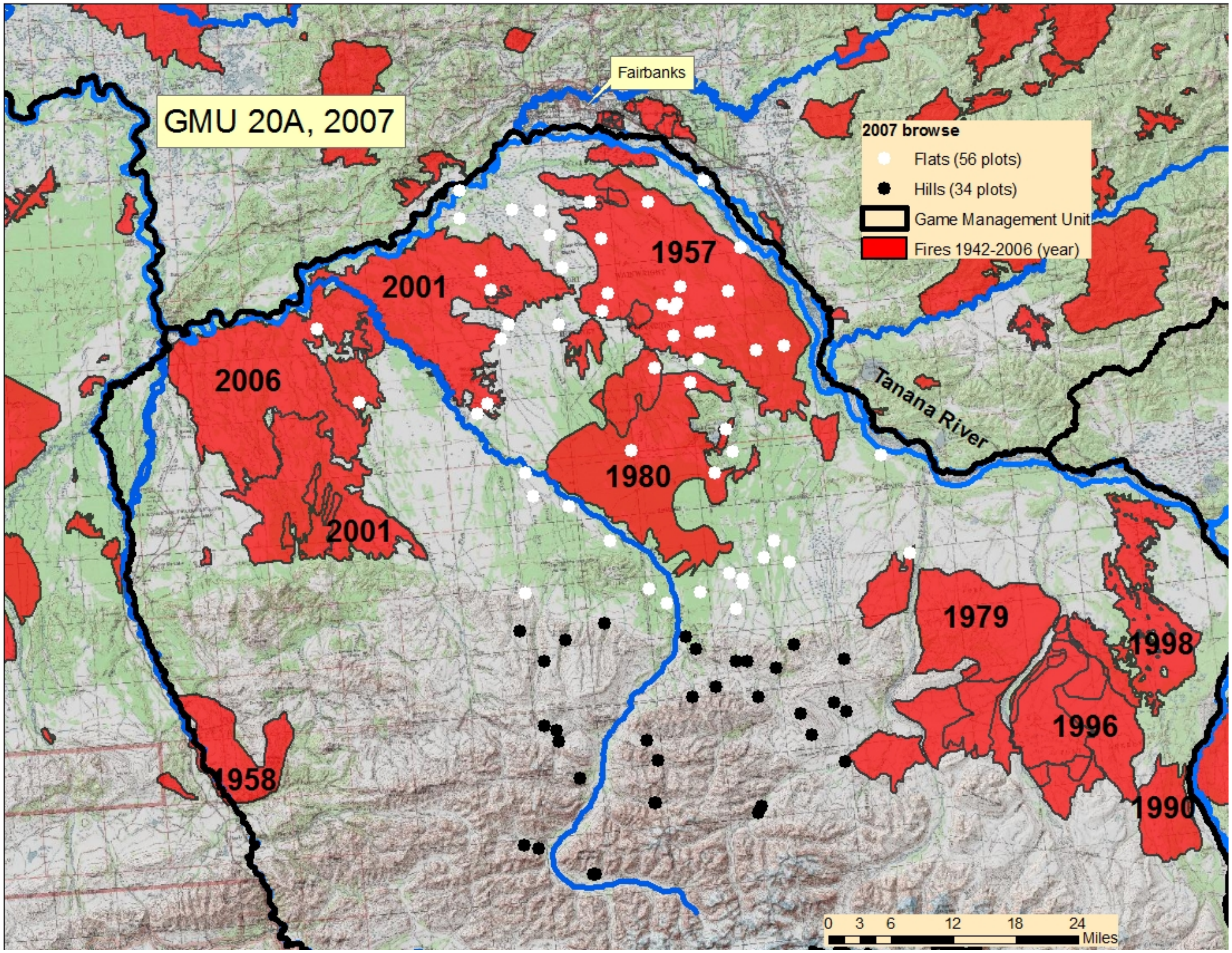
Table 3. Proportion of parturient cow moose with twin calves in Units 24A and 24B, 2008–2010.

Unit	Year	Total radiocollared cow-calf groups	Total random cow-calf groups	Total cow-calf groups (*n*)	Total collared cows w/twins	Total random cows w/twins	Total cows w/twins	Twinning rate
24A	2008	9	15	24	2	6	8	0.33
24B	2008	17	8	25	7	2	9	0.36
Both	2008	26	23	49	9	8	17	0.35
24A	2009	14	16	30	5	9	14	0.47
24B	2009	12	5	17	9	5	14	0.82
Both	2009	26	21	47	14	14	28	0.60
24A	2010	15	5	20	6	6	12	0.60
24B	2010	12	4	16	8	1	9	0.56
Both	2010	27	9	36	14	7	21	0.58

APPENDIX A. Location of browse plots and associated snow depth along the Anaktuvuk (AN), Chandler (CH), and Colville (CO) rivers in Unit 26A during 13–15 April 2009. See text for description of other plot nomenclature.



APPENDIX B. Location of browse plots sampled in Game Management Unit 20A during 16–21 March 2007.



APPENDIX C. Location of browse plots sampled in Game Management Unit 21D during 16–27 March 2006. Some opportunistic plots are hidden because the presentation scale results in spatial overlap.