FEDERAL AID FINAL RESEARCH PERFORMANCE REPORT

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
PO BOX 115526
Juneau, **AK 99811-5526**

PROJECT TITLE: Habitat evaluation techniques for moose management in Interior Alaska

PRINCIPAL INVESTIGATORS: Thomas F. Paragi and Kalin A. Kellie Seaton, ADF&G

COOPERATORS: Ronald Barry (Ronald Barry Consulting); Jennifer Schmidt (University of Alaska Fairbanks)

FEDERAL AID GRANT PROGRAM: Wildlife Restoration

GRANT AND SEGMENT NO.: W-33-6 through W-33-11

PROJECT NO.: 5.20

WORK LOCATION: Interior Alaska (Region III)

STATE: Alaska

PERIOD: 1 July 2007–30 June 2013

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

Intensive management (IM) of moose (*Alces alces*) populations to produce a high yield for consumptive use by humans was defined and mandated in a 1994 Alaska Statute (AS 16.05.255[e]). The statute listed predator control and habitat enhancement as methods for enhancing sustained yield of caribou, deer, and moose. The statute also required establishment of population objectives by game management unit (GMU) and sustainable yield calculated from those objectives. In March 1998 the Alaska Board of Game determined which GMUs were subject to IM 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) after agency and public input. The Division of Wildlife Conservation (DWC) provided approximations for the amount of moose habitat in a few GMUs, but differences in the quality of moose habitat within and among GMUs were not addressed. Consequently, public input on population objectives was often based on extrapolations of moose density found in relatively small surveyed areas to larger areas that were not surveyed, without adequate consideration of differences in habitat capability (forage production, snow constraints on habitat use or winter movements) or spatial variation in natural mortality and harvest access.

Habitat enhancement to increase availability of winter browse for moose requires targeting treatment sites on known winter range. High moose density in GMU 20A had produced declining productivity for over a decade (Boertje et al. 2007) prior to instituting liberal antlerless harvest in 2004. DWC 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. With continued high density of moose on subalpine winter range in the Alaska Range foothills, experimentation with aerial ignition to conduct a spring burn in subalpine habitats is warranted. Although vegetative 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 population composition have been estimated using aerial surveys in defined geographic areas since the late 1970s, those attributes have not been linked to habitat capability. Similarly, harvest reports for moose and their predators (wolves [*Canis lupus*] and brown bears [*Ursus arctos*] region-wide, black bears [*Ursus americanus*] in areas where hide sealing was required) are also coded to geographic areas (uniform coding unit or UCU). Data from past moose surveys and wildlife harvests can be spatially linked to habitat capabilities and associated socioeconomic variables (e.g., distance to communities). This linkage may aid wildlife managers in formulating achievable objectives for moose and predator populations and harvests.

II. REVIEW OF PRIOR RESEARCH AND STUDIES IN PROGRESS ON THE PROBLEM OR NEED

It is difficult to estimate the capability of habitats to support moose because of their physiological requirements and inherent environmental variability. We must begin by spatially defining attributes of winter browse production and its potential access by moose. A consistent definition will provide a context for relating habitat parameters to moose reproduction and survival so managers can recommend population objectives. To do so, we must quantify browse production by vegetative cover type and assess the effect of snow cover on forage availability to moose. Snow density interacts with depth to impede movements by moose (Coady 1974), but we focus on snow depth because it is a characteristic that is possible to assess in remote areas on a large geographic scale by observations from fixed-wing aircraft. Snow depth may be particularly important in the western Interior, where it commonly exceeds 90 cm in early April (National Weather Service data, 1975–2005). Snow this deep has been shown to cause high energetic expenditure in adult moose (Coady 1974). Traditionally, biologists fly moose surveys in early winter prior to antler drop to obtain estimates of sex and age composition. However, to understand the interaction between moose and the landscape, it is important to observe moose throughout the winter to capture variation in snow depth and its effects on moose distribution relative to forage. In other work, biologists have sought to relate snow depth to observed changes in moose population parameters in boreal Alaska by periodically measuring snow depth from one or a few sites within their study areas (Gasaway et al. 1983, Ballard et al. 1991, Keech et al. 2011).

Decisions on IM objectives for moose ideally begin with an assessment of whether nutritional status is limiting the potential for population growth. Boertje et al. (2007) discussed the value of twinning rate, proportional browse removal, and other indices of nutritional status in moose for gauging population level relative to habitat capability in

Alaska. Recent data from 8 study areas in boreal forest where IM is underway or proposed describe how proportional removal of browse production was inversely related to twinning rate (Seaton 2011). To address habitat capability in other GMUs, similar browse data should be collected to assess whether the potential exists for areas to support larger moose populations. By conducting browse and twinning survey before and after management treatments (e.g., predator control, antlerless harvest), managers will be able to assess moose forage and nutritional condition relative to area IM objectives and, ultimately, the effectiveness of treatments in achieving intended outcomes.

III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND TO PROBLEM OR NEED

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 1A: Define the proportion of each GMU in Region III that contains vegetated cover for year-round moose habitat, and define the proportion of each GMU that contains browse-producing species for winter range.

The LANDFIRE program (http://landfire.cr.usgs.gov/, emphasis on terrestrial fuels) created a seamless vegetative classification across Alaska that has allowed us an opportunity to assess its utility for defining moose forage by GMU. In a portion of GMU 19A, we compared Existing Vegetation Types in LANDFIRE based on 2001 Landsat imagery against a classification of 1989 Landsat data by Ducks Unlimited for broad vegetation types (tall shrub, open forest, closed forest) germane to moose browse assessment. (The Ducks Unlimited Stony MOA classification was validated 90% overall accuracy at 5% precision with an emphasis on wetlands; the validation report can be found at http://www.blm.gov/mwg-internal/de5fs23hu73ds/progress?id=5up1kJ6GTx.) We found the aggregate proportion of these 3 types was similar between the classifications (72% vs. 78%, respectively) but were differed greatly for each type (e.g., tall shrub was 26% vs. 7%, respectively; Paragi and Kellie 2011). Although natural disturbance from fire and fluvial action and associated vegetative succession will affect temporal comparisons, these dramatic differences raised questions on the accuracy of LANDFIRE as a tool for assessing browse potential.

The LANDFIRE classification was subsequently found to have an accuracy of 30% even after vegetation types were combined for a single boreal forest site evaluated (Boucher et al. 2009), including confusion of low and tall shrub with dwarf shrub and coniferous forest with shrub. Despite poor accuracy for categorizing vegetation types in the initial LANDFIRE release, scientists involved in the Alaska accuracy assessment found 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 GMUs in the Interior. Many tall shrub classes contain little or no moose browse (e.g., dominated by dwarf birch or alder), so further inference from LANDFIRE for winter range is presently not possible until a revised classification is validated relative to cover types known to contain browse species.

JOB/ACTIVITY 1B: Conduct sampling of snow accumulation at the landscape scale to predict snow depth.

Our primary intent was to define severe winters for the context of understanding response in moose population parameters at the GMU or study area scale. We sought to verify the utility of a quantitative modeling approach from a single year of data in predicting snow depth at a given point exceeding 70 cm or 90 cm (Coady 1974). We measured snow depth at 580 sites across Interior Alaska using fixed-wing aircraft and a helicopter during 31 March–4 April 2008. Fitted variograms showed a marked decline in spatial correlation of snow depths at relatively small distances (<5 km) (Paragi and Kellie 2011:32). Thus, spatial modeling based solely on observed snow depths would require an impractically fine observation grid to predict snow surfaces for large areas (e.g., GMUs). We contracted a biometrician (R. Barry) to construct a spatial model for predicting depth based on sample location (latitude and longitude), vegetation type (tall shrub, open forest, closed forest, tundra, etc.), and elevation. Rather than producing a predictive surface of snow depth, the goal of this model is to determine the level of observation needed to verify when snow is deep enough (>70 cm) to impede moose movement within a GMU. We continue to work with an ADF&G biometrician (M. Ellis) to refine and apply this model using subsequent information from snow gauges.

Snow is deeper and more variable in the western portion of Interior Alaska (GMUs 19 and 21; Paragi and Kellie 2011:26), yet few snow observations were available for this region. To increase the number of snow depth observations in the western portion of the Interior, we installed 10 snow gauges in GMU 21E in August 2011 in collaboration with project 1.69 (moose movements). These complemented 10 gauges installed in adjacent GMUs 19A, 19B, and 19D in 2007 (project 5.10) and 9 gauges maintained by the Innoko National Wildlife Refuge in GMUs 21A and 21E. McGrath area staff observed snow depth at state-installed gauges from fixed-wing aircraft on or about the first day of winter months (December–April). We will use these data to characterize winter severity for moose with attention to appropriate limits to spatial inference on depth and its precision.

JOB/ACTIVITY 1C: Estimate winter habitat use by moose with respect to snow depth.

This job began with the concept of quantifying spatial location of moose trails in snow of different depth categories (low, moderate, high) to infer extent of change in habitat use. We considered sampling trails during moose abundance surveys conducted by managers. We chose GMU 19A as the study site because modeling of snow data from recent decades suggests it frequently experiences snow >70 cm by late winter (Paragi and Kellie 2011:26), which influences habitat selection by moose (Coady 1974). After initial evaluation of the concept in March 2011 moose survey in GMU 19A (amended job to project 1.69), we decided this technique was not practical because recording trail covariates (e.g., vegetation type) could unduly distract observers from searching for moose.

We instead utilized 1,261 telemetry locations collected during 6 winters on 71 adult female moose in GMU 19D (M. Keech, projects 1.58 and 1.62) to examine habitat use (distance from river floodplain, which has highest browse biomass) in a mixed-effects regression model. Model selection indicated greatest support for including covariates to each moose location: daily snow depth, average winter snow depth, winter severity (measured as number of days where temperatures fell below −28°C), maternal condition (alone, with calf or calves), day of winter, and moose density (increased during course of study because of predator reduction; Keech et al. 2011). We included a repeated measure for individual moose. The data set included 1 winter where severity as indexed by snow depth in McGrath reduced calf survival (Keech et al. 2011). Moose were closer to the river with increasing snow depth, increasing day of the winter, and during warmer winters. Frozen overflow and wind erosion or compaction of snow in active floodplain of large rivers reduces snow depth, thus lowering energy expenditure to access abundant forage (Collins and Helm 1997). Riparian corridors are also characterized by patches of mature conifer forest where canopy provides shade on warm spring days (Schwab and Pitt 1991), intercepts snow, and reduces radiation during cold clear nights. Thus, reduced thermal stress and energy expenditure may have more influence than greater browse abundance in moose decisions to move closer to rivers later in winter and at higher temperatures.

JOB/ACTIVITY 1D: Construct a spatial model of winter range use by moose.

The lack of an accurate, GMU-level vegetative classification for moose browse in Interior Alaska (objective 1A) hinders creation of a spatial model based on information known to be important as moose winter range. Additionally, a spatial coverage of snow depth (job 1B) would be limited to gross characterization of regional patterns of far greater scale than raster cells or polygons of vegetative and terrain metrics obtained from remote sensing classifications. Until these key components are validated, modeled habitat value from satellite imagery pixels is not feasible for evaluating moose population objectives.

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 2A: Estimate browse production (kg/ha) and proportional removal.

Following evidence of an inverse relationship between moose twinning rate and proportional removal of browse biomass across a gradient of moose density (Paragi et al. 2008, Seaton et al. 2011), we sought to determine sensitivity of the browse removal technique relative to increasing or decreasing moose abundance. We conducted 9 browse surveys (Seaton 2002) in boreal forest of GMUs 19D, 20A, 20B, 20C, and 20D during late March and early April 2009–2013 and assisted with a browse survey in a subarctic shrub community of GMU 26A (Region V) in 2009. Most surveys were in subunits of GMU 20 in the middle Tanana Valley where moose density is relatively high and public consideration of periodic antlerless harvest (predominantly females and young) is warranted to reduce moose density and protect forage plants from unsustainable browsing pressure. From each survey we estimated production and removal for the sampled plants alone and for the plot composition.

We found a greater magnitude of change in proportional browse biomass removal with increased moose density (GMU 19D, predation control) and decreased moose density (GMUs 20A and 20D, both antlerless harvest) relative to corresponding twinning rates in these populations. The proportion of twigs browsed (based on count, not biomass), the diameter at which current annual growth is browsed (for some plant species), and the plant architecture affected by moose browsing are also influenced by change in moose density. Change in browse biomass removal based on production during a growing season appears to be more time-sensitive and of greater relative magnitude than change in twinning rate. The latter parameter is a function of standing forage biomass per female, the history of maternal body condition, and other factors in long-lived ungulates.

JOB/ACTIVITY 2B: Conduct moose twinning surveys in browse surveys areas.

The only areas where we conducted browse surveys during project 5.10 that did not otherwise have an associated twinning survey were GMUs 24B and 24C (Paragi et al. 2008). Galena area staff conducted twinning surveys in GMU 24B each year during late May or early June as part of a multi-agency telemetry project conducted in 2008–2013 (Stout 2010:576); this project provided funding assistance for telemetry to estimate twinning rate. By using radiocollared moose, we were able to augment our sample of parturient females beyond just random observations in this low density population. On the basis of this sample, we estimated twinning rates (34–60%) that were relatively high for Interior Alaska (Boertje et al. 2007). These relatively high twinning rates corresponded to a relatively low browse removal rate measured in GMU 24B in 2006 (5%, Paragi et al. 2008:30). This pattern conforms to the observed relationship between browse removal and twinning rate elsewhere in Interior Alaska (Seaton et al. 2011).

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

JOB/ACTIVITY 3: 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.

A post-doctoral student (volunteer J. Schmidt) took the lead on compiling various electronic files of moose survey data back to 1954 into a single spreadsheet for several GMUs in the Interior. Some raw survey data were entered into a database from original paper sheets, and some of the topographic units defined for areas were manually digitized. Moose counts were associated with a search intensity (min/km^2) and sightability correction factor. We coordinated with the facility manager in our regional office to obtain use of a heated storage room as an archive facility and set up shelving units and a map cabinet for organizing hard copies of data previously stored at various office locations.

After presenting initial progress and identifying geographic archive gaps at the December 2011 regional meeting, we identified that it was imperative for paper data files in remote area offices to be electronically scanned and archived to prevent accidental loss from fire, flooding, or vandalism. In fiscal years (FY) 2012 and 2013, a volunteer (C. Grundhauser) scanned moose survey and telemetry information from the Delta and Tok offices, including color images of topographic maps with data through a local commercial service. Due to workload constraint, the original intent of putting survey information and attributes (metadata) into databases was not feasible. Thus, scanned data were simply archived in portable document format (PDF) at multiple sites to reduce risk of loss. As a data management priority, scanned data should be transcribed into a database format in the future to enable full analytical utility. Focus on this job remained with moose survey and telemetry data and did not get into a similar intended procedure for the harvest data, much of which is already in electronic format and simply needs to be linked to the associated harvest recording polygons (UCUs) that represent topographic drainages.

OBJECTIVE 4: <u>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</u>.

We produced memos for individual surveys to archive details, annual federal aid performance reports, and an agency project status report in FY10 (Paragi and Kellie 2011). Three final technical reports are in preparation: 1) assessing winter severity from snow depth (job 1B); 2) modeling winter habitat selection by female moose (job 1C); and 3) assessing browse removal as a nutritional index for moose (job 2A). We have also begun organizing manuscripts for peer-reviewed publications on these 3 topics.

We gave a presentation on moose browse assessment at the April 2011 meeting of the Alaska Chapter of *The Wildlife Society* in Juneau. Data from the 2011 GMU 20C browse survey were presented in a feasibility assessment for IM at the March 2012 meeting of the Alaska Board of Game in Fairbanks. We presented data from the 2010 GMU 20D and the 2012 GMU 20A browse surveys in public workshops on indices for moose management at high density in April 2011 (Delta Junction) and January 2013 (Fairbanks), respectively.

OBJECTIVE 5: <u>Evaluate the potential to increase browse production with prescribed fire in subalpine habitat and the subsequent response in browse removal by moose (amended to study plan 28 October 2008)</u>.

JOB/ACTIVITY 5: <u>Conduct an experimental burn by aerial ignition of fine fuels in spring to evaluate the vegetative response in current annual growth</u>.

We worked with the Alaska Department of Natural Resources, Division of Forestry to conduct a trial burn in early summer for assessing logistic needs, such as helicopter support to conduct prescribed fire in this remote area. From the trial burn with hand firing, we verified post-fire regeneration of aspen and willow at 2,600 feet elevation later in the same growing season. After site assessment for a prescribed burn (3 treatment sites of about 800 ha each) and planning for aerial ignition with Forestry staff, a pre-treatment browse survey occurred in spring 2009 (Paragi and Kellie 2011). The prescribed burn was planned and conducted under the Habitat Management Program using non-federal aid funding.

We visited the proposed burn sites in May 2009 and 2010 with a fire specialist to verify fuel conditions. The burn prescription (weather conditions and fuel moisture) was met periodically during the approved window of dates in the burn plan (15 May–15 June) during 2009 and 2010, but the burn was not conducted because fire specialists or equipment were not available on some dates (competition with wildland fire suppression), military airspace was restricted other dates, and another prescribed burn of higher priority occurred. This job was terminated in FY12 because the project is ending (not enough time to verify post-fire vegetative response) and potential to conduct this burn is low based on our recent experience trying to implement prescribed fire.

IV. MANAGEMENT IMPLICATIONS

At present, spatial data sets on forage potential that are derived from remote sensing and snow depths measured at a few locations are not adequate for quantifying habitat potential for moose in the boreal forest of Interior Alaska. This information is one component with biological basis used to set IM population objectives for moose in specific GMUs. A first step in addressing moose population objectives for winters of low severity would be through defining forage potential alone; restrictions on browse availability imposed by deep snow would have to also be incorporated in areas with periodically severe winters.

Our technique for estimating browse biomass removal by moose (Seaton 2002) appears more sensitive than twinning rate in detecting changes in moose density (positive and negative) resulting from management actions. Corresponding changes in the size of twigs browsed for some species (increase and decrease) provides mechanistic evidence for observed changes in proportion of biomass removed. Biomass removal is a practical index for assessing density-dependent responses, particularly moose nutritional condition at higher densities. It can also be used as a trigger for considering antlerless harvest to slow, stop, or reverse population growth and prevent damage to forage plants (Boertje et al. 2007). Designing browse assessment areas to correspond spatially with moose survey areas and hunt zones strengthens scientific inference and public understanding on how management interventions influence forage resources and their use by moose. Until a validated, spatially-explicit description of habitat capability is feasible (job 1D), twinning rate and browse removal rate are useful metrics in assessing habitat capacity for moose relative to management objectives.

DWC has conducted stand- and landscape-scale prescribed fire in the past to enhance early seral vegetation including browse species (Paragi and Haggstrom 2007; Paragi et al. 2009, job 1E). However, DWC has not planned or conducted prescribed fire in recent years (beyond this study) due to other priorities, public concerns with potential for smoke near communities, and the increased prevalence of wildland fire in the Interior in the last decade (Alaska Fire Service data on fire perimeters since 1940; http://fire.ak.blm.gov/predsvcs/maps.php). Fire suppression that aims to protect human-valued resources near communities maintains flammable conifers that pose an increased fire danger and have no value as moose forage. The limited wood market (particularly for small diameter black spruce) and complicated ownership patterns hinder mechanical fuels management at scale and locations that could enhance the ability of suppression agencies to allow more wildland fires, which are means to reduce or fragment continuous areas of hazardous fuels near the urban interface. There is presently private sector interest in developing a wood energy market in the Tanana Valley that could utilize conifers and deciduous trees. Such a strategy could potentially facilitate hazardous fuels management and enhance winter forage for moose by benefitting early successional browse plants.

In the future, active management of moose abundance and hunter access to large natural burns near the road system may be a more feasible strategy to enhance moose harvest than prescribing fires near settlements to improve moose range. This will require collaborative efforts by DWC with land managers to create roads or trails. Managing for an upper threshold of moose density in recent burns near settlements may be warranted to prevent excessive damage to regenerating hardwoods and shrubs; however, such conditions might hasten vegetative succession toward dominance by more flammable conifers. High levels of vertebrate herbivory on shrubs and deciduous seedlings post-disturbance (fire, fluvial, or logging) can reduce forage biomass production over time by hastening succession of non-palatable species (Butler et al. 2007) especially in smaller disturbance patches (Smith et al. 2011) and may also reduce biomass regeneration for energy markets.

V. SUMMARY OF WORK COMPLETED ON JOBS IDENTIFIED IN ANNUAL PLAN FOR LAST SEGMENT PERIOD ONLY

JOB/ACTIVITY 1B AND 1C: We continued data analysis.

JOB/ACTIVITY 2A: We conducted 2 browse surveys in GMU 20A and continued data analysis.

JOB/ACTIVITY 3: We completed electronic scanning of moose survey data from 2 rural offices and assisted a contractor who produced a prototype database of the 24 moose browse surveys conducted during 2000–2013.

JOB/ACTIVITY 4: We wrote this final research performance report and began drafting agency technical reports and manuscripts for publication.

VI. ADDITIONAL FEDERAL AID-FUNDED WORK NOT DESCRIBED ABOVE THAT WAS ACCOMPLISHED ON THIS PROJECT DURING THIS SEGMENT PERIOD

JOB/ACTIVITY 2A**:** We trained 2 colleagues from Glennallen (F. Robbins and B. Schwanke) and 1 from Palmer (K. King) and a UAF graduate student (C. Brown) in moose browse survey methods. They assisted us in conducting the browse survey in GMU 20A during 2012 and 2013. Glennallen staff collected data in GMU 13A in April 2012, and both groups collected data on the Watana impoundment project on the Susitna River (GMU 13E) in April 2013. Paragi proofed their 2012 electronic data entry and estimated biomass removal and plant architectural indices. A contractor (J. Schmidt) created a prototype Microsoft Access® (Microsoft Corporation, Redmond, Washington) database for consolidating browse vegetation data and meta-content (plot images, spatial data) collected during 2000–2013 that will enable queries for more efficiently analyzing data from multiple surveys.

JOB/ACTIVITY 3: We worked with the regional analyst/programmer (R. DeLong) to evaluate an online archive for metadata that describes in detail the purpose of data collection and definition of variables so data sets (paper and electronic) may be archived in digital format for safer long-term storage and use by future researchers. We tested the software program Morpho (http://knb.ecoinformatics.org/morphoportal.jsp) and the archive process in summer 2012 with 2 researchers preparing to leave the agency. Further consideration of data storage and archive including meta-content began in spring 2013 through a working group on data management as part of statewide process on implementing the *2012 Science Policy for the Division of Wildlife Conservation*. Paragi is co-leading the process to implement the science policy for research and management.

VII. PUBLICATIONS

Kellie Seaton and Schmidt coauthored and submitted a publication examining bias in harvest data to the *Journal of Wildlife Management.*

References:

BALLARD, W. B., J. S. WHITMAN, AND D. J. REED. 1991. Population dynamics of moose in southcentral Alaska. Wildlife Monographs No. 114.

BOERTJE, R. D., K. A. KELLIE, C. T. SEATON, M. A. KEECH, D. D. YOUNG, B. W. DALE, L. G. ADAMS, AND A. R. ADERMAN. 2007. Ranking Alaska moose nutrition: Signals to begin liberal antlerless harvests. Journal of Wildlife Management 71:1494–1506.

BOUCHER, T., K. BOGGS, L. FLAGSTAD, AND M. DUFFY. 2009. Alaska LANDFIRE application project: Map and classification review in seven locations across Alaska. Unpublished report, Alaska Natural Heritage Program, Anchorage, Alaska.

BUTLER, L. G., K. KIELLAND, T. S. RUPP, AND T. A. HANLEY. 2007. Interactive controls of herbivory and fluvial dynamics on landscape vegetation patterns on the Tanana River floodplain, interior Alaska. Journal of Biogeography 34:1622–1631.

COADY, J. W. 1974. Influence of snow on behavior of moose. Naturaliste Canadien 101:417–436.

COLLINS, W. B., AND D. J. HELM. 1997. Moose, *Alces alces*, habitat relative to riparian succession in the boreal forest, Susitna River, Alaska. Canadian Field-Naturalist 11:567–574.

GASAWAY, W. C., R. O. STEPHENSON, J. L. DAVIS, P. E. K. SHEPHERD, AND O. E. BURRIS. 1983. Interrelationships of wolves, prey, and man in Interior Alaska. Wildlife Monographs 84.

KEECH, M. A., M. S. LINDBERG, R. D., BOERTJE, P. VALKENBURG, B. D. TARAS, T. A. BOUDREAU, AND K. B. BECKMEN. 2011. Effects of predator treatments, individual traits, and environment on moose survival in Alaska. Journal of Wildlife Management 75:1361–1380.

KELLIE, K. A., AND R. A. DELONG. 2006. Geospatial survey operations manual. Alaska Department of Fish and Game. Fairbanks, Alaska.

MANLY, B. F. J., L. L. MCDONALD, D. L. THOMAS, T. L. MCDONALD, AND W. P. ERIKSON. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic Publishers, Norwell, Massachusetts.

PARAGI, T. F., AND D. A. HAGGSTROM. 2007. Short-term responses of aspen to fire and mechanical treatments in Interior Alaska. Northern Journal of Applied Forestry 24:153–157.

PARAGI, T. F., D. A. HAGGSTROM, C. T. SEATON, AND K. A. KELLIE. 2009. Identifying and evaluating techniques for wildlife habitat enhancement in Interior Alaska. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Final Research Performance Report, Project 5.10. Juneau, Alaska.

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 1 July 2007–30 June 2010, Project 5.20. ADF&G/DWC/PSR-2011-1-R3. Juneau, Alaska.

PARAGI, T. F., C. T. SEATON, AND K. A. KELLIE. 2008. Identifying and evaluating techniques for wildlife habitat management in Interior Alaska: Moose range assessment. Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration, Final Research Technical Report, Project 5.10. Juneau, Alaska.

SCHWAB, F. E, AND M. D. PITT. 1991. Moose selection of canopy cover types related to operative temperature, forage, and snow depth. Canadian Journal of Zoology 69:3071–3077.

SEATON, C. T. 2002. Winter foraging ecology of moose in the Tanana Flats and Alaska Range foothills. Master's Thesis, University of Alaska Fairbanks.

SEATON, C. T., T. F. PARAGI, R. D. Boertje, K. Kielland, S. DuBois, and C. L. Fleener. 2011. Browse biomass removal and nutritional condition of moose *Alces alces.* Wildlife Biology 17:55–66.

SMITH, E. A., D. O'LOUGHLIN, J. R. BUCK, AND S. B. ST. CLAIR. 2011. The influences of conifer succession, physiographic conditions and herbivory on quaking aspen regeneration after fire. Forest Ecology and Management 262:325–330.

STOUT, G. W. 2010. Unit 21D moose. Pages 572–610 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2007 through 30 June 2009. Alaska Department of Fish and Game, Project 1.0. Juneau, Alaska.

VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

Our goal in objective 1 was to construct a spatial model of moose winter range that incorporated vegetative cover type and moose distribution at specified ranges of snow depth. We sought to use predictor variables important to moose seasonal movements or foraging ecology (e.g., terrain metrics, mean browse production by cover type) to map a resource selection function for specific geographic areas (Manly et al. 2002:164–179). However, this approach will not be feasible until a vegetative classification in spatial data sets is validated for browse species, at a minimum (see Management Implications).

The poor validation of existing vegetation types in the initial LANDFIRE release for Alaska (job 1A) has prompted vegetation ecologists with the Alaska Natural Heritage Program at the University of Alaska Anchorage to propose a revised classification that includes tall shrub types with several willow components. The Access database created for browse data (jobs 2A and 3) provides species-specific information for about 950 sites (plots) across the Interior that could be used to validate the more recent classification for use in defining winter range of moose. This validation effort should be pursued once the prototype database is proofed for accuracy and completeness. A validated classification of summer and winter moose habitat by GMU could also be an objective basis for 1) identifying initial strata for moose density in new survey areas (Kellie and DeLong 2006:19); 2) estimating sightability correction factors where overhead cover influences the proportion of moose observed from aircraft (project 1.66); 3) extrapolating density estimates to areas not surveyed as a first approximation in survey planning; or 4) evaluating population objectives for IM.

Inference on winter severity for moose in a defined area (job 1B) is a challenge because metrics on snow may have spatially high seasonal and annual variation in some areas, such as western Interior Alaska. In the technical report we will review approaches to describe winter severity for inference on moose population dynamics and discuss a broader context of scale and limits to sampling environmental variables for the goal of inferring effects on biological parameters in specific areas.

Our analysis of winter habitat use by female moose (job 1C) was a post hoc use of telemetry data collected for other purposes by colleagues (Keech et al. 2011), but it proved instructive as to the importance of physical environmental variables in describing habitat use in the context of maternal condition. In the technical report we will describe the gradient of browse biomass decrease with increasing distance from river floodplain to provide researchers with additional context of spatial scale in future study design.

The technique for estimating biomass removal (job 2A) has proven useful in detecting change in vegetation metrics that showed response to measurable change in moose density. Understanding the limits of false detection of change in biomass removal for "stable" moose populations due to sampling error or environmental noise may be a next avenue of research. Changes in browse production or proportion removed are potentially confounded by climatic factors independent of measurable change in moose abundance in a study area. Factors that affect browse production include precipitation, length of growing season (temperature), and fire or fluvial disturbance. Factors that influence browse removal include duration and depth of snow as it affects moose energy demand as well as forage availability to moose.

Archive of data (job 3) in rural offices and at DWC Region III headquarters should continue as help is available to comply with the DWC science policy. Moose has been the sole species focused on to date because of the volume of data, but other species should be included in the effort as time permits. Electronic imaging of paper data (field sheets and maps) allows storage off-site to prevent catastrophic loss. Software with optical character recognition may automate data entry from PDF into file formats that can be proofed, analyzed, and archived in databases.

IX. APPENDICES

None.

PREPARED BY: Thomas F. Paragi, ADF&G

DATE: 15 August 2013