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DIVISION OF WILDLIFE CONSERVATION
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WORK LOCATION: Gustavus, Alaska**.**

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

Moose play an important role in both the cultural and ecological landscape of southeastern Alaska. Moose are the primary harvestable ungulate species in several communities across the region and, further, represent a critical subsistence resource in some of the more isolated, northern communities, such as Yakutat and Haines. Moose are also important ecologically not only for the role they play in nutrient cycling in low-productivity northern ecosystems (Pastor and Naiman 1992, Bowyer et al. 1996), but also through interactions with plant communities that result in trophic cascades and subsequent effects on avian (Berger et al. 2001) and invertebrate communities (Suominen et al. 1999).

Winter population density estimates for moose in the Gustavus Forelands are among the highest recorded for the species in Alaska, and appear to be increasing. These data combined with winter browse monitoring information, suggesting very high utilization rates of preferred forages (Barten, unpub.), and limited evidence of predator-caused mortality provide increasing evidence that this population is near or above carrying capacity and exhibiting irruptive population growth.

Understanding how moose interact with their environment has important management and conservation implications. For example, moose populations in southeastern Alaska have a relatively short history as a result of recent de-glaciation of regional landscapes

(Dinneford 1988). The colonization trajectories of populations in southeastern Alaska have been characterized by irruptive fluctuations. In such cases, following an initial period of establishment, populations typically undergo a period of explosive growth and exceed K-carrying capacity resulting in a dramatic population crash and an associated decline in short- and long-term carrying capacity (Caughley 1970, 1976, McCullough 1997). The negative, density-dependent effects of such outcomes can be particularly acute for species such as moose that predominantly feed on perennial plant species that can be slow to recover from effects of prolonged over-browsing.

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

High rates of herbivory can negatively affect habitat carrying capacity following well-documented pathways (Augustine and McNaughton 1998). For instance, over-utilization of preferred browse species such as, perennial shrubs in the willow family (*Salix* sp.), result in suppressed productivity and/or direct mortality of individual plants thereby reducing the amount of plant forage biomass per unit area available to moose (Singer et al. 1998). Ultimately, such preferred species, which may be common in early successional landscapes, are out-competed by other less- or non-palatable plant species (Pastor et al. 1988) such as, conifers. Further, increased herbivory of preferred plants can result in associated increases in production of secondary plant compounds, such as tannins, that decrease nutritional quality of forage (Bryant et al. 1989). The net result is an overall reduction in the distribution, productivity and quality of preferred species and reduction in overall habitat carrying capacity. In relatively stable landscapes, such as post-glacial sites in southeastern Alaska, the transition from willow vegetative communities to conifer-dominated types is likely to be accelerated and irreversible and consequent reductions in carrying capacity permanent.

Clearly, the natural trajectory of “irruptive populations” does not represent an ideal situation for wildlife managers responsible for managing populations for maximum sustained yield (MSY). Fortunately, several tools are available for researchers to determine the relationship between populations and their habitat carrying capacity. Therefore it is possible to identify critical thresholds for a given population and apply appropriate management responses in order to avert dramatic population crashes and associated long-term reductions in carrying capacity. Here, we outline a research approach to address this important management problem in a moose population that appears to be near or above habitat carrying capacity.

The overall objective of the study is to determine how variation in habitat quality, availability and spatial distribution affect moose body condition and productivity (see Testa and Adams 1998) in a rapidly increasing, high density moose population. We also plan to evaluate the extent to which vital biological parameters of moose, such as ovulation, pregnancy and twinning rates, are affected by harvest mediated changes in moose population density. These data will then be used to develop an adaptive harvest management model for the Gustavus moose population. Ultimately, these research results will enable a more complete understanding of moose-habitat relationships and will provide an empirical basis for interpreting moose habitat monitoring data in the Gustavus area

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

Objective 1: Assess body condition, reproductive success, and population density of moose.

This objective will provide information about nutritional condition, productivity, and population density of moose on the Gustavus forelands. These data will enable comparisons with other coastal moose populations and yield insights into the extent that food-limitation effects this population. Also, monitoring changes in productivity parameters following harvest-mediated changes in population density will provide additional critical information about.

<u>Job/Activity 1a: Determine age-specific body condition and pregnancy of adult female moose.</u>

Moose will be captured in fall and the following spring each year. Each fall 5-10 adult females will be captured and deployed with GPS collars. In spring, these same animals, and an additional 10-20 adult females and 10-month old calves. Specific data or samples collected during captures will include: 1) rump fat thickness via ultrasonography (Stephenson et al. 1998), 2) collection of 50cc of blood from the jugular vein, 3) collection of fecal specimens, 4) measuring neck circumference, body girth, total body length and hind foot length and, 5) extraction of a lower incisor and photography of tooth wear patterns. Acquisition of rump fat measurements will enable estimates of total body fat (>6%) following equations developed by Stephenson et al. (1998). Processed blood and serum samples will analyzed for pregnancy-specific protein B concentration to determine incidence of pregnancy and twinning (Huang et al 2000). Additionally, blood samples will be collected for disease and genetic archival purposes. Collection of fecal samples will enable determination of food selection patterns via micro-histological analyses and catalogued for possible future analyses of pregnancy specific fecal metabolites (following Berger et al. 1999). Tooth samples will be processed to determine age from cementum annuli (Sergeant and Pimlott 1959) to provide data relevant to age-specific reproduction.

<u>Job/Activity 1b: Determine age-specific body condition and pregnancy for harvested cows.</u>

In addition to collecting physiological data from live animals, data will also be collected from harvested female moose during each fall hunt. Field staff will collect ovaries and, when possible, measure rump fat thickness of hunter killed animals. Ovaries will be preserved and examined following procedures described Sand (1998) in order to determine ovulation rate and occurrence of pregnancy and twinning. Additionally, tooth specimens will be collected and processed to determine age of harvested females.

Objective 2: Evaluate relationships between moose winter range conditions, body condition and reproductive success.

Variability in moose habitat conditions, such as forage availability, nutritional quality and spatial distribution, is expected to influence moose body condition (Moen et al. 1997) and, ultimately, reproductive productivity (Testa and Adams 1998). However information is lacking to properly determine how these factors interact in moose populations in Gustavus. Advancing our understanding of these relationships will improve our ability to interpret habitat survey information and the role that food limitation plays in regulating moose populations. In order to address this objective, fine-scale winter spatial use data will be gathered for individuals of known body condition and reproductive status, and combined with field-based habitat survey information.

Job/Activity 2a: Determine spatial distribution of GPS collared individuals.
GPS location data will be downloaded from telemetry collars following spring captures. These data will be used to determine movement paths and putative foraging sites of individuals during the preceding winter. Foraging sites will be determined via activity sensor data linked to GPS locations.

Job/Activity 2b: Conduct ground-based surveys to characterize habitat conditions within individual home ranges.
Vegetative characteristics of a random selection of putative foraging sites will be characterized using 4-m^2 plots. Sensitivity analyses will be conducted using preliminary data to determine sampling intensity. Each plot will be georeferenced and habitat type will be recorded using existing GIS habitat classifications (Streveler et al. 2002). Detailed vegetative measurements will be collected in each plot and include: 1) availability and utilization of current annual growth (CAG) for preferred plant species, 2) plant density, 3) plant vigor (Keigley et al. 2002), 4) plant size class distribution (ie. rooted stem diameter), 5) percent cover of secondary forage species (e.g. *Equisetum* sp.). In conjunction with species-specific mass-diameter regressions (MacCraken and VanBallenberghe 1993), these data will enable estimation of available forage biomass at each site. Additionally, specimens of important winter forage species will be collected and analyzed for nutritional quality. Measures of digestible protein and dry matter will be estimated following established procedures for tannin-containing forages (Robbins et al. 1987a, 1987b, Hanley et al. 1992). Moose pellet-groups will be enumerated along transects (following Kirchhoff and Pitcher 1988) in order to provide an index of moose density within home ranges.

Objective 3: Evaluate landscape-level habitat use patterns and population carrying capacity.
Fine-scale analyses of relationships between moose habitat conditions, reproduction, and body condition provide a framework from which landscape-level questions about moose habitat use and carrying capacity can be addressed. We will combine moose location data with GIS data layers to develop predictive models that describe relative winter habitat use across the landscape (Manly et al. 2002). These methods will also enable quantitative determination of moose winter distribution, a necessary precondition for estimating habitat carrying capacity. Next, we will combine field and GIS based information about spatial and biological characteristics of moose food resources (i.e. distribution, quality, availability, and utilization) with published estimates of intake rates and physiological

constraints (see Moen et al. 1997) to derive carrying capacity estimates for the Gustavus winter range.

Job/Activity 3a: Develop resource selection models to determine winter habitat use patterns and range distribution.
Location data will be combined with ecological and physiographic GIS data layers to develop resource selection models (Manly et al. 2002). Models will be validated following procedures described by Boyce et al. (2002). These products will not only provide an understanding of landscape-level habitat use patterns but also allow a quantitative determination of the winter range distribution of the population. This information will be important for developing estimates of habitat carrying capacity.

Job/Activity 3b: Estimate winter range carrying capacity for the Gustavus moose population.
Estimates of winter habitat carrying capacity will follow methods described by MacCracken et al. (1997), or adapted from Hanley and Rogers (1989) and be based either on data collected during other phases of the study or from the published literature (see Moen et al. 1997 for summary). Specifically, we will use high-resolution aerial imagery (Frennette and Nichols 2003) along with pre-existing GIS vegetation data layers (Streveler et al. 2002) to delineate ecologically relevant habitat types of the moose winter range. Within each habitat type, biomass estimates for important forage types will be combined with species-specific nutritional quality information. These data will be used along with measures of pre-winter body condition, forage intake rates, and energetic requirements to model winter habitat carrying capacity. Additionally, we will use data from exclosures and individually marked plants to model differences in carrying capacity in the presence and absence of current rates of herbivory.

Objective 4: **Develop adaptive management model (AHM) for moose population in the Gustavus forelands.**

Job/Activity 4a: Develop quantifiable management objectives and a list of feasible management actions.
Development of management objectives and an associated list of management actions will be determined by regional ADF&G staff Nevertheless, consultation with selected individuals outside ADF&G may be necessary to refine these components; a limited amount of public participation may also be incorporated, used if determined to be necessary.

Job/Activity 4b: Develop models relating objectives, management actions, monitoring data, and the Gustavus moose/habitat system.
Develop models that predict the effects of management actions on the population/system being managed. We will develop one or more models of the Gustavus moose/habitat system that include the effects of management actions; differences in the models will reflect key uncertainties in our understanding of the moose/habitat system (e.g., high or low carrying capacity). Over time, AHM should reduce this uncertainty by emphasizing models that better predict the effects of management actions.

Job/Activity 4c: Develop monitoring protocols to obtain the necessary data for the moose/habitat models and for assessing whether management goals are being achieved.
Identify necessary data and sampling protocols to monitor moose habitat that provide the maximum information with the minimum survey effort. The protocols will then be tested to determine how effective they are at predicting moose condition. Adaptive resource management is "learning by doing" and uncertainties regarding system processes and the effects of management actions are reduced over time using the monitoring data and updating measures of model credibility.

Objective 5: **Analyze data, prepare reports and reports results.**

Job/Activity 5a: Analyze data from field studies and literature.
Conduct statistical analysis on data sets and develop predictive models that will be used in AHM.

Job/Activity 5b: Prepare Reports.
Write annual progress reports and final reports at the end of the study. Prepare manuscripts for publication for all appropriate data sets.

Job/Activity 5c: Report results.
Communicate status of research and results of the study to a variety of audiences including, but not limited to, peer professionals, the Board of Game, the public, and other interested parties and organizations.

IV. MANAGEMENT IMPLICATIONS

Nothing to report under this section because only preliminary results.

V. SUMMARY OF WORK COMPLETED ON JOBS FOR LAST SEGMENT PERIOD ONLY

OBJECTIVE 1: Assess animal condition and population status

Job/Activity a: Determine age-specific body condition and pregnancy of adult female moose.

Job/Activity b: Determine age-specific body condition and pregnancy for harvested cows.

Body condition and measures of reproductive success were assessed in moose inhabiting the Gustavus forelands during winter from 26 live-captured adult female moose during November 2009 and 26 adult female moose during March 2010. No animals died at the time of capture. During captures, we examined tooth wear and extracted a single 4th incisor (canine) to determine age (if necessary). Unlike originally planned, we only captured adult females; 10-month old calves were not captured because of funding constraints. To assess individual body condition we used a real-time portable ultrasound to measure maximum rump fat thickness of all captured animals. Body condition was also assessed using the Franzmann body condition scoring technique. Additionally, we collected complementary body condition data using muscle palpation techniques (J. Crouse, ADFG-MRC, Soldotna, AK, unpublished). See section 3, objective 1 above.

We estimated calf productivity and survival by monitoring 39 radio-marked moose and their calves. Calving success was evaluated during fixed-wing and/or walk-in surveys during May-June 2009. Subsequent monitoring of calves associated with radio-marked cows during the following year enabled estimates of calf survival. We estimated pregnancy rates for 26 radio-marked adult females using pregnancy specific protein-B (PSPB) blood serum assays. Additionally, we estimated calf productivity/survival based on aerial surveys conducted in fall (November) and spring (March).

Moose population abundance and density data were collected during 2 aerial surveys conducted in November 2009 and January 2010. We estimated sighting probabilities of moose during these surveys using mark-resight techniques that were based on data collected from 40 radio-marked animals that inhabited the study area during survey flights. We used a modified Lincoln-Peterson estimator to calculate moose population abundance and estimate variability.

Objective 2: Assess moose habitat on wintering grounds.

<u>Job/Activity a: Determine spatial distribution of GPS collared individuals.</u>

<u>Job/Activity b: Conduct ground-based surveys to characterize habitat conditions within individual home ranges.</u>

Fresh fecal samples were collected from all captured and most harvested adult female moose. In addition, fresh fecal samples were collected throughout the winter range on a monthly basis. These samples were aggregated based on the geographic location of collection sites and month collected. These samples were subsequently analyzed using micro-histological techniques to determine composition and frequency of occurrence of plant species in 30 aggregate fecal samples. These data provide information about seasonal and micro-geographic patterns of moose diet composition on the Gustavus winter range.

Winter range conditions were evaluated by measuring biomass availability and utilization of key winter forages across the winter range. These data were collected April 2010 on seven long-term browse monitoring transects. Further, we also used moose habitat exclosures in order to investigate how high levels of moose browsing influence willow biomass productivity, reproduction and survival. Overall, we collected data from 6 paired browsed and un-browsed sites. At each site, 20 individual willow ramets were marked and monitored before and after the winter period to estimate current annual growth production and subsequent removal by moose. Willow catkin productivity and ramet survival were also quantified in May-June 2010.

Objective 3: Evaluate habitat use and carrying capacity.

Job/Activity a: Develop resource selection models to determine winter habitat use patterns and range distribution.
Location data collected via GPS and VHF radio-collars have been compiled but will not be analyzed until ongoing data collection efforts are completed.

Job/Activity b: Estimate winter range carrying capacity for the Gustavus moose population.
Habitat-specific forage biomass data have been collected and data management activities are ongoing. Chemical composition data for important winter forages have been collected and summarized.

Objective 4: Develop adaptive management model.

Job/Activity a: Develop quantifiable management objectives and a list of feasible management actions.

Job/Activity b: Develop models relating objectives, management actions, monitoring data, and the Gustavus moose/habitat system.

Job/Activity c: Develop monitoring protocols to obtain the necessary data for the moose/habitat models and for assessing whether management goals are being achieved.

Preliminary population models focusing on the adult female and calf component of the population have been developed. Additional vital rate data is needed on yearling and younger age-class animals to complete this objective.

Objective 5: Data analysis and reports.

Job/Activity a: Analyze data from field studies and literature. Conduct statistical analysis on data sets and develop predictive models that will be used in AHM.

Job/Activity b: Prepare Reports. Write annual progress reports and final reports at the end of the study. Prepare manuscripts for publication for all appropriate data sets.

Job/Activity c: Report results.

Preliminary analyses of adult female body condition, pregnancy and twinning rates, calving success and survival and winter range habitat condition data have been conducted. Adaptive Harvest Management (AHM) modeling analysis is planned, but formal analyses will not be conducted until additional field data is collected. Preliminary findings from this study have been presented at a professional conference and at meetings with local agencies, communities, and advisory committees.

I. PUBLICATIONS

a. White, K.S., N.L. Barten, and J.A. Crouse. 2007. Ecology of moose on the Gustavus forelands: Population irruption, nutritional limitation and conservation implications. Proceedings of the 4th Glacier Bay Science Symposium, 4: 25-28.
b. Hood, E., A.E. Miller, and K.S. White. 2007. Effects of moose foraging on soil nutrient dynamics in the Gustavus forelands, Alaska. Proceedings of the 4th Glacier Bay Science Symposium, 4: 20-24

II. RECOMMENDATIONS FOR THIS PROJECT

a. This project should be continued in order to accomplish project objectives. In particular, the final report is to be prepared. Individual- and population-level data will be critical for assessing the effects of the controversial antlerless moose harvest strategy recently (i.e. 2002) implemented in the project study area.

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