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

PROJECT TITLE: Identifying and evaluating techniques for wildlife habitat enhancement in Interior Alaska

PRINCIPAL INVESTIGATORS: Thomas F. Paragi, Dale A. Haggstrom, C. Tom Seaton, and Kalin A. Kellie

COOPERATORS: Gordon Worum, Doug Smart, Dan Labarre (Alaska Department of Natural Resources–Division of Forestry); Lisa Saperstein (Kanuti National Wildlife Refuge); Scott Rupp, Jason Mercer (University of Alaska Fairbanks–Forest Sciences Department)

FEDERAL AID GRANT PROGRAM: Wildlife Restoration

GRANT AND SEGMENT NO. W-33-7

PROJECT NO. 5.10

WORK LOCATIONS: Game Management Units 12, 19A, 19D, 20A, 20B, 20D, 20E, 21E, 24B, and 24C

STATE: Alaska

PERIOD: 1 July 2008 – 30 June 2009

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

In 1994, Alaska Statute 16.05.255(j)(4) defined prescribed fire and "other habitat improvement techniques" as means to actively enhance abundance of big game prey, thus allowing higher sustained yield for consumptive use by humans. Increasing availability of moose (*Alces alces*) browse in specific areas to benefit herds that are accessible to hunters requires empirical knowledge to prescribe the most cost effective techniques under the range of environmental conditions and acceptable methods.

Wildland fires in Interior Alaska covered 11.2 million acres in 2004 and 2005, the largest and third largest areas burned in the state since records began in 1950 (Todd and Jewkes, 2006). Structures and developments in over 20 communities were threatened in these 2 years. Communities have begun to proactively mitigate fire risk by reducing hazardous fuels (particularly black spruce [*Picea mariana*]) near the wildland–urban interface. Proper design of fuel breaks is required to achieve habitat benefits at the stand and landscape scales by maintaining early-seral forest near communities, protecting features of late-seral forest in the urban interface, and allowing wildland fires to burn safely just outside the urban interface during periods of low fire risk. The *stand* concept was developed by foresters to define groups of trees having similar species composition and age classes and a consistent site index (height or diameter of tree at a given age) indicative of site productivity (Daniel et al. 1979). A *landscape* is comprised of multiple stands that together have emergent properties greater than those of the individual stands, and it is often described in the vernacular as "forest."

Wildlife managers need a means to gauge when nutritional condition of moose may be limiting herd productivity to most effectively direct efforts in habitat enhancement and determine the timing of antlerless hunts to reduce moose density. The proportion of browse biomass produced in a year that is removed by moose (Seaton 2002) is inversely related to twinning rate in moose populations, thus providing such a condition index (Boertje et al. 2007). Further testing of this index across the Interior is warranted to understand where moose populations may be limited by nutrition or other factors, such as predation. Understanding the production of browse biomass among plants species and vegetation types and regional variation in snow depth may also improve definition of available winter range for moose, which would be instructive in setting populations objectives for intensive management of moose (Section 5 Alaska Administrative Code 92.108).

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

Willows (*Salix* spp.) and saplings of deciduous trees are the primary winter forage of moose in the boreal forest (Renecker and Schwartz 1997, Paragi et al. 2008), and the mechanisms by which these forage species are regenerated from wildland fire or forest disturbance (including logging) are generally understood. Haggstrom and Kelleyhouse (1996) and Paragi and Haggstrom (2004, 2005) reviewed background information on application of silviculture and prescribed fire and the management of wildland fire to provide specific features of wildlife habitat in the boreal forest, particularly near communities where wildland fire is suppressed (Todd and Jewkes 2006). Our applied research in the Interior began in 1999 in part to complement earlier studies on habitat enhancement in the boreal forest of Southcentral Alaska (Collins 1996, Collins and Schwartz 1998) and expanded to include collaboration on forecasting the effects of creating fuel breaks near communities (Paragi et al. 2006). Replication of field experiments has been recognized as a means to advance knowledge of natural processes and applied science in renewable resource management (Johnson 2002).

Intensive management for high levels of moose harvest was the impetus to focus on early seral habitat in the Interior, but we also sought to understand the potential for forest management to remove late-seral features that provide habitat for a variety of game and non-game species. Presently the scale of timber harvest in the Interior is small (Wurtz et al. 2006), but rising cost of fossil fuel is increasing interest in local harvest of wood for biomass fuel. More extensive wood harvesting or intensive practices in boreal forest of Canada and Scandinavia has prompted research to quantify effects on late-seral habitat and species and explore silvicultural strategies to restore or maintain biological diversity, often partly through emulation of natural disturbance regimes (Fries et al. 1997, Thompson et al. 2003, Malcolm et al. 2004; but see Spence 2001).

Intensive management of moose to produce high levels of sustainable harvest requires frequent monitoring of density-dependent feedbacks, such as decline in nutritional condition or range damage (Hundertmark and Schwartz 1996, Boertje et al. 2007). The high density of moose near Fairbanks and Delta currently provides about 35% of statewide reported harvest of moose (ADF&G files) but requires liberal antlerless harvest and habitat enhancement to maintain nutritional condition of the herd (Young et al. 2006). Biological responses of wildlife populations to habitat changes are important to understand, but social responses of people to changes (e.g., creating access into roadless areas or increasing risk of wildlife–vehicle collisions) can greatly affect human–wildlife interactions and public perception of habitat enhancement projects (Decker et al. 2001).

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

Some jobs in this project were continued from Federal Aid Study 5.0 on how mechanical treatments and prescribed fire can be used to produce specified outcomes in wildlife habitat through silvicultural prescriptions (Paragi and Haggstrom 2004, 2005). The project statement was revised in October 2006 to document changes in wildlife habitat as part of a multi-agency research burn (Job 1k) and to include moose browse assessment (Job 1h) when the senior author was reassigned to focus on intensive management of big game prey. At that time several jobs in habitat enhancement were dropped because fieldwork other than reconnaissance on them had not yet begun (described below). Remaining jobs were renumbered for the fiscal year 2007 progress report, but the job numbers in the original project statement are used below for the various projects and study sites (Fig. 1).

OBJECTIVE 1: Evaluate habitat response to enhancement techniques.

JOB/ACTIVITY 1A: Determine the relative efficacy and cost of using post-logging site preparations (disk trenching, blade scarification and broadcast burning) to improve establishment of willow shrubs and hardwood saplings after timber is harvested from riparian white spruce (*Picea glauca*) stands.

This job began under Project 5.0 to establish a study design and collect baseline data on vegetation and wildlife during 2000-04 (Paragi and Haggstrom 2004, 2005). Pre-treatment data were archived at the regional office (senior author), and electronic copies of data were stored at the regional and Tok Area offices.

The job continued into Project 5.10 to evaluate treatment effects, but a decision by Department of Natural Resources–Division of Forestry (DOF) to salvage timber in areas burned by wildland fires in 2004 delayed harvests in the study area. In the interim, staff turnover at the Tok Area Forestry Office resulted in a new Area Forester and loss of the Area Fire Management Officer. When the priority for timber harvests shifted back to the Tok River stands, the current Area Forester and the Regional Fire Management Officer were not comfortable with the broadcast fire portion of the study plan (M. Henderson and J. Hermanns, personal communication, 13 Mar 2009). The study design was subsequently modified to limit evaluation to mechanical treatments (disk trenching and blade scarification).

Timber harvest in the experimental study sites at Tok River (Fig. 2) began during spring 2009, but limited market demand precluded harvest of all 3 experimental blocks during a single year. To account for a time effect, harvesting was directed to the block randomly designated for harvest in year 1 in the study design (Paragi and Haggstrom 2004:21). The remaining treatment blocks will be harvested in successive years.

We are planning a separate Federal Aid project to begin in 2011 to revisit permanent plots for vegetation, moose pellets, small mammal density, and furbearer tracks after 2 years of vegetative response on each of the 3 treatment blocks.

JOB/ACTIVITY 1B: Determine the relative efficacy and cost of crushing or shearblading to create age diversity in aspen (*Populus tremuloides*) regeneration following large wildland fires along the road system.

This job was terminated in October 2006 because no work had begun. The intent was to determine if younger forest created by large burns near the road system could be fragmented to introduce forest age diversity (hence diversity of habitat features) over time in accessible areas. An advantage of crushing younger aspen forest is the less amount of debris that can shade the ground and reduce sprouting (Paragi and Haggstrom 2007). Subsequent to termination of this job, a crushing project that would have met the design requirement of this job was conducted in a 20-year-old burn east of Delta Junction by the Habitat Management Program. Approximately 116 ha of aspen and 64 ha of aspen–broadleaf mix were treated during March and April 2008 (Haggstrom 2008). The Habitat Management Program can evaluate sprouting response after 2 growing seasons for comparison to sprouting response from other nearby shearblading treatments in mature aspen (Paragi and Haggstrom 2007).

JOB/ACTIVITY 1C: Evaluate aspen stand development from felling, shearblading, and prescribed fire treatments.

This job was terminated in October 2006 because no work had begun. The monitoring effort following evaluation of the initial response of aspen to these treatments (Paragi and Haggstrom 2007) was transferred to the Habitat Management Program. Data were archived at the regional office (senior author) in hard and electronic copy, and we produced a schedule of plot revisits on a 10-year cycle for the Habitat Program Manager.

Detailed information on the scarification for establishing hardwoods is found in Appendix A. Our trial at Nenana Ridge was proof-of-concept that blade scarification can reestablish Alaska paper birch (*Betula neoalaskana*) seedlings once dense bluejoint grass (*Calamagrostis canadensis*) has become established following surface disturbance from winter logging (minimal scarification). The cost per area of linear scarification with a disk trencher was similar to that of linear dozer blading at Nenana Ridge, but germination and establishment of birch seedlings was substantially higher on the blade treatment. We found a similar magnitude of birch seedling establishment with blade treatments at Standard Creek and Gerstle River.

JOB/ACTIVITY 1D: Evaluate the utility of scarification for establishing hardwoods on timber harvest sites.

Detailed information is found in Appendix A. Our trial at Nenana Ridge was proof-of-concept that blade scarification can reestablish Alaska paper birch (*Betula neoalaskana*) seedlings once dense bluejoint grass (*Calamagrostis canadensis*) has become established following surface disturbance from winter logging (minimal scarification). The cost per area of linear scarification with a disk trencher was similar to that of linear dozer blading at Nenana Ridge, but germination and establishment of birch seedlings was substantially higher on the blade treatment. We found a similar magnitude of birch seedling establishment with blade treatments at Standard Creek and Gerstle River.

Collins (1996) had recommended disk trenching over blade scarification for post-logging site treatment. His research showed that disk trenching is less likely to remove the A-horizon or expose the B-horizon. Nutrient displacement can occur when blade scarification is performed by unskilled dozer operators. However, disk trenching does not appear practical once dense grass has become established because turf windrows tend to fall back into the trench. We produced an archive of permanent plot locations and sampling data to facilitate future visits for monitoring stem density and to assess growth rate of birch seedlings.

JOB/ACTIVITY 1E: Evaluate the success of landscape-scale prescribed burns in converting spruce-dominated stands to early-successional forbs, shrubs, or hardwood saplings.

Our evaluation of the 1998 East Fork prescribed burn began with aerial photography and acquisition of satellite imagery in 2002 under Project 5.0 (Paragi and Haggstrom 2004, 2005). The job was continued in Project 5.10 because of delays due to changes in DOF personnel and a priority shift to GIS mapping of local fuels after extensive wildland fires in 2004. Division of Forestry produced the classification of pre- and post-burn imagery needed to detect vegetation changes in July 2008, and analysis occurred in 2009.

A technical report on this job is nearing completion (Paragi et al., in prep.). A Normalized Difference Vegetative Index (NDVI) applied to a 272 km^2 Quickbird scene from September 2002 that included most of the burn allowed us to revise the 1998 helicopter mapping of the burn perimeter and estimate that fire occurred on 89% of the area within the perimeter. A supervised object-oriented classification of polygons was performed on pre- and post-fire images using eCognition software. The pre-burn classification of 80% conifer, 15% shrub, and 1% grass changed to 7% conifer, 53% shrub, and 38% grass by 4 growing seasons after the fire, with aspen and willow sprouts dominating the shrub class. We did not attempt to estimate burn severity post-hoc from imagery (lack of immediate post-fire imagery) but used a digital elevation model to estimate terrain features of aspect, slope, and elevation. Under the conditions of this burn (single treatment without replication), the principal factors associated with seral conversion of conifer to grass or shrub were elevation and slope.

JOB/ACTIVITY 1F: Evaluate the success of mechanical treatments in converting spruce-dominated forest to early-successional forbs, shrubs, or hardwood saplings.

We had established digital photopoints with GPS location and azimuth during an initial visit to the Little Chena shearblading treatment in October 2005 for baseline conditions from which to infer vegetation change during future visits. A few black spruce trees were cut or cored for age determination, and we took notes on site and scarification conditions. However, this fuel break proved difficult to access in summer because of wet ground, and there were few nearby seed sources for shrubs or hardwood trees. Thus, we did not establish plots for quantitative assessment.

JOB/ACTIVITY 1G*:* Effects of fuel breaks on wildlife habitat in the greater Fairbanks area.

Paragi served on the senior thesis committee for Jason Mercer, an undergraduate student in the UAF Forest Sciences Department whose project contributed data for simulation modeling of how early-successional habitat features (browse and cover) may be produced when dozer shearblading is done as a fuels management treatment near Fairbanks (Paragi et al. 2006). Mercer conducted fieldwork during summer 2006 for a retrospective study of temporary site conversion following mechanical disturbance in black spruce. The pilot study indicated that the greatest potential for hardwood regeneration with mechanical treatments was in areas with adjacent undisturbed Alaska paper birch in the overstory to provide a seed source and where the moss layer was removed (Appendix B). These results will be used by the principal investigator in the UAF Forest Sciences Department (Dr. Scott Rupp) to define state transition probability from one forest type to another for simulating the response of vegetation to shearblading as part of a wood biomass study under the New Crop Opportunities program in the U.S. Department of Agriculture.

JOB/ACTIVITY 1H: Determine the density, characteristics, and dispersion of snags and cavity trees among the major forest types in the greater Fairbanks area.

Fieldwork to determine the density, characteristics, and dispersion of snags and cavity trees among the major forest types in the greater Fairbanks area was completed in summer 2005. Density estimates of snags, cavity trees, and spruce trees with rust brooms among 8 forest stand types were provided to the principal investigator at UAF (S. Rupp) for simulation modeling of the degree to which late-successional habitat features could be lost if dozer shearblading (clearcutting) is done as a fuels management treatment without retention guidelines (modeling described in Job 1g). A revised manuscript is in final review (Appendix C). The most efficient size and shape of plots for sampling each of the late seral features varied among stand types (Appendix D).

JOB/ACTIVITY 1I: Determine snag persistence in timber sales as a function of snag size, surrounding forest type, and terrain influence on wind vector.

This job was terminated in October 2006 because no additional work had begun. We archived the GPS location and attribute data for snags and cavity trees that had been marked with plastic tags on 3 timber sales in the Delta area in March 2003. A copy of the archive was sent to the DOF Resource Forester and the ADF&G–Division of Wildlife Conservation Area Biologist in Delta with a recommendation to revisit the marked features in 2013.

JOB/ACTIVITY 1J: Estimate browse production and proportional removal (kg/ha) as an index of potential for winter forage to limit growth in moose populations under intensive management. Additional operational funds for this activity were provided from non Federal Aid sources.

This job included analysis of browse survey data collected during 2001–2007 (Fig. 3) for various research and management projects in Interior Alaska (Paragi et al. 2008). We added additional study sites to Seaton's (2002) original data to better define the inverse relationship between these indices of moose nutritional condition (Fig. 4).

We obtained historic data on snow depth from village weather stations and snow survey stakes in the western Interior (1975–2005) to define variability in snow depth and its frequency at the game management unit scale and build an initial spatial model for the Interior. The modeling of historic data allowed us to identify major gaps in spatial data from existing gauges or villages. To improve prediction in the deeper snow areas of the western Interior, in May 2007 we built and installed 10 NRCS snow gauges in Units 19A and 19D. Surveys of snow depth and continued evaluation of browse removal were incorporated into Federal Aid Project 5.20 (Habitat evaluation techniques for moose management in Interior Alaska), which began in fiscal year (FY) 2008.

JOB/ACTIVITY 1K: Document changes in wildlife habitat parameters in an experimental simulation of wildland fire behavior in a fuel reduction treatment.

Fuel treatment and control sites were installed at the Nenana Ridge Research Prescribed Burn Area (Fig. 5) by state and federal fire specialists beginning in winter 2006, and pre-burn measurements of the vegetative community were obtained at permanent plots by university cooperators in spring and summer 2006. In 2006 we established 18 browse plots to complement UAF research on fire behavior and vegetative response. Preburn data were collected on browse production and removal by moose (Seaton 2002) and on horizontal and vertical cover (Collins and Becker 2001). The burn prescription was not met in 2007 or 2008, but 1 of the 2 prescribed burn units was successfully ignited on 17 June 2009. The remaining unit and its associated treatment and control plots may be burned during summer 2010. We are planning a separate Federal Aid project to begin in 2011 to revisit browse and cover plots 2 growing seasons after fire treatments.

OBJECTIVE 2: Evaluate wildlife responses to habitat enhancement.

JOB/ACTIVITY 2A: Evaluate the response in rodent density and diversity among post-logging site treatments on timber sales and among mechanical fuel treatments in various forest types.

This job was terminated in October 2006 because the timber sale had not been offered by DOF (see Job 1a) and the fuels management site was unsuitable for consistent study access (see Job 1f). It will be part of a separate Federal Aid project to begin in 2011 (see Job 1a).

JOB/ACTIVITY 2B: Quantify the influence of snag and cavity tree density, their physical characteristics and dispersion, and surrounding landscape features on the presence of nesting land birds and other wildlife.

This job was terminated in October 2006 because no progress had been made. The intent was to collaborate with avian specialists in the non-game program or other organizations to secure funding for bird surveys in collaboration with habitat measurements by our project.

JOB/ACTIVITY 2C: Determine the effect of landscape features and moose ecology on probability of vehicle collisions with moose in the wildland urban interface near Fairbanks.

We had intended to model the effects of hazardous fuels treatments on the risk of moose–vehicle collisions. With a duty reassignment for the senior author and change in the thesis focus of a graduate student who was originally interested in this topic, this job did not progress beyond initial proofing of data on traffic volume and speed zones (provided by Alaska Department of Transportation) and data on the location and date of collision sites (provided by Alaska Department of Public Safety). The effect of landscape features (especially early-seral vegetation) on probability of vehicle collisions with moose in the wildland–urban interface remains a topic of general interest to community planners. In May 2008 the proofed data set was given to a UAF professor (Falk Huettmann) who intends to work with the local municipality to identify additional questions and conduct the analysis. If the project proceeds, the senior author will provide technical advice during the analysis.

JOB/ACTIVITY 2D*:* Determine response of moose to post-logging site treatments in floodplain forest and fuel breaks in upland forest.

We did not determine response of moose to post-logging site treatments in floodplain forest and fuel breaks in upland forest because a timber sale had not been offered by DOF and the fuels management site was unsuitable for consistent study access. It will be part of a separate Federal Aid project to begin in 2011 (see Job 1a).

OBJECTIVE 3: Report and manuscript preparation.

Progress reports, work plans, and budget proposals were produced during FY06–FY08. The project statement was revised in FY07 after Paragi was reassigned to focus on intensive management issues. Research final technical reports were produced for Jobs 1e (Paragi et al., in prep.) and 1j (Paragi et al. 2008), a revised manuscript is in final review on Job 1h (Appendix C), and a draft manuscript is being revised on Job 1j (Appendix E).

IV. MANAGEMENT IMPLICATIONS

Planning of landscape-scale prescribed burns to enhance moose winter range requires choosing areas within a range of upland and floodplain habitats where fire can be safely and effectively applied to maintain or increase stem density of browse species 1.5–3.0 m tall (Seaton 2002). Aside from safety considerations, the area proposed for prescribed burns is primarily based on the flammability of vegetation types and likelihood for seral conversion. Our findings on aerial ignition applied over a range of terrain features in the East Fork prescribed burn (Job 1e) suggested that elevation and slope, but not aspect, may influence seral conversion of spruce to shrubs and young hardwoods. However, our findings will need to be applied to planning new burn prescriptions with caution because we were unable to include important variables such as burn severity in our model, and the East Fork burn is a sample of one study area. A second consideration is that the observed relationship with elevation and slope and the seral conversion from conifer to browse types was not simple (Paragi et al., in prep.), which may limit its usefulness for planning burn areas at a resolution finer than vegetation type. Finally, our initial evaluation after 4 growing seasons was primarily on sprouts. A subsequent evaluation is needed to see what proportion of grass regeneration on sites that were conifer before the burn is followed by shrub or hardwood establishment from seed after another 10–20 years. Our fire treatment conditions should be replicated in a similar suite of vegetation types to verify whether a similar response pattern occurs and should include other explanatory variables that influence seral conversion.

The East Fork burn was the largest prescribed burn accomplished to date. Plans for burns of similar scale closer to settlements have not been implemented. Personnel and resources primarily intended for wildland fire suppression are frequently unavailable for use on prescribed fires. Despite better knowledge of burn effects for planning burn prescriptions, the lack of dedicated resources and personnel for conducting prescribed burns continues to be a major impediment to implementing large prescribed fires. This is particularly true where the use of aerial ignition is desired during periods of moderate to high drought code to maximize the seral type conversion of conifers to shrubs or hardwood saplings.

We anticipate that social factors such as smoke drifting into urban areas, causing health concerns or delays in air traffic, will play an increasing role in determining where and when prescribed burns are done. Outreach to those members of the public who feel most at risk from fires should occur well in advance of the burn period so their concerns can be addressed in the operational planning phase and the steps taken to mitigate risk can be effectively communicated in advance of implementation.

Habitat management at the stand scale (hand firing and mechanical treatments) is often 2 orders of magnitude more costly per unit area (Paragi and Haggstrom 2007) than aerial ignition of prescribed fire at the landscape scale, but stand scale treatments are more focused to achieve an intended response on specific site conditions. Although mechanical treatments may be used to emulate natural disturbance such as fire by top-killing trees and shrubs to stimulate sprouting, a separate scarification treatment (added cost) may be required if skidding or equipment use does not emulate fire severity in exposing mineral soil, particularly on sites where grass regeneration may hinder hardwood establishment. With the spatial focus at the stand scale, it is possible to better ensure retention of rare late-seral features that can remain in treatments designed to increase early-seral vegetation. The potential to provide a variety of habitat features often complicates treatments but results in greater potential to provide life requisites for a variety of game and non-game species, thus appealing to a wider public. Cost efficiency does not necessarily decrease once these provisions become a standard operating practice. Public outreach in advance of treatments, showing results of similar treatments (particularly photo series illustrating regeneration over time), will provide a perspective on the lag time necessary to achieve specific expectations. Timber sales and hazardous fuel mitigation have the potential for multiple positive outcomes (economic gain from stumpage, reduced risk of wildland fire spread, carbon neutral fuel source for local communities) that may offset their cost and allay concerns about habitat enhancement near communities.

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

JOB/ACTIVITY 1E: Evaluate the success of landscape-scale prescribed burns in converting spruce-dominated stands to early-successional forbs, shrubs, or hardwood saplings.

After DOF cooperators used GIS software to produce the classification of vegetation types before and after the burn, we produced the data layer showing where change in vegetation type occurred after the fire. Statistical analysis occurred on the change detection raster by overlaying terrain features with vegetation change pixels.

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

None.

VII. PUBLICATIONS

Paragi, T., S. Rupp, and J. Little. 2006. Modeling outcomes of hazardous fuel reduction near Fairbanks, Alaska. Western Forester 51(6):12–13 <http://www.forestry.org/pdf/dec06.pdf>

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(2):153–157

VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

Rigorous study designs in ecology are conducive to controlling environmental variation and isolating treatment effects, but use of management treatments as defacto experiments is recognized as a means of inference for research and management despite compromises in study design (McNab 1983). The decision to use management treatments for research may be justified if a gain in knowledge is expected or there is belief in long-term utility of experimental results (Walters and Holling 1990). Our evaluations of habitat enhancement techniques that used prescribed fire or large machinery were often designed to learn from management treatments (in some instances post-facto) that were implemented from existing knowledge of vegetative response to disturbance in boreal forest (Collins 1996, Haggstrom and Kelleyhouse 1996). The expense and planning effort required for conducting treatments on public lands required tradeoffs in study design as evident in our experiments being limited to proof of concept (Job 1d), lacking replication (Job 1e), or having an unbalanced experimental design (Paragi and Haggstrom 2007). We recognized that applying treatments cost effectively in specific areas (e.g., near accessible sites or in defined winter range) may be a substantial challenge as strictly a research design, thus justified use of management experiments for gains in empirical knowledge.

Our experience in attempting collaborative research projects with land managers was that optimal treatment location and timing (Jobs 1a and 1f) or timely completion of products for data analysis (Job 1e) are sometimes difficult to achieve within timelines of Federal Aid projects. For example, we collected pretreatment data in a randomized block design to evaluate how post-logging site treatments would influence hardwood regeneration and wildlife habitat use at the Tok River timber sale during 2000–2004 (Job 1a), but timber harvest in the experimental blocks did not begin until March 2009. We also collaborated on pretreatment data collection for a prescribed burn (Job 1k) that was delayed for 3 years. This difficulty in meshing objectives of wildlife research and land management reflects partly the different priorities among agencies or organizations and partly the effects of commodity markets or fire weather on treatment completion. Both examples illustrate the challenge of implementing intensive management to enhance prey abundance in specific areas or time periods (e.g., term of funding appropriations from agencies or legislative bodies). Despite the challenges, we think the value of cooperative projects between wildlife and land managers justify the effort. In situations where another agency has primary control over implementation of treatments or data analysis, formal agreements should be entered for projects of high profile to ensure timely completion of research. Job 1a is a case in point. Both the timely completion of the intended research and integrity of the study design were compromised by the lack of a formal agreement with the DOF that would persevere in the face of other events (wildland fires) and local staff changes.

Forest management activities in the Interior are likely to increase because of increases in fossil fuel prices and the need to manage hazardous forest fuels. Increased shipping cost for dimension lumber and growing interest in use of wood biomass for residential heating and commercial cogeneration of electricity and heat are increasing the economic potential of local wood harvest. For example, a wood pellet mill began operating east of Delta in autumn 2008, a second mill is nearing completion in Delta, and a third is presently under construction in the greater Fairbanks area. Also, the school in Tok has received funding for a wood chip boiler for combined heating and electricity production (J. Hermanns, personal communication, 27 Jul 2009). The developing energy market for small diameter wood (especially black spruce) and hardwoods previously with low value even as firewood (e.g., aspen) may help offset costs in forest road construction to access smaller or scattered stands with high value trees (e.g., white spruce). This expansion of forest management has great potential to enhance game habitat in accessible areas near communities. Proper silviculture can regenerate broadleaf forest and shrub habitat that further protect human resources against large fires originating outside the wildland–urban interface while still maintaining patches of late-seral forest or associated features. However, there is little known about successful application of mechanical treatments in converting black spruce to deciduous woody species in boreal forest (Jobs 1g and 2c). In addition, natural disturbance regimes in the Alaska boreal forest appear to be changing (Chapin et al. 2006). Understanding the extent to which a warmer, drier climate may hinder regeneration of spruce and hardwoods will become an important factor in forest management (Barber et al. 2000, Juday et al. 2005).

IX. APPENDICES

APPENDIX A

JOB/ACTIVITY 1D: Evaluate the utility of scarification for establishing hardwoods on timber harvest sites.

Collins and Schwartz (1998) noted that moose in boreal forest benefit from increased availability of shrubs and young hardwoods following fire, fluvial action, and other disturbance agents. They reviewed forest harvest practices to enhance browse production, including post-logging site preparations to enhance hardwood regeneration by exposing mineral soil for seed germination and seedling establishment. Results of their research on methods to hinder competition for hardwood seedlings from bluejoint grass in southcentral Alaska included management recommendations on scarification. They recommended shallow and narrow scarfication within 1 year of harvest to remove the O-horizon (dominated by organic material) from patches or strips but cautioned against displacement of the deeper A-horizon, which contains plant nutrients. Shallow scarification could be accomplished with disk trenchers pulled behind dozers, whole tree logging in summer (trees dragged behind equipment), or use of land clearing blades by dozer operators who could maintain proper scarification depth. The narrow linear patches produced with disk trenching provide organic substrate close to the rooting zone of growing seedlings (nutrient release over time and water retention) and could be readily achieved without special skill by dozer operators (Collins and Schwartz 1998). Greater detail of review and experimental results from southcentral Alaska are found in Collins (1996).

Alaska paper birch provides winter browse for moose in interior Alaska (reviewed in Seaton 2002). Birch often grows on moist or mesic sites where grass can quickly dominate the canopy and hinder seedling growth. Timber harvest in the Interior is focused on white spruce, but operations are financially marginal, particularly for hardwoods (Wurtz et al. 2006). Thus, natural regeneration is often a default in lieu of costly post-logging site treatments. Dense grass on logged sites may persist in certain conditions as a disclimax for several decades, hindering density and growth of hardwood seedlings (Collins and Schwartz 1998) and thus limiting efforts to enhance moose habitat with forestry practices.

Our objective was to evaluate the effectiveness of disk trenching and blade scarification to enhance reestablishment of willow and Alaska paper birch on sites with organic soil and prevalent grass regeneration, both with and without recent logging disturbance. This proof of concept with a small number of trials was begun under Federal Aid Project 5.10 (Paragi and Haggstrom 2005).

STUDY AREAS

We studied shrub and hardwood response to scarification at three upland locations in the Tanana Valley State Forest (Fig. A1). Two of the locations were disturbed recently by logging, whereas blade scarification occurred between standing trees at the third. At fuelwood sale NC-793-F on Nenana Ridge (12 ha site 50 km southwest of Fairbanks), paper birch was clearcut without scarification in winter 1990–1991 from a stand with 10 factor basal area (B.A.) of 19.5 m^2/ha (84 ft^2/ac) and gross volume of 138m^3/ha (1979 ft^3/ac; DOF files). We observed no seedlings of white spruce or paper birch established in the dense grass by 2002. At Unit 2 of sale NC-968-D near the Little Gerstle River (5 ha site 50 km southeast of Delta), white spruce $\geq$23 cm (9 in) diameter at breast height were harvested for saw timber during winter 1997–1998 with whole-tree skidding on the site having B.A. 16.5 m^2/ha and gross volume of 177 m^3/ha. The site was 52% unstocked with hardwoods in 2002 (DOF files). Fuelwood sale NC-1234-F in the Standard Creek area (15 ha site 40 km W of Fairbanks) was sold in 1996 but never harvested (paper birch B.A. 2.4 m^2/ha and gross volume 50 m^3/ha).

METHODS

Scarification treatments occurred in autumn 2002. A TTS Delta non-powered disk trencher with twin mattock wheels was pulled behind a John Deer 450 dozer at Nenana Ridge ($160/ha [$65/ac]), resulting in parallel trenches about 50 cm wide and 2 m apart. The same style dozer was used for blade scarification at all three locations ($150/ha) to remove the organic soil layer (O-horizon) roughly 2 m wide at 3 m parallel spacing to allow for germination from natural seedfall (Collins 1996). Following scarification, DOF contracted planting of white spruce nursery stock at 2.5 m spacing on disturbed portions of each site the same autumn. We did not assess birch seedfall density during the trial. However, birch trees occurred within 100 m of all plots on all sites, with most plots much closer to a seed source, which should be adequate as a source (reviewed in Collins and Schwartz 1998).

In autumn 2002 and spring 2003 we established permanent plot corners on scarified patches by using galvanized pipe and metal ID tags, and we recorded GPS location. We revisited plots in late August and early September 2006 to count seedling and sprouts of paper birch, quaking aspen, balsam poplar (*Populus balsamifera*), and willows. Sampling effort and estimation of stem density and variance were discussed in Paragi and Haggstrom (2004:6–7). We used 10 rectangular plots (1 m × 5 m) oriented over linear scarification features at Nenana Ridge (5 each in disk trenches and blade trenches) and

Standard Creek. At Gerstle River we modified the technique to use 3 square plots (1 × 1 m) spaced 0, 2, and 4 m from the plot stake over the linear features (data combined to $3m^2$) to facilitate counts of dense birch regeneration. Representative digital images were taken of each plot.

RESULTS

Seedlings of paper birch were the predominant browse species on all treated areas (94–97%), with height ranging from recently germinated plants <1 cm tall through older seedlings to 45 cm. Small numbers of quaking aspen, balsam poplar, and willow stems were also noted. Alder composed 15% of all broadleaf stems combined in plots at Standard Creek and 20% at Gerstle River. We also noted an average of 7 white spruce per plot at Gerstle River (<1 at Standard Creek and none at Nenana Ridge). We observed no birch seedlings in undisturbed areas adjacent to treatment sites at Nenana Ridge and Standard Creek. At Gerstle River we observed scattered birch seedlings to 80 cm at about 10,000/ha (equivalent to 5 seedlings per 1 m x 5 m plot) outside scarification trenches, probably the result of tree skidding by dozer during harvest several years prior.

At Nenana Ridge the turf windrows produced by disking through dense grass often collapsed back into the trench and allowed grass rhizomes to reestablish, whereas the width of dozer blading and periodic pushing aside of grass mats allowed seedlings to establish free of grass competition in bladed areas. Birch seedlings established at 580 per plot (95% CI: 45) in blade trenches at Nenana Ridge compared with 20 per plot (95% CI: 2) in disk trenches. Differences between treatments at Nenana Ridge were unlikely caused by difference in proximity to seed source (Fig. A2). Density of birch seedlings in blade scarified plots at Standard Creek ($\bar{x}$ = 200, 95% CI = 4) and Gerstle River ($\bar{x}$ = 163, 95% CI = 3) was substantially less than regeneration by blade scarification at Nenana Ridge.

DISCUSSION

Blade scarification of the dense turf at Nenana Ridge displaced some of the A-horizon that was bound to the O-horizon by grass rhizomes. We expect that growth of birch seedlings established near the center of the blade width (beyond horizontal growth distance of young roots) will be slower than seedlings established near the edge because soil nutrients in the O-horizon and A-horizon are concentrated on the edges of scarification patches (Collins and Schwartz 1998).

Forest succession still occurs on disturbed sites in the Interior where grass quickly dominated, although the rate of tree establishment can be slowed by a decade or more (Steve Joslin, DOF, Delta, personal communication). Wurtz and Zasada (2001) studied regeneration after logging of upland white spruce forest near Fairbanks and found that initially higher density of birch and willow regeneration on scarified sites experienced high mortality, so that after 27 years it was comparable to density of these species on sites not scarified. They also found that initially greater height and diameter of birch seedlings on scarified sites was comparable to seedlings on sites not scarified in only a few years. Although the ecological endpoints of stand composition were similar among their trials after nearly 3 decades (raising the question of whether scarification for hardwoods is necessary or cost effective), browse production was certainly greater on their scarified sites for the first 12 years and likely longer, especially for willow (Wurtz and Zasada 2001).

A desire to maintain hardwood fuel breaks that reduce fire hazard (Paragi et al. 2006) combined with rising fuel cost,and interest in hardwoods for fiber, fuel, and chemical extracts may justify expanded forest access and increased hardwood silviculture in the Interior. However, recent trends toward warmer and drier conditions in the Interior may inhibit growth of Alaska birch (Juday et al. 2005) and prolong a grass disclimax once established following disturbance. More intensive silviculture may be required in that circumstance to reestablish birch on sites of high social value (e.g., residential or recreation areas).

CONCLUSIONS AND RECOMMENDATIONS

Disk trenching in heavy grass was marginally successful in reestablishing birch once a dense rhizome mat developed, but blade scarification provided an adequate germination substrate in our trials. Similar to Wurtz and Zasada (2001), we propose to re-measure seedling density on our three trials (potentially after 10 growing seasons) to determine attrition rate in stem density through a combination of self-thinning and grass competition. Although density was low on disk trenching sites, it will be instructive to compare density between disked and bladed treatments. Browsing by relatively high moose density may reduce height of young trees, but we may be able to measure diameter as a means to compare growth rate between seedlings in the center and near the edge of blade patches. Assessment of horizontal and vertical cover might also be prudent at that time to gauge the extent of concealment provided for wildlife.

Whole tree logging of birch in summer should be encouraged on dry sites with low erosion potential to reduce the need for a separate site-preparation treatment. Where winter logging is required because of soil moisture, we concur with Collins and Schwartz (1998) that scarification to enhance short-term birch regeneration for browse biomass should occur immediately after logging where grass is present, especially on moist sites. We know of only one disk trencher in the Interior (owned by DOF), and the cost to transport it among scattered birch logging sales across the Tanana Valley would be high relative compared with the hourly cost of blade scarification using a dozer or skidder already on site. Weight restrictions on roads during spring thaw would also hinder movement of heavy equipment. Disk trenching may be more cost effective if birch sales become concentrated in an area, reducing transportation distance.

The cost of mechanical scarification to increase the rate of birch regeneration is prohibitive on the landscape scale when compared with the cost of prescribed fire through aerial ignition (Job 1e), but mechanical treatments are more controlled and safer to use near communities. If scarification is not supported by logging revenue, it may nonetheless be done on selective sites of high value to wildlife viewing or hunting or to establish fuel breaks.

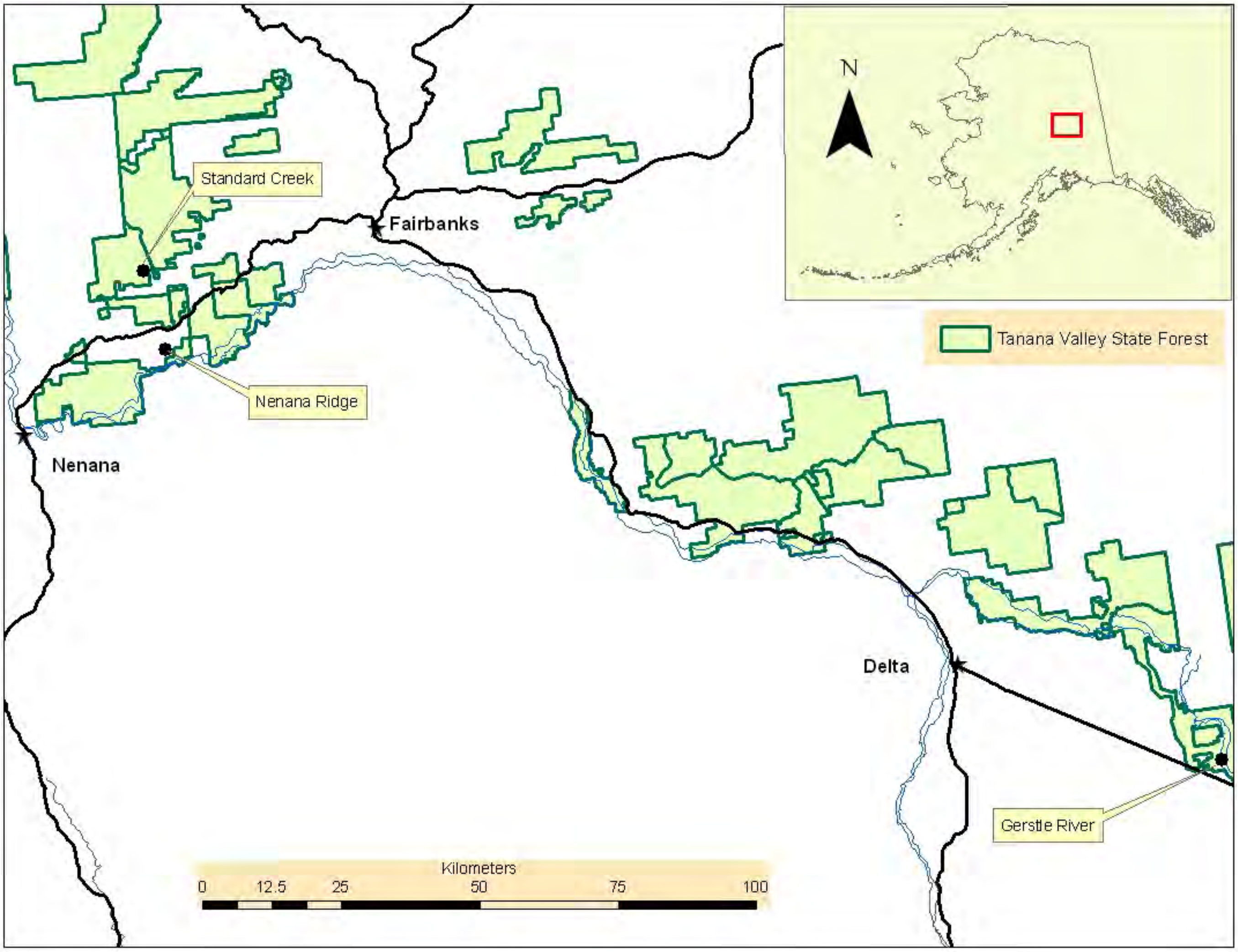


FIGURE A1. Location of scarification study sites in Interior Alaska.

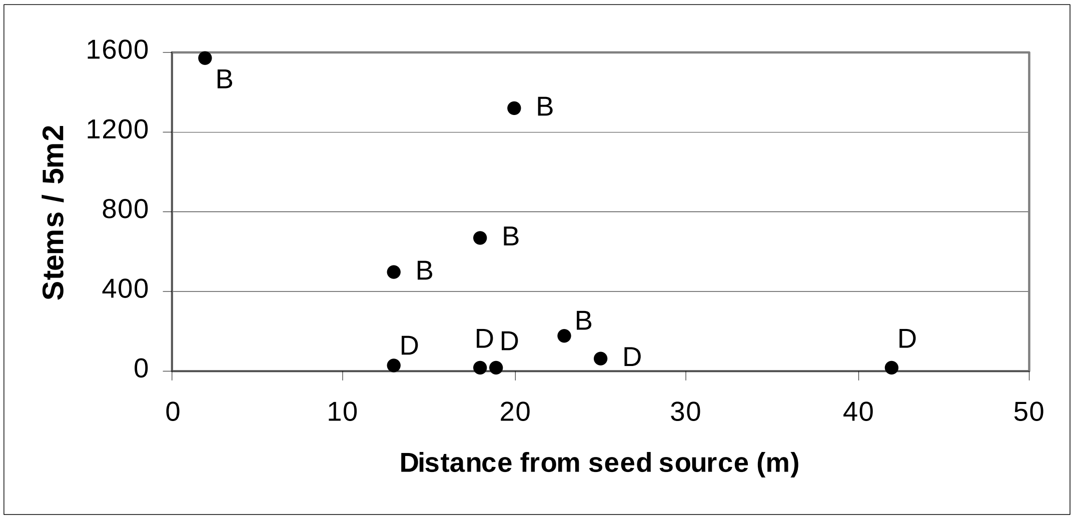


FIGURE A2. Density of Alaska paper birch seedlings in plots as a function of distance from seed trees for blade scarification (B) and disk trenching (D) at Nenana Ridge, Alaska, 31 August 2006.

APPENDIX B

Mercer, J.J. 2007. Predicting hardwood density following mechanical disturbance of the black spruce forest type. Senior Thesis, School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks.

ABSTRACT: Largely in response to the 2004 Alaska wildfire season, local fire managers have begun to install fuel treatments in mature black spruce forests around wildland–urban interface areas. The objectives of these fuel treatments are to reduce fuel load and to promote hardwoods. Local wildlife managers also favor hardwood promotion, because these tree species are an important habitat component. Thus, by promoting hardwoods after mechanical disturbance, there is the potential to satisfy objectives from multiple management perspectives. The circumstance under which hardwoods are promoted after mechanical disturbance has not been well studied. Therefore we examine some potential treatment, biotic, and abiotic variables that may be useful in predicting hardwood density following mechanical disturbance, in an effort to supply managers with desired information. We employ a retrospective approach, comparing mechanically disturbed plots with adjacent undisturbed plots. We then used on-site and derived data to create a multiple linear regression model predicting hardwood density. The model produced has an r-squared of 0.73 and indicates that time since disturbance, removal of moss during disturbance, Alaskan paper birch density in the undisturbed stands, and an interaction term between the latter two variables are useful in predicting hardwood density. These results indicate that managers, when provided a choice, should focus fuel treatments in areas that have birch in the overstory, and treatments should remove as much of the moss layer as possible.

APPENDIX C

Paragi, T.F. Density and size of snags, trees cavities, and spruce rust brooms in Alaskan boreal forest.

ABSTRACT: To forecast the potential effects of forest management on wildlife habitat, I surveyed late-seral features in boreal forest near Fairbanks, Alaska. I sampled 75 randomly selected plots stratified among 9 stand types to count and record physical characteristics of snags, cavity trees, and *Picea* spp. trees with rust brooms. Snag density differed among some stand types (range: $\bar{x}$ = 10–72/ha) and increased with mean age of stand type, whereas cavity density (2–17/ha) and broom density (3–46/ha) showed no trend with stand age. Only 15% of 199 cavity openings were large enough (>50 cm^2) and had a shape (width:height ratio = 0.5–1.5) that are likely suitable for use by larger birds or arboreal mammals. The oldest and most valuable stand type for timber harvest (*Picea glauca* ≥23 cm dbh) often had trees with larger cavity openings and larger broom volumes than trees in other types. I recommend retention of rare specimens of late-seral features and considerations for feature recruitment in managed forest and further documentation of wildlife use and associated fitness.

APPENDIX D

Plot dimensions (width × length, m) that produced the lowest variance in estimated density (number/ha) of late-seral feature trees (snag ≥13 cm dbh, cavity tree, broom tree) in boreal forest near Fairbanks, Alaska, 2005.

Stand type[a]	*n* plots[b]	Snag	Cavity tree	Broom tree
White Spruce-sawlog	20	40 × 100	40 × 100	20 × 100
Black Spruce/White Spruce-sawlog/pole	20	40 × 100	10 × 100	30 × 100
Black Spruce/Birch/Aspen-sawlog	16	40 × 100	30 × 100	40 × 100
White Spruce/Birch/Aspen-sawlog	20	40 × 100	40 × 100	20 × 100
White Spruce/Birch/Aspen-pole	18	40 × 100	40 × 100	30 × 100
Birch/Aspen/Poplar-sawlog/pole	20	10 × 100	40 × 100	30 or 40 × 100
Coniferous/Mixed-seedling/sapling	20	10 × 100	10 × 100	30 × 100
Deciduous-seedling/sapling	12	40 × 100	20 × 50	no data

[a] Single canopy species were >75% of canopy cover, whereas mixed canopy species had each component 25–75% of canopy cover. Diameter classes differed by canopy species for sawlog (coniferous >23 cm diameter at breast height [dbh], deciduous >28 cm dbh) and pole (coniferous 13–23 cm dbh, deciduous 13–28 cm dbh) but were the same for sapling (2.5–13 cm dbh) and seedling (<2.5 cm diameter).
[b] Number of 50-m long plots indicates whether recommended sample size of 20 plots per stand type was achieved for a pilot study using this technique (Bate et al. 1999). Eight options for plot size for density estimates included width of 10, 20, 30, or 40 m and length of 50 or 100 m.

APPENDIX E

Browse Biomass Removal and Nutritional Condition of Alaska Moose

C. TOM SEATON, *Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701-1599, USA*
THOMAS F. PARAGI, *Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701-1599, USA*
RODNEY D. BOERTJE, *Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701-1599, USA*
KNUT KIELLAND, *Institute of Arctic Biology, University of Alaska Fairbanks, AK 99775, USA*
STEPHEN D. DUBOIS, *Alaska Department of Fish and Game, P.O. Box 605, Delta Junction, AK 99737-0605, USA*
CRAIG L. FLEENER, *Alaska Department of Fish and Game, P.O. Box 115526, Juneau, AK 99811-5526, USA*

ABSTRACT: We present methodology for assessing browse removal to help evaluate resource limitation among moose (*Alces alces*) populations in large, potentially remote areas of boreal forest. During 2000–2007, we compared proportional removal (ratio of browse consumption to browse production) in 8 areas of Interior Alaska, USA, with multi-year twinning rates of the respective moose populations. Several prior studies have concluded that twinning rate provided an index to moose nutritional condition. We theorized that a plant based sampling of proportional use of browse by moose in late winter would correlate with moose nutritional condition. For example, as proportional browse use increased, moose nutritional condition would decline. We sampled willow (*Salix* spp.), quaking aspen (*Populus tremuloides*), balsam poplar *(P. balsamifera*), and Alaska paper birch (*Betula neoalaskana*) plants with current annual growth (CAG) between 0.5 m and 3.0 m aboveground. We estimated the biomass of CAG and biomass removed by moose based on bite diameters and diameter–mass regressions specific to each browse species. Mean browse removal by moose varied among study areas from 9% to 43% of CAG. Moose twinning rate (range 7–64%) was highly correlated with proportional browse removal by moose (Spearman's *rho* = –0.863, $P < 0.005$). Proportional browse removal appears useful in linking foraging ecology and population dynamics of moose and thus may be used to help quantitatively assess resource limitation in Alaska moose populations inhabiting boreal forest.

LITERATURE CITED

Barber, V.A., G.P. Juday, and B.P. Finnery. 2000. Reduced growth of Alaskan white spruce in the twentieth century from temperature-induced drought stress. Nature 405:668–673.

Bate, L.J., E.O. Garton, and M.J. WISDOM. 1999. Estimating snag and large tree densities and distributions on a landscape for wildlife management. USDA Forest Service, PNW-GTR-425, Pacific Northwest Research Station, Oregon.

Boertje, R.D., K.A. Kellie, C.T. Seaton, M.A. Keech, D.D. Young, B.W. Dale, L.A. Adams, and A. R. Aderman. 2007. Ranking Alaska moose nutrition: Signals to begin liberal antlerless harvests. Journal of Wildlife Management 71:1494–1506

Chapin, F.S., III, T. Hollingsworth, D.F. Murray, L.A. Viereck, and M.D. Walker. 2006. Floristic diversity and vegetation distribution in the Alaskan boreal forest. Pages 81-99 in *Alaska's Changing Boreal Forest*, Chapin, F.S., III, M. Oswood, K. Van Cleve, L.A. Viereck, and D.L. Verbyla (eds.). Oxford University Press, New York.

Collins, W.B. 1996. Wildlife habitat enhancement in the spruce-hardwood forest of the Matanuska and Susitna River Valleys. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Final Research Report. Study 1.44. Juneau, Alaska, USA.

———, and E.F. Becker. 2001. Estimation of horizontal cover. Journal of Range Management 54:67–70.

———, and C.C. Schwartz. 1998. Logging in Alaska's boreal forest: Creation of grasslands or enhancement of moose habitat. Alces 34:355–374.

Daniel, T.W., J.A. Helms, and F.S. Baker. 1979. Principles of silviculture, Second edition. McGraw-Hill, New York, USA.

Decker, D.J., T.L. Brown, and W.F. Seimer. 2001. Human dimensions of wildlife management in North America. The Wildlife Society, Bethesda, Maryland, USA.

Fries, C., O. Johansson, B. Pettersson, and P. Simonsson. 1997. Silvicultural models to maintain and restore natural stand structures in Swedish boreal forests. Forest Ecology and Management 94:89–103.

Haggstrom, D.A., 2008. Wildlife habitat management performance report. Project 25.0. Alaska Department of Fish and Game, Juneau, Alaska. <http://www.wildlife.alaska.gov/pubs/techpubs/federal_aid/survey_inven/hab08perf.pdf> Accessed 24 August 2009.

Haggstrom, D.A., and D.G. Kelleyhouse. 1996. Silviculture and wildlife relationships in the boreal forest of Interior Alaska. Forestry Chronicle 72:59–62.

Hundertmark, K.J., and C.C. Schwartz. 1996. Considerations for intensive management of moose in Alaska. Alces 32:15–24.

Johnson, D.H. 2002. The role of hypothesis testing in wildlife science. Journal of Wildlife Management 66:272–276.

Juday, G.P. (Lead Author), V. Barber, E. Vaganov, S. Rupp, S. Sparrow, J. Yarie, H. Linderrholm (Contributing Authors), and numerous Consulting Authors. 2005. Forests, land management, agriculture. Pages 781–862 *in* Arctic Climate Impact Assessment. Arctic Council. Cambridge University Press.

Malcolm, J.R., B.D. Campbell, B.G. Kuttner, and A. Sugar. 2004. Potential indicators of the impacts of forest management on wildlife habitat in northern Ontario: a multivariate application of wildife habitat suitability matrices. Forestry Chronicle 80:91–106.

McNab, J. 1983. Wildlife management as scientific experimentation. Wildlife Society Bulletin 11: 397–401.

Paragi, T.F., and D.A. Haggstrom. 2004. Identifying and evaluating techniques for wildlife habitat enhancement in interior Alaska. Alaska Department of Fish and Game, Research Interim Technical Report, Project 5.0. Juneau, Alaska. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/hab-mgt03dwc.pdf> Accessed 24 July 2009.

———, and ———. 2005. Identifying and evaluating techniques for wildlife habitat enhancement in interior Alaska. Alaska Department of Fish and Game. Research Final Report, Project 5.0. Juneau, Alaska. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/hab-mgt05.pdf> Accessed 24 July 2009.

———, and ———. 2007. Short-term responses of aspen to fire and mechanical treatments in Interior Alaska. Northern Journal of Applied Forestry 24(2):153–157.

———, S. Rupp, and J. Little. 2006. Modeling outcomes of hazardous fuel reduction near Fairbanks, Alaska. Western Forester 51(6):12–13. <http://www.forestry.org/pdf/dec06.pdf>

———, C.T. Seaton, and K.A. Kellie. 2008. Identifying and evaluating techniques for moose range assessment in interior Alaska. Alaska Department of Fish and Game, Research Final Technical Report. Project 5.10, Juneau. <http://www.wildlife.alaska.gov/pubs/techpubs/research_pdfs/hab-mgt08final.pdf> Accessed 24 July 2009.

———, B.D. Taras, and D.A. Haggstrom. (in prep.) Identifying and evaluating techniques for wildlife habitat management in Interior Alaska: Prescribed burn assessment. Alaska Department of Fish and Game, Research Final Technical Report. Project 5.10, Juneau, Alaska.

Renecker, L.A., and C.C. Schwartz. 1997. Food habits and feeding behavior. Pages 403–439 *in* A. W. Franzmann and C. C. Schwartz, editors. Ecology and management of the North American moose. Smithsonian Institution Press, Washingon, D.C.

Seaton, C.T. 2002. Winter foraging ecology of moose in the Tanana Flats and Alaska Range Foothills. Thesis, University of Alaska Fairbanks. <http://www.wildlife.alaska.gov/pubs/techpubs/propubs/seaton_thesis.pdf> Accessed 23 Sep 2009.

Spence, J.R. 2001. The new boreal forestry: adjusting timber management to accommodate biodiversity. Trends in Ecology and Evolution 16:591–593.

Thompson, I.D., J.A. Baker, and M. Ter-Mikaelian. 2003. A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. Forest Ecology and Management 177:441–469.

Todd, S.K., and H.A. Jewkes. 2006. Wildland fire in Alaska: a history of organized fire suppression and management on the last frontier. Agriculture and Forestry Experiment Station Bulletin No. 114, University of Alaska, Fairbanks. <http://www.uaf.edu/salrm/afes/pubs/bul/B114.pdf>

Walters, C.J., and C.S. Holling. 1990. Large scale management experiments and learning by doing. Ecology 71:2060–2068.

Wurtz, T.L., R.A. Ott, and J.C. Maisch. 2006. Timber harvest in interior Alaska. Pages 302–308 *in* Chapin, F. S., III, M. Oswood, K. Van Cleve, L. A. Viereck, and D. L. Verbyla, editors. Alaska's Changing Boreal Forest. Oxford University Press, New York.

______, and J.C. Zasada. 2001. An alternative to clear-cutting in the boreal forest of Alaska: A 27-year study of regeneration after shelterwood harvesting. *Canadian Journal of Forest Research* 31:999–1011.

Young, D.D., R.D. Boertje, C.T. Seaton, and K.A. Kellie. 2006. Intensive management of moose at high density: Impediments, achievements, and recommendations. Alces 42:41–48.

PREPARED BY:

Thomas F. Paragi
Wildlife Biologist III

Dale A. Haggstrom
Wildlife Biologist III

SUBMITTED BY:

Scott M. Brainerd
Research Coordinator

Roy A. Nowlin
Management Coordinator

Laura A. McCarthy
Publications Technician II

APPROVED BY:

Clayton R. Hawkes
Federal Assistance Coordinator
Division of Wildlife Conservation

Douglas N. Larsen, Director
Division of Wildlife Conservation

APPROVAL DATE: __________________

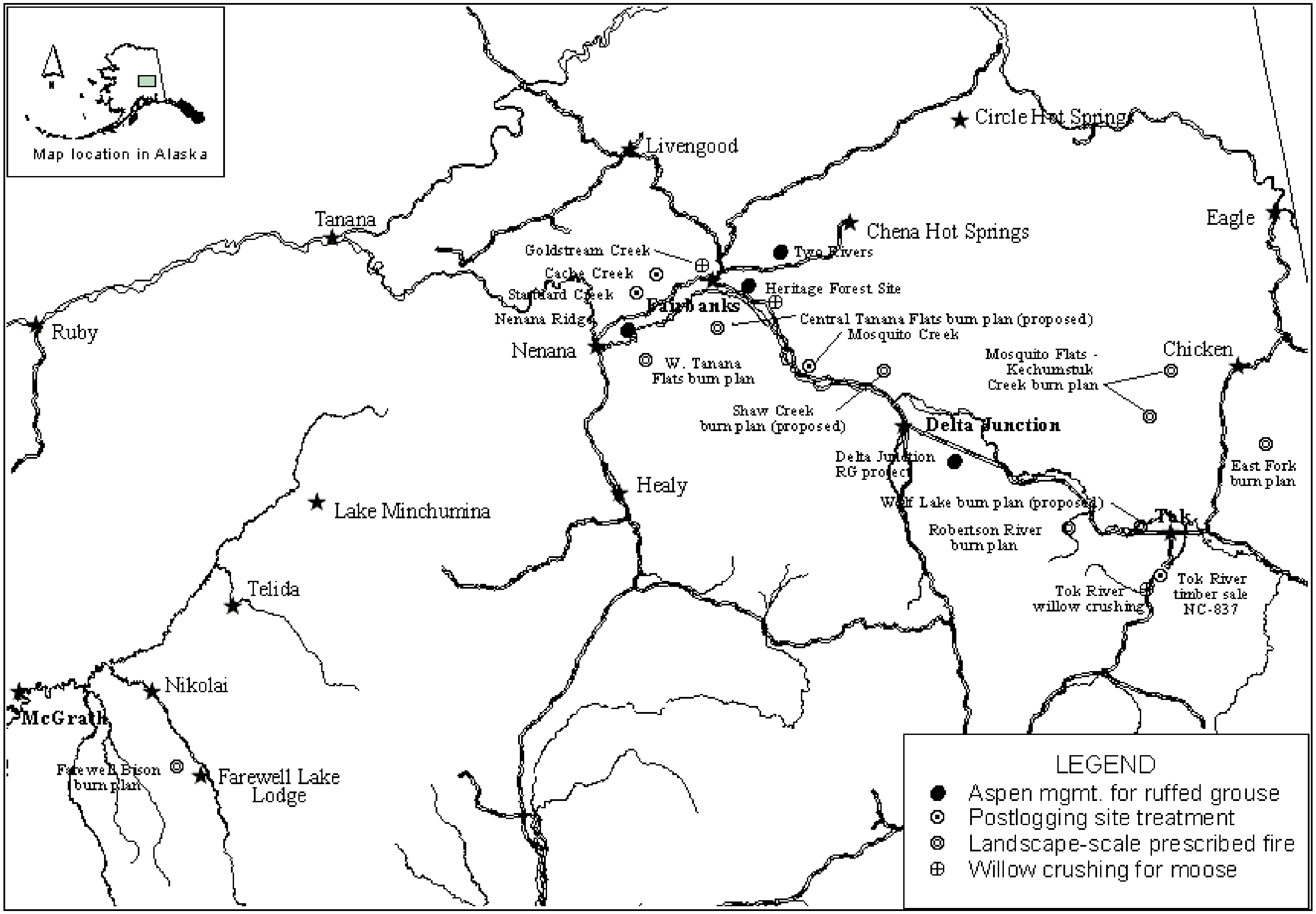


FIGURE 1. Location of ADF&G/DWC Region III habitat enhancement activities and research projects.

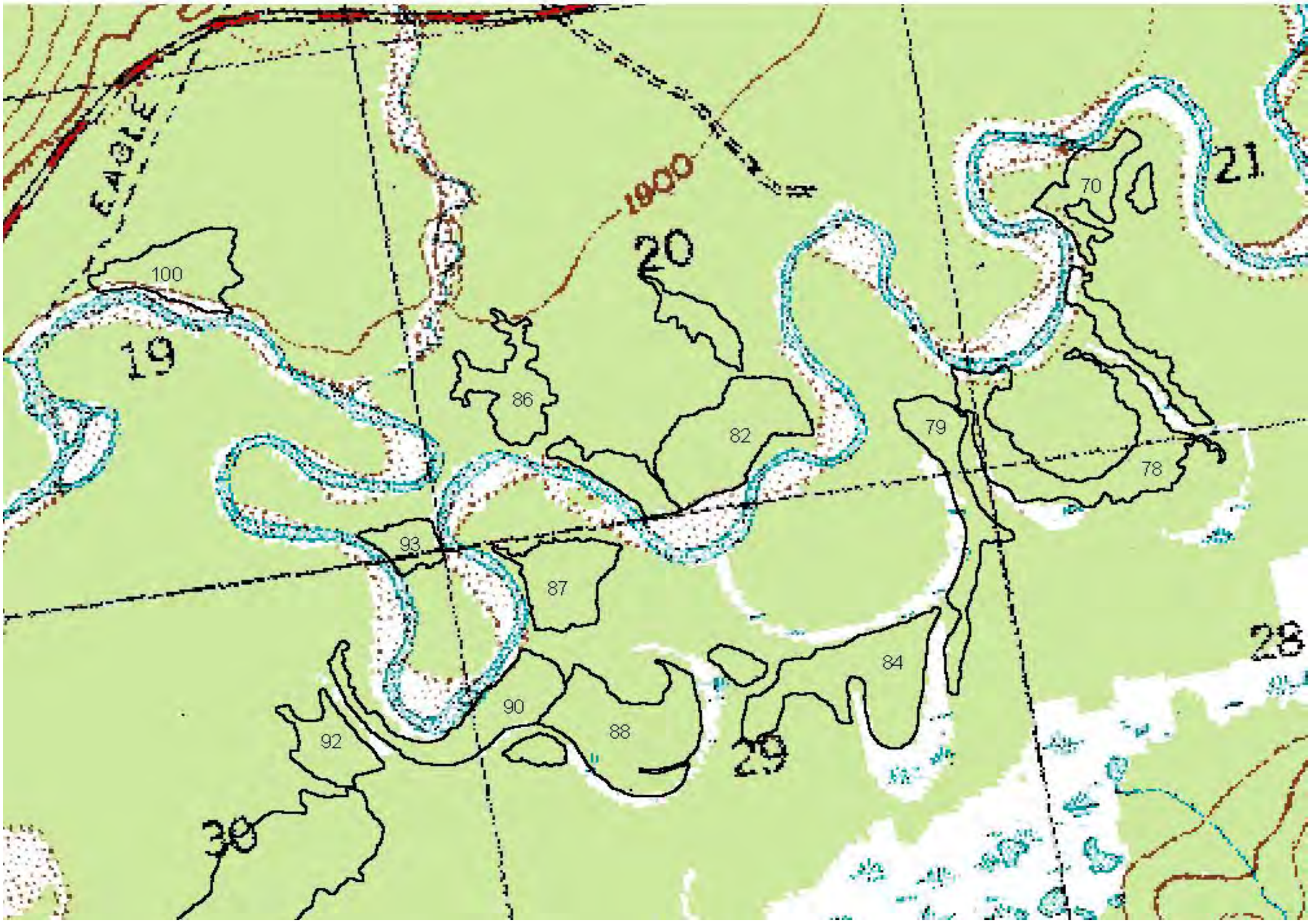


FIGURE 2. Twelve study sites at the proposed timber sale NC-837-T (Tok River) about 15 miles south of Tok along the Glenn Highway. One mile section lines of T16N, R12 E, Copper River Meridian, are visible on the 1:63,360 scale Tanacross A-5 map.

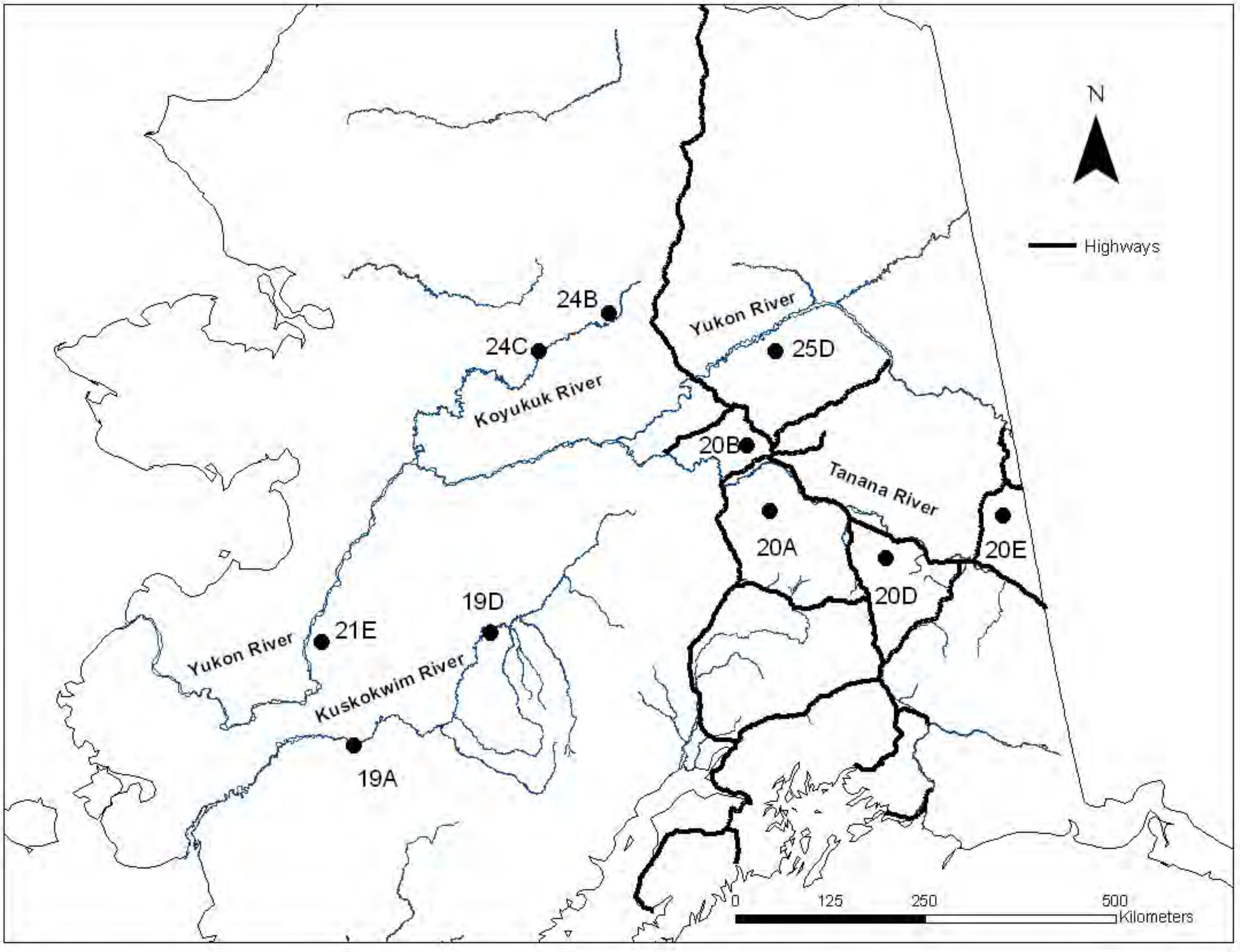


FIGURE 3. Location of 10 study areas identified by game management unit where browse production and its removal by moose were sampled during 2000–2007 in Interior Alaska.

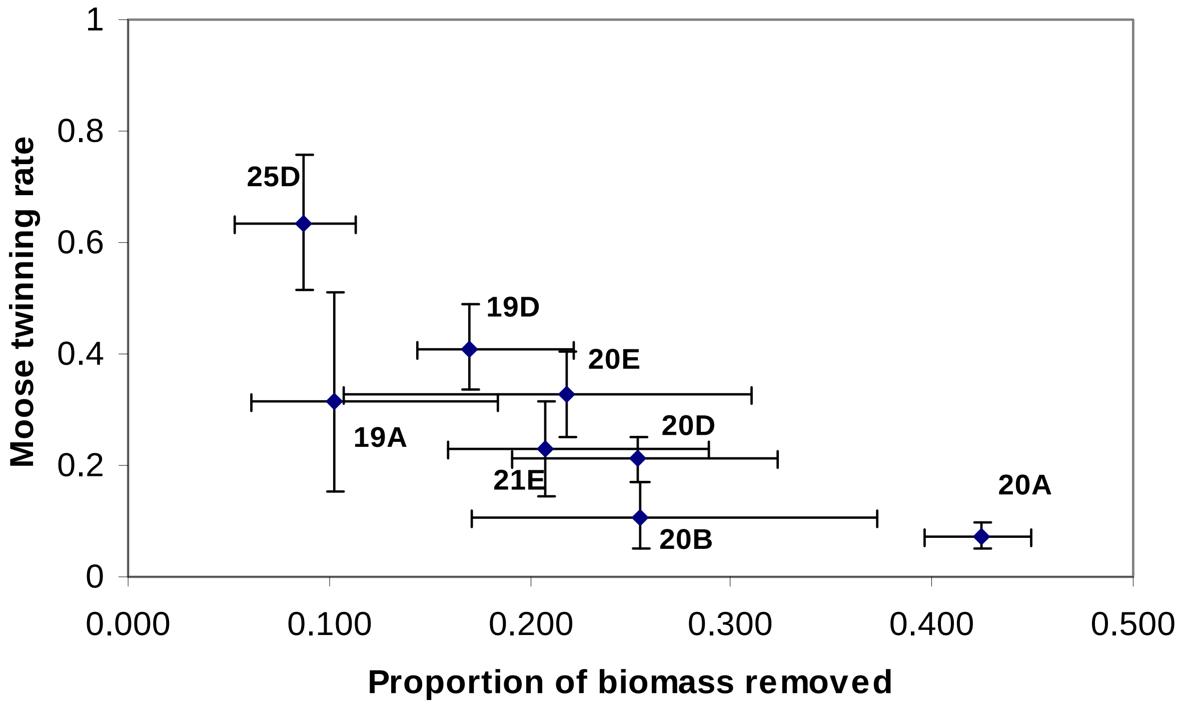
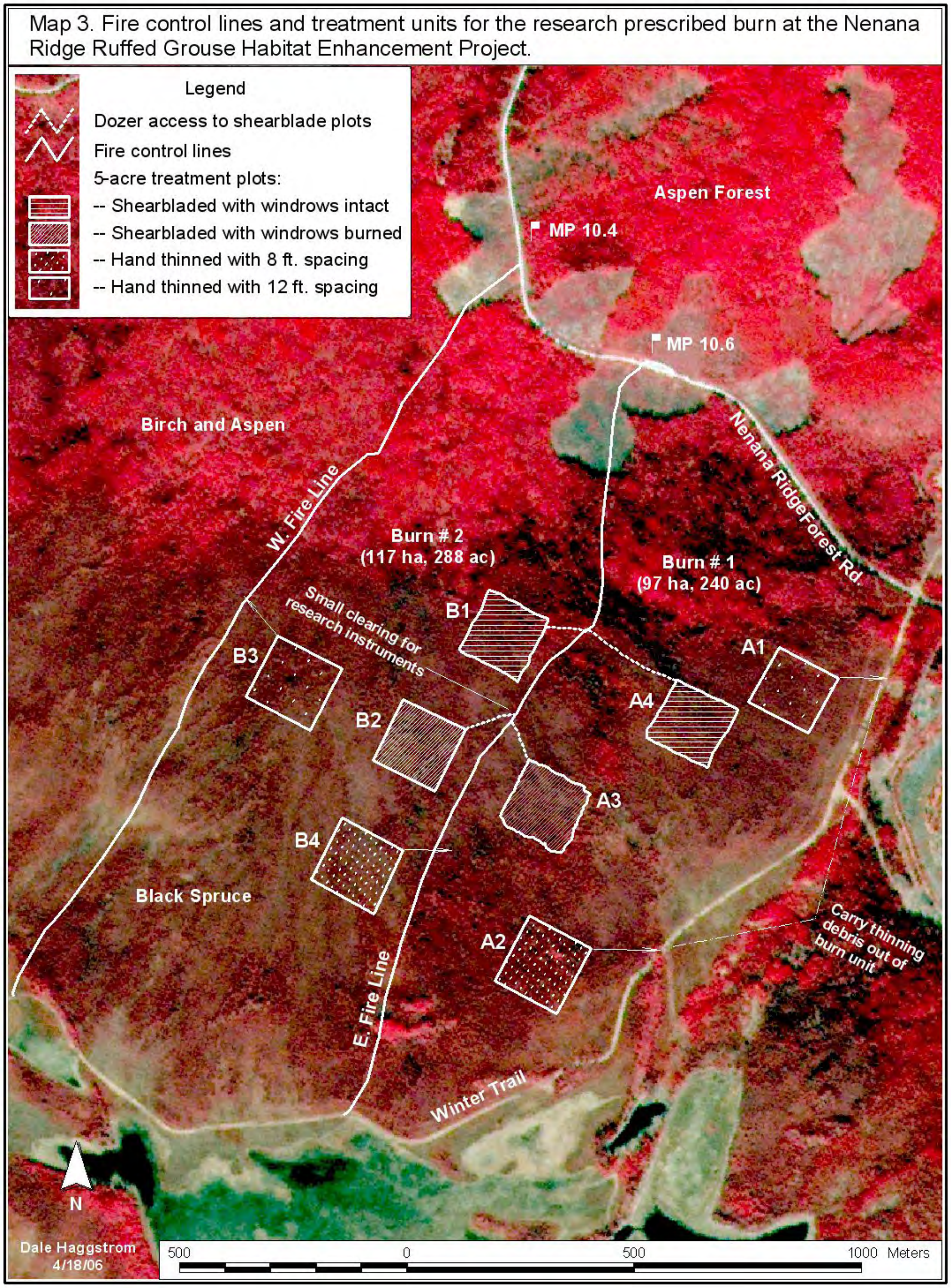


FIGURE 4. Relationship between proportion of browse biomass removed (current annual growth, sampled twigs only) by moose and proportion of cow moose with twin calves for 8 study areas in Interior Alaska, 2000–2007. Estimates were derived by bootstrapping, and error bars indicate bootstrap 95% confidence limits.



Map 3. Fire control lines and treatment units for the research prescribed burn at the Nenana Ridge Ruffed Grouse Habitat Enhancement Project.

FIGURE 5. Overlay of experimental design for testing effect of treatments for hazardous fuel reduction about 45 km southwest of Fairbanks, Alaska. "A" units were burned 17 June 2009.