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Moose population ecology and habitat use along the Juneau Access road corridor, Alaska

Kevin S. White, David P. Gregovich, Neil L. Barten and Ryan Scott

May 2012

Alaska Department of Fish and Game Division of Wildlife Conservation

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Cover Photo: Photograph of an adult female moose (BM-61) and twin calves, lower Lace River, AK ©2010 ADF&G/photo by Kevin White.

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ABSTRACT

The Alaska Department of Fish and Game (ADFG) conducted a moose population ecology study in the Berners Bay area during 2006-2012. The primary purpose of this project was to acquire biological data necessary to manage local moose populations in the event the proposed Juneau Access highway is constructed. A secondary purpose was to provide the Alaska Department of Transportation and Public Facilities (ADOT/PF) with highway mitigation and design recommendations for reducing the likelihood of moose-vehicle collision. Specific objectives included estimating moose population size, body condition, vital rates, resource selection and movement patterns in the vicinity of the Juneau Access highway alignment. Data collection efforts focused on capture and monitoring of radio-marked moose (n = 68 females, 6 males) deployed with Global Positioning System (GPS) and Very High Frequency (VHF) radio-collars (GPS, n = 39; VHF, n = 29). During capture biological data were gathered to assess age, body condition, diet composition and pregnancy status. Aerial monitoring of marked animals enabled determination of population size (via Bayesian mark-resight procedures), reproductive success and survival. Moose GPS location data and GIS remote sensing data were used develop resource selection function (RSF) models to characterize seasonal habitat use patterns.

During the study period, the Berners Bay moose population (ca. 120-85) was characterized by low productivity and declined by 30% between 2006-2010 following severe winter conditions (i.e. deep winter snow). Annual survival of adult females (87%) and associated calves (25%) was low, relative to the nearby Gustavus population. Moose body condition was relatively high in fall but declined to low levels by the end of winter, relative to other populations in Alaska. Declines in late-winter body condition was exacerbated by severe winter conditions. Nonetheless, pregnancy (84%) and twining rates (44%) were considered typical for Alaska moose populations. Activity and movement rates of moose demonstrated distinct seasonal changes such that movement rates and activity patterns were 2-2.5 times lower in winter relative to summer. Resource selection function (RSF) modeling indicated that moose strongly selected for low elevation (i.e. valley bottom) habitats in the Berners Bay area. Within this context, moose selected for habitats characterized by moderate-high biomass of deciduous shrubs. However, conifer habitats were also selected but only during winter, presumably due to reduced snow accumulation in such habitats. Otherwise, summer and winter resource selection patterns were similar. The proposed Juneau Access highway alignment intersects areas characterized by high probability of use in the lower Berners Bay and Katzehin River watersheds, and to a lesser extent areas near Slate Cove.

The implications of highway construction for local moose populations include the potential for moose-vehicle collisions, increased human access and disturbance. Such conditions will result in changes to moose management strategies and are likely to include geographic reconfiguration of the Berners Bay hunt area to avoid disproportionate harvest near highway access points, changing the existing RM046 registration hunt (i.e. areas draining into Lynn Canal between Pt. St. Mary and Eldred Rock) to a drawing hunt and creating a separate hunt in the Katzehin River to avoid exceeding harvest quotas. Under current conditions, the Berners Bay moose population should be managed conservatively due to the recent population decline, relatively low calf recruitment and severe winter conditions.

INTRODUCTION

This report was prepared to meet the reporting requirements for ADOT/PF. This report summarizes data collected between November 2005-May 2012.

Background

The Alaska Department of Transportation and Public Facilities (DOT/PF) is planning to construct an all-season highway between Echo Cove and the Katzehin Flats (ca. 50 miles in length). Among the wildlife species potentially affected by road construction activities and use are moose (*Alces alces*), particularly populations in the Berners Bay and, possibly, Katzehin River areas. The key concerns for moose (and human) populations are related to moose-vehicle collisions and increased human access to previously isolated areas.

Moose can be very vulnerable to vehicle collisions, especially during snowy winter months in places where key winter concentration areas intersect road corridors (Del Frate and Spraker 1991). Vehicle-induced mortality can have significant effects on moose population abundance and productivity, especially when pregnant cows (typically the highest fraction of moose populations) are killed (Child 1997). Such incidental harvest typically requires wildlife managers to reduce allowable hunter harvest accordingly in affected areas. For example, in areas of northern British Columbia with higher, but comparable, traffic volumes to the projected Juneau Access road, direct mortality of moose due to vehicle collisions resulted in a 4-20% reduction in allowable hunter harvest (Child 1991). Thus, reduction of allowable harvest for the popular Berners Bay moose hunt (i.e. 738-1774 permit applications received, 1999-2004) as a result of increased vehicle collisions may be a very real, albeit undesirable, possibility. Perhaps more importantly, moose-vehicle collisions represent a significant threat to human life and property. While mitigation strategies leading to reduced incidence of moose-vehicle collisions are feasible, implementation has met with mixed success and is requisite on baseline understanding of moose movement and population ecology.

The construction of roads into areas with otherwise limited access can also have important indirect effects on moose populations. In particular, increased human access is likely to result in parallel increases in disturbance resulting in displacement of moose from key foraging (Colescott and Gillingham 1998), calving and/or breeding areas. For example, a recent study on the Yakutat forelands indicated that off-road vehicle activity negatively affected adult female moose utilization of forage rich willow habitats and calculated that such effects existed up to 1000 m from motorized travel routes (Shanley and Pyare 2011). If such effects are chronic, moose populations could potentially suffer reduced body condition, productivity and survival.

In response to the above concerns, DOT&PF and ADFG implemented a cooperative monitoring and assessment program to collect baseline moose population data in the Berners Bay and surrounding areas. Specifically, the program involved collection of movement, habitat use, survival, and reproductive data on a sample of radio-marked moose in addition to conducting annual aerial population abundance and productivity surveys. These efforts were aimed at providing information necessary for appropriately managing moose and mitigating, to the extent possible, human safety concerns and possible displacement of moose along the proposed highway corridor.

STUDY OBJECTIVES

This project was designed to investigate the spatial relationships, vital rates and abundance of moose in the Berners Bay and surrounding areas. The specific objectives were as follows:

1) determine seasonal movement patterns, habitat use and key concentration areas in the vicinity of the Juneau Access road corridor,

2) characterize body condition, reproductive performance and survival in the vicinity of the Juneau Access road corridor, and

3) annually estimate moose population abundance and composition in the vicinity of the Juneau Access road corridor.

STUDY AREA

Moose were studied in a ca. 115 km^2 watershed complex located immediately north of Berners Bay (Figure 1, Appendix 1). The study area is dominated by four major rivers of current (Lace, Antler and Gilkey) or recent (Berners) glacial origin. Elevation within the study area ranged from sea level to 6300 feet however most moose activity occurred at elevations below 500 feet. This area is an active glacial terrain underlain by late cretaceous-paleocene granodiorite and tonalite geologic formations (Gehrels 2000). Specifically, it is a geologically young, dynamic and unstable landscape that harbors a matrix of perennial snowfields and small glaciers at high elevations (i.e. above 4000 feet) and rugged, broken terrain that descend to broad, low gradient river valleys. Rivers are prone to substantial seasonal changes in water flow and stream side vegetation disturbance events are relatively common.

The maritime climate in this area is characterized by cool, wet summers and relatively, warm snowy winters. Annual precipitation at sea-level averages 55 inches and winter temperatures are rarely less than 5° F and average 30° F (Haines, AK; National Weather Service, Juneau, AK, unpublished data). Elevations at 2600 feet typically receive ca. 250 inches of snowfall, annually (Eaglecrest Ski Area, Juneau, AK, unpublished data). Sea-level snowfall averages 156 inches annually (Haines, AK; National Weather Service, unpublished data) however substantial variability occurs spatially with areas closer to the coast accumulating less snow than areas further inland. Maximum winter snow depths in the Berners Bay watershed vary between 3-5.5 feet (K. White, unpublished data).

Predominant vegetative communities important for moose that occur in the study area consist of deciduous shrublands, emergent herbaceous meadows, conifer forest and unvegetated riparian and upland habitats (White et al. 2007). Due to glacial retreat and episodic flooding events lowland plant communities are dynamic and represent several different stages of plant succession.

METHODS

Moose Capture

Moose were captured using standard helicopter darting techniques and immobilized by injecting 3.3-4.2 mg of carfentanil citrate (depending on season) and 100-120 mg of xylazine hydrochloride (Taylor 2000) via projectile syringe fired from a Palmer dart gun (Cap-Chur, Douglasville, GA). During handling, all animals were carefully examined and monitored following standard veterinary procedures (Taylor 2000) and routine biological samples and morphological data were collected (Figure 2). Moose body condition was estimated by measuring maximum rump fat thickness using ultrasongraphy techniques developed by Stephenson et al. (1996). Additional body condition data was collected using muscle and skeletal palpation methods (John Crouse, ADFG Moose Research Center, unpublished). Following handling procedures, the effects of the immobilizing agent was reversed with 100 mg of naltrexone hydrochloride per 1 mg of carfentanil citrate and 0.5 mg tolazoline per lb of estimated body weight (Taylor 2000). All capture procedures were approved by the State of Alaska Animal Care and Use Committee.

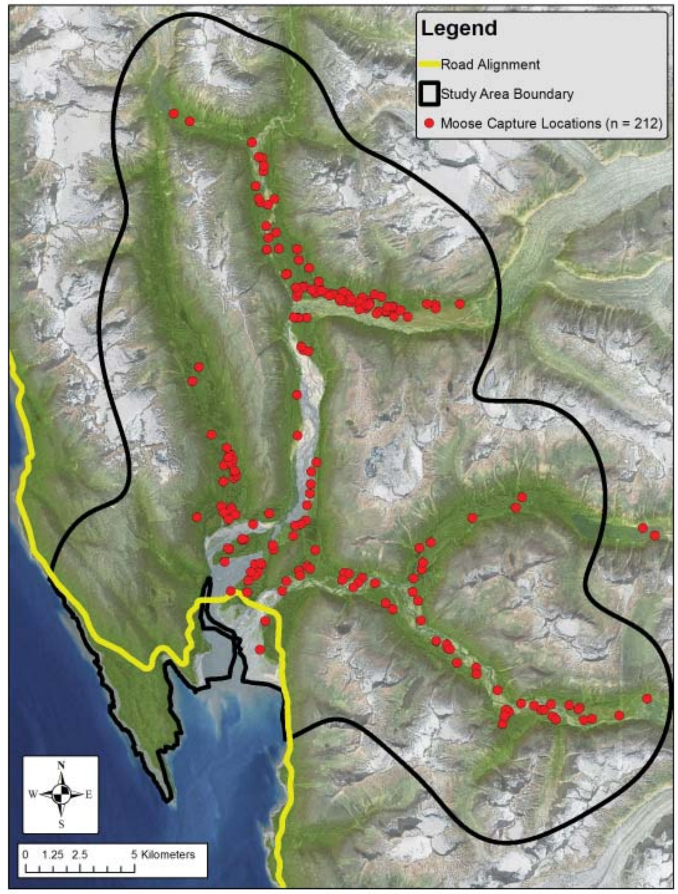

Figure 1: Location of moose captured (n = 212) and subsequently monitored in the Berners Bay study area, 2006-2011.


Figure 2: Moose capture site in the east fork of the Lace river. ADFG wildlife biologist, Stacy Crouse, mesures moose rump fat thickness using a portable ultrasound while ADFG wildlife technician, Chad Rice, records data.

GPS Location Data

Telonics TGW-3700 GPS and MOD-600 VHF radio-collars (Telonics, Inc., Mesa, AZ) were deployed on all animals captured. GPS radio-collars were programmed to collect location data at 3-hour intervals (collar lifetime: 3.5 years). During each location attempt, ancillary data about collar activity (i.e. percent of 1-second switch transitions calculated over a 15 minute period following each GPS fix attempt) and temperature (degrees C) were simultaneously collected. All GPS and associated data are stored "on-board" collars and can only be accessed when collars are in-hand. As a result, all collars were deployed with remote release devices that ensure that collars will release from animals prior to the end of battery life. In cases where animals died or GPS collars were otherwise handled, location data were manually downloaded. Location data were post-processed and filtered for "impossible" points and 2D locations with PDOP (i.e. position dilution of precision) values greater than 10, following D'Eon et al. (2002) and

D'Eon and Delparte (2005).

Habitat Selection and Movement Patterns

Activity.—Activity sensor data were summarized at daily intervals for each individual GPS radio-collared moose. Individual daily estimates were then averaged to provide an overall (i. e. population-level) estimate of moose activity for each day of the calendar year. This procedure enabled determination of how moose activity varied seasonally. Previous field validation trials determined that activity sensor data are useful for predicting the proportion of time moose are engaged in active (i.e. feeding, walking, vigilant) vs. inactive (i.e. bedded) behavior (K. White, unpublished data).

Movement Patterns.—Planimetric distance between consecutive GPS locations for each individual was estimated using the Geospatial Modeling Environment (GME), a GIS software program. Estimates were then standardized by including only consecutive locations separated by 3-hour intervals. Movement distances were then summarized by individual animal and date in order to estimate average daily movement rates.

Habitat Selection and Modeling.—Resource selection function (RSF) models (i.e. Boyce 2002) were developed using moose GPS location data and remote sensing covariate data layers in a GIS framework in order to describe where important winter and summer habitats occur in the study area. A resource selection function can be defined as a model that yields values proportional to the probability of use of a given resource unit (Boyce et al. 2002). Specifically, we employed a logistic regression-based "used" vs "available" study design to estimate resource selection patterns at the population-level (i.e. 1st-order selection, Johnson 1980). In order to estimate resource availability in the study area, we randomly selected locations throughout the study area at a density of 30 locations per km^2, a density determined to reliably describe resource availability patterns in our study area (D. Gregovich, unpublished data). Moose GPS locations (ie. "used"; Appendix 2) and "available" locations were then intersected (using GME) with a suite of biologically relevant remote sensing data layers (Table 1). These data were then analyzed using logistic regression (GLM function, stats package, Program R, ver. 2.13.1) to derive selection coefficients for each covariate by individual animal. The average inter-individual coefficient value (and confidence interval) was computed for each covariate (ie. the "two-stage" modeling framework; Fieberg et al. 2010) and stratified by season (winter vs. summer). Covariates considered to be significant were evaluated by examining whether confidence intervals for a given covariate include zero. Significant coefficient values were then multiplied by respective covariate remote sensing data layers in GIS using the following equation:

Table 1: Terrain and landcover variables used to predict moose resource use in Berners Bay, AK, 2005-2011.

Variable	Definition	Source Data
Terrain		
Elevation	elevation (meters)	SRTM DEM[1]
Landcover		
deciduous	deciduous landcover types	TSYS[2]
conifer	conifer landcover types	TSYS[2]
emergent meadow	emergent landcover types	TSYS[2]
riparian	riparian landcover types	TSYS[2]
water	freshwater landcover types	TSYS[2]
unvegetated	unvegetated landcover types	TSYS[2]

[1]Shuttle Radar Topography Mission Digital Elevation Model

[2]Terrestrial Ecosystems Landcover derived by the Nature Conservancy (D. Albert, pers. comm., Juneau, AK)

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n) \quad (1)$$

Where, w(x) represents a resource selection function (RSF) that is proportional to the probability of use of variables $x_1 + x_2 + \ldots + x_n$. The resulting output was then categorized (using the quantile function in ArcGIS10) to characterize areas across the study area that differ in their relative probability of use. This output provides a robust tool for indexing the relative importance of specific areas to moose. The predictive performance of RSF models were validated using k-fold cross validation (Boyce et al. 2002).

Snow Conditions

Winter Severity and Snow Conditions.—In order to characterize winter severity, snow depth measurements were opportunistically collected during moose capture activities and other field activities. In addition, daily climate data were archived for a reference weather station located in Haines, AK (National Weather Service, Juneau, AK).

Reproduction and Survival

Pregnancy rates were determined by estimating concentration of pregnancy specific protein-B (PSPB) of blood serum samples collected from moose live-captured during March 2007-2010 (Biotracking, Moscow, ID). Moose calving as well as calf and adult survival estimates were determined by monitoring individual study animals during monthly surveys using fixed-wing (Heliocourier, Piper

Super Cub) or rotary aircraft (Hughes 300) equipped for radio-telemetry tracking. During surveys, radio-collared adult female moose were monitored to determine whether they gave birth to calves and, if so, how long they survived. Mortality of adult moose was determined by detecting radio-frequency pulse rate changes during monthly monitoring surveys. In cases where mortality pulse rates were detected, efforts were made to investigate sites as soon as possible via helicopter. To the extent possible, all mortalities were thoroughly investigated to ascertain the cause of death and relevant biological samples collected. For animals equipped with GPS radio-collars it was possible to specifically determine the date of death based on activity sensor and movement data downloaded from collars after field retrieval. Seasonal and annual survival was estimated using the Kaplan-Meier procedure (Pollock et al. 1989). This technique allows for staggered entry and exit of newly captured and deceased animals, respectively.

Population Abundance and Composition Estimation

Aerial Surveys.—Population abundance and composition surveys were conducted using fixed-wing aircraft (i.e. Piper PA-18, Heliocourier) following the onset of winter snowfall. During surveys the number and age/sex composition of all animals was recorded. However, due to the inability to accurately distinguish between adult males and females following "antler drop", only data collected before December 1, 2006 were used to estimate sex composition of the moose population.

During surveys, the number of radio-collared moose observed was enumerated and these data, combined with knowledge about the number of collared and un-collared animals in the study area, were used to estimate sightability (i.e. the probability of seeing moose on a given survey) and population abundance using modified Lincoln-Peterson mark-resight techniques. In addition, habitat, behavioral and climate data associated with each radio-collared animal seen or not seen (but later radio-tracked) during surveys were also collected.

RESULTS AND DISCUSSION

Moose Capture

Capture Activities.—Moose captures were conducted during 17 days during fall (Nov 16-Dec 3) and 14 days during spring (Feb 26-Mar 30) 2006-2010. Overall, 67 moose (63 females and 4 males) were captured during 105 occasions in fall and 107 occasions during spring (Appendix 3). To the extent possible, moose were seasonally re-captured in order to assess changes in over-winter and over-summer body condition, determine pregnancy status of individual animals and replace expiring GPS-radiocollars with extended lifespan VHF-radiocollars. All moose were captured using standard helicopter darting methods.

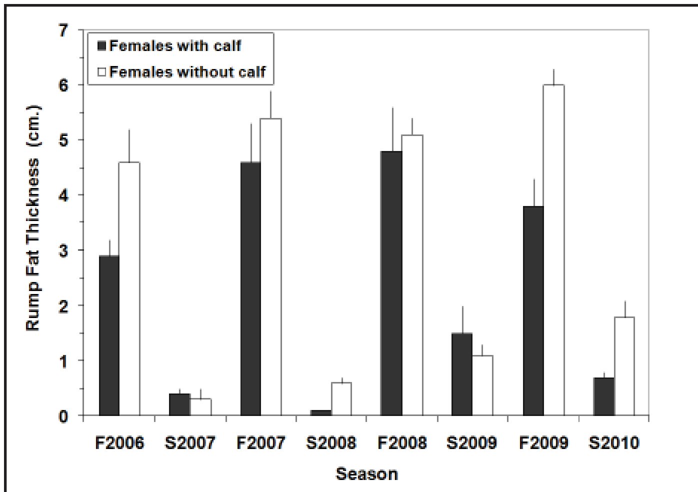

Figure 3: Body fat reserves (rump fat thickness) for female moose with and without calves at heel in fall and spring, 2006-2010, Berners Bay, AK.

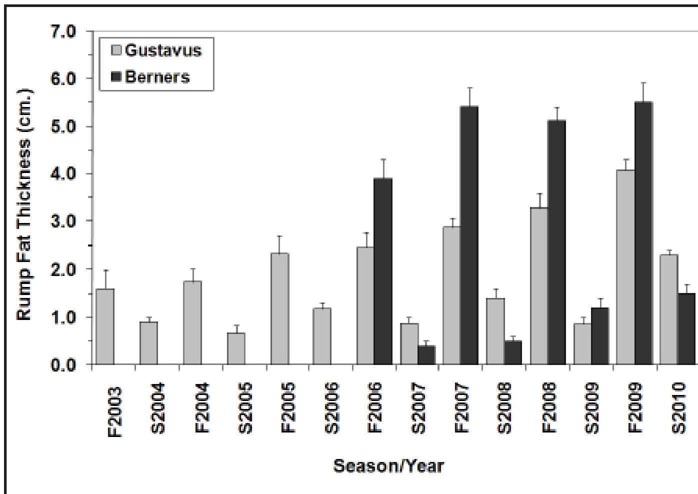

Figure 4: Body fat reserves (rump fat thickness) for female moose (irrespective of calf status) during fall and spring, 2003-2010. Data are presented for Berners Bay and the nutritionally stressed Gustavus forelands population, for comparison.

Biological Sample Collection.—During handling procedures standard biological specimens were collected and morphological data were collected. Specific biological samples collected from study animals included: whole blood (4 mL), blood serum (8 mL), red blood cells (8 mL), ear tissue, hair and fecal pellets. Whole blood, serum and fecal pellet sub-samples were sent to either Dr. Kimberlee Beckmen (ADFG, Fairbanks, AK) for disease screening or archived at Alaska Department of Fish and Game facilities in Douglas, AK. Blood serum sub-samples were analyzed for PSPB concentration to determine pregnancy (Biotracking, Moscow, ID).

Body Condition.—Moose body condition was estimated by measuring maximum rump fat thickness of all animals captured in the field. Maximum rump fat thickness is strongly correlated with percent body fat for animals with greater than 5.6% body fat (Stephenson et al. 1996). Like other moose populations in Alaska (i.e. Testa and Adams 1998), body condition of moose in Berners Bay is affected by presence of calves. Specifically, animals with calves have lower body fat reserves than those without calves (Figure 3). This results from the high energetic costs of lactation experienced by animals bearing calves.

Moose in Berners Bay generally have moderate-high levels of body fat during the fall season (Figure 3-4). However, animals substantially deplete body fat reserves during the winter period and tend to have low levels of body fat by spring (Figures 3, 4). During the particularly severe winter of 2006/2007 this pattern was especially pronounced. However, during the more recent winters animals entered spring with higher fat reserves, a pattern likely linked to less severe winter conditions. Nonetheless, since fall body fat estimates have been similar between years, irrespective of winters, it appears that moose have the ability to recover from significant overwinter nutritional stress during summer; suggesting that summer range conditions in Berners Bay are good, relative to other areas (ie. Gustavus) (Figure 4). Overall, the data collected during the course of this study (2006-2010) have been consistently characterized by severe to very severe winter conditions. Consequently, our knowledge of the nutritional condition of moose during “normal” conditions in this system is limited.

Activity, Movement Patterns and Habitat Selection

Activity.—Moose activity patterns exhibited distinct seasonal patterns (Figure 5). In general, activity was lowest during winter (Nov-March) and highest during summer (June-August). A small but distinct increase in activity was documented during late-September to early-October, a period coinciding with the breeding season, or rut. During late-January to March, activity was lowest and likely related to seasonal peaks in snow depth and seasonal reductions in forage availability, quality and consequent low nutritional condition.

In northern environments, moose experience very substantial seasonal changes in quality and availability of food resources. As a consequence, during winter, moose must conserve nutritional stores that were acquired during the summer season in order to survive and maintain pregnancies (Renecker and Schwartz 1997). One way this is accomplished is by reducing energetic costly behaviors and activity during winter. When snow depths are deep and nutritional stores are impoverished during late winter, reductions in activity are particularly pronounced. In contrast, during summer moose increase activity in order to maximize intakes rates of high quality and abundant summer forages (Renecker and Schwartz 1997). During the breeding season, activity increased slightly and is probably related to parallel increases in both inter- and intrasexual social interactions.

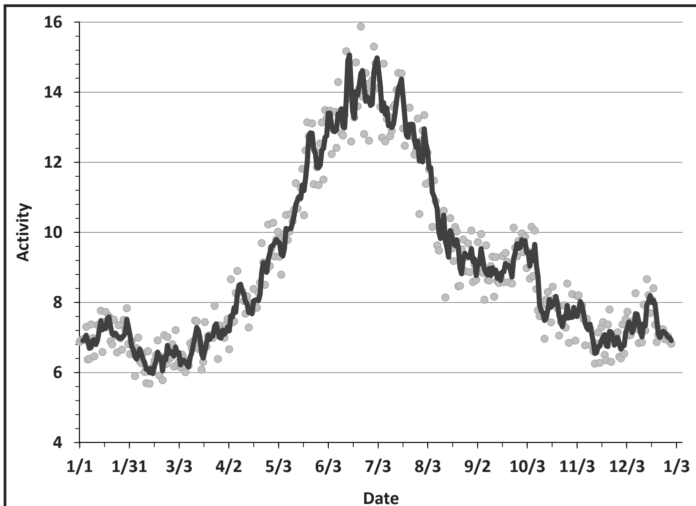

Figure 5: Relationship between moose activity (% tip-switch transitions per 15 minutes) and time of year for GPS-marked adult females, 2005-2011, Berners Bay, AK.

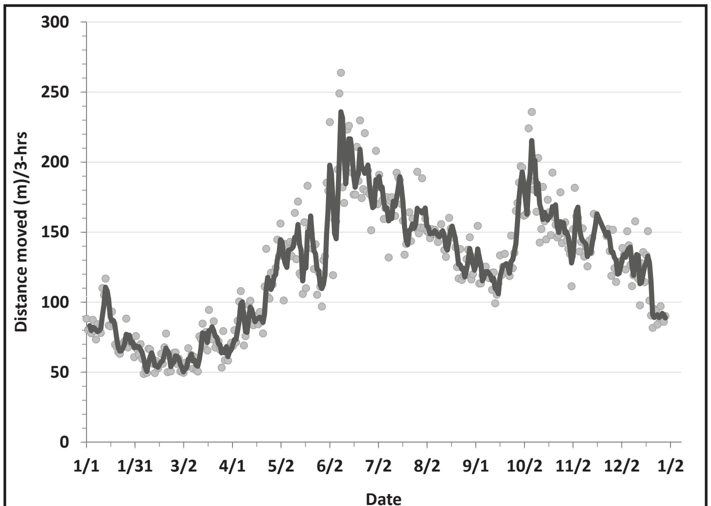

Figure 6: Relationship between moose movement distance and time of year for GPS-marked adult females, 2005-2011, Berners Bay, AK.

Figure 7: Photograph of an adult female moose (BM29) along a tributary of the east fork Lace river in late-winter (3/13/07). Snow depth in upland habitats measured 6.5 feet and restricted moose movement.

Movement Patterns.—Moose movement rates exhibited distinct seasonal variation. Movement rates were low during winter (50-100 m/3-hrs) and 2-5 times higher in summer (200-250 m/3-hrs; Figure 6). Similar to activity patterns, movement generally increased during late-spring and decreased during late-summer/fall, except for a distinct increase in movement during the breeding season in late-September to October. Such increases are likely related to rut-related behavioral changes but also coincide with fall migration of non-resident moose. Overall, movement rates during late-winter are extremely low and occur during a period when moose are nutritionally stressed (Figure 6, 7). Consequently, during this period of the year, moose may be particularly vulnerable to spatial displacement caused by natural or anthropogenic entities.

Resource Selection Modeling.—Moose resource selection function models were developed separately for the summer and winter periods, to account for possible differences in seasonal resource use (Table 2a, 2b). However, we determined that moose resource selection models differed relatively little between summer and winter (Appendix 4). Elevation was an important predictor of moose resource selection. Specifically, moose strongly selected for low elevation and avoided moderate and high elevation areas, irrespective of season. Within low elevation areas, moose selected for deciduous and riparian habitats, relative to other landcover types, during summer. During winter, moose selected for deciduous, riparian, emergent and conifer habitats, relative to other landcover types; however deciduous habitats were selected significantly more than any other habitat.

The resource selection models derived for the Berners Bay study area are broadly comparable to models developed for moose in the Copper River and Yakutat Forelands (MacCraken et al. 1997, Shanley and Pyare 2011) and result in findings consistent with expectations about how moose select habitats in coastal Alaska landscapes. Moose diets in Berners Bay are primarily composed of shrubs (Appendix 5-7) and biomass of such forages is high in deciduous and riparian habitat types and, to a lesser extent, emergent meadows. Consequently, selection for shrub dominated habitats is likely linked to the availability of food resources in such habitat types. Conifer habitats in coastal Alaska have 2-3 time less forage biomass than deciduous dominated types (K. White, unpublished data) but nonetheless tend to be selected by moose in winter to a similar degree as emergent meadows and riparian habitats. This is likely related to snow interception by conifer forest canopy which results in reduced burial of forages and lower energetics costs of locomotion relative to more snowy, open habitats.

Table 2a: Resource selection function (RSF) coefficients for variables used to predict adult female moose resource use during summer in Berners Bay, AK, 2006-2011. [The elevation coefficient is based on the standardized form of elevation (i.e. elevation = (elevation (m)-533.476)/423.174)].

Summer Model			
Variables	**Coefficient**	**LCI**	**UCI**
Terrain variables			
Elevation	**-9.4459**	**-11.7744**	**-7.1173**
Habitat variables			
deciduous	**2.1977**	**1.8065**	**2.5890**
riparian	**2.0299**	**1.2330**	**2.8269**
conifer	**0.7160**	**-0.1014**	**1.5333**
emergent meadow	**0.4011**	**-0.2035**	**1.0057**
water	**-1.5569**	**-2.3488**	**-0.7650**
unvegetated[1]	--	--	--

[1]**reference habitat variable**

Table 2b: Resource selection function (RSF) coefficients for variables used to predict adult female moose resource use during winter in Berners Bay, AK, 2006-2011. [The elevation coefficient is based on the standardized form of elevation (i.e. elevation = (elevation (m)-533.476)/423.174)].

Winter Model			
Variables	**Coefficient**	**LCI**	**UCI**
Terrain variables			
Elevation	**-15.4463**	**-19.8247**	**-11.0678**
Habitat variables			
deciduous	**3.3210**	**2.8907**	**3.7513**
riparian	**1.8444**	**1.0876**	**2.6012**
conifer	**1.9230**	**1.1895**	**2.6565**
emergent meadow	**2.2833**	**1.6961**	**2.8704**
water	**-0.3164**	**-1.0152**	**0.3825**
unvegetated[1]	--	--	--

[1]**reference habitat variable**

Table 3. RSF model validation results for the Berners Bay study area relative to season. The Spearman-rank correlations (r_s) between RSF bin ranks and area-adjusted frequencies for individual and average model sets reported below provide an indication of the extent to which RSF models accurately predicted actual use of iteratively witheld data from GPS-marked animals.

	winter		summer	
Set	r_s	P-value	r_s	P-value
1	0.782	0.012	0.964	<0.001
2	0.745	0.018	0.879	0.002
3	0.224	0.537	0.964	<0.001
4	0.188	0.608	0.370	0.296
5	0.564	0.096	0.879	0.002
Average	0.612	0.066	0.976	<0.001

K-fold cross validation results indicated that resource selection models accurately predicted actual use patterns, as gauged via iterative witholding of data from GPS-marked animals, in the Berners Bay study area (Table 3). The summer model performed better than the winter model. Winter model validation results indicated a marginally significant correlation between actual and predicted use. This occurred beacuse the winter model tended to underestimate use of areas with low RSF scores (i.e. areas categorized as "low-moderate" and "moderate" use in Appendix 4) and overestimates areas of high RSF scores. Consequently, the winter modeling output describes a stronger gradient of predicted use than actually occurs. However, despite these nuances the winter model generally performed adequately based on statistical criteria.

The resource selection models developed for moose in the Berners Bay area are most useful for broad scale applications and may be limited at finer scales of resolution. This occurs because the remote sensing data available to map landcover types (and thus predict moose distribution and use across the landscape) is relatively coarse-scale and not intended for fine-scale applications. In the future, resource selection models and mapping could be improved if higher resolution imagery and landcover classification analyses are made available.

Katzehin River Resource Selection Modeling.—Detailed study of the Katzehin River moose population was beyond the scope of the study objectives. Nonetheless, to accomodate management interest and assessment of proposed highway design and mitigation options, resource selection models developed in the Berners Bay study area were applied to the Katzehin River watershed (Appendix 8). Subjective assessment of ecological similarities between Berners Bay and the Katzehin River suggest that the Berners Bay models are likely to provide a reasonable approximation moose habitat distribution and use within the Katzehin River area. At a broad scale, the Katzehin River modeling output suggested that moose use and distribution is likely to be concentrated along the river corridor and delta areas. This output is consistent with opportunistic field observations collected during aerial surveys. Nonetheless, determination of modeling output accuracy is unknown and future site-specific data collection efforts are recommended in order to properly characterize moose resource selection patterns in this area.

Moose Resource Selection and Highway Construction.—Resource selection models indicate that the Juneau Access highway alignment intersects moose winter and summer habitats along lower reaches of the Berners Bay and Katzehin watersheds. The impact of highway construction moose can include sub-lethal and lethal effects and potentially influence moose population dynamics and harvest management.

In northern environments, moose are vulnerable to vehicle collisions, especially during snowy winter months in places where key winter concentration areas intersect road corridors (Del Frate and Spraker 1991), such as along the lower portions of the Berners Bay and Katzehin watersheds. Vehicle-induced mortality can have significant effects on moose population abundance and productivity, especially when pregnant cows (typically the highest fraction of moose populations) are killed (Child 1997). If such incidental harvest occurs along the Juneau Access highway, wildlife managers will be required to reduce allowable hunter harvest. In areas of northern British Columbia that experience higher, but comparable, traffic volumes to the projected Juneau Access road, direct mortality of moose due to vehicle collisions resulted in a 4-20% reduction in allowable hunter harvest (Child 1991).

Construction of the Juneau Access road will substantially increase public access to areas that are currently difficult to access and rarely visited but represent important areas for moose (i.e. the lower Berners Bay and Katzehin watersheds). Among the key concerns of increased access is dispersed, unregulated off road vehicle (ORV) use. Currently, such activity is widespread in the Echo Cove area but limited in the lower Berners Bay and Katzehin watersheds due to difficult access. Recent studies in the ecologically similar Yakutat forelands have documented negative effects of ORV activity on moose use of key foraging habitats (Shanley and Pyare 2011). Consequently, the presence of the road, and associated construction and maintenance activities, are likely to alter the suitability of habitats within a certain distance of the road corridor (i.e. Shanley and Pyare 2011). The actual disturbance "shadow" of the road is unknown at the present time but is likely to extend beyond 1000 m (Shanley and Pyare 2011), or further (Jiang et al. 2009). Further, due to the close proximity to the large, regional community of Juneau (ca. 30, 000 residents), the potential for ORV-related impacts and implications for Berners Bay and Katzehin moose populations is likely much higher than the Yakutat forelands. In this context, land use planning focused on managing ORV activity can play a key role in minimizing impacts of increased human access on moose in this area.

Winter Severity and Snow Conditions.— Daily climate data were obtained from the National Weather Service database to characterize broader scale climate patterns. Mean daily snow depth and snowfall data were summarized from data collected at the National Weather Service station in Haines, AK (Appendix 9-10). Mean snowfall in Haines during

2005-2011 was 126% of normal (i.e. 11-yr average). Notably, during 4 of the 5 winters of study total snowfall amounts were greater than 125% of normal and should be considered severe or very severe in terms of relative effects on moose. Over the course of the study, only one winter (2010-2011) was characterized by below-average winter conditions.

Survival and Reproduction

Reproduction.— In-utero pregnancy rates were generally similar between 2007-2010, with the exception of 2008 which had a slightly higher rate of pregnancy (Table 3). Overall, the estimates reported here are within the normal range documented for the species (Boer 1992). Since pregnancy rates are related to body condition in moose (Testa and Adams 1998) it is likely that recent severe winter conditions, and associated negative effects on body fat reserves, may have depressed pregnancy rates below levels that are "normal" for this population.

We annually conducted 2-3 fixed-wing and helicopter-based tracking surveys in late-May to early-June 2007-2011 in order to determine whether radio-collared moose gave birth to calves. Since we were unable to conduct daily surveys during this period it was not possible to estimate actual parturition rates (since neonates can be killed by predators shortly after birth). Instead, we estimated early calf recruitment which is a likely underestimate of actual parturition rate. Overall, during 2007-2011, we determined that 56% of adult females had calves of which 44% had twins, on average (Table 4). In addition, we determined that each female produced 0.81 calves, on average. These estimates of fecundity are low relative to other populations and likely reflect underestimation due to survey technique limitations rather than actual biological differences.

Survival.—Annual survival was calculated for adult female moose in Berners Bay and, for comparison, the Gustavus forelands. In order to investigate patterns of seasonality in survival we also calculated survival separately for the summer and winter periods. Annual survival of adult female moose in Berners Bay during 2007/2008 and 2010/2011 were low, compared to Gustavus (Table 5) and other moose populations in Alaska. However, adult female survival rates were statistically higher in 2008/2009 and 2009/2010, and within the range of normal values for the species in Alaska. Overall, survival during winter tended to be lower than summer survival (Table 5). These findings are not surprising considering the occurrence of severe winters during the study period. Consequently, it is likely that the adult female winter survival estimates reported here might be lower than normal for this population. Adult female survival is a key determinant of population productivity and the relatively low estimates for the Berners Bay population suggest that this population should be managed conservatively.

Table 3: In-utero pregnancy rates (and standard error, SE) of adult female moose in Berners Bay and, for comparison, Gustavus, AK, 2004-2010.

	Berners Bay			Gustavus		
Year	Pregnancy	SE	n	Pregnancy	SE	n
2004	--	--	--	0.75	0.11	16
2005	--	--	--	0.77	0.09	22
2006	--	--	--	0.82	0.07	34
2007	0.84	0.07	25	0.78	0.07	32
2008	0.92	0.05	26	0.87	0.06	30
2009	0.82	0.08	22	0.87	0.06	31
2010	0.84	0.07	25	0.96	0.04	26
Total	0.86	0.04	98	0.84	0.03	191

Table 4: Summary of calf recruitment by early-June in Berners Bay, 2007-2011. Data are based on observations of attendent neonates associated with radio-collared adult female moose.

Year	# of Cows Monitored	# of Cows with Calves	# Cows with Twins	P(calf)	P(twins)	Calves/Cow
2007	27	9	4	0.33	0.44	0.48
2008	27	20	6	0.74	0.30	0.96
2009	31	17	9	0.55	0.53	0.84
2010	28	14	6	0.50	0.43	0.71
2011	24	17	9	0.71	0.53	1.08
All Years	137	77	34	0.56	0.44	0.81

Survival of calves (associated with radio-collared mothers) was also lower in Berners Bay than in nearby Gustavus (Table 6). Calf survival was significantly lower in summer than winter (Table 2). This seasonal difference in calf survival has been widely documented throughout Alaska and is generally attributed to high vulnerability of calves to predation during the first 6 weeks of life. Overwinter survival estimates of calves was similarly high during the four winters between 2007-2010 and substantially higher than the severe winter of 2006/2007 (Table 6). This may have occurred because snow conditions were not nearly as severe during 2007-2010. Nonetheless, sample sizes for yearly winter survival comparisons are small and these findings should be treated with caution due to the high variance of estimates. In general, calf survival is relatively low and, in combination with relatively low adult female survival, indicates that the Berners Bay moose population was characterized by relatively low productivity during the study period, relative to other areas in coastal Alaska.

Table 5: Summer, winter and annual survival (ŝ) estimates (and standard error, SE) for adult female moose in Berners Bay and, for comparison, Gustavus, AK.

	Summer Survival				Winter Survival				Annual Survival			
Year	At Risk[1]	Died	Ŝ	SE	At Risk	Died	Ŝ	SE	At Risk	Died	Ŝ	SE
Berners												
2006	--	--	--	--	32	5	0.85	0.06	--	--	--	--
2007	28	2	0.93	0.05	30	4	0.87	0.06	29	6	0.81	0.06
2008	27	1	0.96	0.04	31	2	0.94	0.04	29	3	0.91	0.05
2009	31	0	1.00	0.00	32	2	0.94	0.04	32	2	0.94	0.04
2010	32	2	0.94	0.04	31	4	0.88	0.06	32	6	0.82	0.06
2011	25	1	0.96	0.04	27	0	1.00	0.00	26	1	0.96	0.04
All Years	143	6	0.96	0.02	183	17	0.91	0.02	167	23	0.87	0.02
Gustavus [2]												
2003	--	--	--	--	12	0	1.00	0.00	--	--	--	--
2004	21	0	1.00	0.00	24	0	1.00	0.00	23	0	1.00	0.00
2005	26	0	0.98	0.02	30	2	0.93	0.04	28	3	0.91	0.05
2006	37	0	1.00	0.00	36	6	0.84	0.06	36	6	0.84	0.06
2007	34	1	0.97	0.03	33	3	0.91	0.05	33	4	0.89	0.05
2008	35	2	0.94	0.04	39	5	0.89	0.05	37	7	0.84	0.05
2009	40	0	1.00	0.00	40	3	0.93	0.04	41	3	0.93	0.04
2010	40	2	0.95	0.03	37	2	0.95	0.04	38	4	0.90	0.05
2011	33	3	0.91	0.05	33	0	1.00	0.00	33	3	0.91	0.05
All Years	266	8	0.97	0.01	282	22	0.93	0.01	275	30	0.90	0.02

[1] At Risk: average number of animals monitored per month.
[2] White et al. (unpublished)

Table 6: Summer, winter and annual survival (ŝ) estimates (and standard error, SE) for moose calves (associated with radio-collared mothers) in Berners Bay and, for comparison, Gustavus, AK.

	Summer Survival				Winter Survival				Annual Survival			
Year	At Risk[1]	Died	Ŝ	SE	At Risk	Died	Ŝ	SE	At Risk	Died	Ŝ	SE
Berners												
2006	--	--	--	--	15	8	0.47	0.08	--	--	--	--
2007	13	8	0.39	0.08	4	1	0.75	0.19	13	9	0.29	0.12
2008	27	20	0.26	0.04	7	2	0.71	0.14	27	22	0.19	0.06
2009	24	17	0.29	0.05	7	6	0.86	0.12	24	18	0.25	0.08
2010	18	9	0.50	0.08	9	0	1.00	0.00	18	9	0.50	0.12
2011	24	16	0.33	0.06	8	1	0.88	0.11	24	17	0.29	0.09
All Years	106	70	0.34	0.03	50	13	0.74	0.05	106	83	0.25	0.03
Gustavus [2]												
2003	--	--	--	--	7	0	1.00	0.00	--	--	--	--
2004	13	3	0.77	0.10	10	2	0.85	0.12	13	5	0.62	0.12
2005	9	5	0.44	0.11	6	2	0.85	0.10	9	7	0.30	0.10
2006	20	11	0.45	0.08	8	1	0.94	0.11	20	12	0.39	0.11
2007	21	10	0.52	0.08	10	0	1.00	0.00	21	10	0.52	0.11
2008	27	22	0.19	0.03	9	5	0.44	0.11	33	29	0.07	0.02
2009	29	21	0.28	0.04	9	3	0.67	0.13	30	24	0.18	0.05
2010	23	17	0.26	0.05	12	3	0.75	0.11	29	20	0.20	0.05
2011	30	18	0.40	0.06	12	0	1.00	0.00	30	18	0.40	0.09
All Years	172	107	0.38	0.02	85	18	0.79	0.04	172	125	0.30	0.03

[1] "At Risk" sample sizes reflect maximum number of animals monitored during the period of interest. Staggered-entry statistical design includes animals that were not monitored the entire year for annual estimates.

[2] White et al. (unpublished)

Timing of Mortality and Scavenging Activity.—Since the inception of the study (November 2006) 23 adult females and one male have died. Of these, most have occurred during late-winter or the calving season (Figure 8). Due to lag times between moose death, detection via monthly aerial surveys, and field investigations it was often difficult to unequivocally assign cause of death. This results because of the tendency of large carnivores (i.e wolves and bears) to actively pursue and kill moose in addition to scavenging animals that died from other causes. Consequently, it is often difficult to distinguish between predation and scavenging at moose mortality sites.

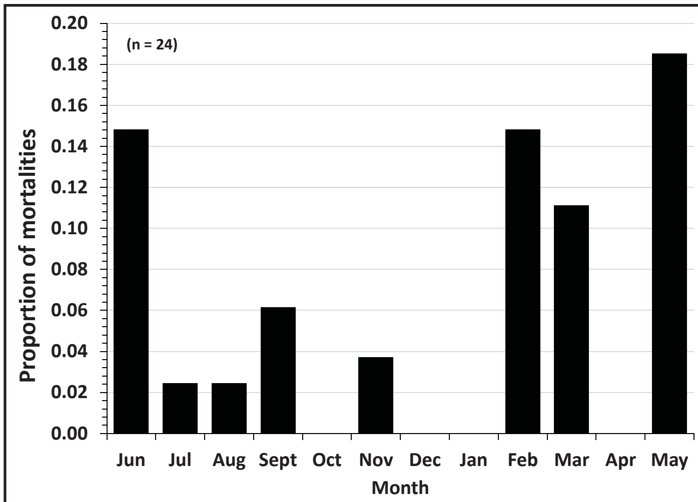

Figure 8: Seasonal frequency of radio-marked adult female moose mortalities in Berners Bay, AK, 2006-2011.

Population Abundance and Composition

Aerial Surveys: Berners Bay.—During 2006-2011, 14 aerial surveys were conducted in order to estimate population abundance, composition and sighting probability in Berners Bay (Table 7a, 7b, Figure 9). During winter surveys, most animals in the population were distributed in three key concentration areas located in the upper Lace River, Gilkey River and the Berners Forelands. However, a small proportion of marked females (i.e. 10-20% annually) were located during surveys in forested areas in the vicinity of Slate Cove/Pt. St. Mary, an area outside of the Berners Bay watershed survey area. Movement of animals into this area prior to surveys negatively biased raw counts of moose during surveys but were accounted for in population estimates, which adjust for variation in moose sighting probabilities within a given survey.

During the winter of 2009/2010, aerial survey population estimate data indicated that 78±14 inhabited the Berners Bay watershed (Table 7a). This represented an approximate 30% decline in the number of moose in Berners Bay since the winter of 2006/2007. The decline is likely due to the extreme winter conditions observed between 2006-2009 which resulted in poor spring body condition and moderate to low adult survival and pregnancy rates. Low calf survival rates (related to both summer and winter phenomena) represent an additional key factor responsible for the recent population trajectory. More recent populations estimates conducted in 2010 and 2011 indicate that population abundance may be increasing, but the population has not yet recovered to levels observed in 2006.

Sighting probability was estimated during 13 surveys and averaged 0.59 but exhibited substantial variation between surveys (range = 0.38-0.82; Table 7a). Variation in sighting probability among surveys was attributed to variable survey conditions and seasonal shifts in distribution. Specifically, when surveys were conducted later in the winter radio-marked animals were more often located in closed canopy conifer forest than when surveys were conducted earlier in winter.

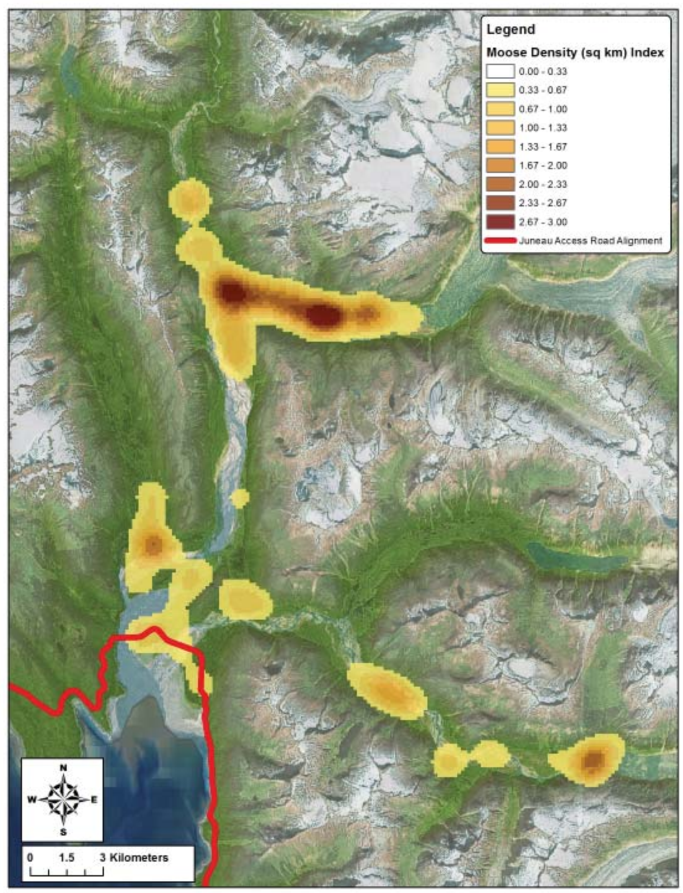

Figure 9: Winter distribution and index of moose density observed during 8 surveys conducted in the in Berners Bay watershed, AK, 2006-2011. The moose density index is based on aerial field observations and does not adjust for spatial variation in sighting probabilities, and probably underestimates actual moose density in the more forested lower reaches of the watershed.

Composition of the moose population was estimated during a subset of the surveys, those conducted prior to mid-December. After this date, data relating to bull composition of the population is compromised by the likelihood of "antler drop". Even still, bulls have been observed to drop antlers

Table 7a: Moose population estimates calculated during replicate aerial surveys conducted in Berners Bay, AK, 2006-2011.

Survey Year	Survey Date	Total Moose Seen	Total Marked Moose	Marked Moose Seen	Prop. Moose Observed	Population Est.
2006	11/11/2006	75	0	--	--	--
2006	11/25/2006	85	31	22	0.71	119 ± 22
2006	1/11/2007	76	31	20	0.65	116 ± 25
2006	1/26/2007	69	31	16	0.52	131 ± 36
2006	2/13/2007	78	30	19	0.63	121 ± 27
2007	12/19/2007	59	30	17	0.57	102 ± 25
2007	1/7/2008	62	30	18	0.60	102 ± 23
2007	2/18/2008	41	28	13	0.46	86 ± 26
2007	2/23/08	34	28	11	0.39	84 ± 29
2008	12/16/08	33	32	12	0.38	85 ± 28
2008	2/17/09	55	32	21	0.66	83 ± 15
2009	12/15/09	51	34	22	0.65	78 ± 14
2010	12/3/10	73	34	28	0.82	88 ± 10
2011	11/19/11	73	27	18	0.67	108 ± 23

Table 7b: Moose population composition data collected during aerial surveys in Berners Bay, AK, 2006-2011.

Survey Year	Survey Date	Bulls	Cows	Calves	Unknown Adults	Total	Prop. Bulls	Prop. Calves
2006	11/11/2006	10	56	9	0	75	0.13	0.12
2006	11/25/2006	10	60	12	3	85	0.12	0.14
2006	1/11/2007	3	9	11	53	76	--	0.14
2006	1/26/2007	1	6	7	55	69	--	0.10
2006	2/13/2007	0	6	8	64	78	--	0.10
2007	12/19/2007	10	44	5	0	59	0.17	0.08
2007	1/7/2008	5	5	5	47	62	--	0.08
2007	2/18/2008	0	0	5	36	41	--	0.12
2007	2/23/08	0	0	2	32	34	--	0.06
2008	12/16/08	3	22	3	5	33	0.09	0.09
2008	2/17/09	0	8	8	39	55	--	0.15
2009	12/15/09	12	20	4	15	51	--	0.08
2010	12/3/10	18	45	10	0	73	0.25	0.14
2011	11/19/11	22	41	10	0	73	0.30	0.14

as early as mid-November and even our earliest surveys probably underestimate the proportion of bulls in the population to an unknown degree. As such, our estimates of the number of bulls is probably most accurately regarded as an index of bull composition in the population. During the 6 composition surveys we estimated that the proportion of bulls varied between 0.09-0.30 and the proportion of calves ranged between 0.06-0.15 (Table 7b). Since the overall number of moose in the population is relatively small it is not surprising that estimates exhibit substantial variability, as estimates not only track actual biological trends but are also influenced by variability in survey conditions, moose distribution and sample size.

Aerial Surveys: Katzehin.—In order to gather baseline population information about moose in the Katzehin River area, we conducted nine winter surveys during seven winters between 2005-2011 (Tables 8a, 8b). The number of moose seen during surveys ranged between 7 -39 animals and varied substantially between surveys and years. During the fall of 2008 and spring of 2010, seven adult female moose were radio-collared in order to provide information about survey variability. The results of this work can only provide a coarse estimate of the number of moose and population trends in this area, due to small samples sizes. Nonetheless, existing data suggest that the Katzehin harbors between 30-40 moose. While limited in scope, these findings likely provide a more realistic approximation of the total number of moose in the Katzehin than uncorrected raw survey data.

Table 8a: Moose population estimates calculated during replicate aerial surveys conducted in the Katzehin river valley, AK, 2006-2011.

Survey Year	Survey Date	Total Moose Seen	Total Marked Moose	Marked Moose Seen	Prop. Moose Observed	Population Est.
2005	2/10/2006	19	0	--	--	--
2006	1/26/2007	11	0	--	--	--
2006	2/9/2007	12	0	--	--	--
2007	12/27/2007	39	0	--	--	--
2008	12/19/2008	34	5	5	1.00	34 ± 0
2008	2/18/2009	19	5	2	0.40	39 ± 26
2009	1/23/2010	7	4	1	0.25	19 ± 15
2010	1/7/2011	39	6	3	0.50	69 ± 38
2011	1/5/2012	18	5	2	0.40	37 ± 24

Table 8b: Moose population composition data collected during aerial surveys in the Katzehin river valley, AK, 2006-2011.

Survey Year	Survey Date	Bulls	Cows	Calves	Unknown Adults	Total	Prop. Bulls	Prop. Calves
2005	2/10/2006	0	0	2	17	19	--	0.11
2006	1/26/2007	0	0	0	11	11	--	0.00
2006	2/9/2007	0	0	0	12	12	--	0.00
2007	12/27/2007	5	1	2	31	39	--	0.05
2008	12/19/2008	4	2	2	26	34	--	0.06
2008	2/18/2009	0	0	0	19	19	--	0.00
2009	1/23/2010	0	2	2	3	7	--	0.29
2010	1/7/2011	2	22	12	3	39	--	0.31
2011	1/5/2012	1	3	2	12	18	--	0.11

SUMMARY

1. The Alaska Department of Fish and Game (ADFG) conducted a moose population ecology study in the Berners Bay area during 2006-2012. The primary purpose of this project was to acquire biological data necessary to manage local moose populations in the event the proposed Juneau Access highway is constructed. A secondary purpose was to provide ADOT/PF with highway mitigation and design recommendations for reducing the likelihood of moose-vehicle collision. Specific objectives included estimating moose population size, body condition, vital rates, resource selection and movement patterns in the vicinity of the Juneau Access highway alignment.

2. During the study period, the Berners Bay moose population (ca. 120-85) was characterized by low productivity and declined by 30% between 2007-2010. This period was characterized by severe winter conditions (i.e. deep winter snow; Figure 10). Annual survival of adult females (87%) and associated calves (25%) was low, relative to the nearby Gustavus population.

3. Moose body condition (measured via rump fat thickness) was relatively high in fall but declined to low levels by the end of winter, relative to other populations in coastal Alaska. Declines in late-winter body condition was exacerbated by severe winter conditions. Nonetheless, pregnancy (84%) and twining rates (44%) were considered typical for coastal Alaska moose populations.

4. Activity and movement rates of moose demonstrated distinct seasonal changes such that movement rates and activity patterns were 2-2.5 times lower in winter relative to summer.

5. Resource selection function (RSF) modeling indicated that moose strongly selected for low elevation (i.e. valley bottom) habitats in the Berners Bay area. Within this context, moose selected for habitats characterized by moderate-high biomass of deciduous shrubs. However, conifer habitats were also selected for but only during winter, presumably due to reduced snow accumulation in such habitats. Otherwise, summer and winter resource selection patterns were similar.

6. The proposed Juneau Access highway alignment intersects areas characterized by moderate to high probability of use by moose in the lower Berners Bay and Katzehin River watersheds, and to a lesser extent areas near Slate Cove.

7. The implications of highway construction for local moose populations include the potential for moose-vehicle collisions and increased human access and disturbance. Such conditions will result in changes to moose management strategies and are may include geographic reconfiguration of the Berners Bay hunt area to avoid disproportionate harvest near highway access points and creating a separate hunt in the Katzehin River to avoid exceeding harvest quotas. Under current conditions, the Berners Bay moose population should be managed conservatively due to the recent population decline, relatively low calf recruitment and severe winter conditions.

RECOMMENDATIONS

The primary purpose of this project was to acquire biological data necessary to manage local moose populations in the event the proposed Juneau Access highway is constructed. A secondary purpose was to provide ADOT/PF with highway mitigation and design recommendations for reducing the likelihood of moose-vehicle collision. As such, the following recommendations are intended to address these specific objectives.

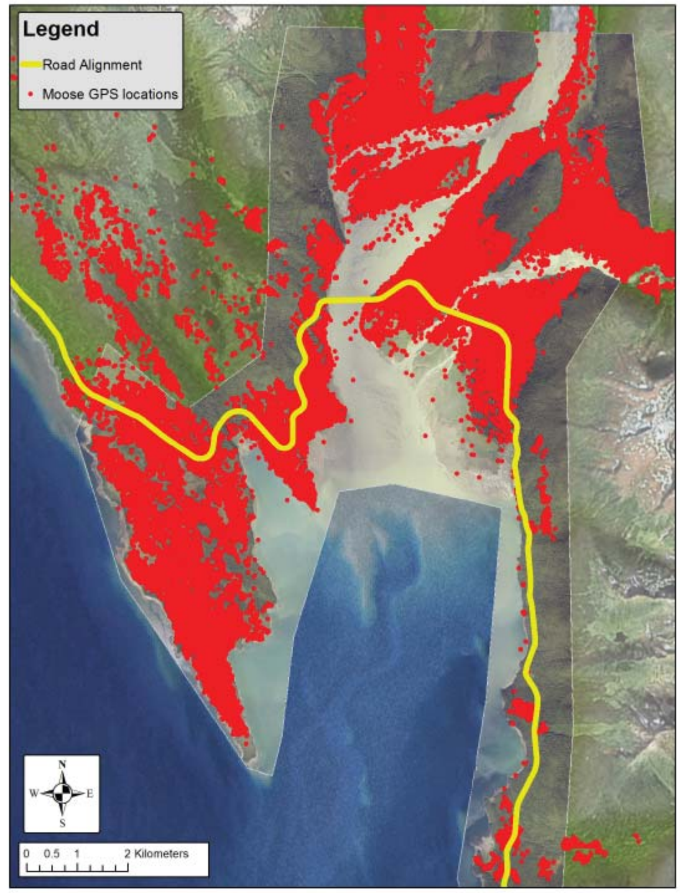

Figure 10: Map depicting all locations collected from GPS radio-collared adult female moose in the lower Berners Bay area, 2006-2011 (n = 78,306 locations). The distribution of moose locations relative to the road alignment illustrates the potential for moose-vehicle collision along the proposed highway.

Moose Population Management

Population Size and Productivity.—The Alaska Department of Fish and Game and the Board of Game have constitutionally mandated obligations to manage moose populations in Berners Bay, Katzehin River and surrounding areas for sustained yield. Data from this study indicate the Berners Bay population is relatively small (ca. 85-120 moose), declined in recent years and is characterized by relatively low productivity as a result of severe winters (Figure 11) and low calf recruitment. Harvest in this population was curtailed following the severe winter of 2006/2007 and has yet to recover to pre-2006 levels. Based on data collected from this study re-opening the limited-entry drawing permit hunt in Berners Bay is not recommended until the moose population has recovered fully to pre-2006 levels.

Study of the Katzehin River moose population was not officially part of the scope of this project. Nonetheless, annual aerial surveys were conducted in this area. These data indicate that this population is not only geographically isolated but very small (ca. 35-40 moose). Ecological similarities between the Katzehin and Berners Bay suggest that productivity and vulnerabilities of these populations are similar. In the absence of additional field data, the Katzehin River population should be managed following an equally or more conservative strategy than is recommended for the Berners Bay moose population. In fact, based on the small population size, the viability of sustained harvest in this population is questionable and should be assessed in a demographic modeling framework.

Human Access.—The construction of the Juneau Access highway would result in increased human access to areas determined to be high value moose habitats. Hunter harvest in the Berners Bay moose population has been managed as a limited-entry drawing permit hunt since 1971. Consequently, increased human access is unlikely to alter the ability of managers to ensure harvest quotas are not exceeded as long as the population continues to be managed in a limited-entry drawing hunt format. However, highway access is likely to alter hunter transport patterns by allowing non-boat based hunters access to the population. Thus, managers should be prepared to closely monitor the spatial distribution of harvested moose in order to avoid localized depletion of moose near the road corridor in order to maintain spatially distributed harvest of the population. If localized depletion is detected new hunt units should be created to ensure equal proportions of moose are harvested from each portion of the watershed (as was conducted under similar conditions for the Gustavus moose population in 2006-2009).

Moose hunting in the western portion of the study area (i.e. drainages flowing into Lynn Canal from Point St. Mary to Eldred Rock) is currently managed under a registration permit (RM046); separately from the Berners Bay drawing hunt. The proposed road corridor lies within or adjacent to areas managed by this registration hunt. The proposed road would provide increased access to areas within this hunt unit that are presently difficult to reach. Under existing regulations, additional access would result in increased moose harvest in this area. To appropriately manage moose harvest in this area managers will likely submit a proposal to the Alaska Board of Game to include the area in the Berners Bay moose drawing permit hunt area.

Management of the moose population in the Katzehin River valley is encompassed within the single Haines area hunt unit. This population currently receives limited harvest (i.e. 0-2 moose annually) due to difficult access. Highway access to the Katzehin River flats would increase the number of potential hunters to the area and may require creation of a separate hunt in the Katzehin River area to avoid exceeding harvest quotas.

Figure 11: Aerial photograph of five adult female moose during the deep snow conditions observed during the winter of 2006/2007, east fork of the Lace river, AK.

Post-construction Highway Effects.—As described above, findings from this study document spatial overlap of the Juneau Access highway corridor and high value moose habitat. In such areas the probability of lethal and sub-lethal (i.e. Shanley and Pyare 2011) highway effects on moose will increase following highway construction. Such effects should be carefully documented and explicitly integrated into moose harvest strategies. For example, coordination between ADFG and law enforcement agencies will be required to accurately document moose-vehicle collisions and reduce harvest quotas accordingly. In order to assess the extent to which sub-lethal effects alter population size and productivity future studies are recommended that compare the existing baseline data to comparable data collected during and after construction of the highway. Such studies would help wildlife managers determine how the highway affects moose habitat use and population dynamics and, ultimately, ensure that local moose populations are managed in a manner that explicitly incorporates sub-lethal effects.

Highway Mitigation and Design

Moose-Vehicle Collisions.—The Alaska Department of Transportation and Public Facilities has a stated interest in reducing or mitigating the likelihood of moose-vehicle collisions along the Juneau Access highway, in the event it is constructed. Findings from this study indicate that road corridor bisects areas of high probability of use by moose on the Berners Bay and Katzehin River forelands and, to a lesser extent, in select upland areas in the vicinity of Slate Cove; the area along Lynn Canal north of Independence Lake to south of the Katzehin River is not considered moose habitat (Figure 10, Appendix 4, 8, 11). Consequently, to avoid moose-vehicle collisions ADOT/PF should concentrate mitigation and design efforts in the Berners Bay and Katzehin River forelands areas and, secondarily, in the vicinity of Slate Cove. Moose-vehicle collision risk is likely to be highest during the winter months when moose densities tend to be higher in the lower watershed and deep snow may result in moose opportunistically using plowed road surfaces. Also, reduced winter daylight may result in increased difficulty of drivers seeing dark-colored moose in low-light conditions. Appropriate design strategies would involve, but are not limited to, "wildlife crossing" signage, reduced speed limits, structural design features (i.e. Clevenger and Huijser 2011), re-vegetation of road cuts with non-palatable forage and adequate sight lines to enable drivers to see moose that are in close proximity to the road (particularly relevant in conifer forest areas). Ultimately, fine-scale highway design that integrates field visits to identify traditionally used moose trails, moose GPS location data and geotechnical highway construction constraints is recommended in order to maximize efficacy of moose-vehicle collision planning and mitigation. Such site specific analyses was beyond the scope of the current study but is recommended via future collaboration between ADFG and DOT/PF.

Mitigation strategies designed to reduce the incidence of moose-vehicle collisions, as described above, are feasible but implementation has met with mixed success elsewhere in Alaska. Detailed post-development studies designed to determine effectiveness of site-specific mitigation prescriptions are recommended to ensure mitigation strategies are optimized for reducing moose-vehicle collisions.

FUTURE WORK

The current project, completed with funding provided by ADOT/PF, FHWA and ADFG, has been completed. However, ADFG has committed funding (2011-2014) to continue low-intensity monitoring of the Berners Bay moose population. The objective of this project includes estimation of calf recruitment during parturition, annual survival of adult females and associated calves and estimation of moose population abundance (via mark-resight methods) and composition. The above efforts are contingent on maintaining 30-40 VHF radio-marked moose in the population. Funding is not currently available to continue collection of movement or habitat use data.

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White, K.S., N. L. Barten and D. Larsen. 2007. Moose Assessment and Monitoring along the Juneau Access Road Corridor, Southeast Alaska. Wildlife Research Progress Report. Alaska Department of Fish and Game, Juneau, AK.

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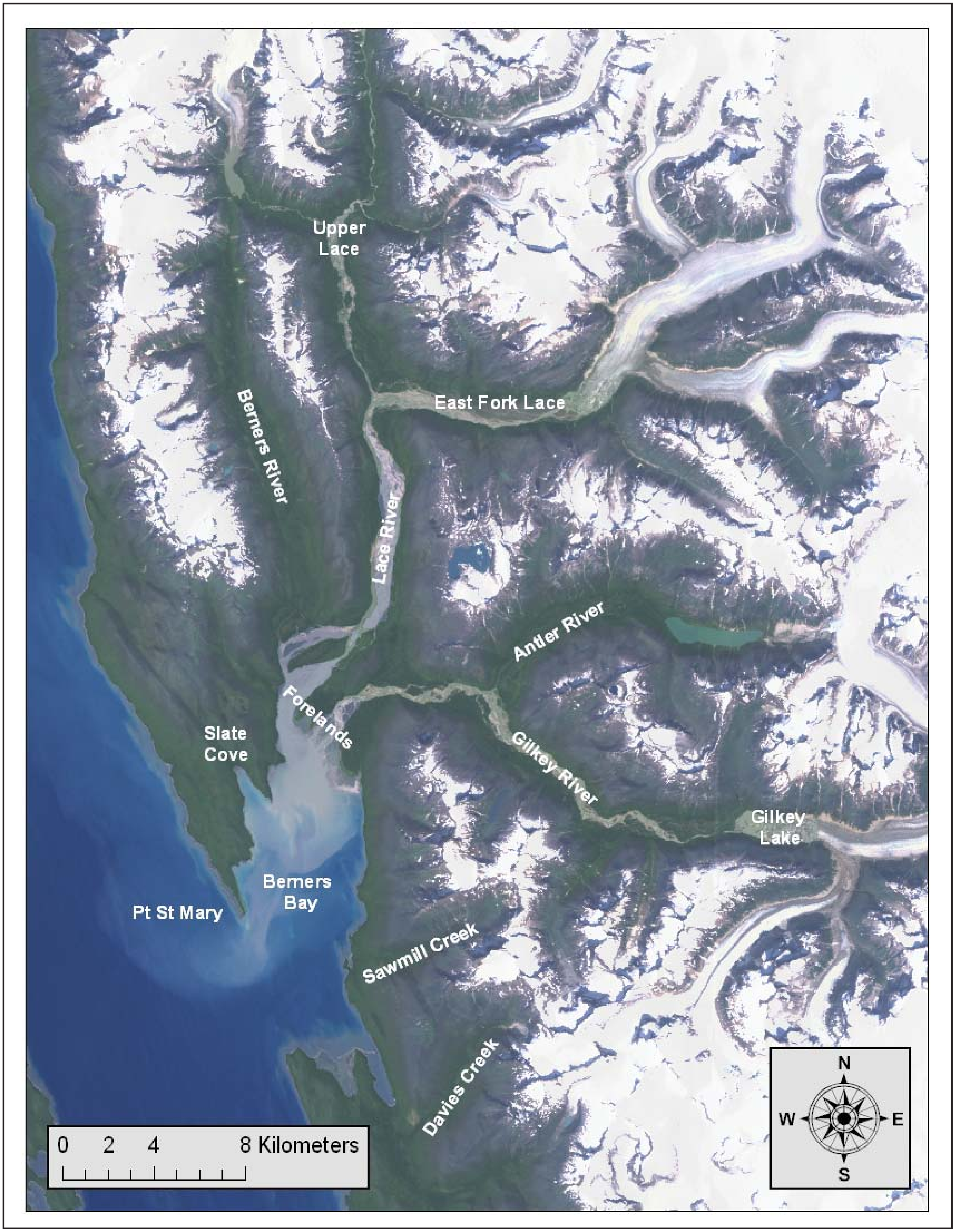
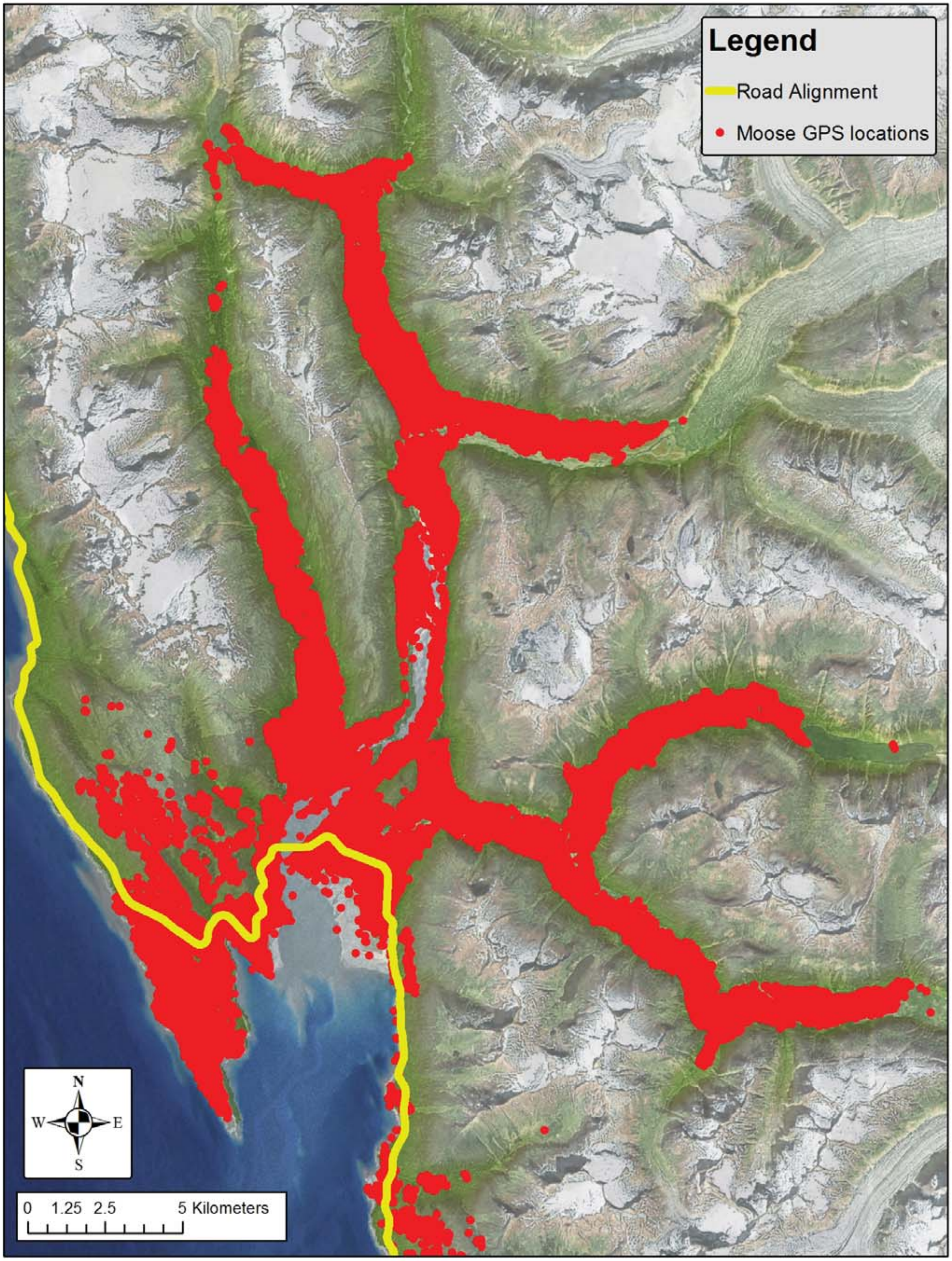
Appendix 1. Map of the moose study area, including key geographic features, in the Berner Bay area, AK.



Appendix 2: Map depicting all locations collected from GPS radio-collared adult female moose and used to develop resource selection function model for moose in the Berners Bay study area, 2006-2011 (n = 39 animals, n = 209,144 locations).



Moose ID	Date	Season	Sex	Est. Age	Calf Status	Rump Fat (cm)	Area	Collar Type
BM01	11/16/2006	Fall 2006	F	1	0	0.0	Antler/Gilkey	GPS
BM01	3/13/2007	Spring 2007	F	1	0	0.0	Berners Forelands	GPS
BM01	11/19/2007	Fall 2007	F	2	0	4.5	Berners Forelands	GPS
BM01	3/13/2008	Spring 2008	F	2	0	0.0	Berners Forelands	GPS
BM01	11/19/2009	Fall 2009	F	4	0	7.9	Berners Forelands	VHF
BM02	11/16/2006	Fall 2006	F	5	0	0.0	Antler/Gilkey	GPS
BM03	11/16/2006	Fall 2006	F	6	0	0.8	Antler/Gilkey	GPS
BM03	3/20/2007	Spring 2007	F	6	0	0.0	Antler/Gilkey	GPS
BM03	11/18/2007	Fall 2007	F	7	0	3.4	Antler/Gilkey	GPS
BM03	3/13/2008	Spring 2008	F	7	0	0.4	Berners Forelands	GPS
BM03	12/3/2008	Fall 2008	F	8	0	3.3	Antler/Gilkey	GPS
BM03	3/19/2009	Spring 2009	F	8	0	0.1	Antler/Gilkey	GPS
BM03	2/27/2010	Spring 2010	F	9	1	1.1	Antler/Gilkey	VHF
BM04	11/16/2006	Fall 2006	F	13	1	3.9	Antler/Gilkey	GPS
BM04	3/30/2007	Spring 2007	F	13	0	0.2	Berners River	GPS
BM04	3/13/2008	Spring 2008	F	14	1(M)	0.0	Berners Forelands	GPS
BM04	11/18/2008	Fall 2008	F	15	1	4.3	Antler/Gilkey	GPS
BM04	3/17/2009	Spring 2009	F	15	1(M)	1.0	Berners Forelands	GPS
BM04	2/27/2010	Spring 2010	F	16	0	1.8	Berners Forelands	VHF
BM05	11/17/2006	Fall 2006	F	14	1	3.0	Antler/Gilkey	GPS
BM05	3/20/2007	Spring 2007	F	14	1	0.2	Berners Forelands	GPS
BM05	3/13/2008	Spring 2008	F	15	0	1.3	Antler/Gilkey	GPS
BM05	12/3/2008	Fall 2008	F	16	0	5.1	Antler/Gilkey	GPS
BM05	3/16/2010	Spring 2010	F	17	1	0.8	Antler/Gilkey	VHF
BM06	11/17/2006	Fall 2006	F	6	1	2.7	Antler/Gilkey	GPS
BM06	3/13/2007	Spring 2007	F	6	1	0.4	Berners Forelands	GPS
BM06	11/18/2007	Fall 2007	F	7	0	7.2	Antler/Gilkey	GPS
BM06	3/13/2008	Spring 2008	F	7	0	0.0	Berners Forelands	GPS
BM07	11/17/2006	Fall 2006	F	6	1	2.5	Antler/Gilkey	GPS
BM07	3/13/2007	Spring 2007	F	6	1	0.0	Berners Forelands	GPS
BM08	11/17/2006	Fall 2006	F	6	0	5.0	Antler/Gilkey	GPS
BM08	3/20/2007	Spring 2007	F	6	0	0.3	Antler/Gilkey	GPS
BM08	11/18/2007	Fall 2007	F	7	1	4.8	Antler/Gilkey	GPS
BM08	3/13/2008	Spring 2008	F	7	0*	0.0	Antler/Gilkey	GPS
BM08	11/18/2008	Fall 2008	F	8	0	4.4	Antler/Gilkey	GPS
BM08	3/19/2009	Spring 2009	F	8	0	0.3	Antler/Gilkey	GPS
BM08	11/20/2009	Fall 2009	F	9	1(M)	4.2	Antler/Gilkey	GPS
BM09	11/17/2006	Fall 2006	F	6	1	3.9	Antler/Gilkey	GPS
BM09	3/20/2007	Spring 2007	F	6	1	0.7	Antler/Gilkey	GPS
BM10	11/17/2006	Fall 2006	F	2	1	3.3	Antler/Gilkey	GPS
BM10	3/20/2007	Spring 2007	F	2	0	1.0	Antler/Gilkey	GPS
BM10	11/18/2007	Fall 2007	F	3	0	6.5	Antler/Gilkey	GPS
BM11	11/17/2006	Fall 2006	F	10	1	4.3	Antler/Gilkey	GPS
BM12	11/18/2006	Fall 2006	F	11	1	2.5	Upper/East Lace	GPS
BM12	11/18/2007	Fall 2007	F	12	0	4.8	Berners Forelands	GPS
BM13	11/18/2006	Fall 2006	F	7	2	2.8	Upper/East Lace	GPS
BM13	3/13/2007	Spring 2007	F	7	2	0.9	Upper/East Lace	GPS
BM13	11/19/2007	Fall 2007	F	8	0	6.5	Upper/East Lace	GPS
BM13	3/14/2008	Spring 2008	F	8	0	1.3	Upper/East Lace	GPS
BM13	12/3/2008	Fall 2008	F	9	0	6.2	Upper/East Lace	GPS
BM13	3/21/2009	Spring 2009	F	9	0	2.9	Upper/East Lace	GPS
BM13	11/19/2009	Fall 2009	F	10	0	6.6	Upper/East Lace	VHF
BM13	2/26/2010	Spring 2010	F	10	0	1.8	Upper/East Lace	VHF
BM14	11/18/2006	Fall 2006	F	10	1	3.3	Upper/East Lace	GPS
BM14	3/20/2007	Spring 2007	F	10	0	0.0	Upper/East Lace	GPS
BM15	11/18/2006	Fall 2006	F	7	2	2.8	Upper/East Lace	GPS
BM15	3/13/2007	Spring 2007	F	7	1	0.2	Upper/East Lace	GPS
BM15	11/19/2007	Fall 2007	F	8	0	9.0	Upper/East Lace	GPS
BM16	11/18/2006	Fall 2006	F	7	0	6.5	Upper/East Lace	GPS
BM16	3/22/2007	Spring 2007	F	7	0	0.2	Upper/East Lace	GPS
BM16	11/17/2007	Fall 2007	F	8	1	4.3	Upper/East Lace	GPS
BM16	3/14/2008	Spring 2008	F	8	1(F)	0.0	Upper/East Lace	GPS
BM17	11/18/2006	Fall 2006	F	1	1	0.9	Upper/East Lace	GPS
BM17	3/30/2007	Spring 2007	F	1	0	0.0	Upper/East Lace	GPS
BM17	11/17/2007	Fall 2007	F	2	0	3.2	Upper/East Lace	GPS
BM17	3/19/2008	Spring 2008	F	2	0	0.0	Upper/East Lace	GPS
BM17	11/16/2008	Fall 2008	F	3	0	5.3	Upper/East Lace	GPS
BM17	11/22/2009	Fall 2009	F	4	1	3.3	Upper/East Lace	VHF
BM17	2/26/2010	Spring 2010	F	4	1(M)	0.8	Upper/East Lace	VHF
BM18	11/18/2006	Fall 2006	F	8	0	6.0	Upper/East Lace	GPS
BM18	3/20/2007	Spring 2007	F	8	0	0.0	Upper/East Lace	GPS
BM18	11/19/2007	Fall 2007	F	9	0	5.5	Upper/East Lace	GPS
BM18	3/19/2008	Spring 2008	F	9	0	0.6	Upper/East Lace	GPS

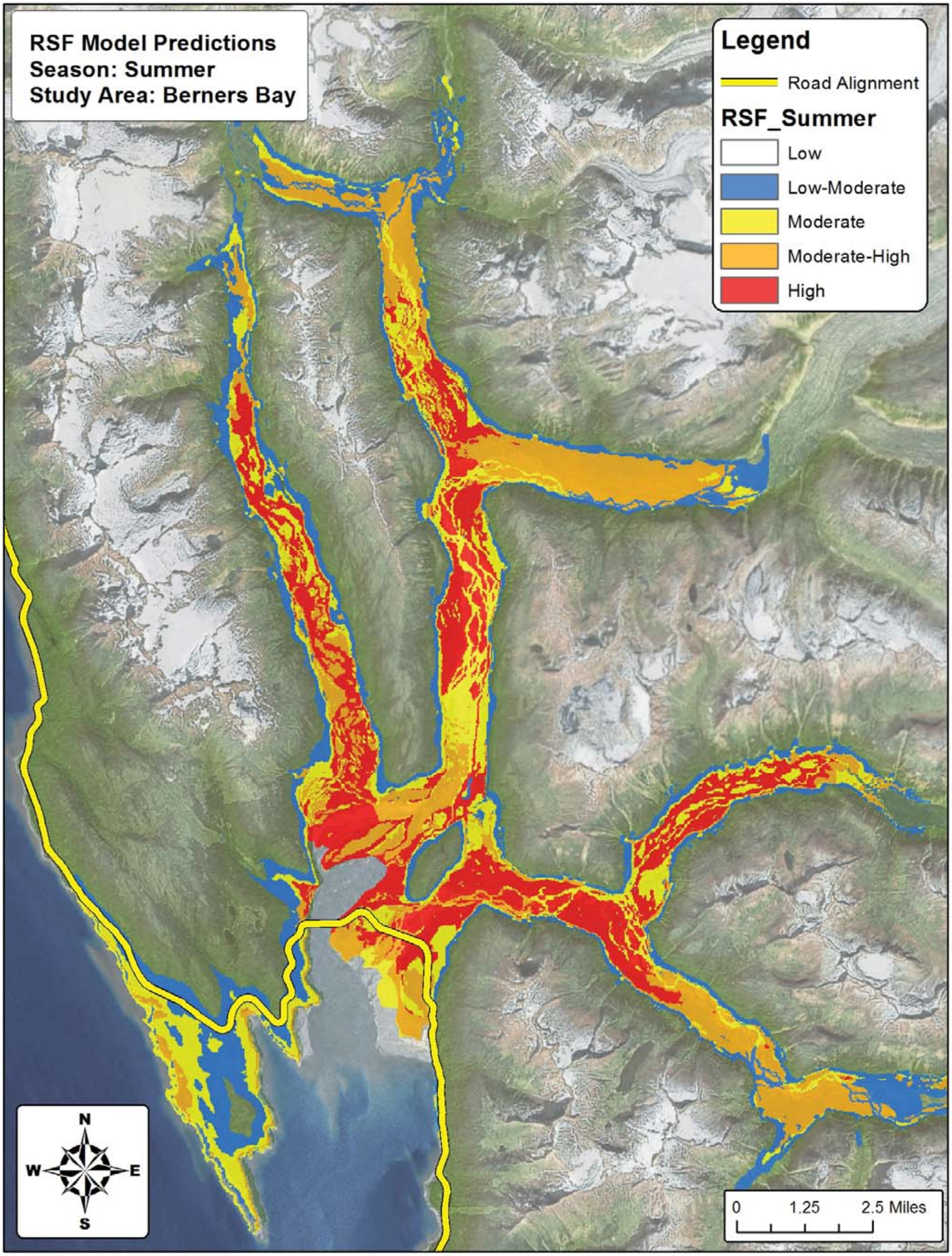
Appendix 3 (continued). Moose capture summary, 2006-2011, Berners Bay, AK

Moose ID	Date	Season	Sex	Est. Age	Calf Status	Rump Fat (cm)	Area	Collar Type
BM19	11/20/2006	Fall 2006	F	4	0	3.7	Berners River	GPS
BM19	11/17/2007	Fall 2007	F	5	0	2.9	Berners River	GPS
BM19	12/2/2008	Fall 2008	F	6	0	4.0	Berners River	GPS
BM20	11/20/2006	Fall 2006	F	3	0	5.0	Berners River	GPS
BM20	3/22/2007	Spring 2007	F	3	0	0.9	Upper/East Lace	GPS
BM20	11/15/2007	Fall 2007	F	4	1	5.1	Berners River	GPS
BM20	3/14/2008	Spring 2008	F	4	0*	0.0	Upper/East Lace	GPS
BM20	12/1/2008	Fall 2008	F	5	1(F)	3.6	Berners River	VHF
BM20	3/17/2009	Spring 2009	F	5	1	1.0	Upper/East Lace	VHF
BM20	11/22/2009	Fall 2009	F	6	1(F)	5.0	Berners River	VHF
BM20	3/16/2010	Spring 2010	F	6	1	0.6	Upper/East Lace	VHF
BM21	11/20/2006	Fall 2006	F	2	0	3.3	Berners River	GPS
BM21	3/30/2007	Spring 2007	F	2	0	0.0	Upper/East Lace	GPS
BM21	11/15/2007	Fall 2007	F	3	0	6.0	Berners River	GPS
BM21	3/13/2008	Spring 2008	F	3	0	0.0	Berners Forelands	GPS
BM21	12/1/2008	Fall 2008	F	4	0	5.2	Berners River	GPS
BM21	3/21/2009	Spring 2009	F	4	1	0.8	Upper/East Lace	GPS
BM21	11/22/2009	Fall 2009	F	5	0	7.2	Berners River	VHF
BM21	3/16/2010	Spring 2010	F	5	0	0.6	Upper/East Lace	VHF
BM22	11/20/2006	Fall 2006	F	15	0	4.4	Berners River	GPS
BM22	3/30/2007	Spring 2007	F	15	0	0.0	Berners River	GPS
BM23	11/20/2006	Fall 2006	F	4	0	4.7	Berners River	GPS
BM23	11/15/2007	Fall 2007	F	5	0	6.2	Berners River	GPS
BM23	11/18/2007	Fall 2007	F	5	0	--	Berners Forelands	GPS
BM23	11/18/2008	Fall 2008	F	6	0	6.2	Berners River	GPS
BM23	11/20/2009	Fall 2009	F	7	0	6.3	Berners River	VHF
BM24	11/20/2006	Fall 2006	F	2	1	1.7	Berners River	GPS
BM24	11/19/2007	Fall 2007	F	3	0	3.0	Berners Forelands	GPS
BM24	12/1/2008	Fall 2008	F	4	0	2.6	Berners Forelands	GPS
BM25	11/21/2006	Fall 2006	F	14	0	3.4	Berners River	GPS
BM25	11/18/2007	Fall 2007	F	15	0	5.6	Berners River	GPS
BM25	12/1/2008	Fall 2008	F	16	0	3.6	Berners River	GPS
BM25	11/22/2009	Fall 2009	F	17	0	3.7	Berners River	VHF
BM26	11/21/2006	Fall 2006	F	2	0	2.6	Berners River	GPS
BM26	11/17/2007	Fall 2007	F	3	0	4.6	Berners River	GPS
BM27	11/21/2006	Fall 2006	F	10	0	5.8	Berners River	GPS
BM27	11/17/2007	Fall 2007	F	11	0	6.0	Berners Forelands	GPS
BM27	11/20/2009	Fall 2009	F	13	0	5.8	Berners River	GPS
BM28	11/21/2006	Fall 2006	F	5	0	6.3	Upper/East Lace	GPS
BM28	3/20/2007	Spring 2007	F	5	0	0.9	Upper/East Lace	GPS
BM28	11/19/2007	Fall 2007	F	6	0	7.7	Upper/East Lace	GPS
BM28	3/14/2008	Spring 2008	F	6	0	1.0	Upper/East Lace	GPS
BM28	11/16/2008	Fall 2008	F	7	0	7.7	Upper/East Lace	GPS
BM28	3/17/2009	Spring 2009	F	7	0	2.1	Upper/East Lace	GPS
BM28	11/19/2009	Fall 2009	F	8	0	6.5	Upper/East Lace	VHF
BM29	11/21/2006	Fall 2006	F	9	0	8.8	Upper/East Lace	GPS
BM29	3/13/2007	Spring 2007	F	9	0	3.2	Upper/East Lace	GPS
BM29	11/15/2007	Fall 2007	F	10	1	6.6	Upper/East Lace	GPS
BM29	3/14/2008	Spring 2008	F	10	1(F)	0.0	Upper/East Lace	GPS
BM29	11/16/2008	Fall 2008	F	11	1(M)	8.6	Upper/East Lace	GPS
BM29	3/21/2009	Spring 2009	F	11	1	3.3	Upper/East Lace	GPS
BM29	2/26/2010	Spring 2010	F	12	0	2.8	Upper/East Lace	VHF
BM30	11/21/2006	Fall 2006	F	4	0	8.4	Upper/East Lace	GPS
BM30	11/15/2007	Fall 2007	F	5	0	8.9	Berners River	GPS
BM30	3/19/2008	Spring 2008	F	5	0	2.0	Berners River	GPS
BM30	12/3/2008	Fall 2008	F	6	1(F)	7.0	Upper/East Lace	VHF
BM30	3/21/2009	Spring 2009	F	6	1(M)	2.8	Berners River	VHF
BM31	11/21/2006	Fall 2006	F	3	0	7.7	Upper/East Lace	VHF
BM31	3/13/2007	Spring 2007	F	3	0	0.0	Upper/East Lace	VHF
BM31	11/17/2007	Fall 2007	F	4	0	7.0	Upper/East Lace	VHF
BM31	3/19/2008	Spring 2008	F	4	0	0.5	Upper/East Lace	VHF
BM31	11/16/2008	Fall 2008	F	5	0	6.8	Upper/East Lace	GPS
BM31	3/17/2009	Spring 2009	F	5	0	0.7	Upper/East Lace	GPS
BM31	2/26/2010	Spring 2010	F	6	0	2.6	Upper/East Lace	VHF
BM32	3/20/2007	Spring 2007	F	8	0	0.0	Antler/Gilkey	GPS
BM32	11/18/2007	Fall 2007	F	9	0	4.6	Antler/Gilkey	GPS
BM32	3/13/2008	Spring 2008	F	9	0	0.9	Antler/Gilkey	GPS
BM32	11/18/2008	Fall 2008	F	10	1(M)	2.4	Antler/Gilkey	GPS
BM32	3/19/2009	Spring 2009	F	10	1(M)	0.0	Antler/Gilkey	GPS
BM32	11/20/2009	Fall 2009	F	11	0	5.4	Antler/Gilkey	VHF
BM33	3/30/2007	Spring 2007	F	2	0	0.0	Antler/Gilkey	GPS
BM33	3/13/2008	Spring 2008	F	3	0	1.1	Antler/Gilkey	GPS
BM34	3/30/2007	Spring 2007	M	--	--	--	Antler/Gilkey	VHF

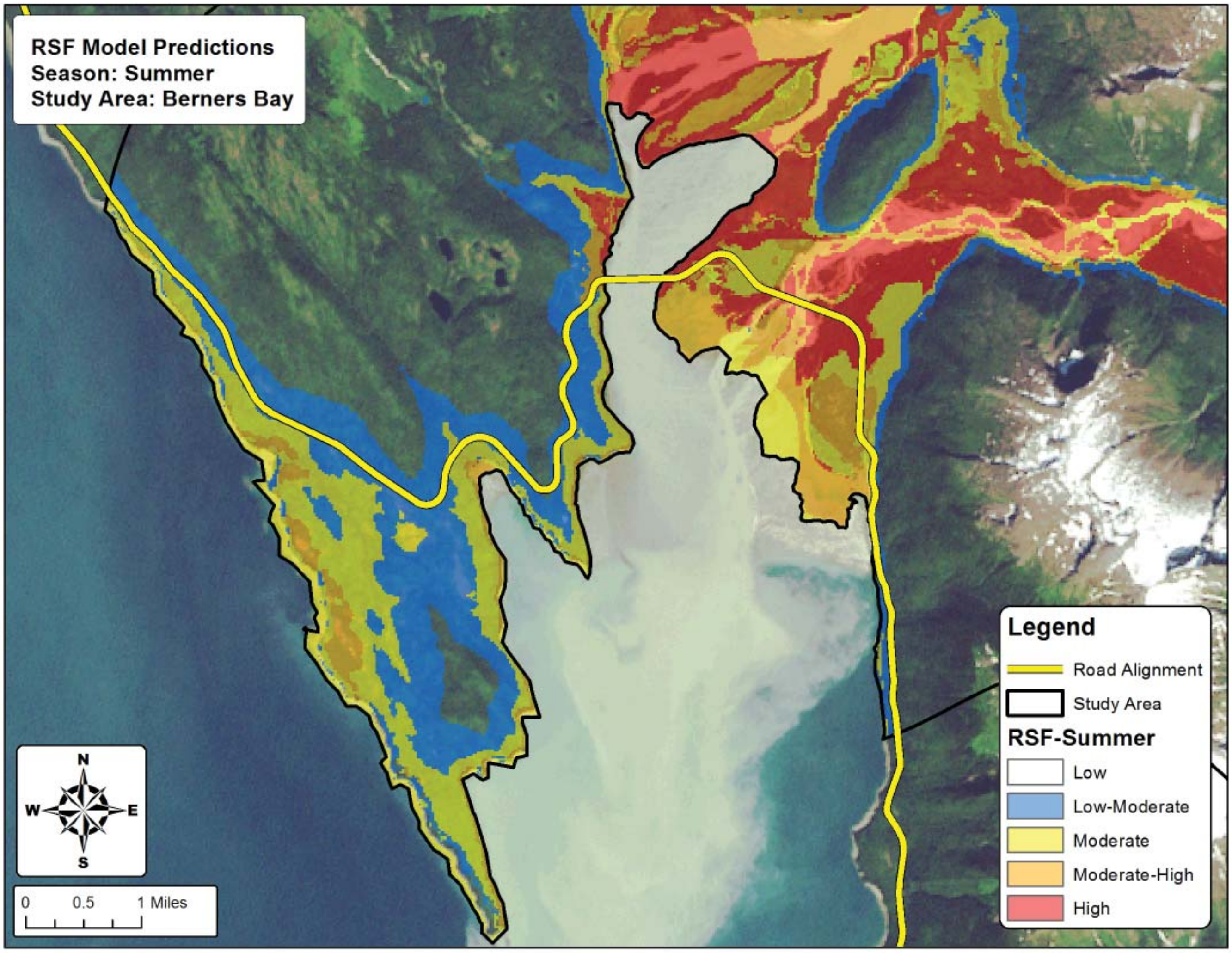
Appendix 3 (continued). Moose capture summary, 2006-2011, Berners Bay, AK

Moose ID	Date	Season	Sex	Est. Age	Calf Status	Rump Fat (cm)	Area	Collar Type
BM35	3/30/2007	Spring 2007	F	14	0	0.0	Antler/Gilkey	VHF
BM36	3/30/2007	Spring 2007	F	12	0	0.0	Antler/Gilkey	VHF
BM37	3/30/2007	Spring 2007	F	0	--	--	Upper/East Lace	VHF
BM37	11/15/2007	Fall 2007	F	1	0	0.4	Upper/East Lace	GPS
BM37	3/19/2008	Spring 2008	F	1	0	0.0*	Upper/East Lace	GPS
BM37	11/16/2008	Fall 2008	F	2	0	2.4	Upper/East Lace	GPS
BM37	3/21/2009	Spring 2009	F	2	0	0.7	Upper/East Lace	GPS
BM37	2/26/2010	Spring 2010	F	3	0	1.0	Upper/East Lace	VHF
BM38	11/19/2007	Fall 2007	F	8	1	2.4	Upper/East Lace	GPS
BM38	3/14/2008	Spring 2008	F	8	1(F)	0.3	Upper/East Lace	GPS
BM38	11/16/2008	Fall 2008	F	9	0	7.0	Upper/East Lace	GPS
BM38	3/21/2009	Spring 2009	F	9	0	0.8	Upper/East Lace	GPS
BM38	11/22/2009	Fall 2009	F	10	0	6.5	Upper/East Lace	VHF
BM38	2/27/2010	Spring 2010	F	10	0	--	Upper/East Lace	VHF
BM39	3/13/2008	Spring 2008	F	4	0	0.0	Antler/Gilkey	GPS
BM39	11/18/2008	Fall 2008	F	5	0	5.4	Antler/Gilkey	GPS
BM39	3/19/2009	Spring 2009	F	5	0	0.4	Antler/Gilkey	GPS
BM39	2/27/2010	Spring 2010	F	6	1	0.6	Antler/Gilkey	VHF
BM40	3/13/2008	Spring 2008	F	2	0	1.4	Antler/Gilkey	GPS
BM41	3/14/2008	Spring 2008	F	3	0	0.2	Antler/Gilkey	VHF
BM41	11/18/2008	Fall 2008	F	4	0	5.2	Antler/Gilkey	GPS
BM41	3/19/2009	Spring 2009	F	4	0	1.5	Antler/Gilkey	GPS
BM41	11/20/2009	Fall 2009	F	5	0	5.6	Antler/Gilkey	GPS
BM41	3/16/2010	Spring 2010	F	5	0	1.3	Antler/Gilkey	VHF
BM42	3/14/2008	Spring 2008	F	3	0	0.2	Antler/Gilkey	VHF
BM43	3/14/2008	Spring 2008	F	2	0	0.8	Antler/Gilkey	VHF
BM43	11/18/2008	Fall 2008	F	3	1(M)	5.2	Antler/Gilkey	GPS
BM43	3/19/2009	Spring 2009	F	3	0	0.2	Antler/Gilkey	GPS
BM44	3/14/2008	Spring 2008	F	6	1(F)	0.2	Upper/East Lace	VHF
BM44	11/16/2008	Fall 2008	F	7	0	4.8	Upper/East Lace	VHF
BM44	3/19/2009	Spring 2009	F	7	0	0.9	Upper/East Lace	VHF
BM44	2/26/2010	Spring 2010	F	8	0	3.6	Upper/East Lace	VHF
BM45	3/19/2008	Spring 2008	M	2	NA	0.0	Upper/East Lace	VHF
BM45	2/27/2010	Spring 2010	M	4	NA	0.0	Upper/East Lace	VHF
BM46	12/1/2008	Fall 2008	F	11	0	3.8	Berners Forelands	GPS
BM46	11/19/2009	Fall 2009	F	12	1(M)	2.7	Berners Forelands	VHF
BM47	12/2/2008	Fall 2008	F	17	0	2.2	Katzehin	GPS
BM48	12/2/2008	Fall 2008	F	4	0	5.9	Katzehin	VHF
BM49	12/2/2008	Fall 2008	F	11	0	4.0	Katzehin	VHF
BM50	12/2/2008	Fall 2008	F	6	0	7.4	Katzehin	GPS
BM51	12/2/2008	Fall 2008	F	11	0	4.2	Katzehin	VHF
BM52	12/3/2008	Fall 2008	F	2	0	4.6	Upper/East Lace	VHF
BM52	3/17/2009	Spring 2009	F	2	0	1.7	Upper/East Lace	VHF
BM52	2/27/2010	Spring 2010	F	3	0	2.1	Upper/East Lace	VHF
BM53	12/3/2008	Fall 2008	F	11	0	5.2	Upper/East Lace	VHF
BM53	3/21/2009	Spring 2009	F	11	0	1.5	Upper/East Lace	VHF
BM53	11/19/2009	Fall 2009	F	12	0	4.9	Upper/East Lace	VHF
BM53	2/26/2010	Spring 2010	F	12	0	2.0	Upper/East Lace	VHF
BM54	3/17/2009	Spring 2009	F	5	0	1.2	Berners Forelands	VHF
BM54	2/26/2010	Spring 2010	F	6	0	3.3	Berners Forelands	VHF
BM55	3/17/2009	Spring 2009	M	--	--	0.0	Berners Forelands	VHF
BM56	3/17/2009	Spring 2009	F	--	0	2.6	Berners Forelands	VHF
BM56	2/26/2010	Spring 2010	F	--	0	0.9	Berners Forelands	VHF
BM57	3/21/2009	Spring 2009	F	--	0	0.7	Berners Forelands	VHF
BM57	11/19/2009	Fall 2009	F	--	0	6.0	Upper/East Lace	VHF
BM57	2/27/2010	Spring 2010	F	--	0	3.1	Berners Forelands	VHF
BM61	3/16/2010	Spring 2010	F	5	2(M)	0.8	Berners Forelands	VHF
BM62	3/16/2010	Spring 2010	F	5	1(F)	0.7	Berners Forelands	VHF
BM63	3/16/2010	Spring 2010	F	4	0	3.1	Upper/East Lace	VHF
BM64	3/16/2010	Spring 2010	F	10	0	1.1	Upper/East Lace	VHF
BM65	3/20/2010	Spring 2010	F	2	1(F)	0.5	Upper/East Lace	VHF
BM66	3/20/2010	Spring 2010	F	4	0	0.2	Katzehin	VHF
BM67	3/20/2010	Spring 2010	F	10	1(F)	0.0	Katzehin	VHF
BM68	3/20/2010	Spring 2010	M	7	NA	0.0	Upper/East Lace	VHF
BM69	3/20/2010	Spring 2010	F	13	0	0.0	Upper/East Lace	VHF
BM70	3/20/2010	Spring 2010	F	8	0	0.3	Upper/East Lace	VHF

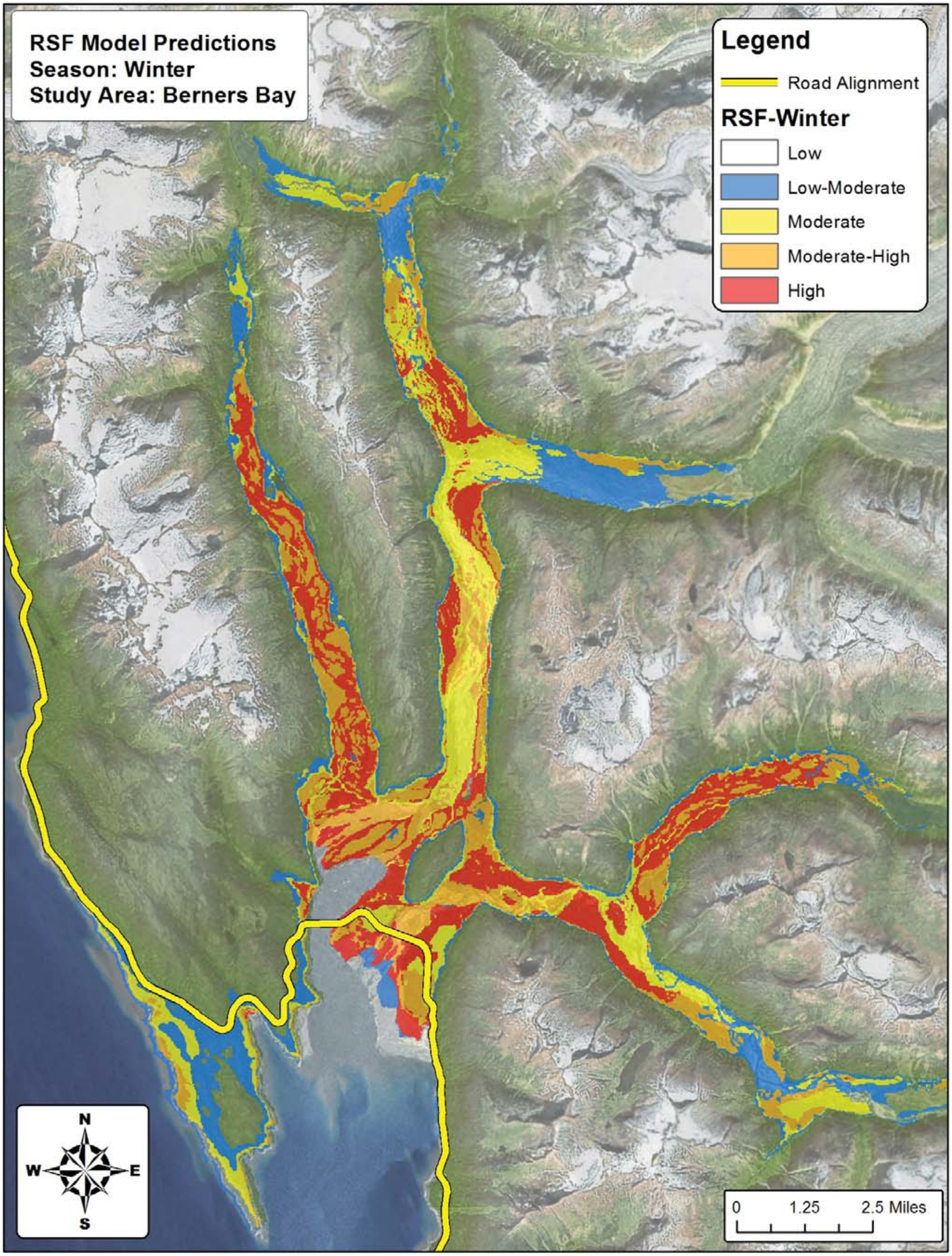
Appendix 4a: Map predicting relative probability of use for moose during summer in the Berners Bay study area, 2006-2011. Areas in the "Low" category are transparent; only areas within the study area boundary were modeled .



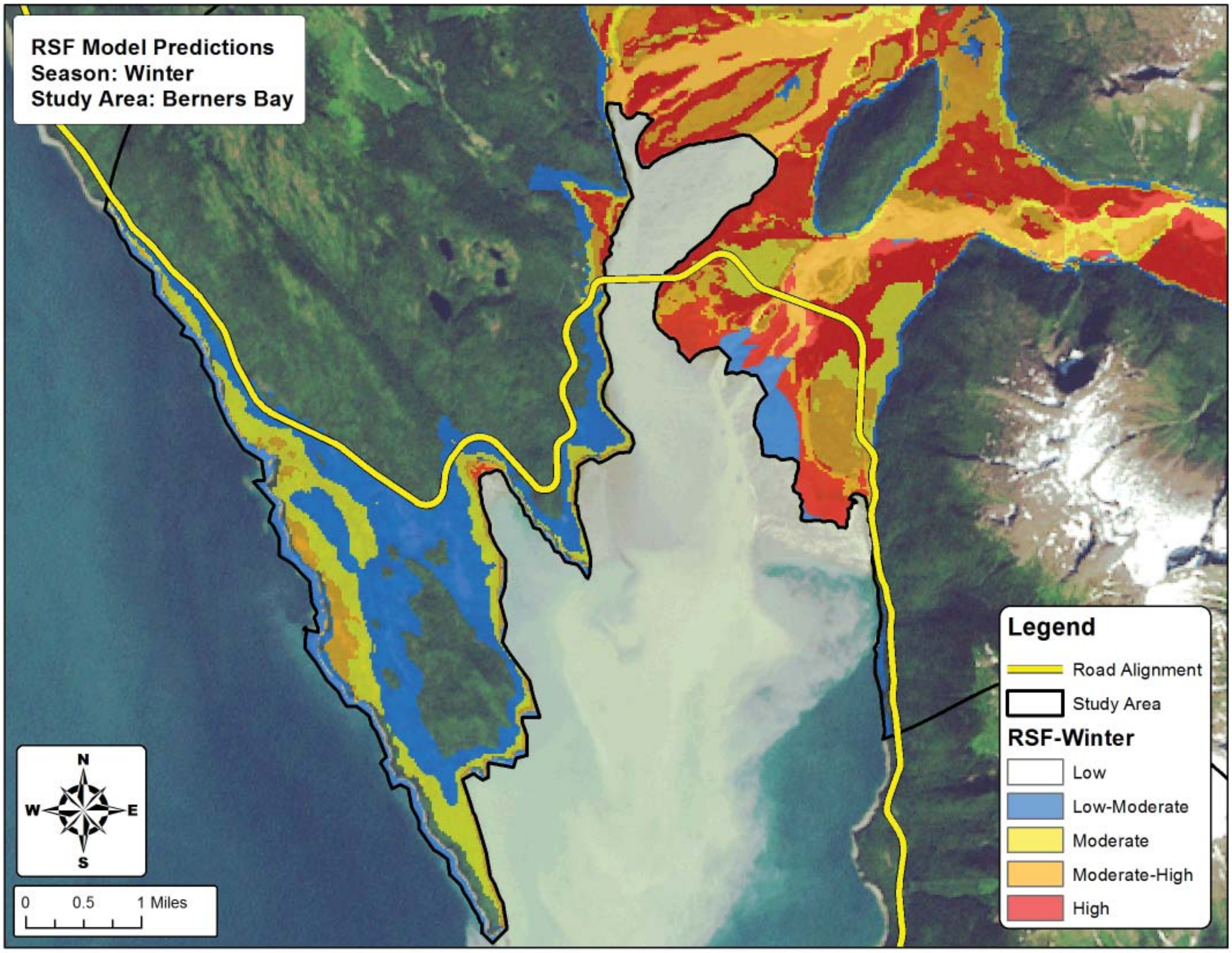
Appendix 4b: Map predicting relative probability of use for moose during summer in the Berners Bay study area, 2006-2011. Areas in the "Low" category are transparent; only areas within the study area boundary were modeled .



Appendix 4c: Map predicting relative probability of use for moose during winter in the Berners Bay study area, 2006-2011. Areas in the "Low" category are transparent; only areas within the study area boundary were modeled .



Appendix 4d: Map predicting relative probability of use for moose during winter in the Berners Bay study area, 2006-2011. Areas in the "Low" category are transparent; only areas within the study area boundary were modeled .



Appendix 5: Diet composition of live-captured adult female moose (determined via microhistological analyses) in Berners Bay and the Katzehin River areas, 2006-2010. Data are summarized with respect to season, year, winter severity and primary wintering area.

Area	Season	Shrubs	Equisetum	Tsuga	Ferns	Lichen	Other	Snowfall[1]	Snow Depth[1]
Antler/Gilkey	Fall 2006	95.8	--	2.8	--	--	1.4	43	11
Antler/Gilkey	Fall 2007	59.5	--	--	37.9	1.6	1.0	5	0
Antler/Gilkey	Fall 2008	96.4	1.8	--	1.8	--	--	25	3
Antler/Gilkey	Fall 2009	100.0	--	--	--	--	--	47	5
Antler/Gilkey	Spring 2007	98.8	--	--	--	--	1.2	78	82
Antler/Gilkey	Spring 2008	98.4	--	--	--	--	1.6	30	34
Antler/Gilkey	Spring 2009	86.8	--	13.2	--	--	--	42	33
Antler/Gilkey	Spring 2010	100.0	--	--	--	--	--	58	26
Berners R.	Fall 2006	98.6	--	1.4	0.0	--	--	43	11
Berners R.	Fall 2007	88.3	--	9.6	2.1	--	--	5	0
Berners R.	Fall 2008	96.2	1.9	--	1.9	--	--	25	3
Berners R.	Fall 2009	97.0	3.0	--	--	--	--	47	5
Berners R.	Spring 2007	100.0	--	--	--	--	--	78	82
Berners R.	Spring 2008	72.9	25.5	--	--	--	1.6	30	34
Berners R.	Spring 2009	95.0	--	--	--	--	5.0	42	33
Berners R.	Spring 2010	69.0	25.0	1.5	--	--	4.5	58	26
Forelands	Fall 2006	98.8	--	--	1.2	--	--	43	11
Forelands	Fall 2007	93.6	4.6	--	--	--	1.8	5	0
Forelands	Fall 2008	93.0	--	--	5.8	--	1.2	25	3
Forelands	Fall 2009	97.9	--	--	--	--	2.1	47	5
Forelands	Spring 2007	45.8	--	50.6	--	--	3.6	78	82
Forelands	Spring 2008	19.1	--	76.3	--	--	4.6	30	34
Forelands	Spring 2009	62.4	1.2	33.9	--	--	2.5	42	33
Forelands	Spring 2010	75.1	--	24.9	--	--	--	58	26
Lace R.	Fall 2006	96.4	2.4	--	--	--	1.2	43	11
Lace R.	Fall 2007	63.6	34.9	--	--	--	1.5	5	0
Lace R.	Fall 2008	42.1	57.9	--	--	--	--	25	3
Lace R.	Fall 2009	97.2	2.8	--	--	--	--	47	5
Lace R.	Spring 2007	100.0	--	--	--	--	--	78	82
Lace R.	Spring 2008	18.2	8.6	61.6	--	3.4	8.2	30	34
Lace R.	Spring 2009	77.1	--	22.3	--	--	0.6	42	33
Lace R.	Spring 2010	100.0	--	--	--	--	--	58	26
Katzehin	Fall 2008	100.0	--	--	--	--	--	25	3
Katzehin	Spring 2010	74.5	--	23.9	--	--	1.6	58	26

[1]snow depth (total, in.) and snowfall (average, in.) represent measurments recorded at the Haines NWS during November and March, for Fall and Spring, respectively.

Appendix 6: Diet composition of live-captured adult female moose (determined via microhistological analyses) in Berners Bay and the Katzehin River areas, 2006-2010. Data are pooled among years and summarized with respect to season and primary wintering area.

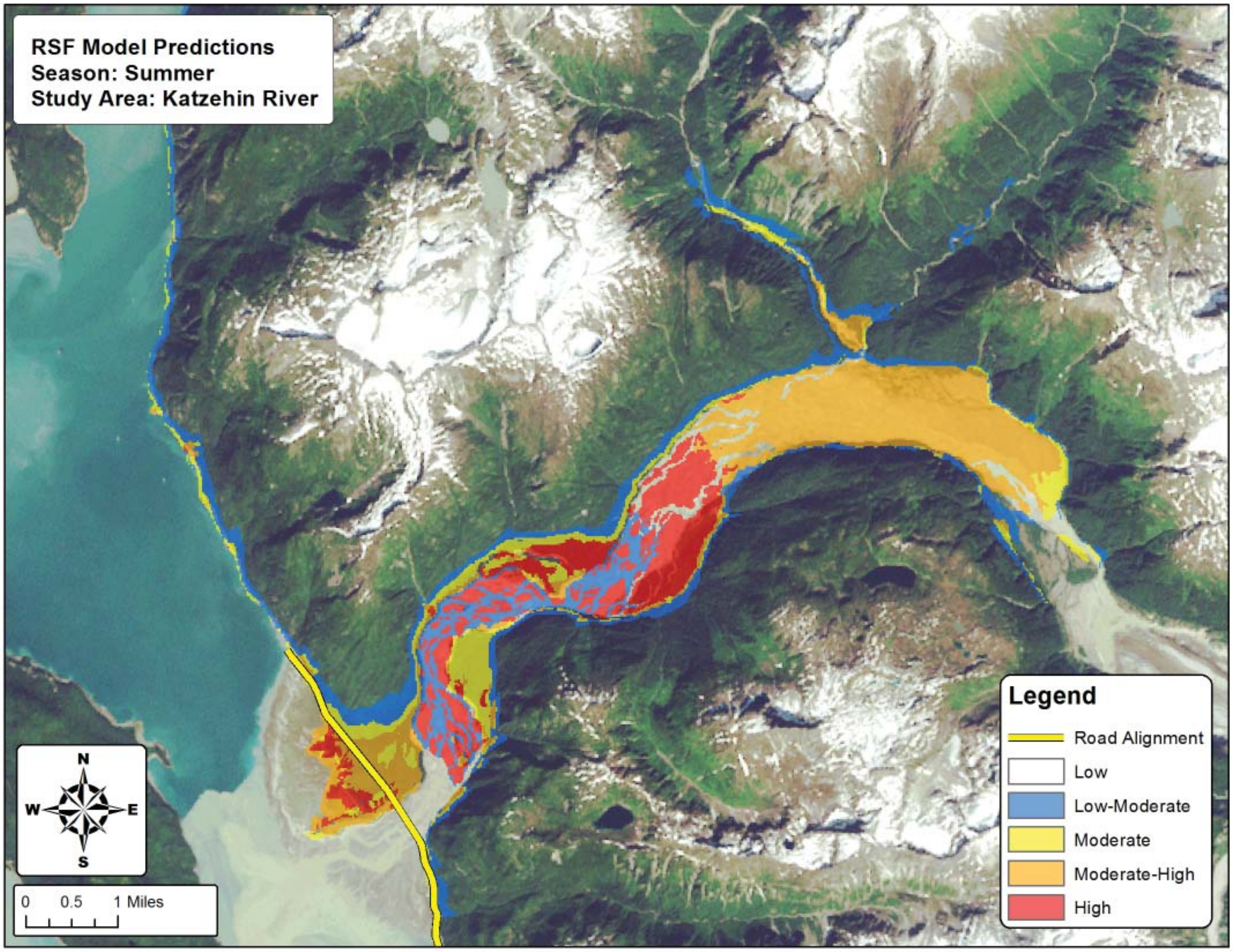
Area	Shrubs	Equisetum	Tsuga	Ferns	Lichen	Other	Snowfall[1]	Snow Depth[1]
Fall:								
Antler/Gilkey	87.9	0.5	0.7	9.9	0.4	0.6		
Berners R.	95.0	1.2	2.8	1.0	0.0	0.0		
Forelands	95.8	1.2	0.0	1.8	0.0	1.3		
Lace R.	74.8	24.5	0.0	0.0	0.0	0.7		
Katzehin	100.0	0.0	0.0	0.0	0.0	0.0		
Total	90.7	5.5	0.7	2.5	0.1	0.5	29.0	4.7
Spring:								
Antler/Gilkey	96.0	0.0	3.3	0.0	0.0	0.7		
Berners R.	84.2	12.6	0.4	0.0	0.0	2.8		
Forelands	50.6	0.3	46.4	0.0	0.0	2.7		
Lace R.	73.8	2.2	21.0	0.0	0.9	2.2		
Katzehin	74.5	0.0	23.9	0.0	0.0	1.6		
Total	75.8	3.0	19.0	0.0	0.2	2.0	53.1	40.4

[1]snow depth (total, in.) and snowfall (average, in.) represent measurments recorded at the Haines NWS during November and March, for Fall and Spring, respectively.

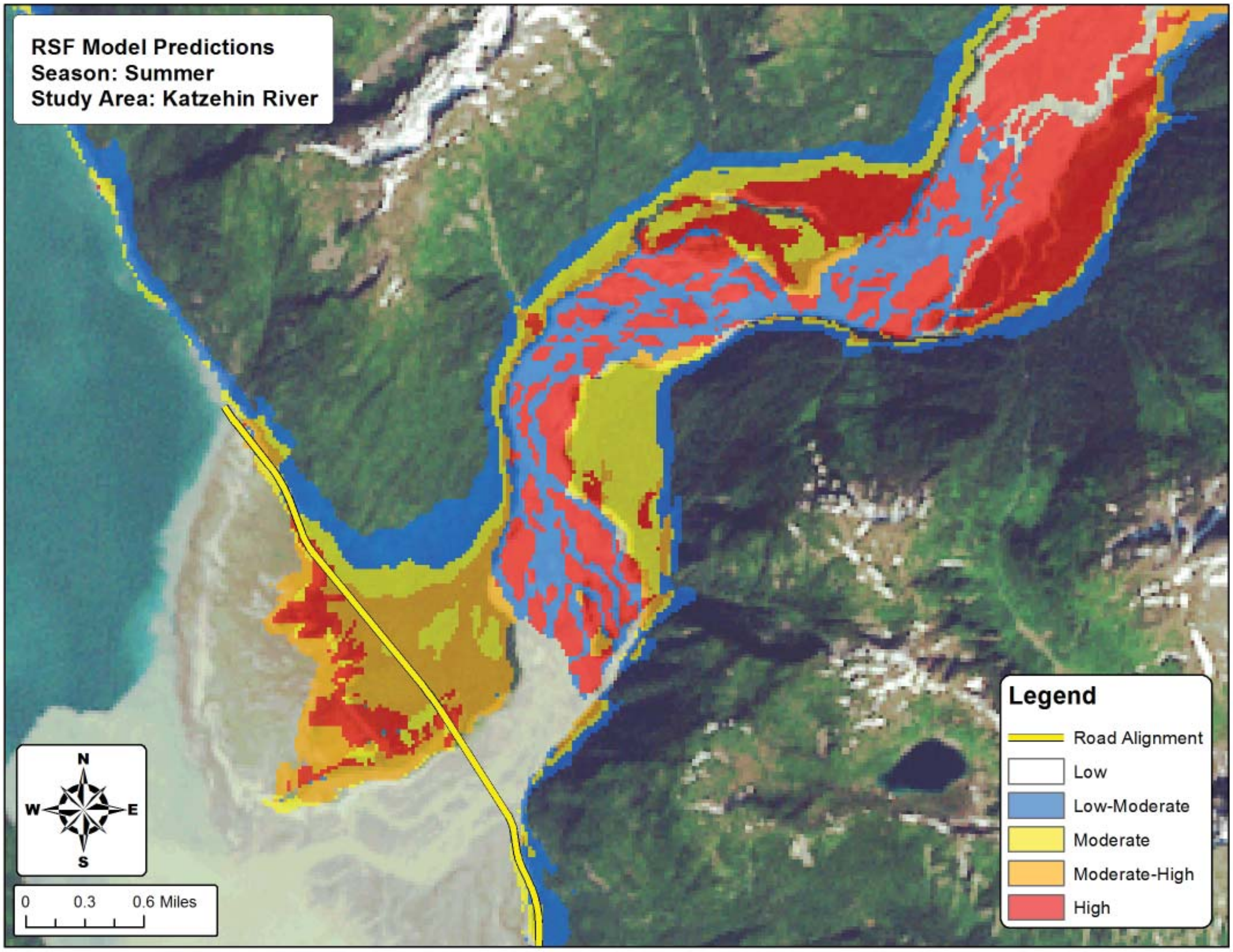
Appendix 7: Proportion of species identified as “shrubs” in microhistological analyses of adult female moose diets in Berners Bay, 2006-2010.

Species	Percent
***Salix* sp.**	**51.0**
Myrica gale	**33.1**
Cornus stolonifera	**19.4**
Populus balsamifera	**14.4**
***Vaccinium* sp.**	**12.1**
Viburunum edule	**8.6**
***Alnus* sp.**	**6.8**
Menziesii ferruginea	**6.6**

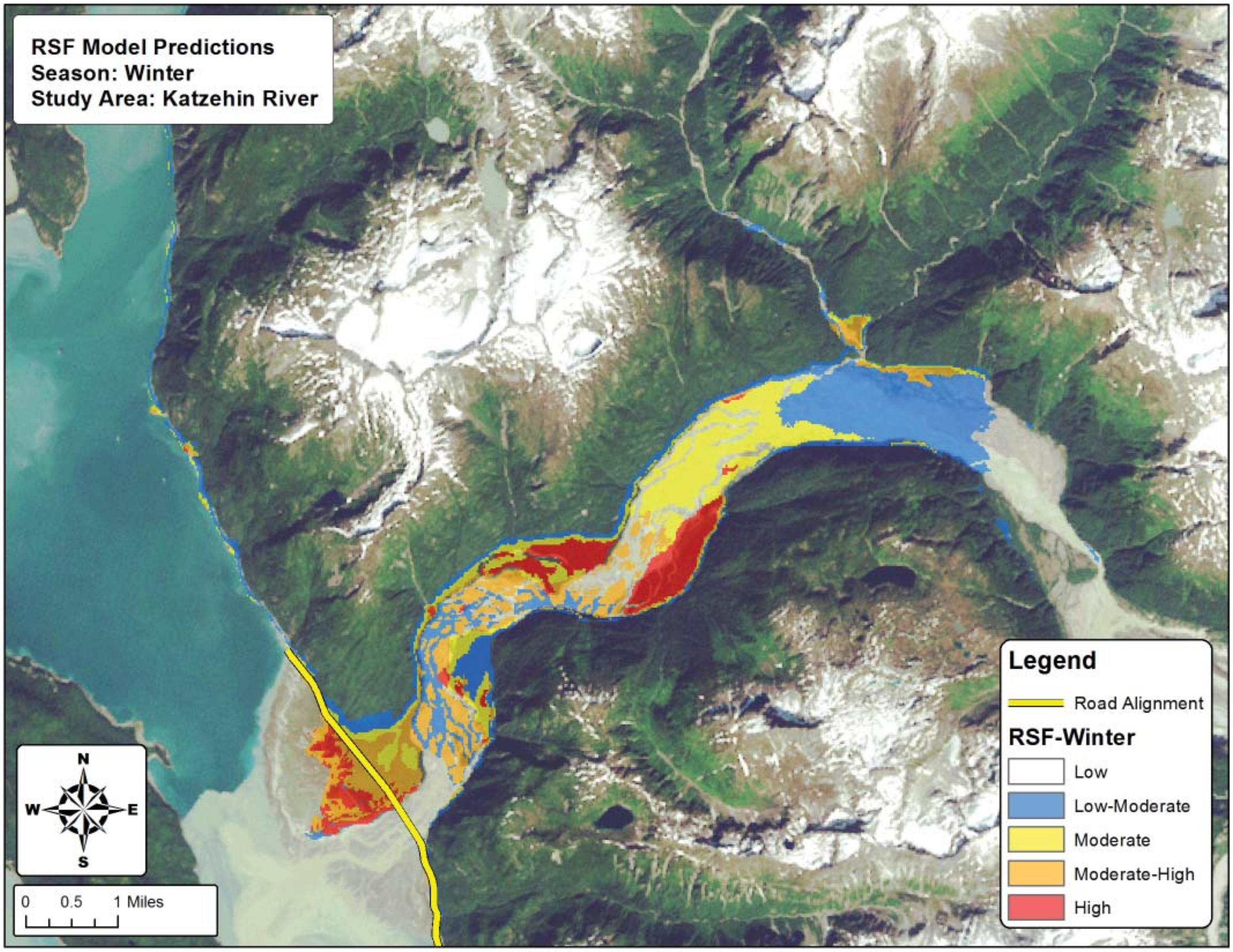
Appendix 8a: Map predicting relative probability of use for moose during summer in the Katzehin River area. RSF modeling output is based on the Berners Bay summer RSF model. Areas in the "Low" category are transparent; only areas within the study area boundary were modeled .



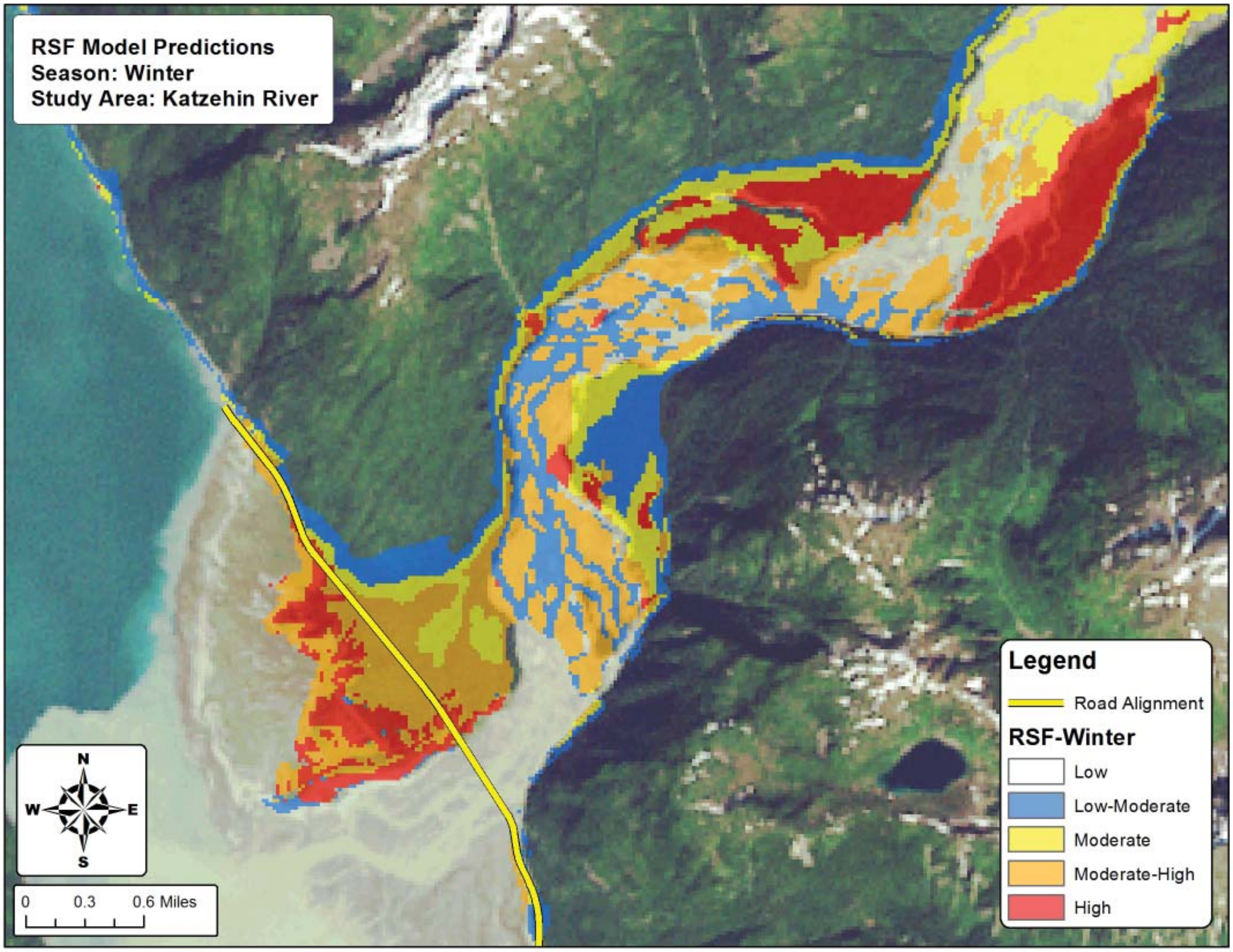
Appendix 8b: Map predicting relative probability of use for moose during summer in the Katzehin River area. RSF modeling output is based on the Berners Bay summer RSF model. Areas in the “Low” category are transparent; only areas within the study area boundary were modeled .



Appendix 8c: Map predicting relative probability of use for moose during winter in the Katzehin River area. RSF modeling output is based on the Berners Bay winter RSF model. Areas in the “Low” category are transparent; only areas within the study area boundary were modeled .



Appendix 8d: Map predicting relative probability of use for moose during winter in the Katzehin River area. RSF modeling output is based on the Berners Bay winter RSF model. Areas in the “Low” category are transparent; only areas within the study area boundary were modeled .



Appendix 9. Summary of NWS snow depth and snowfall data collected at the Haines weather station between 2006-2010. Preliminary data suggest that snow conditions in Berners Bay are similar to Haines though conditions vary depending upon proximity to the coastline.

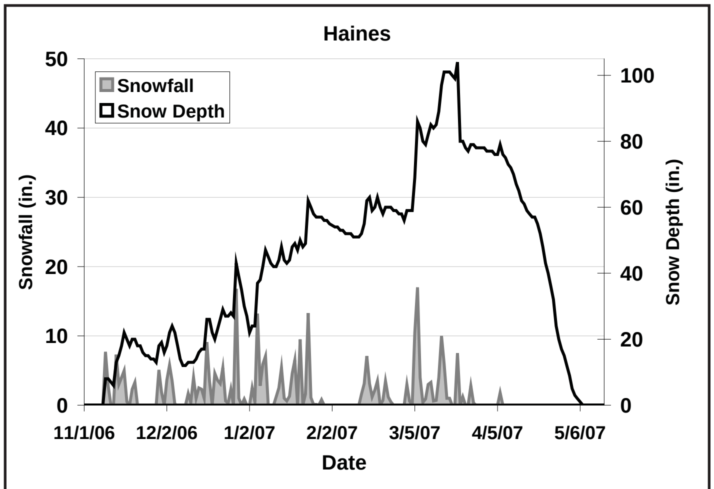


Figure 1a: Daily measures of snowfall and snow depth recorded at the NWS station in Haines, AK during the winter of 2006-2007.

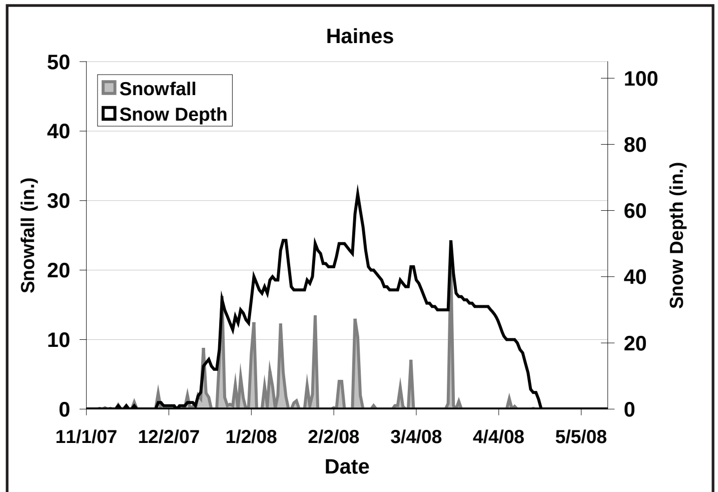


Figure 1b: Daily measures of snowfall and snow depth recorded at the NWS station in Haines, AK during the winter of 2006-2007.

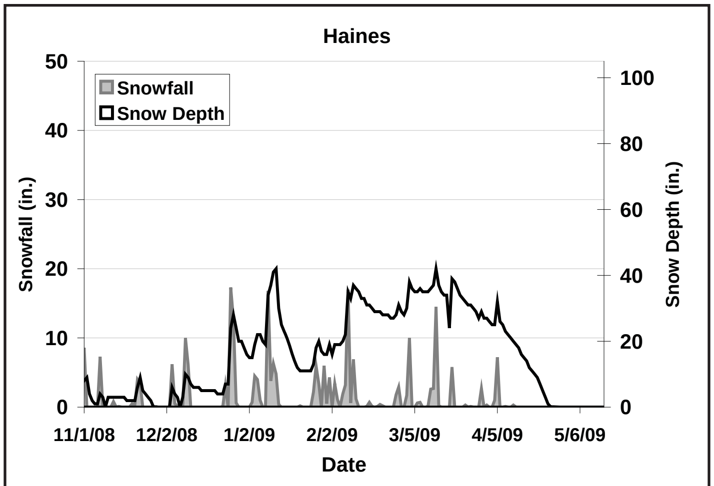


Figure 1c: Daily measures of snowfall and snow depth recorded at the NWS station in Haines, AK during the winter of 2008-2009.

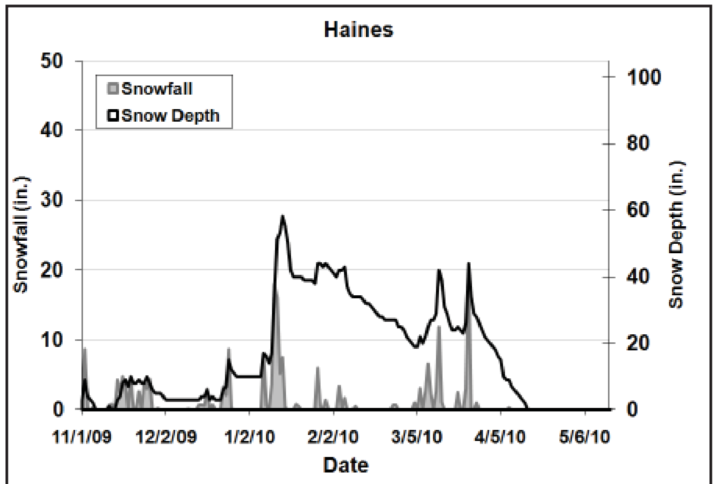


Figure 1d: Daily measures of snowfall and snow depth recorded at the NWS station in Haines, AK during the winter of 2009-2010.

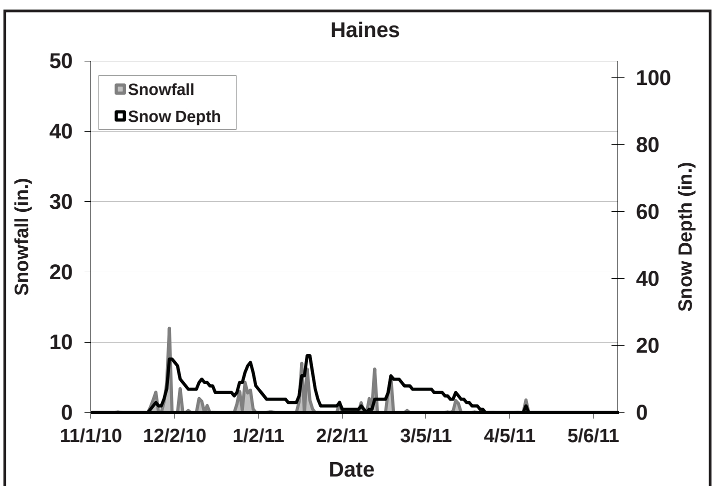


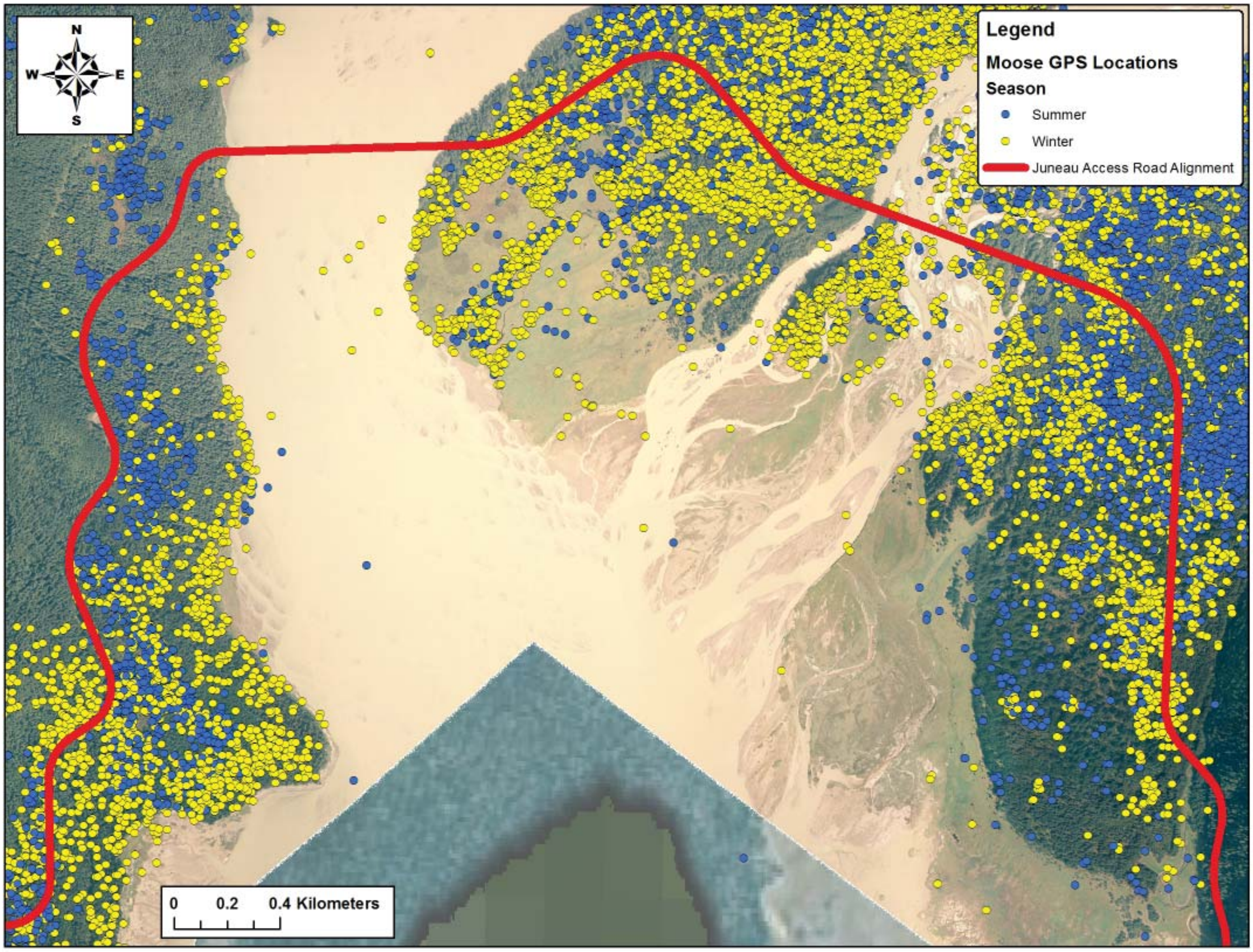
Figure 6: Daily measures of snowfall and snow depth recorded at the NWS station in Haines, AK during the winter of 2010-2011.

Appendix 10: Monthly snowfall (in.) recorded at the NWS weather station in Haines, AK between 2005-2011.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total	% of normal
2005	1.4	28.6	8.6	39.6	21.9	14.8	0.0	0.3	115.2	73%
2006	0.1	42.9	77.1	81.6	27.7	77.8	1.8	0.0	309.0	197%
2007	0.5	4.8	55.4	76.5	38.6	30.3	2.0	0.0	208.1	133%
2008	19.4	25.1	56.8	60.6	45.9	42.0	8.9	0.0	258.7	165%
2009	0.0	47.2	20.1	67.9	8.3	57.7	0.3	0.0	201.5	128%
2010	0.0	23.8	23.7	17.2	20.4	3.4	1.8	0.0	90.3	58%
Average, Study period	3.6	28.7	40.3	57.2	27.1	37.7	2.5	0.1	197.1	126%
Average, Long-term[1]	2.5	29.2	40.0	46.9	23.9	22.7	2.1	0.0	156.9	100%

[1] Haines COOP NWS Station, 1999-2011

Appendix 11a: Map depicting summer and winter moose GPS locations relative to the Juneau Access road alignment in lower Berners Bay, AK, 2006-2011.



Appendix 11b: Map depicting summer and winter moose GPS locations relative to the Juneau Access road alignment in the vicinity of Slate Cove, AK, 2006-2011.