Tanana Flats Training Area Moose Calving Site Study

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Final Report

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Moose (*Alces alces*) is the most important game resource in Interior Alaska (Nelson et al. 2008, Fall 2010). Detailed information on moose movement and habitat selection is required to effectively manage the species and maximize hunting opportunities for people nutritionally and culturally dependent on the resource. Knowledge of movements and habitat use by moose during the calving season (May-June) is particularly important because moose have high nutritional demands (fetus growth, lactation: Reese and Robbins 1994, Regelin et al. 1985, Schwartz and Hundertmark 1993) and elevated sensitivity to disturbance (human and natural) during this time (Bogomolova and Kurochkin 2002, Bowyer et al. 1999).

Located in interior Alaska near the city of Fairbanks, the US Army Fort Wainwright Tanana Flats Training Area (TFTA) contains high densities of moose and is thought to encompass critical calving habitat (Bishop and Rausch 1974, Keech et al. 2000, Kellie 2005). The area experiences high levels of natural and military disturbance. Wildfires have burned large portions (approximately 75%) of this area and routine military activity frequently occurs within the TFTA. Very little is known about how these disturbances overlap with calving habitat. The Army seeks to improve the way in which it designs, manages, and uses its ranges and training lands to ensure long-term environmental sustainability (http://www.usarak.army.mil/conservation/ITAM_home.htm). Therefore, we conducted a study to facilitate these efforts by identifying both important calving habitat and the relationship between landscape disturbance (wildfire and military) and calving activity in the TFTA.

More specifically, our objectives were to:

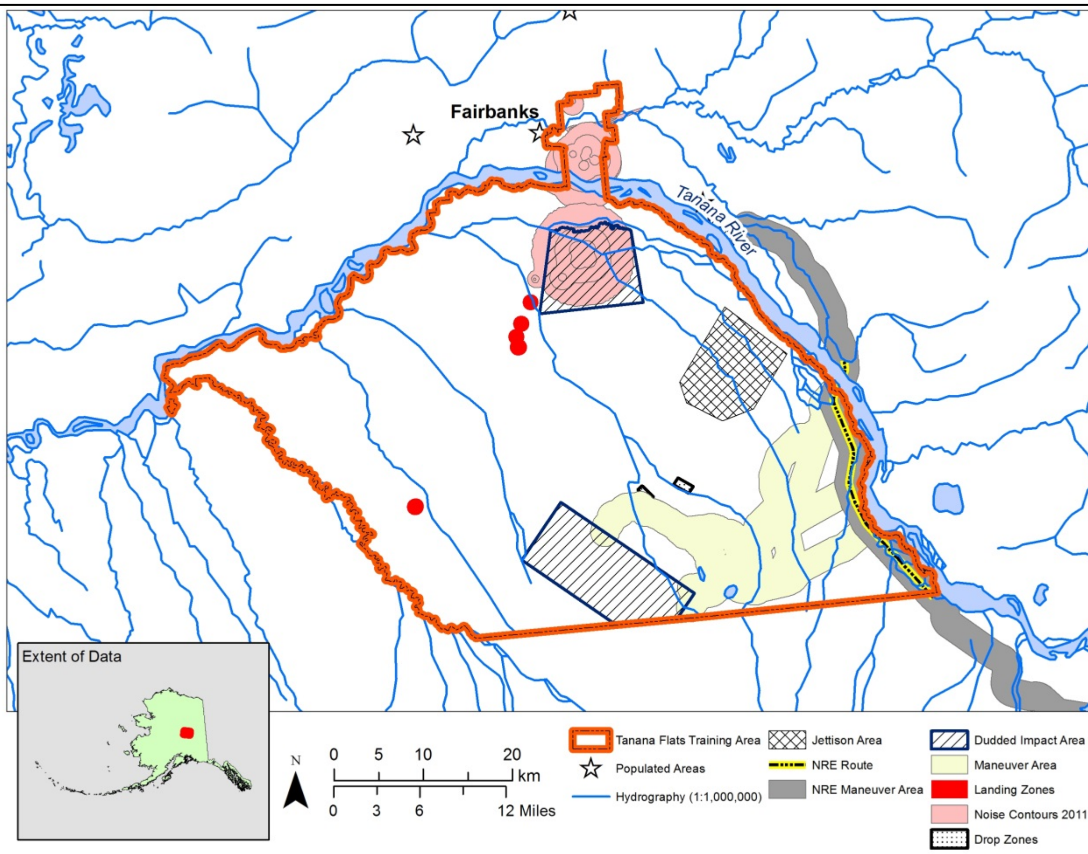
1) Digitize, compile, and organize Alaska Department of Fish and Game's (ADF&G) moose calving-site data into a single database.
2) Document vegetation characteristics (cover, browse quality) selected for calving sites by radiocollared female moose.
3) Identify the effects of wildfire on calving site locations.
4) Determine the extent of spatial overlap between important calving habitat and military activity areas.

Addressing these objectives will help facilitate moose management and may assist planning of military activity in the area. Our study did not directly evaluate behavioral responses of moose to military activity. However, the degree of overlap determined during objective four may provide data to evaluate whether a behavioral study may be warranted in the future.

STUDY AREA

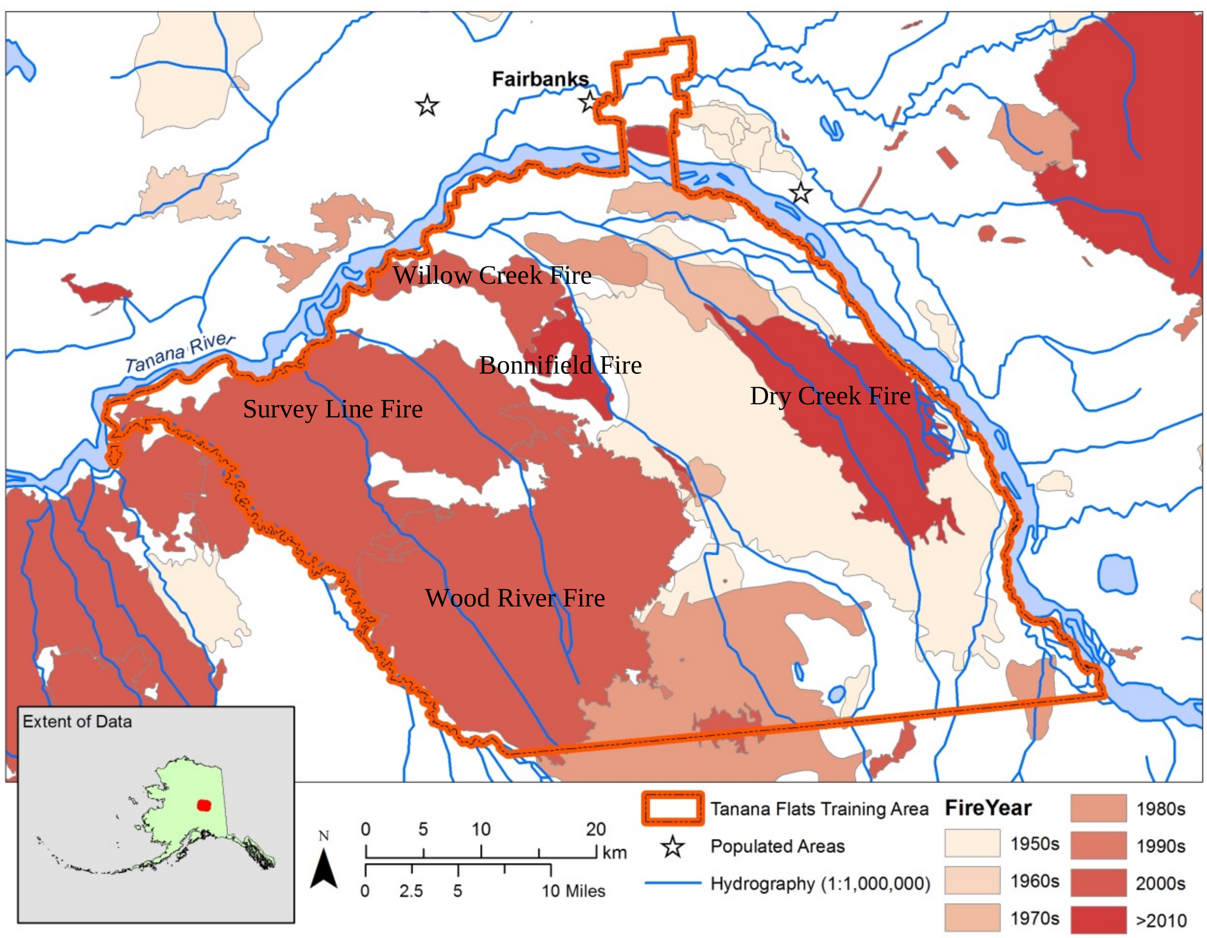
The Tanana Flats Training Area is approximately 660,000 acres, with 86% of the total area available for military training (Fig. 1). The TFTA is located within Tanana Flats of interior Alaska which is within ADF&G's Game Management Unit (GMU) subunit 20A. Moose density within 20A ranged from 2.0-3.5 moose/mi^2 during our sampling period (1996-2014). This moose density was considered high compared to other areas in Alaska and North America (Boertje et al. 2007, 2009). Female moose are segregated from adult males during calving and they seclude themselves from other all other moose roughly 24-48 hours before giving birth (Bowyer et al. 1999). Wolves (*Canis lupus*), coyotes (*C. latrans*), black bears (*Ursus americanus*), grizzly bears (*U. arctos*), wolverines (*Gulo gulo*), and lynx (*Lynx canadensis*) occupy the study area. Bears and wolves are considered the most significant source of moose calf mortality (Keech et al. 2011).

Figure 1. The Tanana Flats Training Area is located south of Fairbanks, Alaska. We included several military activities (jettison area, Northern Railway Extension (NRE) route, NRE maneuver area, dudded impact areas, maneuver areas, landing zones, noise contours, and drop zones) in our evaluation of moose calving habitat.



Fire is the dominant disturbance in the Tanana Flats. Approximately 42 wildfires >100 acres have occurred within the TFTA boundaries since 1950, burning approximately 75% of the TFTA (Fig. 2). Since 1996, 25 wildfires >100 acres have occurred within TFTA, burning roughly 470,000 acres of land. We use the term "roughly" because this value represents the entire area within the fire parameter. In reality, many patches within the fire parameter did not burn. Fire severity varies within and across burns and influences post-fire forest characteristics by altering successional pathways and species richness and distribution (Shenoy et al. 2011). Fire has shaped the mosaic of vegetation in the Tanana Flats. Dominant vegetation species include spruce (*Picea sp.*), paper birch (*Betula papyrifera*), quaking aspen (*Populous tremuloides*), willow (*Salix sp.*), dwarf birch (*B. glandulosa and B. nana*), and alder (*Alnus*). The area also contains numerous lakes, bogs, and streams (Gasaway et al. 1983). Temperatures frequently reach 25°C in the summer and -40°C in the winter. Mean snow depth is generally <70cm.

Figure 2. Wildfire activity (1950-present) within and around the Tanana Flats Training Area.



METHODS

Our efforts primarily focused on organizing, merging, and analyzing existing data sets on moose, habitat, wildfire, and military activity in the TFTA. Between 1996-2014, ADF&G collected data on movements and locations of individual radiocollared female moose that used the TFTA. For these moose, calving sites were located by aerial observance of moose every 48 hours throughout the calving season using fixed-wing aircraft. Over the years, moose calving site data were stored in multiple databases (including undigitized hard copies) in multiple formats. To meet Objective one, we entered, compiled, and organized all moose calving site data into a single database in a single format. We converted the database to a spatially-explicit GIS file that can be used for future spatial analyses and mapping. We calculated descriptive statistics on calving site data and calving dates.

To meet objectives 2-4, we assessed the relationship between moose calving sites and three spatially-explicit habitat variables: vegetation (i.e., cover, browse quality), fire activity (location and severity), and military activity. To estimate the relationships between calving site location, vegetation, and fire, we used well-established habitat selection protocols (Manley et al. 2002, McDonald et al. 2005). To quantify moose habitat selection (i.e., choosing among alternative habitats that are available), we quantified both habitat *use* (i.e., association with certain habitat types) and *availability* (i.e., area of habitat accessible to the animal). Habitat selection or avoidance occurs only if *use* is disproportionate to *availability*. Area *available* to female moose was quantified by calculating mean straight-line distance between the calving site location and the location of the radiocollared female moose 48 hours prior to calving. The 48-hour time period was chosen because female moose typically exhibit large movements within 2-3 days of calving (Bowyer et al. 1999). We buffered all calving locations using the mean distance travelled during the 48-hour period and assumed that any habitat within the buffered area was *available* to the radiocollared female moose for calving. Within the availability area, we generated 10,000 random points and identified the habitat under each point (based on GIS landcover maps). We arrived at the 10,000 random points following practical guidance provided by Northrup et al. (2013) on the calculation of availability. We calculated the percentage of random points in each habitat type to determine the *availability* of each habitat type to calving females. *Use* was quantified by identifying the habitat type at each calving-site location, and then calculating the percentage of calving sites in each habitat type. Habitat selection was quantified by calculating the ratio of habitat used over the habitat available. Thus, the ratio represents the relative probability of that a moose will use of a particular habitat type for calving compared to the probability that a moose would use that that habitat type by random chance. Spatial analyses were performed in ArcGIS 10.1, and descriptive statistics were calculated using SPSS software.

Moose habitat characteristics were identified using the United States Army Garrison in Alaska (USAGAK) Habitat and Forestry Map. The USAGAK map included a Main Vegetation Type (MVT) description that was based on Viereck et al.'s (1992) Alaska Vegetation Classification level IV coding scheme. For more recently disturbed landscapes (e.g., burns), we used Jorgenson et al.'s (1999) Alaska Biological Research Vegetation Description (ABRVD). We grouped MVTs and ABRVDs to create three categories (high, medium, low) of vegetation cover and browse quality relevant to moose (Kellie 2005, Kellie et al. 2011, Appendix A). For example, the "closed needleleaf Forest (60-90% canopy) Black Spruce" MVT would be classified as high cover and low quality browse habitat. A total of 128 vegetation classes were grouped into our 3 categories (Appendix A).

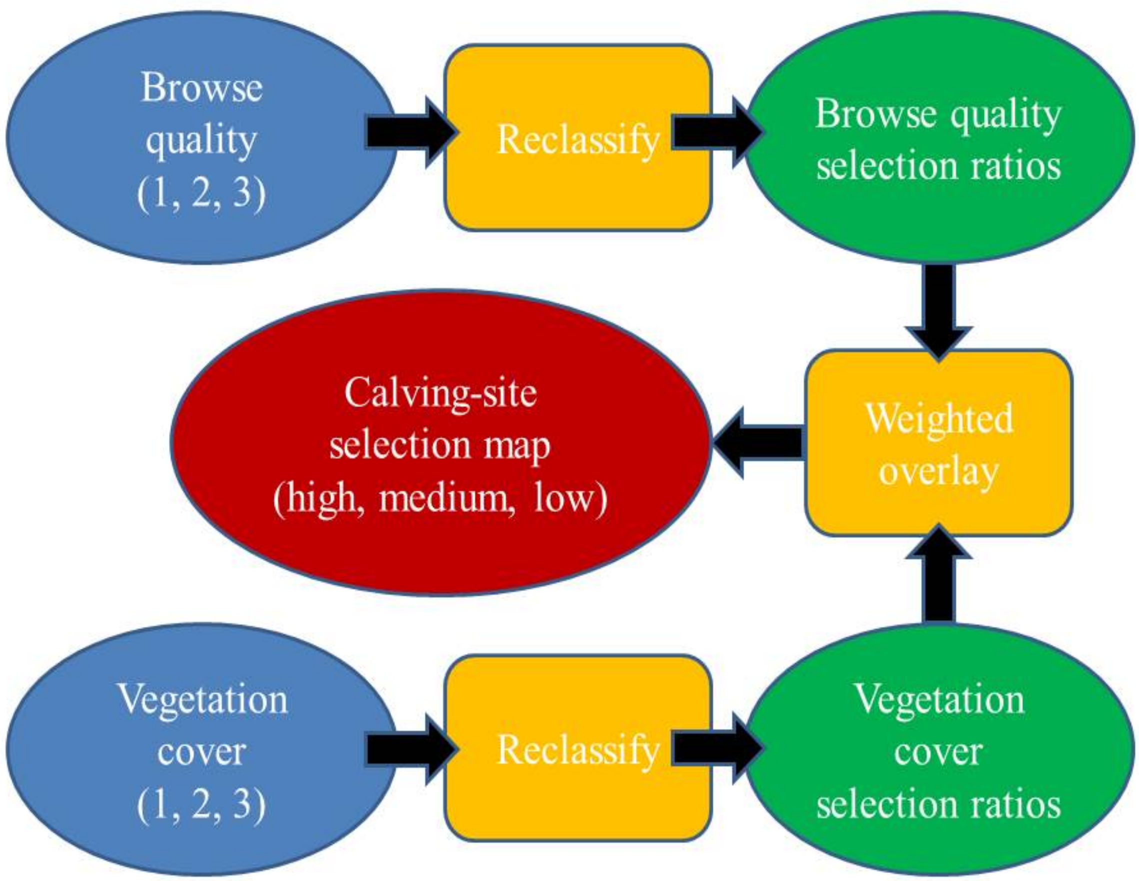
To assess the relationships between calving site location and fire, we accounted for the effects of burn age and burn severity. We analyzed all calving sites that were recorded during a 3-year period after a burn occurred. For example, if a burn occurred in 2011, then we analyzed all calving site locations between 2012-2014. We limited our analysis to ≤3 years since a burn to increase the number of fires we could compare for calving-site use.

We used the Bureau of Land Management-Alaska Fire Services burn perimeter database records (data available at http://fire.ak.blm.gov) to map and calculate fire activity (i.e., total area burned [acres], proportion of area burned [acre burned/acre available], age of burn [years since most recent burn]) within the TFTA. The BLM database maps fires back to 1950. Because of the vegetation and hydrological mosaic in the TFTA, many areas within the burn perimeters do not burn or burn at varying severities. Burn severity can significantly influence post-fire vegetation characteristics and successional pathways (Shenoy et al. 2011). Research indicates habitat quality for moose peaks between 10-30 years following a burn (Maier et al. 2005), and level of use during that time period may be linked to burn severity (Lord 2008). However, recent data suggests that moose start using burns shortly (within 1-2 years) after a fire, depending on severity (Gasaway and Duboise 1985, K. Seaton, ADF&G unpublished data). Therefore, we accounted for potential effects of fire by considering spatially-explicit data on burn severity. We used data from the Monitoring Trends in Burn Severity (MTBS) project (data available at http://www.mtbs.gov/) to incorporate burn severity into our analysis. MTBS provides 30-meter resolution data and uses similar image processing and analysis methods currently utilized by the USFS and USGS (Eidenshink et al. 2007) to estimate burn severity. The MTBS burn severity has four main thematic categories: 1) unburned to low severity within the burn parameter, 2) low severity, 3) moderate severity, and 4) high severity. We used these severity categories to estimate the relationship between moose calving-site location and burn severity. We used the same selection calculation (use/availability) for fire severity as we used for vegetation (browse, cover) selection.

We combined habitat-variable (vegetation cover, browse quality) selection ratios to create a single relative probability map of moose calving-site selection. We used ArcGIS model builder to reclassify the three categories (high, medium, and low) of vegetation cover and browse quality to match their selection ratios (Fig. 3). We used the weighted overlay tool in ArcGIS to create single relative probability map of calving site selection. We overlaid the calving-site selection map with several types of military activities and calculated the proportion of area with high, medium, and low selection scores for habitat. Our partners at the US Army Garrison Alaska

Natural Resources Management (USAG-AK NRM) provided GIS spatial data on routine military activity for the TFTA including: drop zones, Northern Rail Extension (NRE) routes, jettison areas, NRE maneuver areas, landing zones, noise contours, and dudded impact areas (Fig. 1). The USAGAK should be consulted for a description of these military activities. Our modelled output provided the current status of calving-site selection in the TFTA. However, the map also may be used to assess future military activity and speculate about the extent of disturbance on important calving areas.

Figure 3. ArcGIS model used to merge browse quality and vegetation cover layers into a single map of habitat selection for moose calving sites within the Tanana Flats Training Area (TFTA). We classified browse quality and vegetation cover were into three moose-relevant (Kellie 2005) categories (high, medium, low) using 128 Main Vegetation Types (MVTs) from Viereck et al.'s (1992) Alaska Vegetation Classification system. Each spatially-explicit category was reclassified based on relative selection by moose. Selection ratios for browse quality and vegetation cover were weighted equally and overlay to produce a map of calving-site selection across the TFTA.



RESULTS

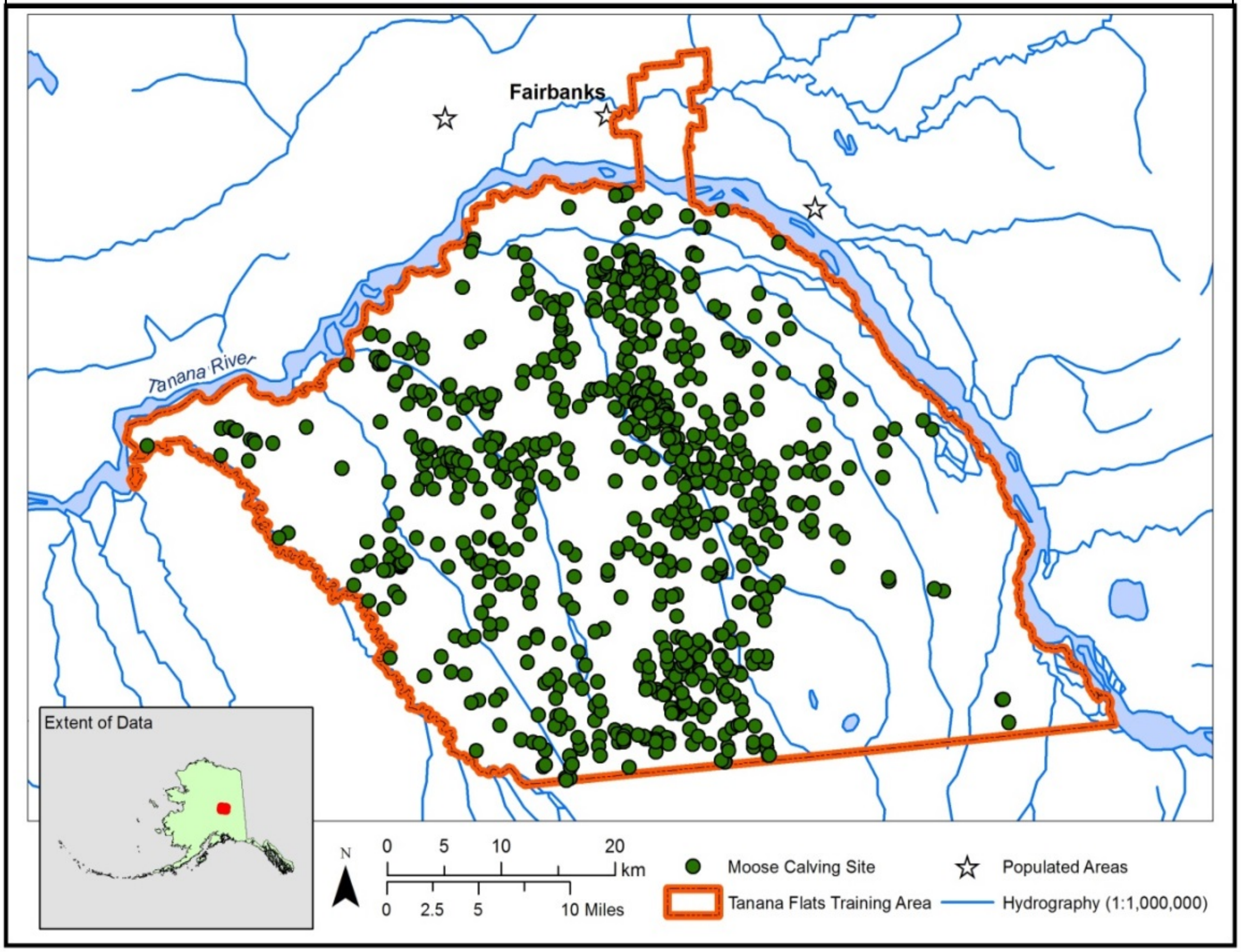
Calving site characteristics

All calving sites (1996-2014) were organized into a single database that included the following columns of data: radiocollared female moose ID number, calving date, latitude and longitude of calving site, and the number of calves observed at site. Between 1996-2014, ADF&G monitored 224 individual radiocollared female moose within the TFTA and 175 females had their calving sites located ≥2 years (mean = 3.6 calving sites/moose, SD=2.28). During this period, ADF&G located 810 calving sites (Table 1, Fig. 4). We think it is important to note that areas without calving sites do not necessarily indicate that there are not calving sites in those areas. Calving site locations were limited to radiocollared female moose and additional uncollared breeding female moose are present and may use other areas of the TFTA for calving. ADF&G documented calving between May 11 and June 20, the annual minimum (variance = 2.4) and mean (variance = 3.5) calving dates had a very small dispersion around the mean (Table 1). However, maximum calving date had relatively high dispersion (variance = 54.7).

Table 1. Number of calving sites (N = 810) and calving date characteristics each year ADF&G monitored radiocollared moose in the Tanana Flats Training Area.

Year	Calving sites	Mean calving date	Minimum calving date	Maximum calving date
1996	27	May 19	May 14	May 29
1997	19	May 23	May 16	June 05
1998	24	May 22	May 15	May 29
1999	24	May 24	May 14	June 11
2000	40	May 25	May 16	June 13
2001	36	May 23	May 14	June 06
2002	64	May 23	May 15	June 17
2003	48	May 22	May 12	June 01
2004	77	May 21	May 11	June 20
2005	52	May 21	May 12	May 28
2006	59	May 21	May 12	June 01
2007	44	May 22	May 13	June 01
2008	55	May 22	May 12	June 08
2009	35	May 21	May 12	June 08
2010	33	May 21	May 13	June 03
2011	53	May 25	May 16	June 23
2012	47	May 23	May 13	June 03
2013	34	May 27	May 14	June 09
2014	39	May 24	May 14	June 12
Mean (SD)	43 (15)	May 23 (1.9)	May 14 (1.5)	June 7 (7.4)

Figure 4. ADF&G calving-site locations (N=810) of radiocollared moose in Tanana Flats Training Area (TFTA) between 1996-2014.



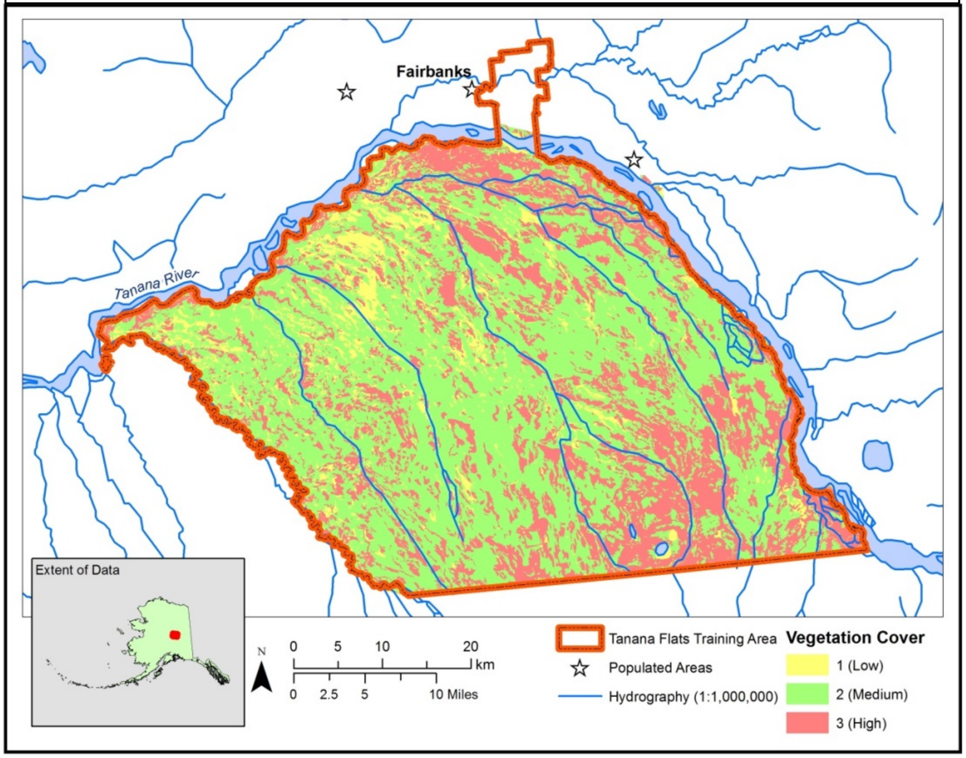
Vegetation Characteristics: Cover and Browse Quality

Our moose-relevant classification scheme of vegetation (Appendix A) indicated that most habitat within the study area contained medium to high vegetation cover (~90%) (Table 2, Fig. 5). Proportions of browse quality in each category were relatively similar (Table 2, Fig. 6).

Table 2. Area (acres) and proportion (%) of high, medium, and low categories of moose habitat characteristics in the Tanana Flats Training Area (TFTA).

Vegetation cover			Browse quality		
High	Medium	Low	High	Medium	Low
212,405 (32.5%)	379,085 (58.0%)	62,345 (9.5%)	268,811 (41.1%)	139,394 (21.3%)	245,631 (37.6%)

Figure 5. Moose vegetation cover with and without moose calving-site locations in the Tanana Flats Training Area was classified into three moose-relevant (Kellie 2005) categories (high, medium, low) using 128 Main Vegetation Types (MVTs) from Viereck et al.'s (1992) Alaska Vegetation Classification system.



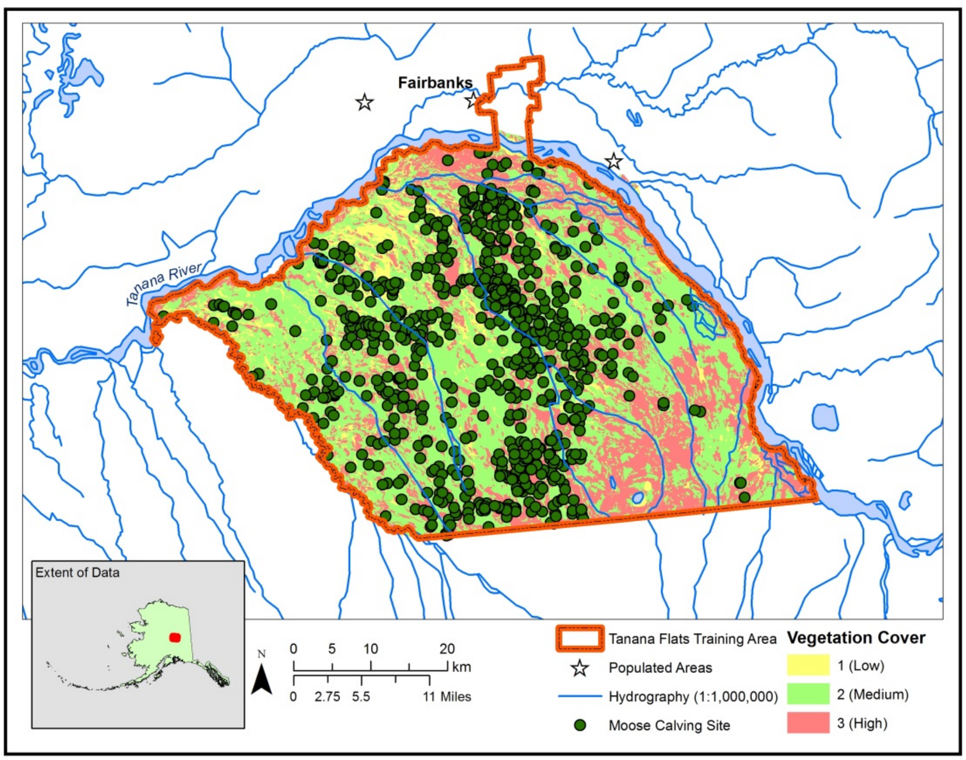
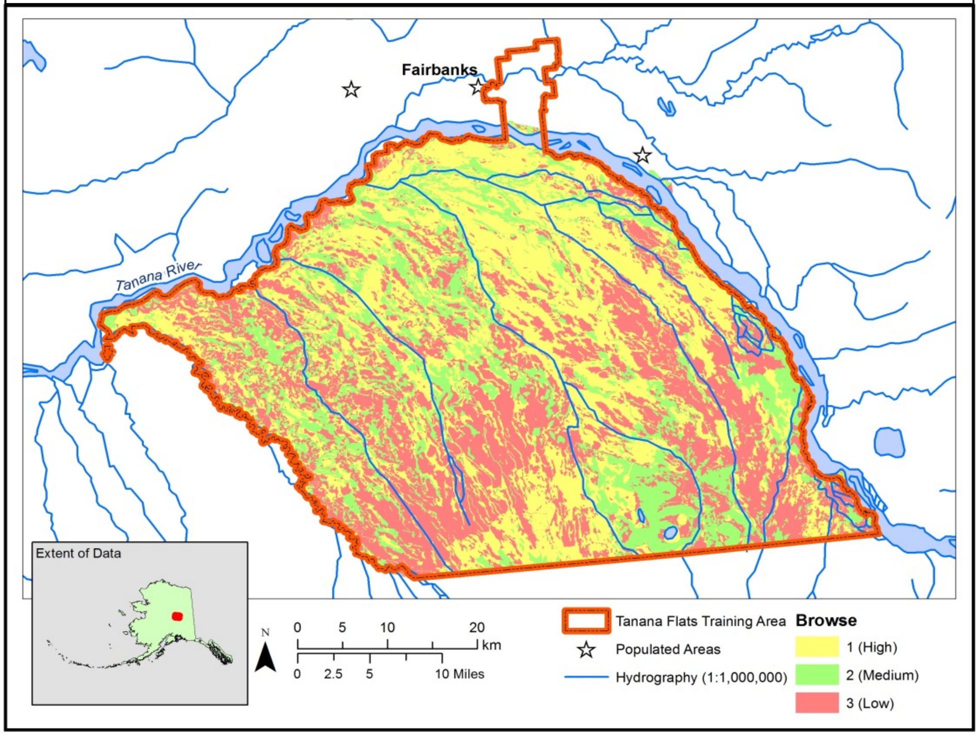
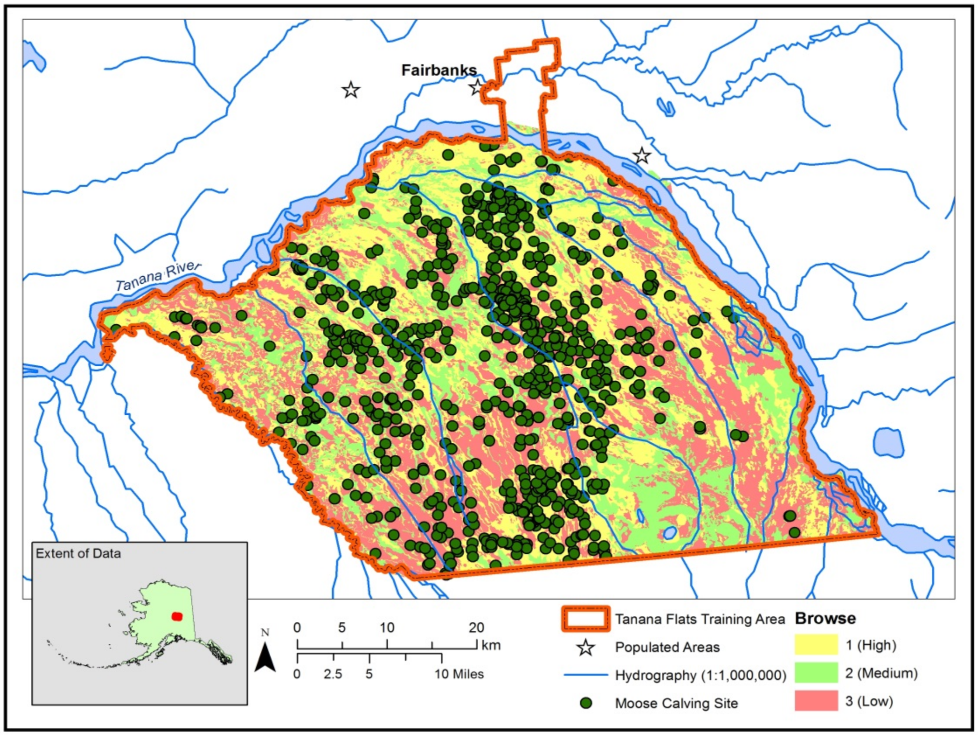


Figure 6. Moose browse quality with (A) and without (B) calving site locations in the Tanana Flats Training Area was categorized into three moose-relevant (Kellie 2005) categories (high, medium, low) using 128 Main Vegetation Types (MVTs) from Viereck et al.'s (1992) Alaska Vegetation Classification system.





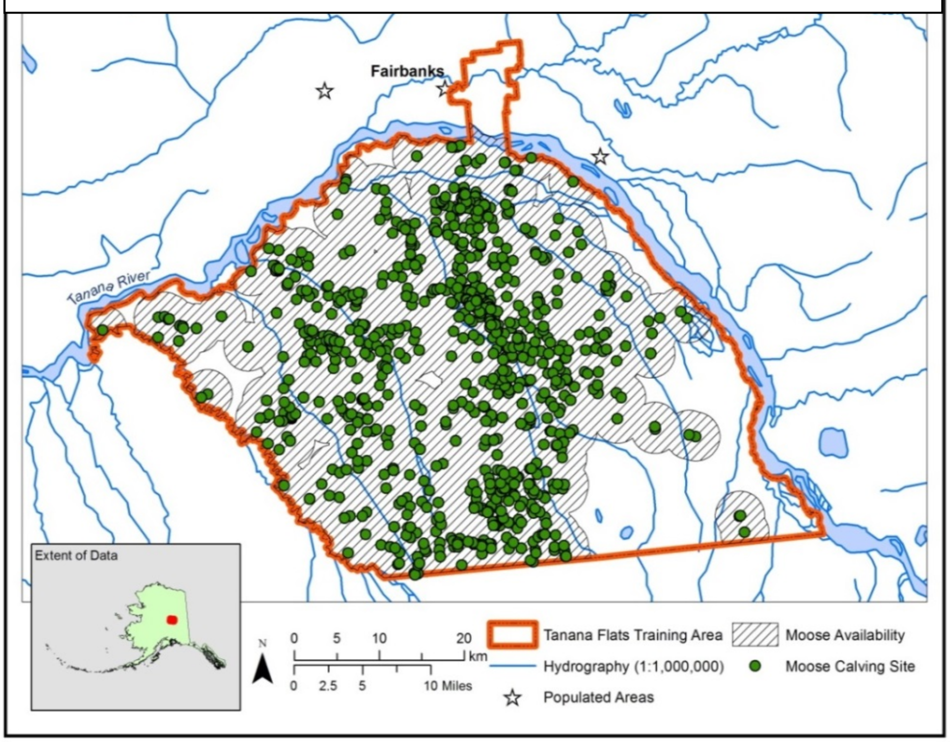
The mean distance between an individual calving-site location and the location of radiocollared female moose 48 hours prior to using individual calving sites was 3.4 km (SD=5.7) (Fig. 7). We used this distance to buffer calving sites and estimate the area of habitat available (Table 3) to radiocollared moose for selection of calving sites (Fig. 7). We estimated the percentage of each habitat used by calculating the percentage of calving sites located in each habitat type. The ratio of used points to available points provided a description of the relative level of selection or avoidance of each habitat category (Table 3). We assumed any ratio >1.1 was selection for and any ratio <0.9 was selection against a particular habitat type. We found that moose were selecting for habitat with high quality browse (1.33) and selecting against vegetation patches with low and medium quality browse (0.74) for calving-site locations disproportionately to each habitat category's availability. Moose also were selecting again vegetation with high (0.72) cover characteristics.

Table 3. Ratio of habitat (vegetation cover & browse quality) used for calving sites by radiocollared moose compared to habitat available in the Tanana Flats Training Area.

Vegetation				Browse			
Cover	Available	Used	Ratio[1]	Quality	Available	Used	Ratio
High	10%	7%	0.72	High	44%	58%	1.33
Medium	62%	68%	1.10	Medium	19%	14%	0.74
Low	28%	25%	0.87	Low	38%	28%	0.74

[1]Ratio of habitat used divided by habitat available. Values above and below 1.0 indicate relative probability of selection or avoidance, respectively.

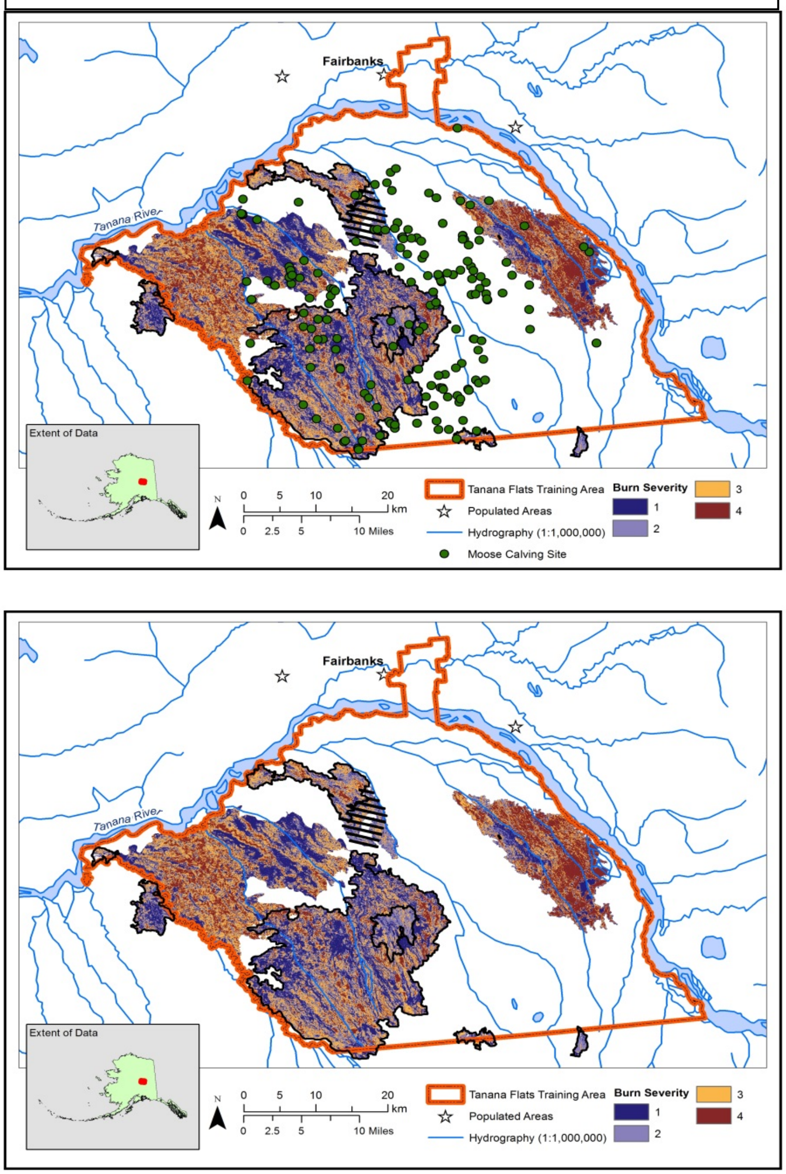
Figure 7. Area available to radiocollared moose for selection of calving sites. Availability area was based on an analysis of radiocollared female movements within 48 hours of calving.



Fire Characteristics

Because of data limitations (i.e., number of calving sites within a small number of burns with fire severity information in the TFTA), we only estimated how burns influenced calving site selection in relatively large (>5000 acres) and recent burns (1-3 years old). This approach allowed us to analyze the potential influence of four recent burns: Survey Line fire (2001), Wood River fire (2009), Willow Creek fire (2010), and Bonnifield fire (2011) (Fig. 2 & 8). A small sample size of calving sites and only 2 years of data (2013-2104) prevented us from analyzing the Dry Creek fire (2012).

Figure 8. Burn severity maps of fires included in our analysis of the relationship between moose calving sites and fire severity. 1 = unburned to low severity within the burn parameter, 2 = low severity, 3 = moderate severity, and 4 = high severity.



The mean number of radiocollared moose analyzed during the three-year period following each burn was 144 female moose (SD=30.7). The mean number of moose within each burn parameter varied significantly with the size of the burn (Survey Line = 32 moose, Wood River = 22 moose, Willow Creek = 7 moose, Bonnifield = 5 moose). This limited inference on the precision of relative selection or avoidance. When we grouped data from all fires, we found slight selection for areas within the fire parameter that were unburned or had a low severity of burn (Table 4). Our data suggests that high severity areas within a burn were strongly selected against (Ratio = 0.14). Moose calving sites are approximately 7 times less likely to be located in a high severity burn than a point randomly placed on the landscape. This finding corroborates with our vegetation selection analysis that moose are selecting areas with high browse quality. Recent high-severity burns are likely void of browse during the first few years following a fire.

Table 4. Ratio (R) of habitat (fire severity) used (U) compared to habitat available (A) for calving sites by radiocollared moose within the first three years of four wildfires in the Tanana Flats Training Area.

Severity category	Survey Line Fire-2001 (n=32)			Wood River Fire-2009 (n=22)			Willow Creek Fire-2010 (n=7)			Bonnifield Fire-2011 (n=5)			All Fires (n=66)		
	U	A	R	U	A	R	U	A	R	U	A	R	U	A	R
1	5%	3%	1.39	9%	9%	0.97	0%	1%	0.00	2%	1%	3.33	4%	4%	1.12
2	5%	5%	0.87	4%	6%	0.64	4%	1%	3.09	3%	1%	2.21	4%	3%	1.09
3	7%	6%	1.20	4%	5%	0.70	1%	1%	1.39	0%	0%	0.00	3%	3%	1.07
4	1%	2%	0.28	0%	2%	0.00	0%	0%	0.00	0%	0%	0.00	0%	1%	0.14
Within Fire Parameter	17%	17%	1.03	17%	23%	0.72	5%	3%	1.59	4%	2%	1.72	11%	12%	0.99

[1]Ratio of habitat used divided by habitat available. Values above and below 1.0 indicate selection and avoidance, respectively.

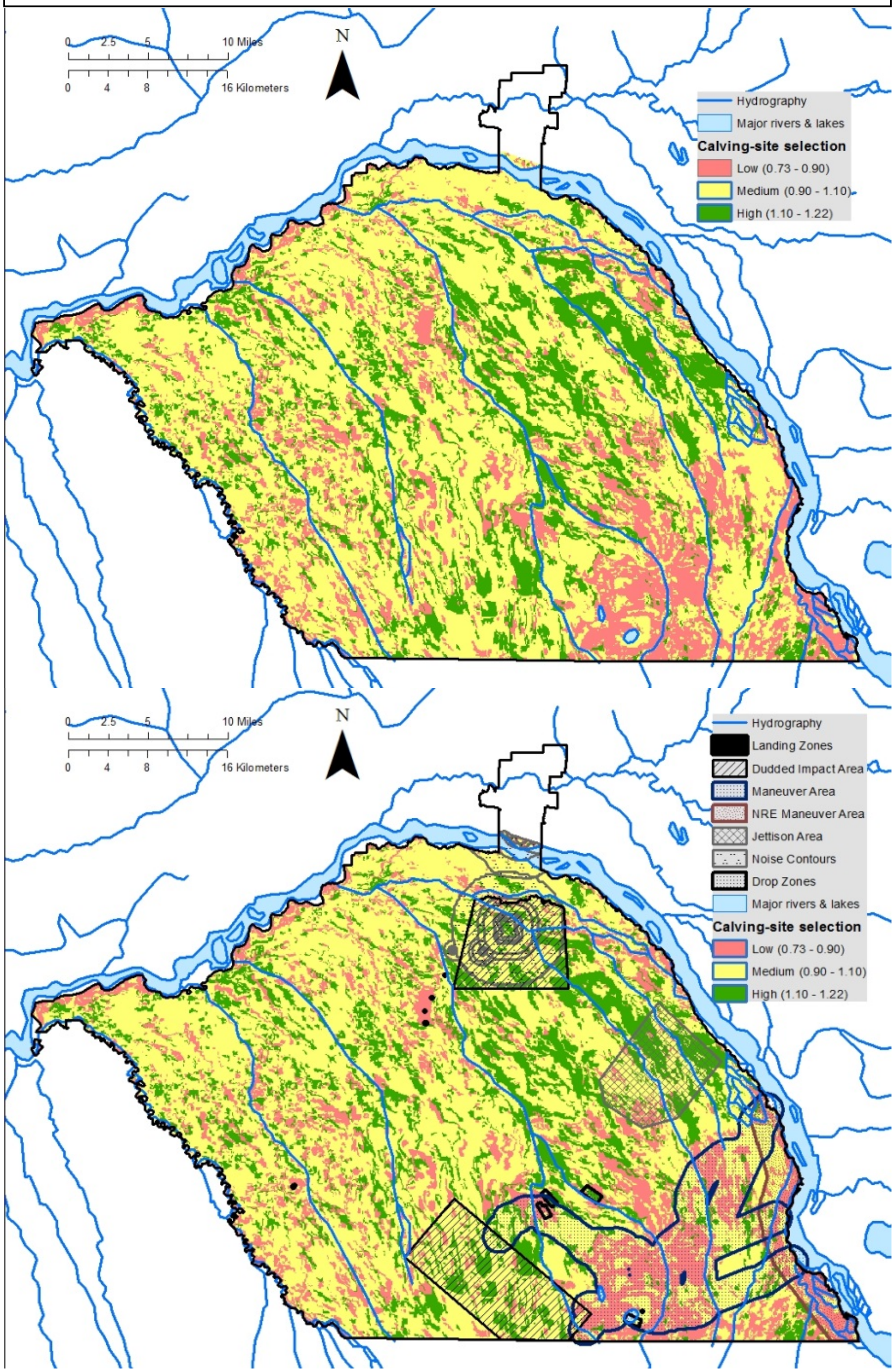
Mapping Moose Calving-site Selection

We used selection scores for each category of vegetation cover and browse to parameterize a map of overall selection for moose calving sites within the TFTA (Fig. 3 & 9). Within the TFTA, a relatively equal percentage of habitat is selected for (20%) and against (21%). We evaluated overlap between relative calving-site selection and each type of military activity. We found that jettison areas, drop zones, and dudded impact areas had relatively high overlap with habitat selected for (>1.10) calving sites (Table 5). Our model suggests that the NRE Maneuver area and the maneuver area have very little highly selected habitat for calving.

Table 5. Percentage of high (selection ratio = >1.1), medium (selection ratio = 0.9-1.1), and low (selection ratio >1.1) quality habitat for calving within areas where different types of military activity are conducted in the Tanana Flats Training Area.

Military activity	Total Area (acres)	High selection	Medium selection	Low selection
Drop Zones	1,339	37%	38%	25%
Dudded impact areas	55,487	27%	65%	8%
Jettison area	22,101	38%	50%	12%
Landing zones	7	0%	12%	88%
Maneuver area	75,447	9%	46%	45%
Noise contours	31,484	18%	74%	7%
NRE maneuver area	18,312	4%	41%	55%
TFTA	660,000	20%	59%	21%

Figure 9. Relative quality (high, medium, low) of calving-site habitat, with and without military activity, based on radiocollared female moose selection of habitat vegetation cover and browse quality in the Tanana Flats Training Area.



DISCUSSION

Calving timing

Within the TFTA, moose began calving at approximately the same time (mean = May 14, SD =1.5 days) but the end date of calving was variable (mean=June 7, SD=7.4). Therefore, the Army may be able to estimate, with relatively good precision, dates that military activity may overlap with calving in May. However, late-season calving activity may be more difficult to predict. Climatic, nutritional, and demographic characteristics provide insight into peak times of vulnerability for newborn calves and their mothers. Previous research indicated that the mother's age and condition were related to calving date (Schwartz and Hundertmark 1993). Female moose in poor condition because of harsh winters and/or low forage availability may give birth later. Further, a female moose population with a relatively young age structure may also result in later calving dates (Solberg et al. 2007).

Browse quality and vegetation cover

We determined that calving-site selection was strongest in habitat with high browse quality. Findings corroborate with previous research. Moose in Denali National Park, Alaska, were reported to select calving sites with high quality forage (Bowyer et al. 1999). Selection for high quality forage was likely related to the high nutritional demands associated with lactation (White and Luick 1984). We also determined that moose avoid calving in areas with thick cover. Bowyer et al. (1999) speculated that female moose may select areas with low vegetation cover and superior views to improve detection of approaching predators. With some vegetation types, browse quality may have an inverse relationship with vegetation cover. Expanding the number of browse-quality and vegetation-cover categories may provide opportunities to better assess the interactions and tradeoffs of these characteristics as they relate to calving sites. Because of the dynamic nature of the landscape within the TFTA, we suggest that future research that evaluates the effects of fine-scale differences in vegetation on moose space use also includes ground-truthing to control for changes in vegetation due to disturbance or forest succession. Our broad approach boosted the sample size in each of our three categories and provided useful information on the effects of cover and browse in general.

Fire severity

We determined that treating all areas within a wildfire parameter the same would provide a misleading description of moose calving-site selection because the severity of the burn influences the extent of selection. Moose avoided calving in areas with high severity burns. In contrast, moose used areas with low to moderate burn severity as much or more than areas outside the burn. Although we did not analyze the influence of the 2012 Dry Creek fire, we can extrapolate our findings. The MTBS data suggested that a relatively high percentage (49%) of the 2012 Dry Creek fire (Fig. 2) burned at a high severity. Therefore, we speculate that much of this burn is not being heavily used for calving at this time.

Monitoring moose calving activity in burns beyond 3-years old may provide important information on how forest succession influences calving activity. With four relatively large fires occurring in the TFTA since 2009, USAG-AK NRM is perfectly situated to monitor these relationships. Findings from this type of monitoring program may be of great value to resources managers on all Army lands in the boreal forest. Wildfire has been and probably will continue to be (at least until 2100) the most common landscape disturbance in Alaska (Kasischke and Turetsky 2006, Rupp et al. 2007) and, therefore, warrants land managers attention. Routine remote sensing by the Army may provide sufficient images to regularly update vegetation characteristics in the TFTA following a fire. This information will help the Army stay current on not only areas important for calving, but also provide invaluable data to track the relationship between forest succession and moose space use and demographics.

Relative probability of selection map

According to our findings, the southeast section of the TFTA has relatively poor-quality calving habitat for moose. Therefore, the NRE maneuver area and the maneuver area may have a relatively low level of disturbance to moose calving compared to military activity in other sections of the TFTA. In contrast, many of the other military activities overlap extensively with some of the best calving habitat. The military may consider minimizing activity in those areas during the calving period that could displace or directly harm moose. However, this action may require research on the level of disturbance necessary to cause a disturbance to calving.

Importance of predator space use

Predator distribution and density, especially bear, may significantly alter moose calving-site selection and space use (Bowyer et al. 1999). Predation on moose is greatest during parturition and in the 1st weeks after birth (Ballard 1992). Therefore, most research has suggested the selection of calving location is a tradeoff between forage quality and risk of predation (Bowyer et al. 1999, Poole et al. 2007). We did not account for the influence of predators in this study. Integration of bear habitat data during calving may provide a more thorough explanation of calving-site locations. We speculate that some areas within parameters may be selected for by moose because of bear avoidance of burns during the first few years after a fire (C. Gardner, ADF&G unpublished data).

Limitations of habitat selection studies

Resource use studies can help identify patterns of habitat and food selection. However, habitat need is different than selection, and biologists should not assume that selection is an indicator of moose fitness. For instance, creating more habitat that moose select for calving will not necessarily increase moose survival and population size.

SUMMARY OF FINDINGS & MANAGEMENT IMPLICATIONS

- Moose calving in the TFTA begins around May 12 and varies little across years.
- Moose calving end date is around June 7, but it is highly variable. Severe-long winters and a young age-structure of females in poor condition may prolong the calving period.
- Moose are selecting habitats for calving with high-quality browse (i.e., forage).
- Moose are avoiding habitats for calving with medium- to low-quality browse (i.e., forage).
- Moose are avoiding habitats for calving with high vegetation cover (thick forest with closed canopy).
- In burns ≤3 years old, moose are avoiding high-severity burn areas, and selecting for unburned to low-severity burn areas within the parameter of the fire.
- Maneuver areas contain primarily low-quality calving habitat.
- Jettison, dudded impact, and noise contour areas contain high percentages of habitat selected for calving.
- Future research should consider the effects of predators.
- Moose calving-site monitoring should continue in recent burns to advance knowledge on the effects of forest succession following burns of varying severities.
- Ultimately, this research helps the Army better understand when and where moose are likely to be calving, and what the biophysical characteristics are of those locations.

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Appendix A. Vegetation cover and browse quality was reclassified into 3 moose-relevant (Kellie 2005) categories (high, medium, and low) using 128 Main Vegetation Types (MVTs) from Viereck et al.'s (1992) Alaska Vegetation Classification system.

MVTdesc	Browse Quality	Vegetation Cover
Barren Alluvial Deposits: Fluvial deposits	Low	Low
Barren Other: Agricultural lands	Low	Low
Barren Other: Cultural: roads, paved areas, buildings, right of ways, maintained yards, etc.	Low	Low
Barren Other: Recent burns (ABR vegetation description = willow, shrub birch, graminoid, herbaceous, sedge, water)	High	Low
Barren Other: Recent burns (ABR vegetation description = Everything else)	Medium	Medium
Barren Other: Recent burns (ABR vegetation description = Conifer, needleleaf, alder, closed canopy)	Low	High
Barren Rock: Felsenmeer (broken boulder field)	Low	Low
Barren Rock: Other; including bare soil and eroded gullies	Low	Low
Barren Rock: Scree; talus slopes	Low	Low
Barren Rock: Solid outcrop	Low	Low
Closed Broadleaf Forest (60-100% Canopy): Balsam poplar	Medium	High
Closed Broadleaf Forest (60-100% Canopy): Paper birch	Medium	High
Closed Broadleaf Forest (60-100% Canopy): Paper birch - balsam poplar	Medium	High
Closed Broadleaf Forest (60-100% Canopy): Paper birch - quaking aspen	Medium	High
Closed Broadleaf Forest (60-100% Canopy): Quaking aspen	Medium	High
Closed Broadleaf Forest (60-100% Canopy): Quaking aspen - balsam poplar	Medium	High
Closed Dwarf Tree Forest (60-100% Canopy, Trees <= 3m): Black spruce	Low	High
Closed Dwarf Tree Forest (60-100% Canopy, Trees <= 3m): Mixed Conifer	Low	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Alder	Low	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Low alder - willow	High	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Low willow	High	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Mixed shrub - sedge tussock	High	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub birch	High	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub birch - willow	High	High
Closed Low Scrub (76-100% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub brich - ericacious shrub	High	High
Closed Mixed Forest (60-100% Canopy): Balsam poplar - white spruce	Medium	High
Closed Mixed Forest (60-100% Canopy): Quaking aspen - spruce	Medium	High
Closed Mixed Forest (60-100% Canopy): Spruce - paper birch	Medium	High
Closed Mixed Forest (60-100% Canopy): Spruce - paper birch - quaking aspen	Medium	High
Closed Mixed Forest (60-100% Canopy): White spruce - paper birch - balsam poplar (black cottonwood)	Medium	High
Closed Needleleaf Forest (60-100% Canopy): Black spruce	Low	High
Closed Needleleaf Forest (60-100% Canopy): Black spruce - tamarack	Low	High

Closed Needleleaf Forest (60-100% Canopy): Black spruce - white spruce	Low	High
Closed Needleleaf Forest (60-100% Canopy): White spruce	Low	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Alder	Low	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Alder - Willow	High	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Shrub birch	High	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Shrub birch - willow	High	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Shrub swamp	High	High
Closed Tall Scrub (76-100% Cover, Shrubs > 1.5m Tall): Willow	High	High
Dry Forb Herbaceous (Herbaceous Tundra): Alpine herbs	High	Low
Dry Forb Herbaceous (Herbaceous Tundra): Seral herbs	High	Low
Dry Graminoid Herbaceous: Midgrass - herb	High	Low
Dry Graminoid Herbaceous: Midgrass - shrub	High	Low
Dryas Dwarf Scrub (Shrubs < 0.2m Tall): Dryas - lichen tundra	Medium	Low
Dryas Dwarf Scrub (Shrubs < 0.2m Tall): Dryas - sedge tundra	Medium	Low
Dryas Dwarf Scrub (Shrubs < 0.2m Tall): Dryas tundra	Medium	Low
Ericaceous Dwarf Scrub (Shrubs < 0.2m Tall): Bearberry tundra	Medium	Low
Ericaceous Dwarf Scrub (Shrubs < 0.2m Tall): Vaccinium tundra	Medium	Low
Ericaeous Dwarf Scrub (Shrubs <0.2 M Tall): Mixed Shrub Community	High	Low
Freshwater Aquatic Herbaceous: Pond lily	High	Low
Impact Area, severly disturbed	High	Low
Mesic Graminoid Herbaceous: Bluejoint - herb	High	Low
Mesic Graminoid Herbaceous: Bluejoint - shrub	High	Low
Mesic Graminoid Herbaceous: Bluejoint meadow	High	Low
Mesic Graminoid Herbaceous: Mesic sedge - grass meadow tundra	Medium	Low
Mesic Graminoid Herbaceous: Mesic sedge - herb meadow tundra	High	Low
Mesic Graminoid Herbaceous: Sedge - birch tundra	High	Low
Mesic Graminoid Herbaceous: Sedge - willow tundra	High	Low
Mesic Graminoid Herbaceous: Tussock tundra	Medium	Low
Open Broadleaf Forest (25-59% Canopy): Balsam poplar	Medium	Medium
Open Broadleaf Forest (25-59% Canopy): Paper birch	Medium	Medium
Open Broadleaf Forest (25-59% Canopy): Paper birch - aspen	Medium	Medium
Open Broadleaf Forest (25-59% Canopy): Paper birch - balsam poplar	Medium	Medium
Open Broadleaf Forest (25-59% Canopy): Quaking aspen	Medium	Medium
Open Broadleaf Forest (25-59% Canopy): Quaking aspen - balsam poplar	Medium	Medium
Open Dwarf Tree Forest (25-59% Canopy, Trees <= 3m): Black spruce	Low	Medium
Open Dwarf Tree Forest (25-59% Canopy, Trees <= 3m): Mixed Conifer	Low	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Ericaceous shrub bog	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Low alder	Low	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Low alder - willow	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Mesic shrub birch - ericaceous shrub	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Mixed shrub - sedge tussock bog	High	Medium

Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Mixed shrub - sedge tussock tundra	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Sagebush - grass	Medium	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Sagebush - juniper	Medium	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub birch	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub birch - ericaceous shrub bog	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Shrub birch - willow	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Willow	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Willow - graminoid shrub bog	High	Medium
Open Low Scrub (25-75% Cover, 0.2m <= Shrubs <= 1.5m Tall): Willow - sedge shrub tundra	High	Medium
Open Mixed Forest (25-59% Canopy): Paper birch - balsam poplar (black cottonwood) - spruce	Medium	Medium
Open Mixed Forest (25-59% Canopy): Quaking aspen - spruce	Medium	Medium
Open Mixed Forest (25-59% Canopy): Spruce - balsam poplar	Medium	Medium
Open Mixed Forest (25-59% Canopy): Spruce - paper birch	Medium	Medium
Open Mixed Forest (25-59% Canopy): Spruce - paper birch - aspen	Medium	Medium
Open Needleleaf Forest (25-59% Canopy): Black spruce	Low	Medium
Open Needleleaf Forest (25-59% Canopy): Black spruce - tamarack	Low	Medium
Open Needleleaf Forest (25-59% Canopy): Black spruce - white spruce	Low	Medium
Open Needleleaf Forest (25-59% Canopy): White spruce	Low	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Alder	Low	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Alder - willow	High	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Shrub birch	High	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Shrub birch - willow	High	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Shrub swamp	High	Medium
Open Tall Scrub (25-75% Cover, Shrubs > 1.5m Tall): Willow	High	Medium
Water Lakes/Ponds: Census Greater than 8ha (40 acres)	High	Low
Water Lakes/Ponds: Non - census Less than 8 ha	High	Low
Water Streams/Rivers/Canals: Census More than 200m (1/8 mile or 660 ft wide)	High	Low
Water streams/Rivers/Canals: Non - census Less than 200m wide	High	Low
Wet Forb Herbaceous (Wetland Herbs): Fresh herb marsh	High	Low
Wet Forb Herbaceous (Wetland Herbs): Subartic lowland herb bog meadow	High	Low
Wet Forb Herbaceous (Wetland Herbs): Subartic lowland herb wet meadow	High	Low
Wet Graminoid Herbaceous: Fresh grass marsh	High	Low
Wet Graminoid Herbaceous: Fresh sedge marsh	High	Low
Wet Graminoid Herbaceous: Subartic lowland sedge - moss bog meadow	High	Low
Wet Graminoid Herbaceous: Subartic lowland sedge - shrub wet meadow	High	Low
Wet Graminoid Herbaceous: Subartic lowland sedge bog meadow	High	Low
Wet Graminoid Herbaceous: Subartic lowland sedge wet meadow	High	Low
Wet Graminoid Herbaceous: Wet sedge - grass meadow tundra	High	Low
Wet Graminoid Herbaceous: Wet sedge meadow tundra	High	Low

Woodland Broadleaf Forest (10-24% Canopy): Balsam poplar	Medium	Medium
Woodland Broadleaf Forest (10-24% Canopy): Paper birch	Medium	Medium
Woodland Broadleaf Forest (10-24% Canopy): Paper birch - aspen	Medium	Medium
Woodland Broadleaf Forest (10-24% Canopy): Paper birch - balsam poplar	Medium	Medium
Woodland Broadleaf Forest (10-24% Canopy): Quaking aspen	Medium	Medium
Woodland Dwarf Tree Forest (10-24% Canopy, Trees <= 3m Tall): Black spruce	Low	Medium
Woodland Dwarf Tree Forest (10-24% Canopy, Trees <= 3m Tall): Mixed Conifer	Low	Medium
Woodland Mixed Forest (10-24% Canopy): Balsam poplar - spruce	Medium	Medium
Woodland Mixed Forest (10-24% Canopy): Quaking aspen - spruce	Medium	Medium
Woodland Mixed Forest (10-24% Canopy): Spruce - paper birch	Medium	Medium
Woodland Mixed Forest (10-24% Canopy): Spruce - paper birch - aspen	Medium	Medium
Woodland Needleleaf Forest (10-24% Canopy): Black spruce	Low	Medium
Woodland Needleleaf Forest (10-24% Canopy): Black spruce - tamarack	Low	Medium
Woodland Needleleaf Forest (10-24% Canopy): Black spruce - white spruce	Low	Medium
Woodland Needleleaf Forest (10-24% Canopy): Mixed conifer	Low	Medium
Woodland Needleleaf Forest (10-24% Canopy): White spruce	Low	Medium