Annual movement patterns, nutrition and antler characteristics of moose in Game Management Unit 20D

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Overview

The southwest portion of Game Management Unit (GMU) 20D (Southwest 20D, Fig. 1) is an important resource to Alaskans because it is easily accessible to hunters and provides a large harvest of moose each year. Prior to and throughout this study, the moose population in Southwest 20D was at an elevated density (Gasaway et al. 1992; Dubois 2010). In addition, twinning rates, a measure of population nutrition, were declining (Boer 1992, Gasaway et al. 1992, DuBois 2010). From 2007-2008 the population was reduced through large harvests of antlerless moose from 5.5 moose/mi^2 in 2006 to 3.8 moose/mi^2 in 2008 to reduce density-related nutritional stress, reduce long-term range damage and increase opportunity for harvest (Boertje et al. 2007, DuBois 2010). Following this reduction in moose density, additional indices were needed to document and assess resulting moose nutrition and range condition. Also, managers lacked information on moose movement patterns and shifts in distribution between population surveys, twinning surveys and hunting seasons. The Alaska Department of Fish and Game (ADF&G) prioritized additional moose research in Southwest 20D to improve estimates of nutrition, population abundance and moose movement relative to harvest and surveys.

The Gerstle River Training Area (GRTA) is a U.S. Army Garrison Alaska (USAGAK) military operating area within Southwest 20D. Decades ago, the GRTA area was used as a test site for chemical weapons. Residents of nearby Healy Lake village (Fig. 1) recently voiced concerns that the weapons testing may have caused long-term contamination of plants and animals harvested for subsistence. As a result, the USAGAK prioritized research to measure contamination levels in subsistence foods, including moose. Further, USAGAK prioritized research to document moose movement patterns around the GRTA and areas that residents of the Healy Lake village use to hunt moose.

Federal Aid Project 1.67 combined ADF&G and USAGAK priorities for moose research. We document movements and distribution of moose relative to Southwest 20D, the GRTA, the Healy Lake village traditional hunting area (HLVTHA), population survey areas, and twinning survey areas. Contaminant testing was conducted by the U.S. Fish and Wildlife Service (USFWS) on moose tissue samples (reported elsewhere) obtained during this study. In addition, we collected several indices to measure moose nutrition and winter range condition following the reduction in moose density in Southwest 20D. Finally, a correction factor was developed for use with GSPE surveys to improve the accuracy of moose population estimates. This report summarizes the research conducted in Southwest 20D under Federal Aid Project 1.67 and 5.20 (browse survey) and fulfills contract W912CZ-08-D-0012, Delivery Order #7 to U.S. Army Alaska.

Study Area

GMU 20D (5637 mi^2; Fig. 1) encompasses the drainages North and South of the Tanana River from Shaw Creek to the Johnson River (Dubois 2010). Southwest 20D (1502 mi^2; Fig 1) is a portion of GMU 20D that encompasses land south of the Tanana River and west of the Johnson River and includes the town of Delta Junction and large tracts of agricultural land (Fig. 2). Southwest 20D includes the highest densities of moose in GMU 20D and the most extensive access for hunting (Dubois 2010). The northern portion of GMU 20D (20D North; 3207 mi^2; Fig 1) which extends North from the Tanana River to the boundary of GMU 20D has relatively lower moose density, is more difficult to access and includes Healy Lake and Healy Lake village (Dubois 2010). The Gerstle River Training Area (GRTA; 30.5 mi^2; Fig 1) is a parcel of military land located within Southwest 20D adjacent to the west bank of the Gerstle River south of the Alaska Highway. The HLVTHA (300 mi^2; Fig. 1) was delineated by local residents of Healy Lake Village and includes portions of the Tanana River and the Healy River drainage.

The habitat in GMU 20D is typical of northern boreal forest, with the exception of large plots of agricultural land that are frequently disturbed (Fig. 2). Two large burn scars from the Hajdukovich (1994, 34 mi^2) and Donnelly Flats (1999, 29 mi^2, Fig. 1) burns were within the distribution of collared moose (Fig. 3), and the Hajdukovich burn overlaps significantly with the GRTA (Fig 1.). The habitat of Southwest 20D has been described in detail elsewhere (Lord 2008, Seaton et al. 2011)

Methods

Moose Capture

All moose were darted from a Robinson R-44 Raven II helicopter delivered in a dart (1-cc for calves, 3-cc for adults) by a *Palmer Cap-Chur* (Powder Springs, GA) dart gun. Blood and hair samples from adults and some calves were transferred to Angela Matz (USFWS) for contaminants testing. We conducted all aspects of this research in accordance with acceptable methods for field studies adopted by the American Society of Mammalogists (Animal Care and Use Committee 1998; Alaska Department of Fish and Game Protocol 09-001).

In October 2009 ADF&G we captured male moose in 20D North and Southwest 20D with a focus on the GRTA (Fig. 3). We targeted large male moose because their movements would best represent patterns of moose that were legal to harvest (50" antler width or greater) and were therefore the segment most likely to be harvested for human consumption. Moose that have been chemically immobilized should not be harvested within 30 days of immobilization to ensure that no harmful residues remain in meat (Beckmen 2009). Thus, we captured adult males in mid-October because this period was as close to hunting season that we could immobilize animals without interfering with hunting or the rut. Southwest 20D (Fig. 2) experiences high rates of moose harvest and we increased our sample size in this area to correct for sample losses to hunting during the September 2010 season. We collected body and antler measurements, blood and hair for contaminants testing, photos of antlers, and a canine tooth for age estimation. All males were fitted with *Telonics* (Mesa, AZ) VHF radio-collars with an expandable section designed to accommodate neck swelling during the rut and a cotton spacer designed to rot and drop the collar 3-4 years after deployment. We used a mixture of 4.0 mg Carfentanil citrate and 120 mg Xylazine for immobilization, administered 36 mL of procaine penicillin G to prevent infection and 425 mg of Naltrexone and 500 mg of Tolazoline to reverse immobilization. We determined adult ages using counts of cementum annuli (Gasaway et al. 1978).

In late February 2010, we captured female-calf pairs and calves in Southwest 20D (Fig. 3). We chose this time period because it coincided with data collected in other areas of the state and allowed comparisons of body metrics across populations. Sex and litter size are known to cause variation in body mass of calves at birth (Keech et al. 2000) and calves do not compensate for these differences in weight at 9 months (Keech et al. 1999, Boertje et al. 2007). To avoid this additional variation, we only captured singleton female calves and female-calf pairs where the dam was accompanied by a single, female calf. We immobilized adult females using a mixture of 4.2 mg Carfentanil citrate and 160 mg Xylazine and calves received a mixture of 1.2 mg Carfentanil citrate and 60 mg Xylazine. For adult females, we administered 30 ml of procaine penicillin G to prevent infection followed by 425 mg Naltrexone and 340 mg Tolazoline to reverse immobilization. For calves, we administered 125mg Naltrexone and 200mg Tolazoline to reverse immobilization but did not administer any antibiotics. All adult females were fitted with *Telonics* (Mesa, AZ) VHF radio-collars and all calves were given a unique ear tag for identification. We recorded body measurements, collected hair and blood, and pulled a canine tooth for age estimation of adults. All calves were weighed using a net and tripod assembly and a 500-pound dial scale. Blood serum was sent to Biotracking LLC (Moscow, ID) for analysis using the pregnancy-specific protein B (PSPB; Sasser et al. 1986).

Browse assessment

The browse survey was conducted during 5-8 April 2010 according to methods of Seaton et al. (2011) cooperatively with Federal Aid Project 5.20. The 2010 sampling methods were similar to a 2007 browse survey in the same study area (Fig. 4) described in Paragi et al. (2008). In 2010 we used a Robinson R-44 helicopter to sample 21 plots in the foothills and 22 plots in the flats. We accessed an additional 14 plots in the flats using a pickup truck, taking random 15-100 steps toward a plot from the closest perpendicular distance along a road. We used the same browse diameter-dry mass relationships as the 2007 survey to estimate browse production and removal (Paragi et al. 2008).

Monitoring

From capture date until 21 May 2011 radiocollared moose were located twice a month from fixed-wing aircraft and their location recorded using a *Garmin* (Olathe, KS) GPSMap 296. During each flight, we attempted to view every animal and verify the presence of a collar, but on occasion, dense vegetation obscured the moose. In October 2010, we photographed the antlers of radiocollared males. During winters 2009-2010 and 2010-2011 from November through March we recorded the presence or absence of antlers for all male moose that were seen. We also recorded the presence or absence of a calf or yearling for all female moose that were seen. We investigated all mortalities as soon as possible and determined cause of death.

Sightability

We used radiocollared moose to test observers during the 2009 and 2010 GSPE surveys in Southwest 20D. During the 2009 survey, only male moose were available but during the 2010 survey both female and male radiocollared moose were used. To measure sightability of moose, a radiotracking plane verified the presence of a collared moose in a survey unit. After that unit had been surveyed, the radiotracking plane conferred with the survey plane to determine whether the collared moose was seen during the survey. Each opportunity to view a collared moose was considered a sightability trial and all trials were combined to calculate the sightability for that survey (Gasaway et al. 1986; Kellie and Delong 2006). We used the Delta method (Boertje et al. 2009) to calculate the 2009-2010 sightability correction factor (SCF).

Movements

We calculated minimum convex polygons (MCPs; Mohr 1947) using the Minimum Bounding Geometry tool in ArcMap 10.0 (*ESRI*, Redland, CA) to provide basic descriptions of range size and to provide boundaries for random locations used in habitat comparisons. Ranges were only calculated for moose where >15 locations were obtained. We obtained range perimeters by dissolving the MCP ranges of individual moose for particular season/sex/area combinations into a single polygon from which we drew random points. To examine habitat selection, we compared vegetation type at moose locations with vegetation type at an equal number of random locations from within the same range perimeter. We used the National Land Cover Dataset (NLCD, 2001, http://www.epa.gov/mrlc/nlcd-2001.html; Fig. 2) for vegetation classifications. We used the GLM function in R (R statistical software, version 2.10.1, 2009), to examine relationships between age, antler size and study area for adult male moose.

Results

We presented preliminary results from this research to the Delta Fish and Game Advisory Committee and other members of the public in Delta Junction on 27 April 2011. We also prepared a poster displaying antlers for 42 males photographed during handling in October 2009 and aerial photos from October 2010 for the 26 of the remaining males.

Moose Measurements and Nutrition

In October 2009, we captured 15 adult males in 20D North and 27 adult males in Southwest 20D. In addition, in late February 2010 we captured 18 female-calf pairs and an additional 13 female calves (Fig. 3). Based on counts of cementum annuli, 20D North males were on average 1.7 years older than males in Southwest 20D. In Southwest 20D, adult females were on average 3.5 years older than adult males (Table 1). Of the 18 cows tested, 4 were not pregnant (22%;

ages: 5, 5, 7 and 11). One of the 4 that tested negative PSPB was the 5-year-old female that died shortly after capture. Necropsy revealed a large tumor in the cervix that likely prevented pregnancy from occurring.

The mean mass of nine-month old calves in Southwest 20D was 340.2 pounds (n = 31; se = 8.8; Table 2). We focused calf sampling in the flats of Southwest 20D, but also sampled 6 calves in the hills (Fig. 3). Although sample sizes were inadequate for contrasting among smaller areas within Southwest 20D, it appears that calves may be smaller in the Hajdukovich burn and in the lake system just east of Donnelly Dome than in the hills and in the agricultural areas north of the Alaska Highway (Fig. 5).

Male moose in 20D North were larger than males in Southwest 20D (Table 1), but this difference was largely explained by age differences between the two areas rather than developmental differences caused by nutritional stress in Southwest 20D. For example, antler width increased with moose age (t = 9.53; P > 0.001) but there was no difference in antler width between study areas (t = -0.805; P = 0.426) once the relationship with age was considered. The overlap in antler dimensions of individual males from 20D North and Southwest 20D within age classes illustrates the lack of a nutritional effect (Fig. 6). The same individuals were monitored for antler drop in 2009-2010 as 2010-2011, except for those harvested during the autumn 2010 hunting season. Median antler drop occurred in late December overall (n = 70) and within years younger males dropped their antlers later in the winter than older adults (Fig. 7). However, although mean age was one year later in 2010-2011 (6.4 versus 5.3), antler drop was earlier during the 2009-2010 winter (late December, n = 43) than during the 2010-2011 winter (early January, n = 28; Fig. 7). Further, only 15 of 28 (54%) individual males dropped their antlers earlier in 2010-2011 when they were 1 year older.

Proportional removal of browse biomass in the study area was lower in 2010 than 2007 (Z-test, P < 0.0005; Fig. 8). Removal declined predominantly in the flats (Fig. 9), coincident with a decline in moose density by nearly 40% (6.0 to 3.6 /mi^2) in the flats of Southwest 20D through antlerless harvest in the intervening years. Relatively high density of moose likely continued to occur in the foothills based on a trend toward plant architecture increasingly affected by moose browsing in the foothills (Fig. 9).

Mortality

Over the course of the study, we lost 1 adult female to bear predation during the calving season, 2 adult males to unknown natural mortality, 1 adult female to capture mortality, 1 adult female to a vehicle collision, and 12 males during the September 2010 hunting season. All males taken by hunters were killed in Southwest 20D. Hunters that returned collars and provided contact information were given movement and capture information for their animals. Natural survival rates were high (> 93%) for all adults (Table 1).

Movements

Males

We conducted a total of 38 radiotracking flights for adult males from 27 October 2009 through 22 May 2011. We obtained 1182 locations for 42 male moose (= 28 locations/moose). Average home range size for males was 182.2 km^2 (*n* = 40, *se* = 49.4, = 29 locations/ moose). The minimum home range size for an individual male was 28 km^2 (*n* = 33 locations) and the maximum was 490 km^2 (*n* = 34 locations). The average home range was larger in 20D North (= 226.2, *n* = 15, *se* = 75.8) than in Southwest 20D (= 155.9, *n* = 25, *se* = 46.7), but there was considerable overlap in range size among individuals from the 2 areas (z = 1.6, P = 0.109, = 0.05).

From hunting season (September) through late winter (March), the majority of adult male moose from 20D North and Southwest 20D were separated by the Tanana River (Fig. 3). However, two males captured in Southwest 20D spent their winters in the Volkmar River drainage of 20D North (Fig. 10), moving out of Southwest 20D in late November (Fig. 11). In general, males remained at higher elevations for the winter, coming down around mid-March and ascending for the rut season (Fig. 12). A large portion of the males in Southwest 20D used the low, aquatic areas surrounding Healy Lake during the calving and summer seasons (Fig. 10), but were not within the HLVTHA during the hunting season (Fig 13). Males captured in October 2009 in the upper Healy River drainage of 20D North never descended down into the lower Healy Lake area where they would be most accessible to residents of Healy Lake Village (Fig. 14). Males captured near the Hajdukovich burn appeared to concentrate their winter range within the perimeter of that burn (Fig. 15). Two males captured west of the Healy River drainage remained in those general areas throughout the study (Fig. 16). Finally, four males captured on the agricultural lands in Southwest 20D displayed very different movement strategies and range sizes (Fig. 17).

Females

We conducted 28 radiotracking flights from 10 March 2010 through 22 May 2011 for adult female moose. There were 403 locations obtained for 18 moose (= 21 locations/moose). Average range size for females was 154.5 km^2 (*n* = 15, *se* = 19.9, = 25 locations/moose). The minimum range size for an individual female was 11 km^2 (*n* = 24 locations) and the maximum range size was 700 km^2 (*n* = 24 locations). All females were captured in Southwest 20D (Fig. 3) and generally remained in this area except for use of the low, aquatic areas surrounding Healy Lake during calving and summer seasons (Fig. 18). Contrary to migration patterns observed in nearby Central 20A to the east (Fig. 3, Boertje et al. 2007), only 2 of 4 of the Southwest 20D females captured in the hills descended to the flats during summer (Fig. 19). Females in the flats of Southwest 20D used relatively lower elevations for calving (Fig. 12), but within those lower elevations seemed to choose areas with more cover (Fig. 20). Indeed, within their annual movements, females selected both deciduous and evergreen forest types while males chose shrub/scrub communities and woody wetlands (Fig. 21). Females captured in the GRTA also spent the majority of the winter in the Hajdukovich burn, but expanded out into wetland areas during spring and summer (Fig. 22). The adult female that was captured on the agricultural land maintained the smallest range of all female moose (Fig. 17). One female that spent time in the GRTA was within the HLVTHA during hunting season (Fig. 13).

<u>Range Overlap</u>

Eleven moose (4 females, 7 males) were located at least once in both the GRTA and the HLVTHA (Fig. 13). Most of this overlap occurred during calving and summer seasons. These moose were originally captured in Southwest 20D and spent the winter south of the Tanana River. Only one radiocollared moose that used the GRTA was found within the HLVTHA during the month of September. This female was located just north of the Alaska Highway, but on the south side of the Tanana River (Fig. 13).

Distributions of moose during the hunting season in September 2009 were very similar to distributions during the 2010 GSPE survey season in November (Fig. 23). Of 15 males that were located in Southwest 20D in September and still alive in November, only one moved out of Southwest 20D in between hunting season and survey season. This male moved out of Southwest 20D in mid-November. He and 2 others harvested in September 2009 were at the base of Gerstle Mountain in late autumn, then moved to the hills surrounding the lower Volkmar River in early winter, and returned to Southwest 20D in spring (Fig. 11).

Sightability

On 13 December, 2009 we conducted 13 sightability trials using 2 different survey teams. Only male radiocollared moose were available during the 2009 GSPE survey. During 17 – 21 December 2010, an additional 21 sightability trials were conducted using 6 different survey teams. Too few sightability trials were conducted annually to calculate annual sightability estimates and so we pooled the trials from 2009 and 2010. Radiocollared moose were seen in 31 of 34 trials, and the 2009-2010 pooled SCF estimate was 1.10 (range 1.00 - 1.20).

Discussion

Nutrition

It was readily apparent when handling adult males that body condition was better in 20D North than in Southwest 20D. However, small sample sizes and differences in the age structure of adult males captured in Southwest 20D North versus 20D North prevented nutritional comparisons of body and antler size. It is likely that observed differences in age structure among samples of adult moose are the result of harvest regulations. The younger age structure observed in Southwest 20D versus 20D North (Table 1) probably reflects the intense harvest of older males in Southwest 20D where legal restrictions limit harvest to males with antler widths ≥50 inches. The older age structure of collared females versus males in Southwest 20D (Table 1) may only reflect the selective capture of adult females with calves (≥ 4 years old; Boertje et al. 2007). However, regulations for recent, large antlerless harvests specified the taking of adult females without calves, thus directing the harvest toward females < 4 years old and perhaps upwardly biasing the age structure of females in the population.

The high natural survival rate of adult males and females in Southwest 20D (Table 1) suggests that nutrition is not directly affecting the population through mortality. Nevertheless, similarly high survival rates of adult moose have been documented in nearby 20A (97.1% M >24 mos. and 91.7% for F >47 mos.; Boertje pers. comm.), where nutritional stress is apparent (Boertje et al. 2007). We did not monitor adult females during calving season with enough regularity to detect all parturition events. However, by correcting the pregnancy rate determined by PSPB analyses (14 of 18, 77.8%) for the small percentage of births that likely failed (10%; Boertje et al. 2007), the parturition rate of 67.8% among adult females in Southwest 20D was slightly less than the lowest pregnancy rate reported among 8 study areas in Alaska (the Tanana Flats: 70%, Boertje et al. 2007: Table 2). Further, the calf weights measured in Southwest 20D were the lowest among 11 populations in Alaska (Table 2; Boertje et al. 2007: Table 2). Although twinning rates in Southwest 20D were moderate in comparison with other high-density populations in Interior Alaska (Table 2), 2-year average twinning rates declined during this study (16.2% in 2008 to 11.4% in 2010; ADF&G unpublished data). Browse removal rates in Southwest 20D measured some nutritional improvement. The removal rate measured for the 2009- 2010 winter was the lowest among 5 recent surveys, including Northern 20C where moose density is low and nutrition is considered to be high based on other indices (Table 2).

Although we have no immediate explanation for the disparity among nutritional indices collected for Southwest 20D, we suspect that lag times in nutritional improvement may be occurring following the large, recent reduction in density. These lags could cause nutritional indices to differ where the measurements reflect different nutritional response times. For example, browse removal rates estimate range use over a single winter by measuring the percent of stems removed by the end of winter that grew during the previous summer (Seaton et al. 2011). Thus, this index indirectly quantifies intraspecific competition for browse during the previous winter and may be more sensitive to abrupt changes in density. The temporal sensitivity of the browse survey is underscored by a larger decline in browse removal rates in the flats where the greatest decrease in moose density occurred (Fig. 8). In contrast, twinning rate or calf weights measured during the same year are influenced by cumulative effects on dam condition over many years (Mech et al. 1987, Robertson et al. 1992). Calf weights are a sensitive index to differences in nutrition among populations (Boertje et al. 2007), but we do not know how many years are needed before calf weights increase following nutritional improvement among adult females. In Southwest GMU 20D, no increase in twinning rates was seen 2 years after a significant reduction in moose density. It is possible that improvements in adult female nutrition have not yet resulted in improved conception rates. In GMU 20A twinning rates responded to reduced density by increasing from 10% in 1975 to 31% in 1976. This response was 12 years after the initiation of a 10-yr, 8-fold population decline and coincident to a small increase in moose numbers 2 years after the population reached its lowest density (Gasaway et al. 1983, Boertje et al. 2007). Indeed, the lag time between declines in density and increases in calf weights and twinning rates likely depends on the initial state and relative improvement of nutrition in a given moose population.

Antler drop

The timing of antler drop among collared moose in GMU 20D was consistent with other areas of Alaska (Van Ballenberghe 1983), and about 2 weeks later than drop rates reported for Canada (Novak 1981, Hauge and Keith 1981, Oswald 1984). In late November, the majority of males retained their antlers (Fig. 7b) and would have been correctly classified during GSPE surveys. This supports the current department recommendation to complete GSPE composition surveys prior to Dec 5th (Kellie and Delong 2006).

Older males dropped their antlers earlier than younger males (Fig. 7a), which agrees with prior observations of a negative relationship between age and drop date (Hauge and Keith 1981, Oswald 1984). As a result, differences in the age structures between 20D North and Southwest 20D prevented a comparison of drop rates. For individual males, we did not find later drop dates with increasing age when we compared drop dates during two successive winters. Thus, at the scale of an individual over a short period of time, we assume that antler casting is somewhat affected by differences in environmental conditions between years (Fig 7b).

Movements

This study did not find overlap between male moose feeding in the GRTA and available for harvest in the HLVTHA during the September 2009 hunting season (Fig. 13). Based on our observations, we surmise that very few of the moose harvested by residents of Healy Lake Village spent time on the GRTA where they may have been exposed to contamination. There is a slightly higher probability of harvesting a GRTA moose when harvesting females in September or antlerless moose in late winter (Fig 13).

GSPE estimates of population abundance obtained in November likely reflect the moose available for harvest in September (Fig. 10, 18 and 23). Only one moose crossed the boundary of Southwest 20D between the hunting season and the November survey season (Fig. 23). In general, adult males in 20D North moved to higher elevations for the rut, but males in Southwest 20D remained at a similar elevation until late December (Fig. 12). If the timing of movements to higher elevations in Southwest 20D is somewhat variable between winters, differences in habitat related to elevation could change sightability of males among GSPE surveys. Indeed, similar to other studies (Thompson 1979, Gasaway et al. 1985, Miquelle et al. 1992, Björneraas et al. 2011) females in Southwest 20D showed more preference for evergreen forest than males (Fig. 21). If survey intensity is too low (Gasaway et al. 1986) segregation by habitat type could result in lower sightability of females than males and cause underestimation of females in population and composition estimates (Peterson and Page 1993, Anderson et al. 1996, McCorquodale 2001).

Sightability

The 1.10 SCF correction factor estimated for Southwest 20D from these sightability trials was lower than the 1.21 estimate that was developed in GMU 20A and is currently applied to Southwest 20D GSPE estimates (Boertje et al. 2007, Dubois 2010). The harvest implications of estimating population size using an SCF of 1.21 versus 1.10 are relatively large. However, given that the total sample of trials in Southwest 20D is still relatively small (n = 34, 2 years), the SCF estimate is far less robust than multi-year estimates developed elsewhere (GMU 20A: n = 69, 4 years, Boertje et al. 2009; EMMA: n = 225, 6 years, Keech et al. 2011). We suggest refining the 20D composite SCF by obtaining additional years of data before applying it to population management.

Recommendations

- Conduct additional calf weight measurements in Southwest 20D in 2 years with emphasis on differentiating between flats and foothills moose. We hypothesize that calf weights in the flats will increase as the population responds to recent reductions in moose density.

- Conduct 1 – 2 more years of sightability trials to obtain a more robust SCF for 20D.

- Conduct another browse removal estimate in 3-5 years regardless of change in moose density to test for change in proportional biomass removal and plant architecture (flats and foothills that have different accessibility to hunters) and changes in browse species utilization. We hypothesize that browsing impacts will continue to increase in the foothills and moose may shift to less palatable species unless winter density is reduced in order to impacts on forage resources.

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Figures

Figure 1. Various boundaries referenced in this report.

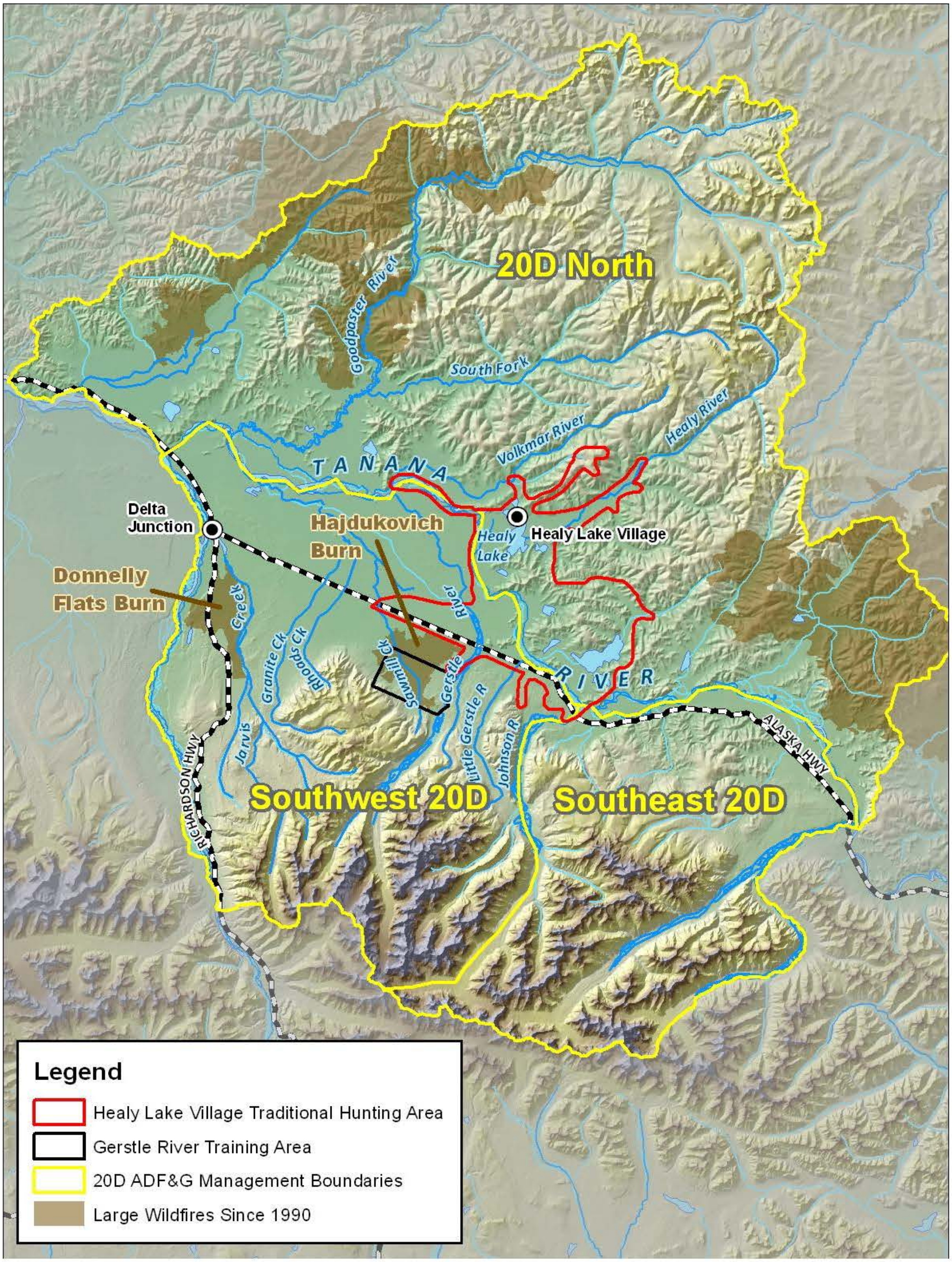


Figure 2. North American Land Cover (NLCD) vegetation classification for the study area. Classification was completed in 2001, but uses LANDSAT satellite imagery from 1998-2001. The Healy Lake village traditional hunting area is outlined in red. Southwest 20D is outlined in yellow.

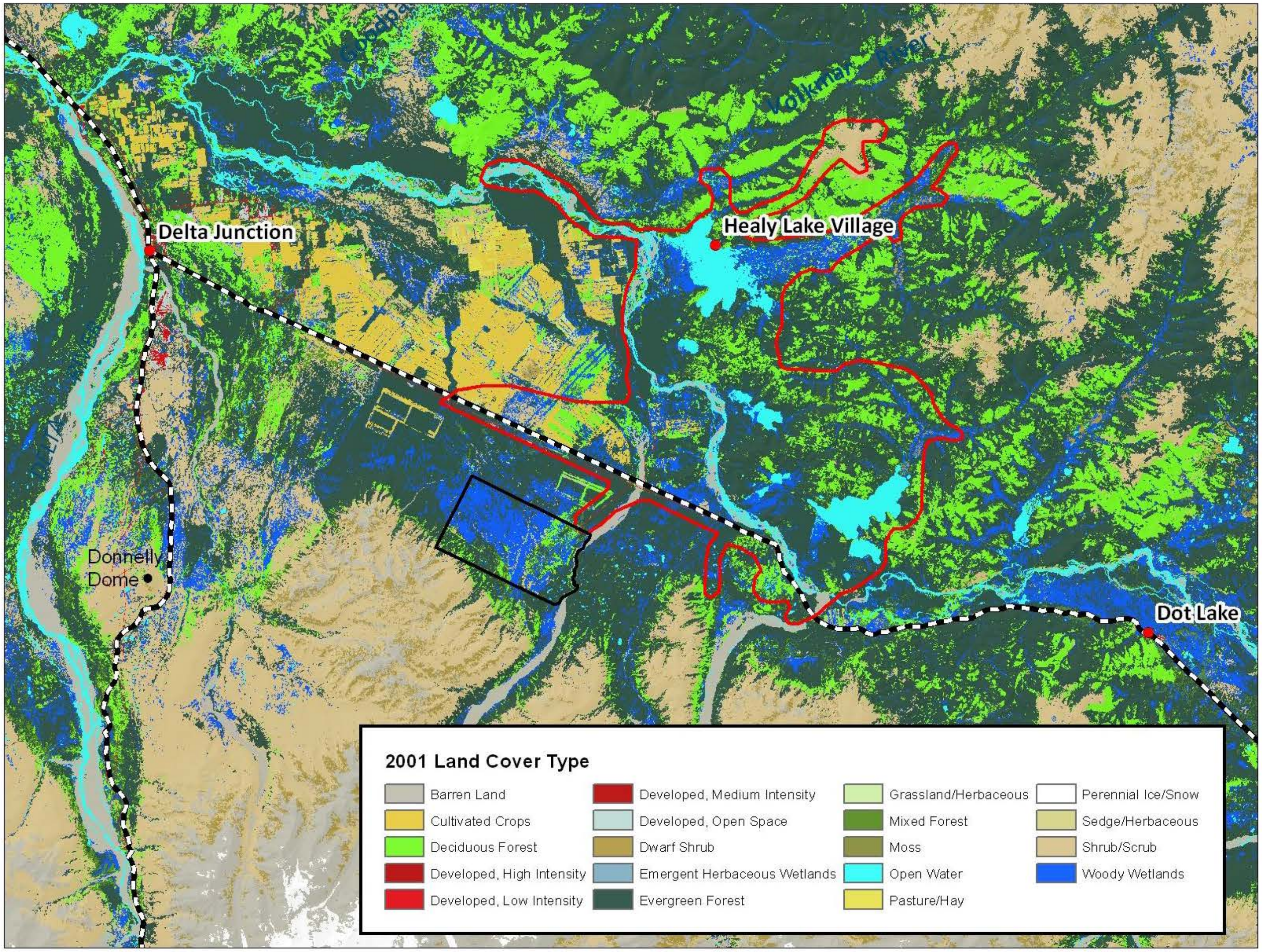


Figure 3. Capture locations. for males (●), female-calf pairs (●) and calves (●). Males were captured in October 2009 and female adults and calves were captured in late Feb, 2010. Adults were fixed with radiocollars for documentation of movement and distribution. Calves of collared cows and 12 additional calves were captured and weighed to evaluate nutritional status of the Southwest 20D population. Two adult males (○) captured in Southwest 20D wintered in 20D North.

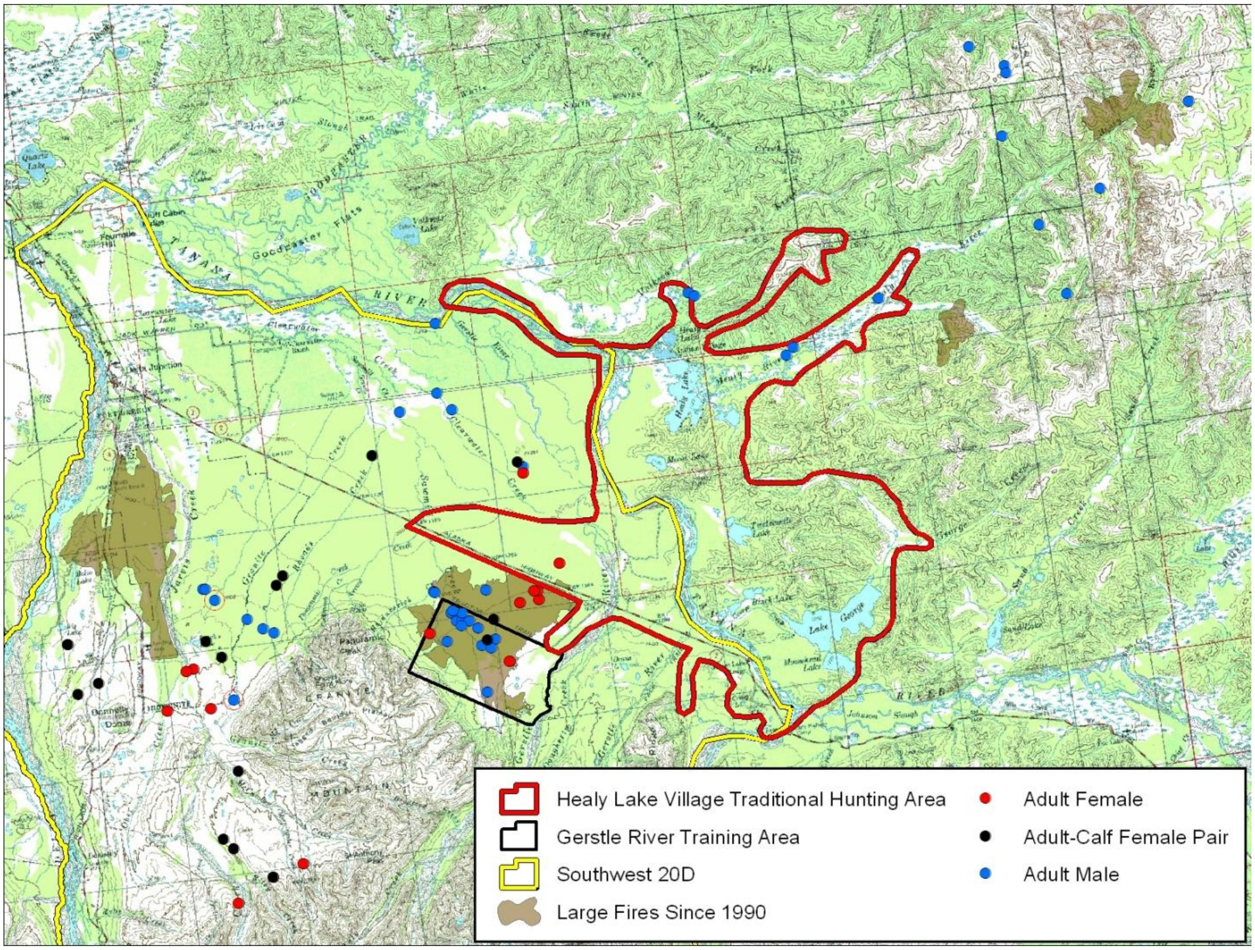


Figure 4. Sampling design for the browse survey conducted in Southwest GMU 20D in March 2010. Samples were stratified into two sub-areas based on elevation.

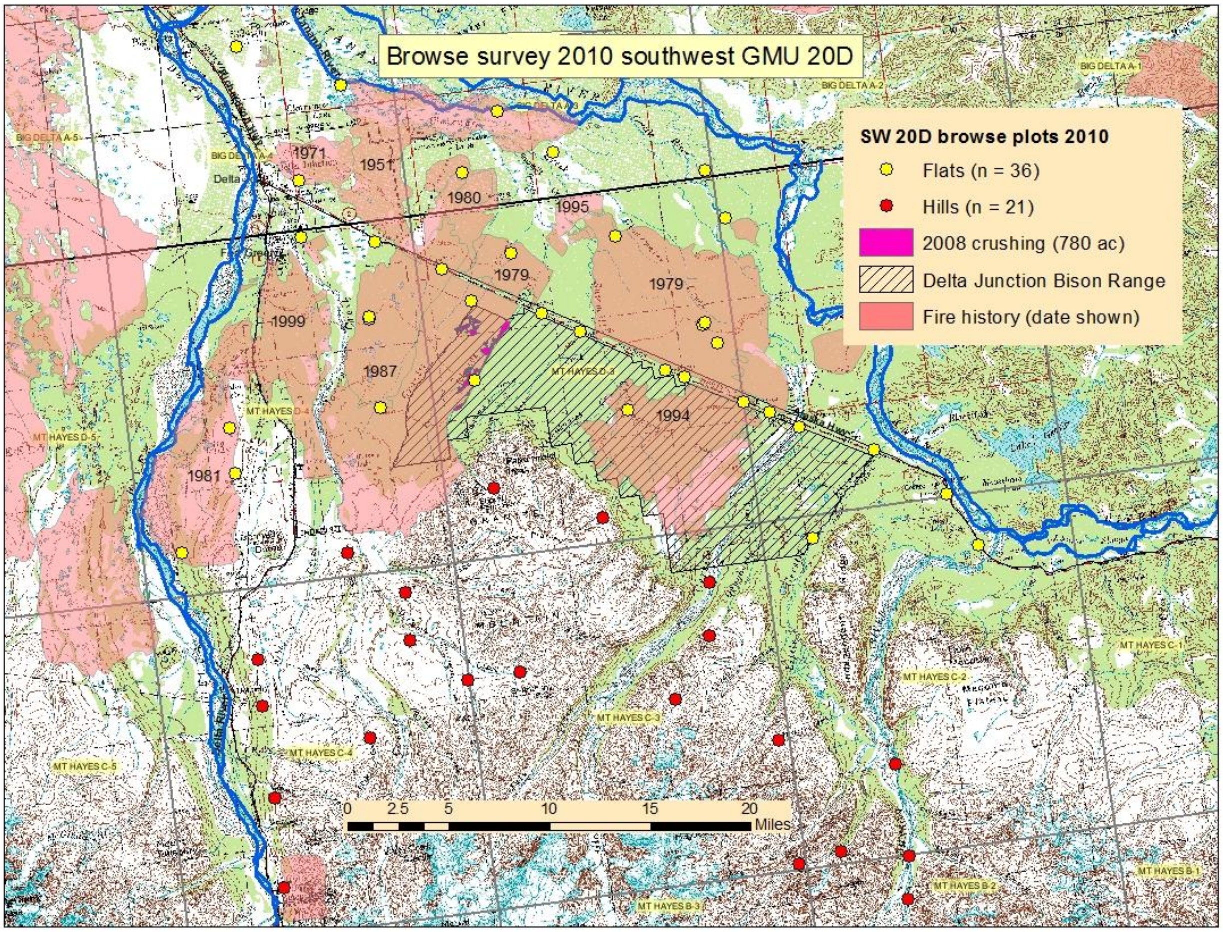


Figure 5. Locations of female calves captured in late Feb 2010 in Southwest 20D. Locations are labeled with measurements of calf body mass (lbs.). Major wildfires since 1990 are outlined in brown. The Gerstle River Training Area is outlined in black. The NLCD vegetation map is used to illustrate the location of the agricultural areas.

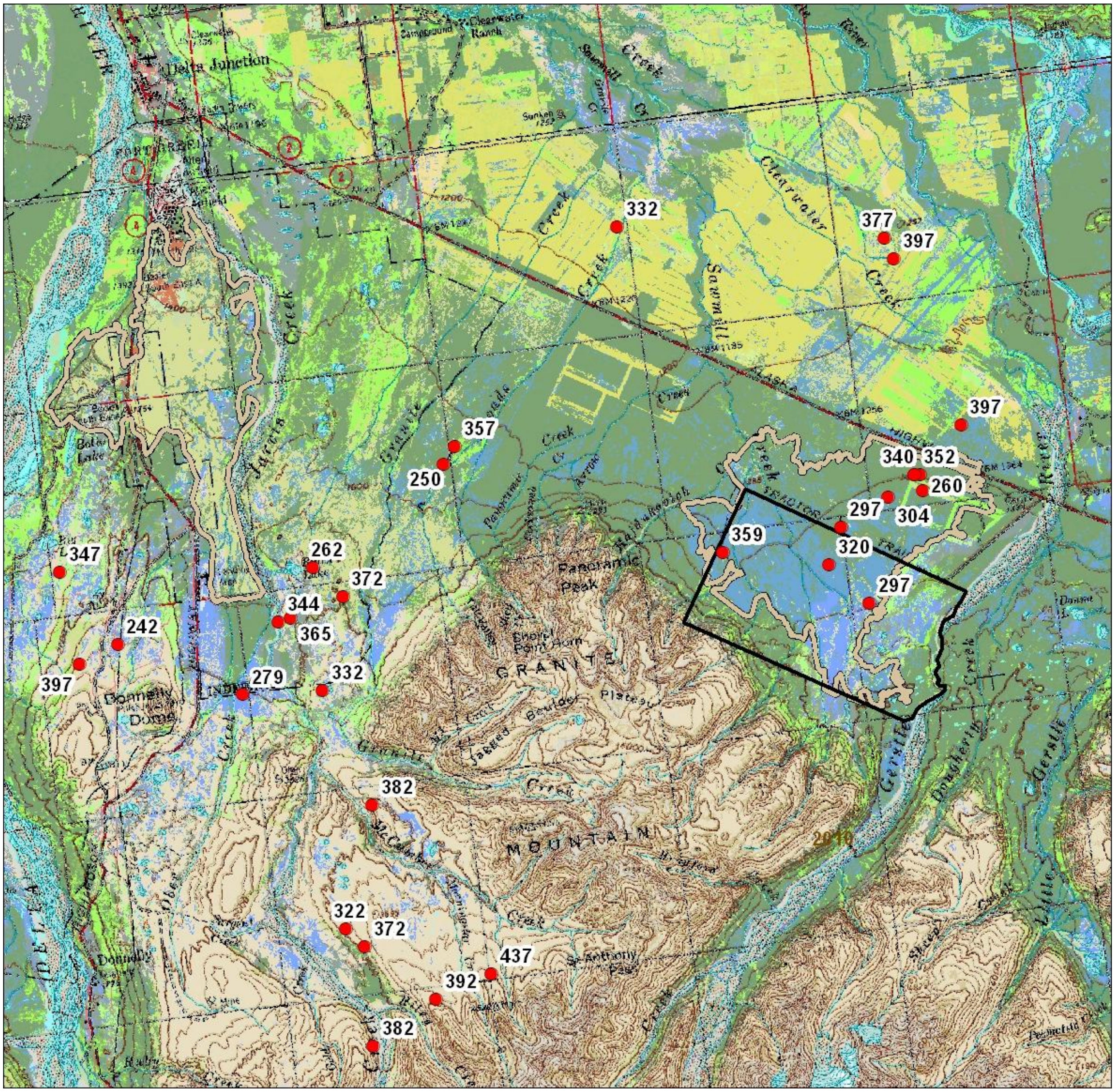


Figure 6. The relationship between age and antler width for adult moose captured in North and Southwest 20D in October 2011 near Delta Junction, Alaska.

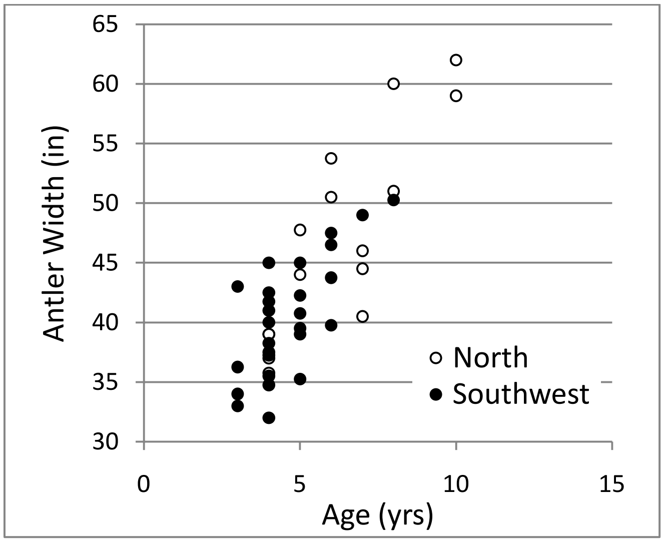


Figure 7. The timing of antler drop among collared male moose in GMU 20D during winters 2009-2010 and 2010-2011, depicted as a cumulative antler drop by age class (A) and by winter (B).

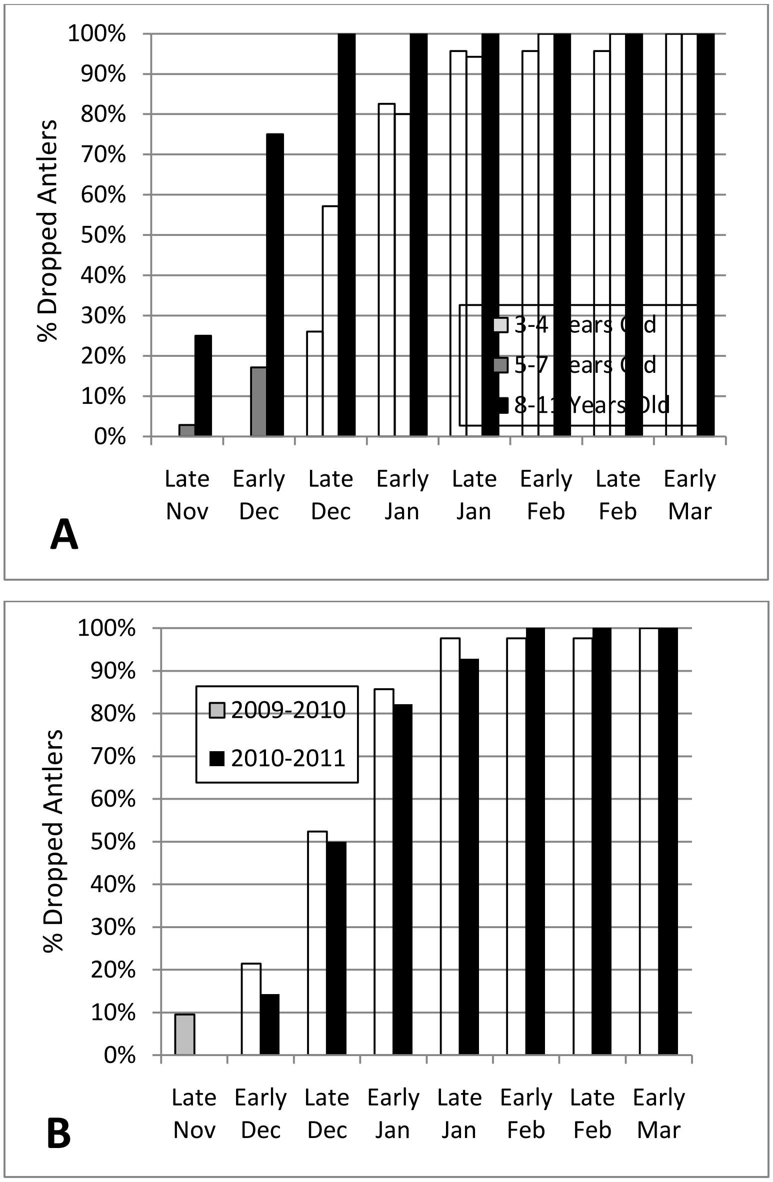
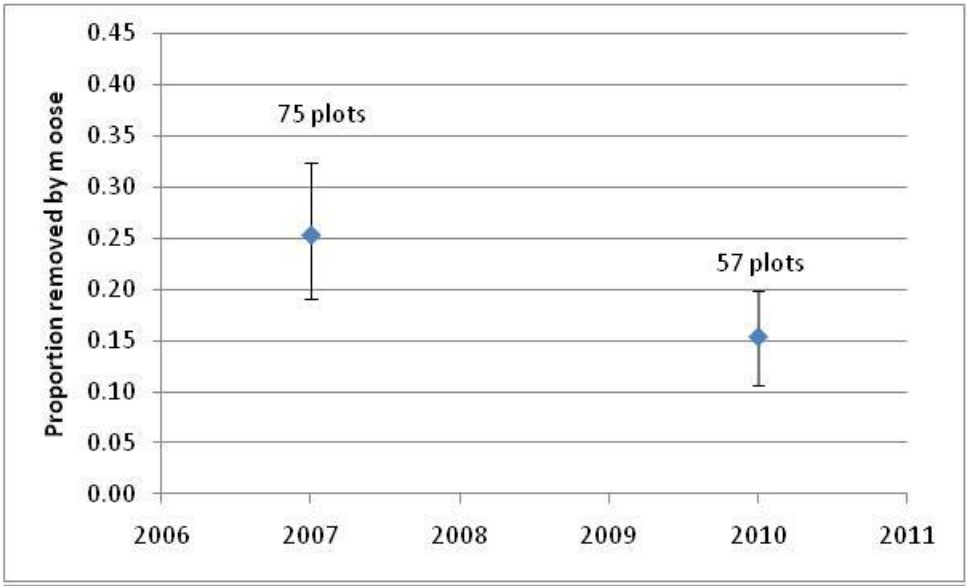


Figure 8. A comparison of 2007 and 2010 browse removal rates by moose in Southwest 20D (A) and within sub-areas of Southwest 20D (B). Browse rates were significantly lower in 2010 than in 2007 in all of Southwest 20D (Z-test, P < 0.0005*),* but were only lower in the Southwest 20D flats (Z-test, *P* < 0.0005) and not the hills (Z-test, *P* > 0.5) when sub-areas were compared.



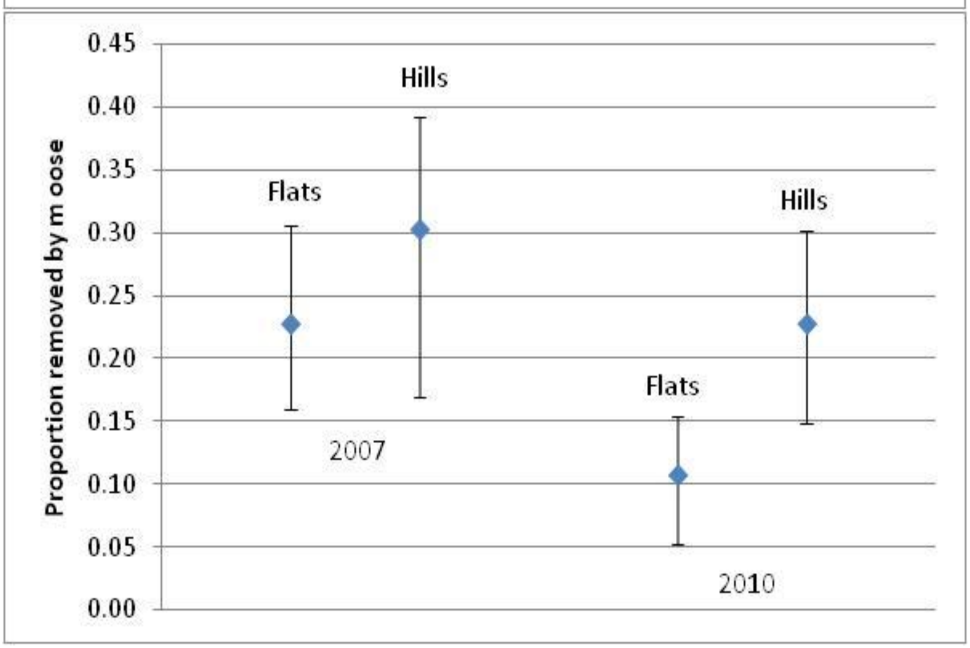


Figure 9. A comparison of browse architecture caused by moose browsing as measured during the 2007 and 2010 browse surveys conducted in Southwest 20D. The number of plants sampled is shown above the bars and 95% confidence limits are displayed.

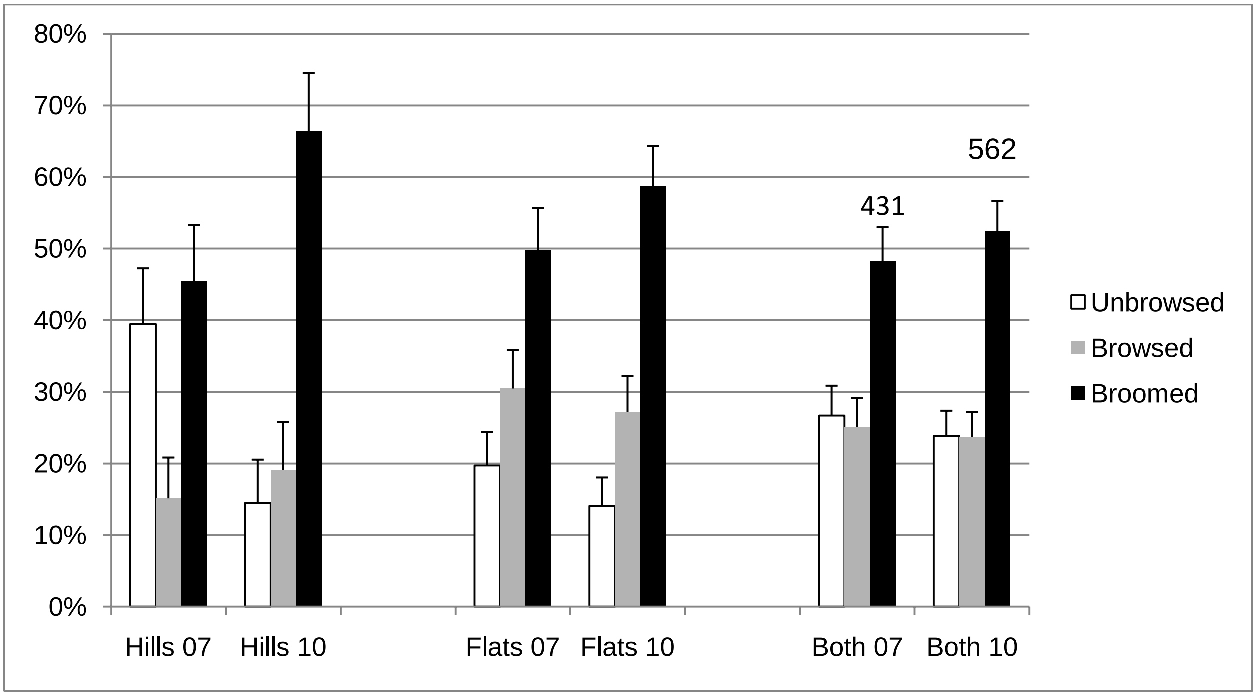


Figure 10. Seasonal distribution of male moose captured in Southwest 20D (●) and 20D North (●). The boundaries of Southwest 20D (yellow), the Gerstle River Training Area (white) and Healy Lake Village traditional hunting area (red) are also illustrated. Seasons are described as calving (May); Summer (June – August); Hunting (September); Rut (October); Early Winter (November – December) and Late Winter (January – March).

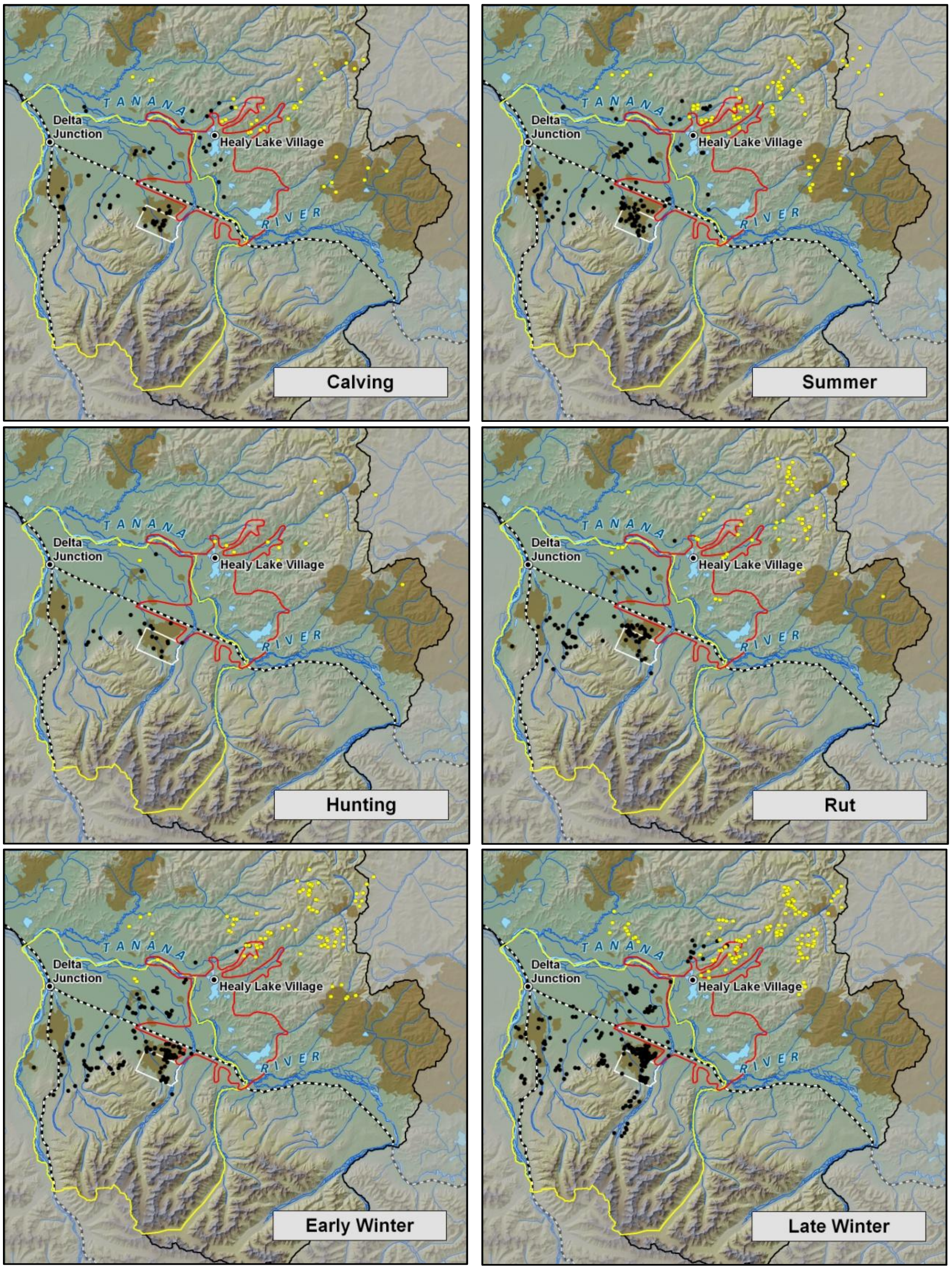


Figure 11. Annual movement patterns of radiocollared moose that were in the eastern flats near Delta Junction, Alaska in mid-October 2009 and 2010 (illustrated as points).

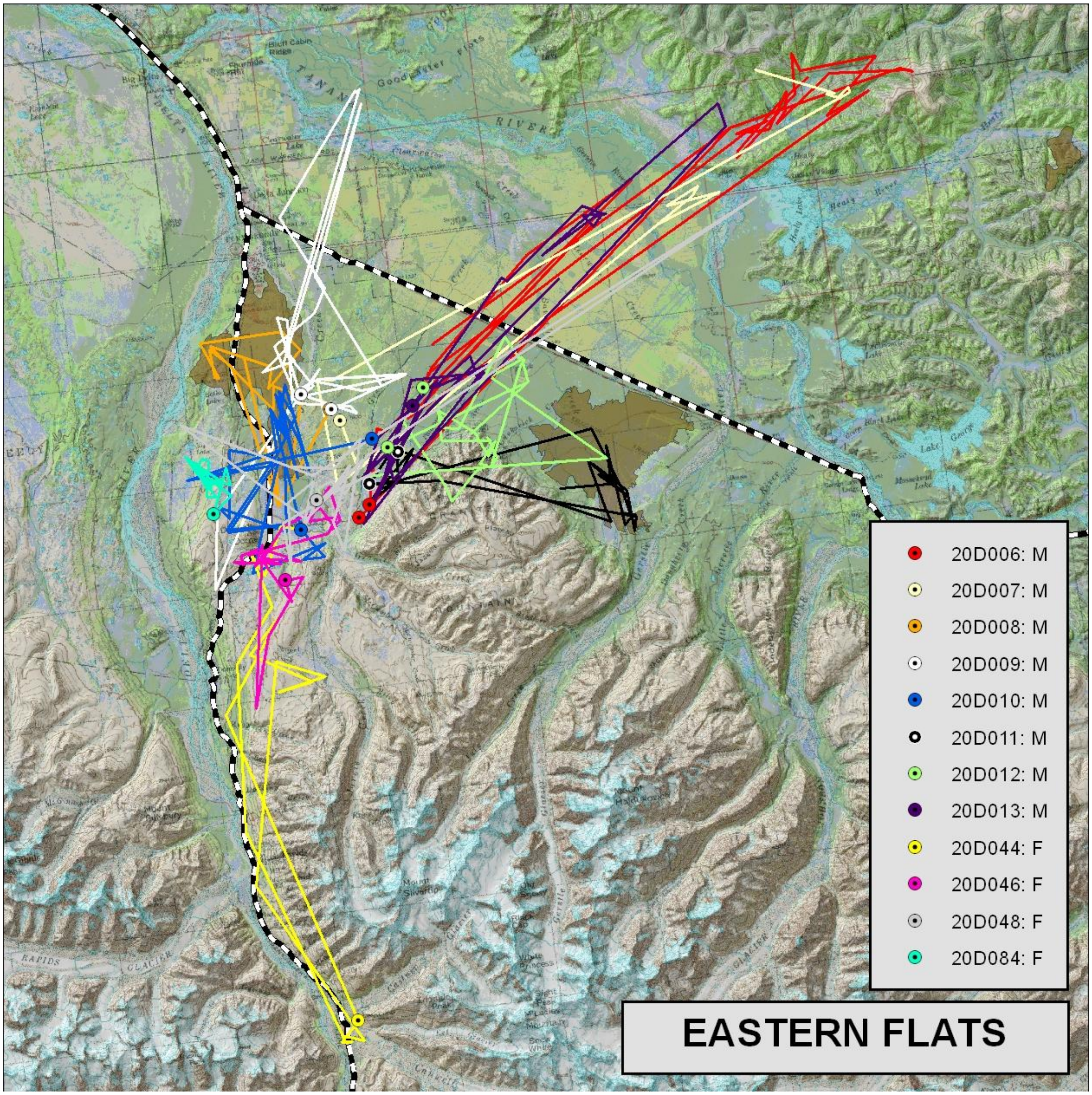


Figure 12. Elevation changes of female (Southwest 20D) and male (20D North and Southwest 20D) radiocollared moose from October 2009 through May 2011. Peak calving periods in 2010 and 2011 are depicted with black dashed lines. Peak rut in 2010 is depicted with an orange dashed line. Three female moose in Southwest 20D that lived in the hills were removed from the analysis because there were no comparable male ranges.

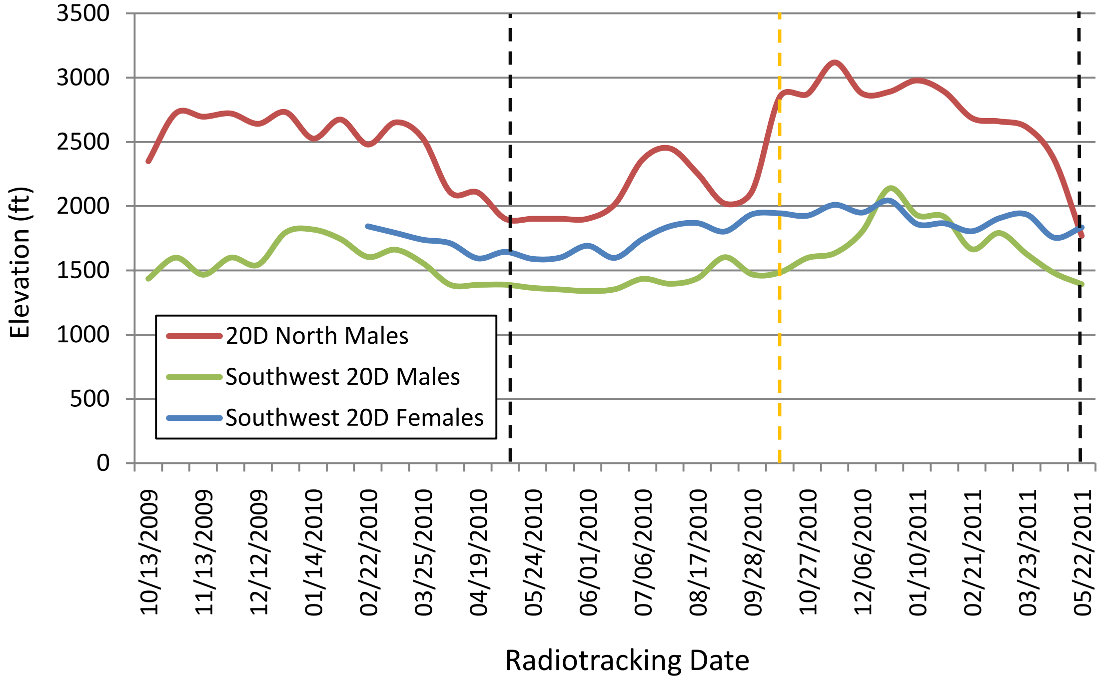


Figure 13. Seasonal distribution of female (●) and male (●) moose captured in Southwest 20D that were located in both the Healy Lake Village traditional hunting area (HLVTHA, red) and the Gerstle River Training Area (GRTA, white) during the study. Seasons are described as calving (May); Summer (June – August); Hunting (September); Rut (October); Early Winter (November – December) and Late Winter (January – March). Moose used the HLVTHA in spring and summer and wintered in the GRTA. Only one moose that wintered on the GRTA was within the boundaries of the HLVTHA during the hunting season.

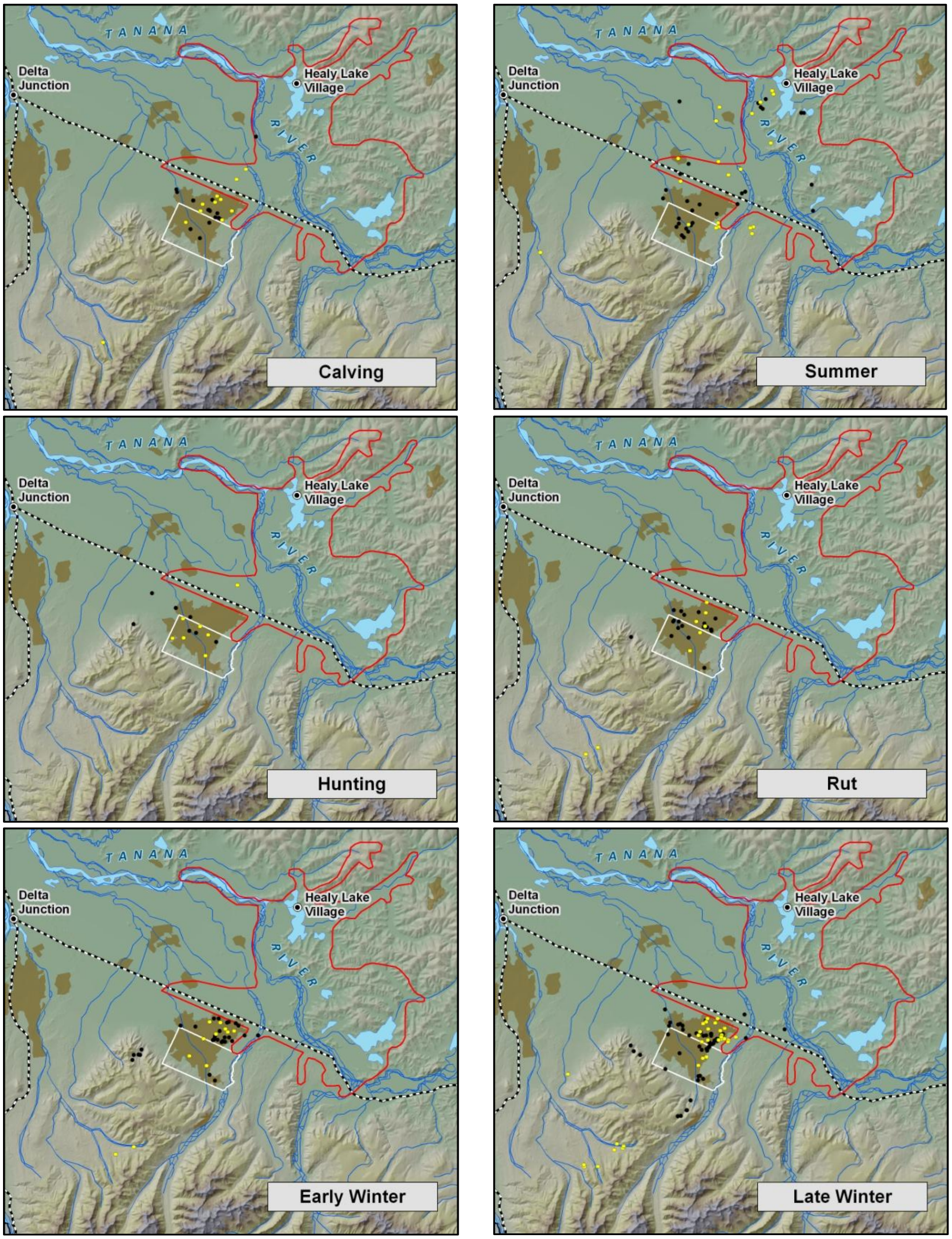


Figure 14. Annual movement patterns of radiocollared adult male moose that were in the drainages of the Healy River and South Fork of the Goodpaster River near Delta Junction, Alaska in mid-October 2009 and 2010 (illustrated as points).

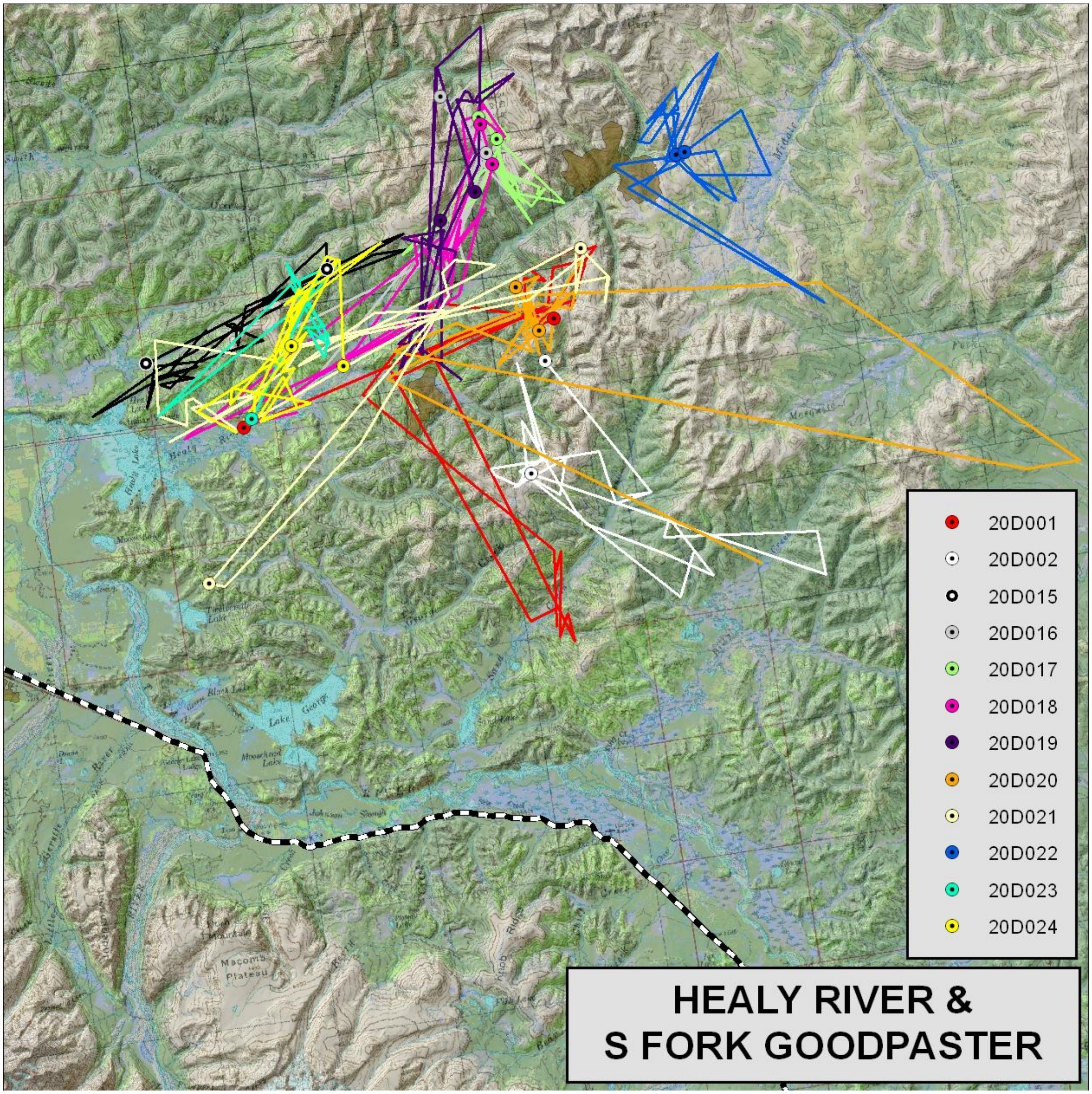


Figure 15. Annual movement patterns of radiocollared adult male moose that were within the Hejdukovich burn near Delta Junction, Alaska in mid-October 2009 and 2010. Mid-October locations are illustrated as points.

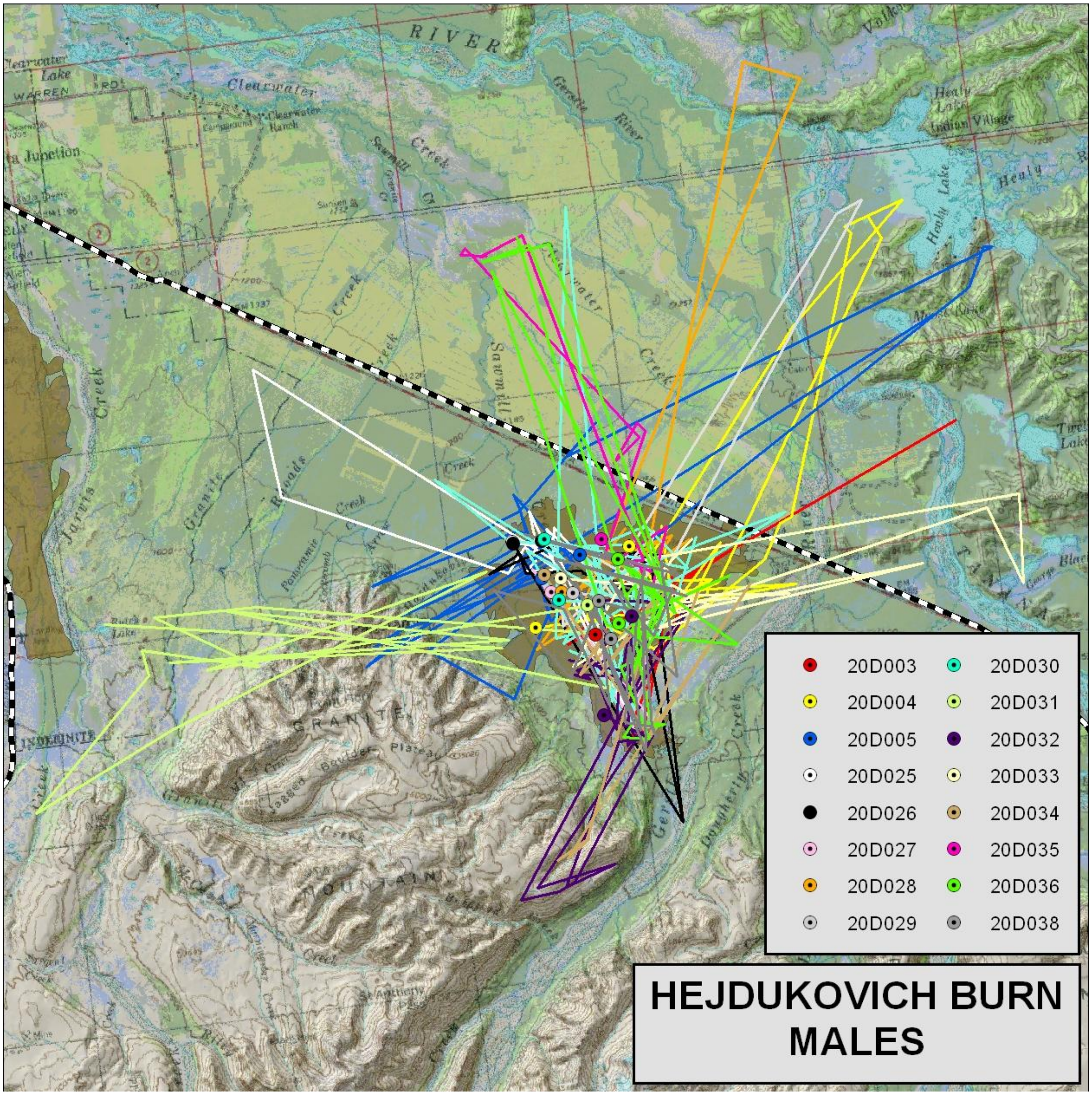


Figure 16. Annual movement patterns of radiocollared adult male moose that were in the drainages of the Tanana River and South Fork of the Goodpaster River near Delta Junction, Alaska in mid-October 2009 and 2010 (illustrated as points).

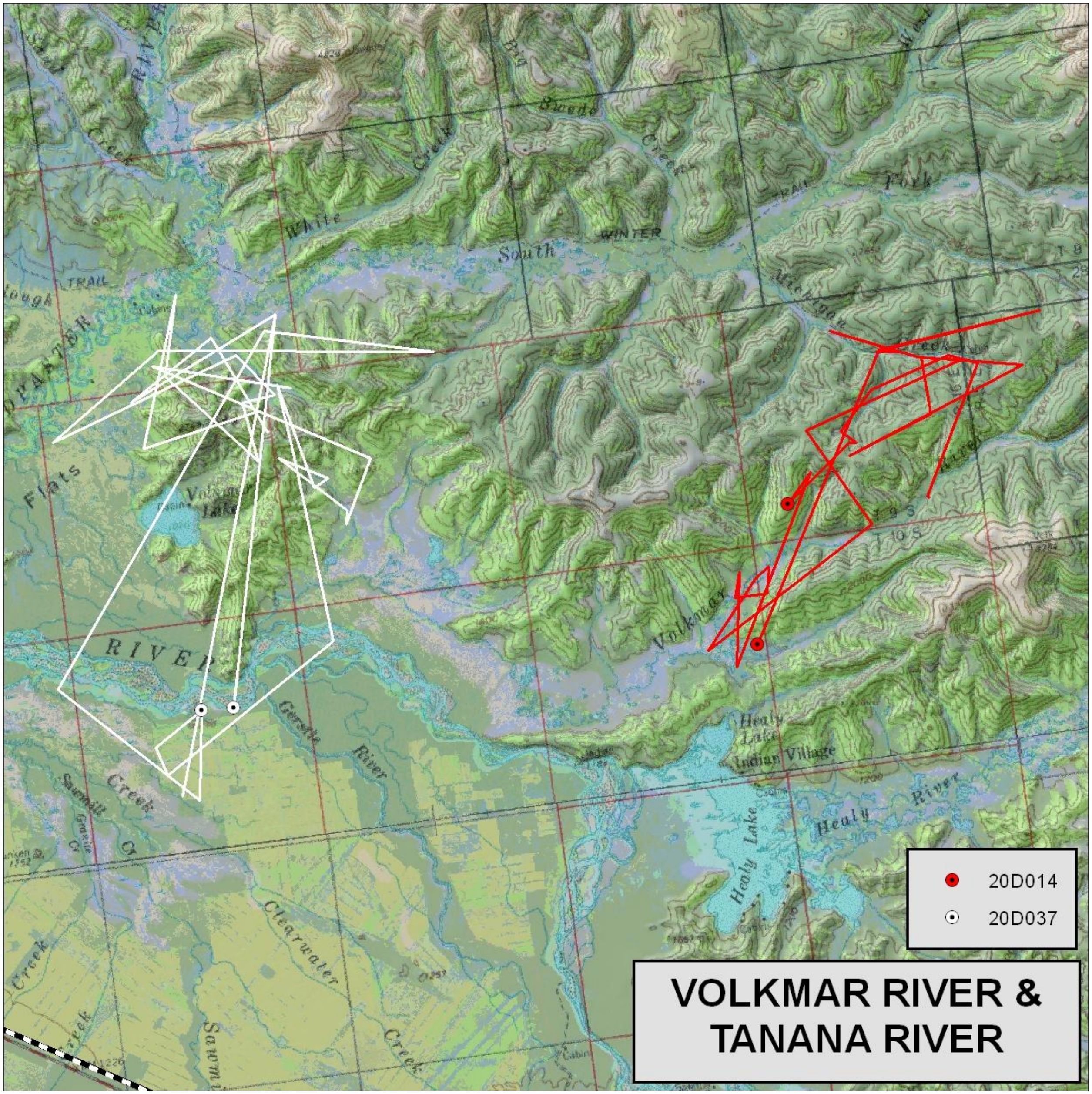


Figure 17. Annual movement patterns of radiocollared moose that were in the agricultural fields near Delta Junction, Alaska in mid-October 2009 and 2010. Mid-October locations are illustrated as points.

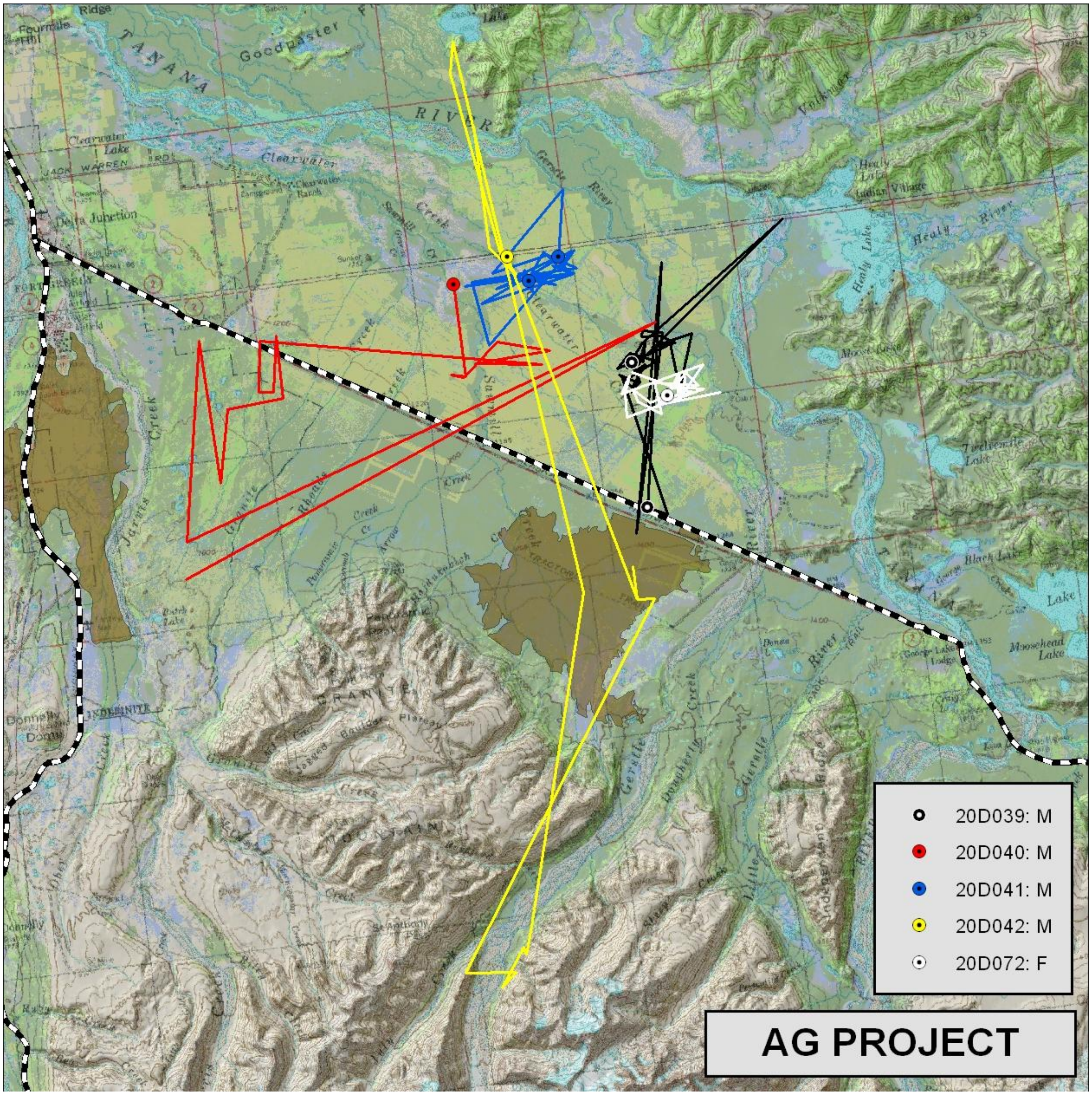


Figure 18. Seasonal distribution of female moose (●) captured in Southwest 20D. The boundaries of Southwest 20D (yellow), the Gerstle River Training Area (white) and Healy Lake Village traditional hunting area (red) are also illustrated. Seasons are described as calving (May); Summer (June – August); Hunting (September); Rut (October); Early Winter (November – December) and Late Winter (January – March).

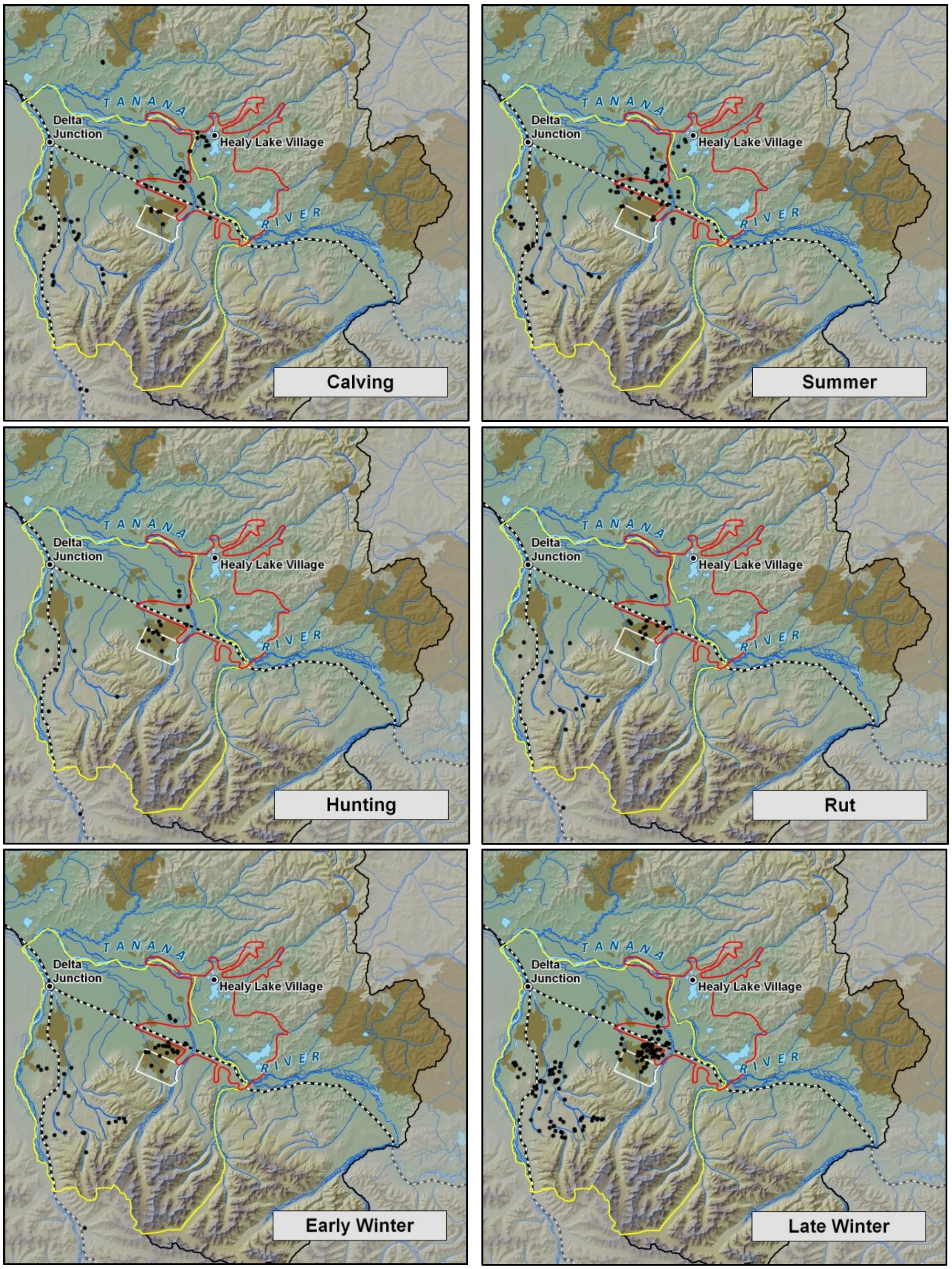


Figure 19. Annual movement patterns of radiocollared adult female moose that were in the foothills of the Alaska Range near Delta Junction, Alaska in mid-October 2009 and 2010 (illustrated as points).

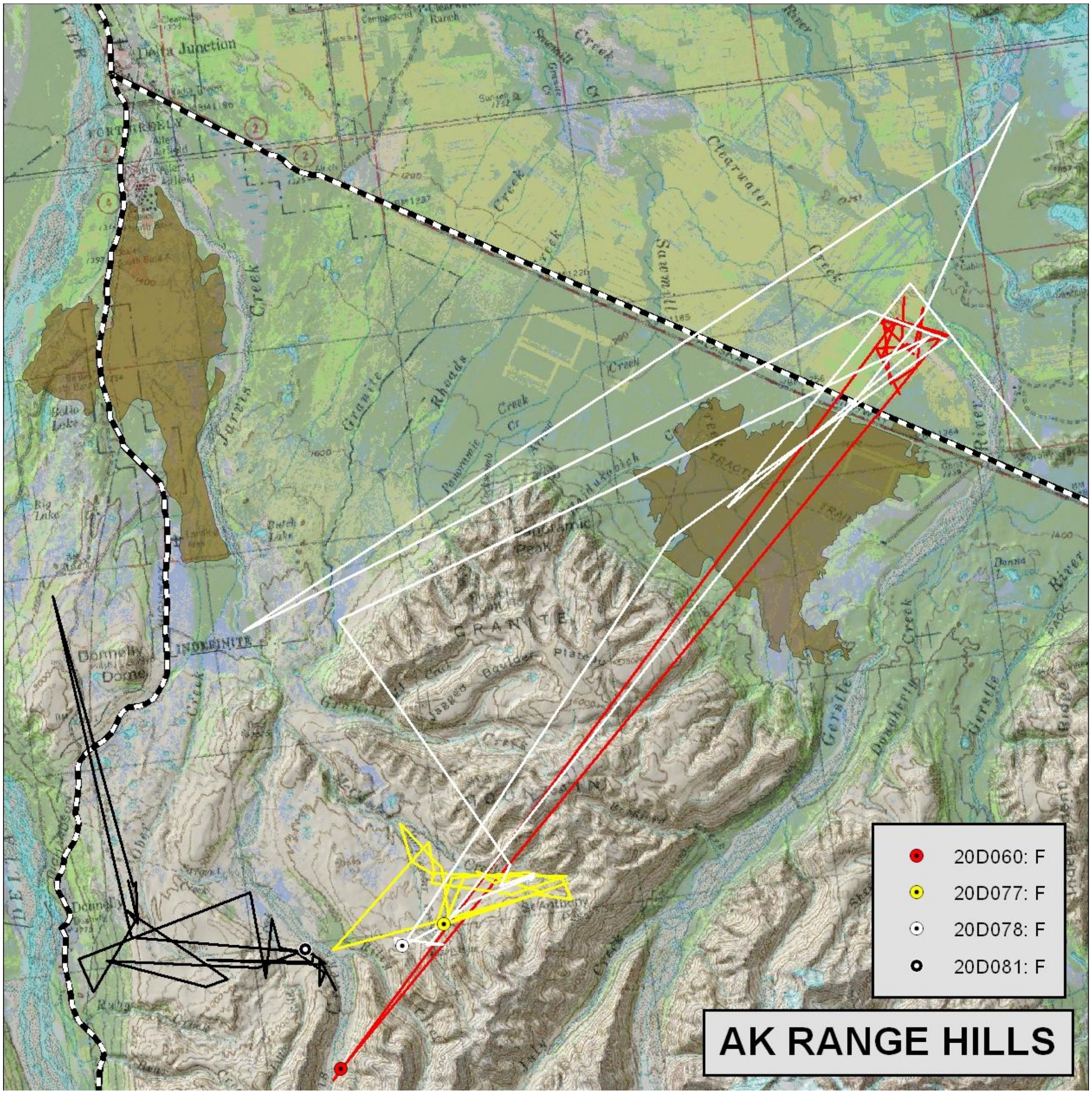


Figure 20. Locations for adult cow moose obtained during the calving season (May). The Gerstle River Training Area is outlined in black and the Healy Lake Village traditional hunting range is outlined in dashed black. The NLCD vegetation map is used to illustrate the variety of habitat types that adult cows used for calving.

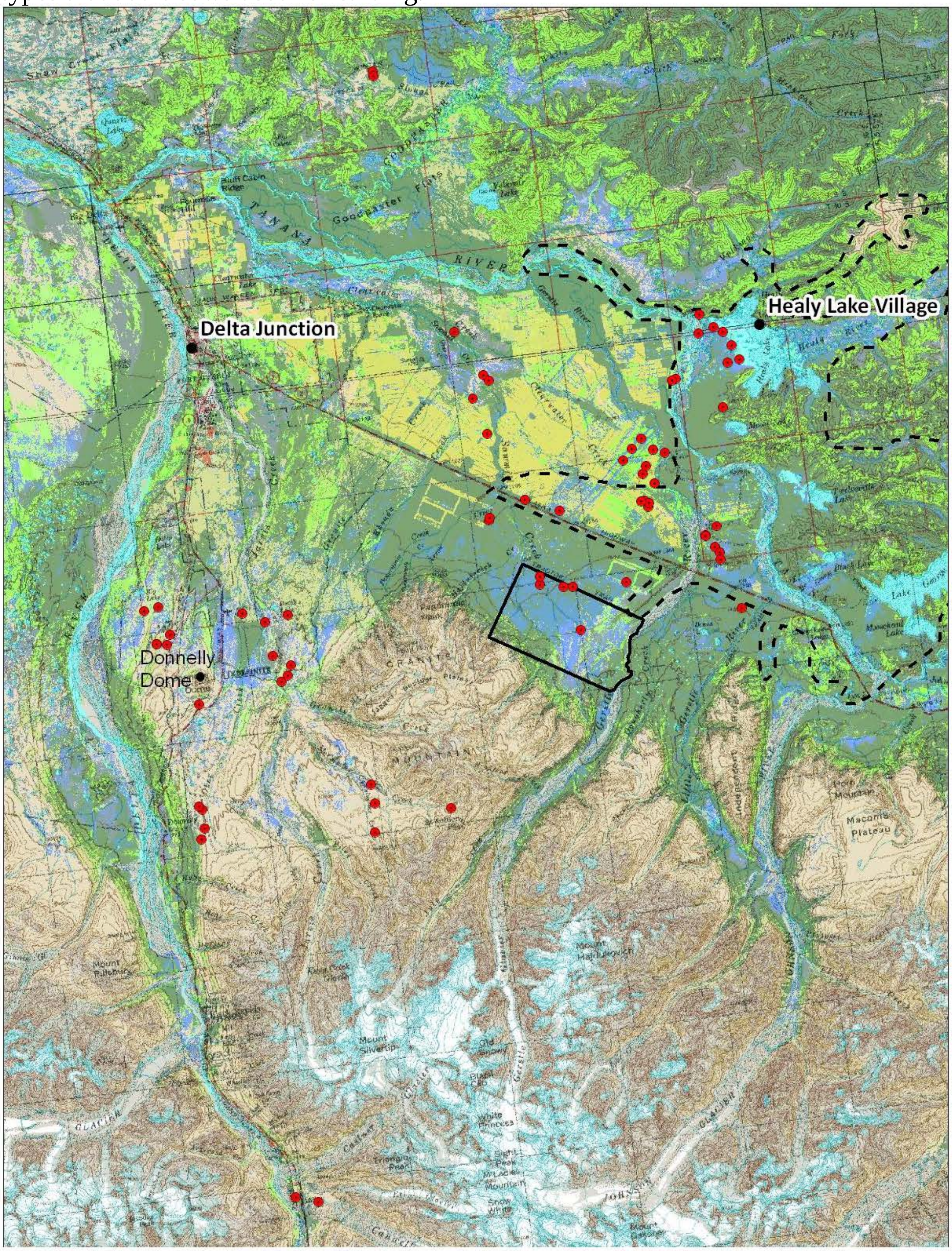
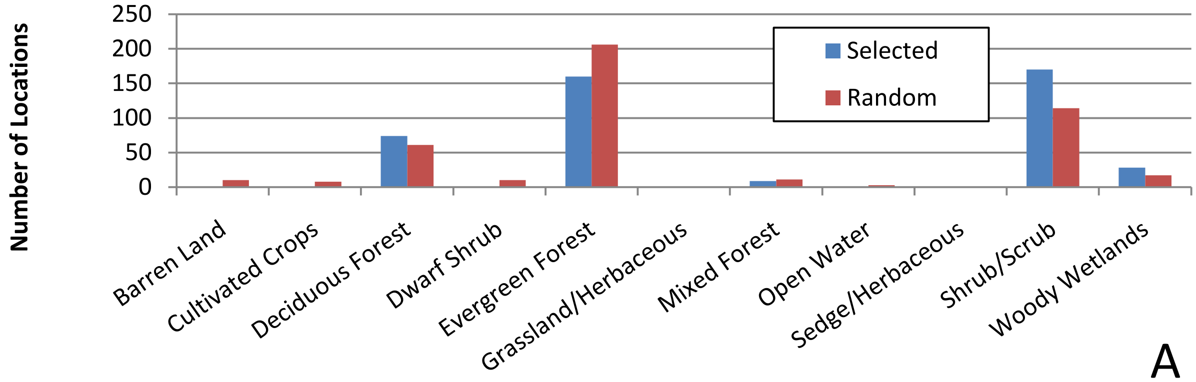
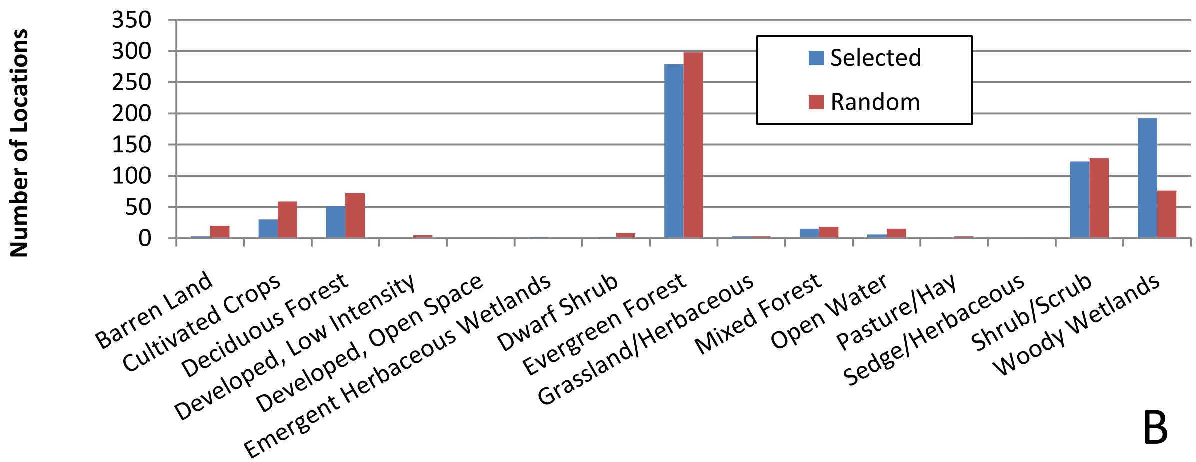


Figure 21. North American Land Cover (2001) vegetation classification at the locations of radiocollared male moose in 20D North (A) and Southwest 20D (B) and female moose in Southwest 20D (C) relative to the same number of random locations in the same range areas.





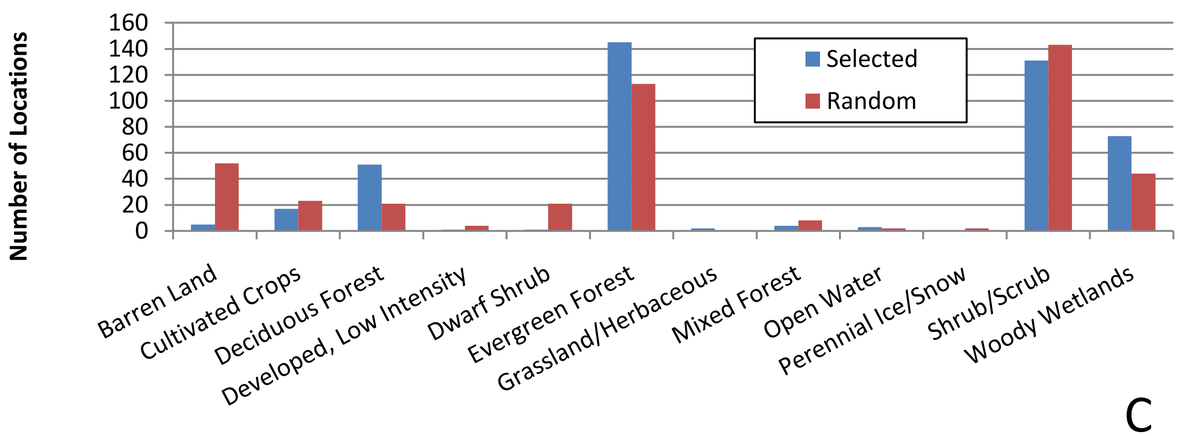


Figure 22. Annual movement patterns of radiocollared adult female moose that were within the Hejdukovich burn near Delta Junction, Alaska in mid-October 2009 and 2010. Mid-October locations are illustrated as points.

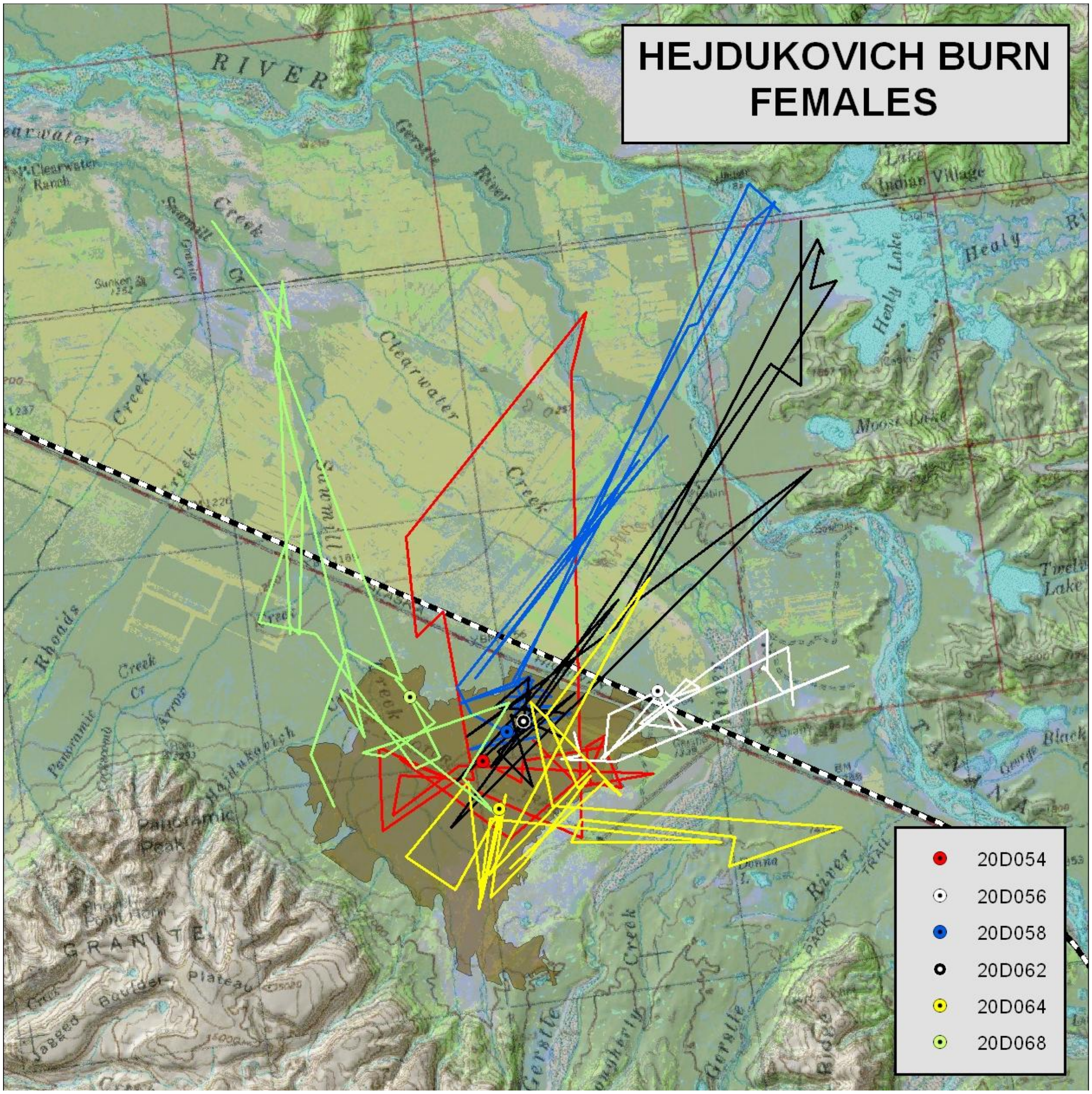
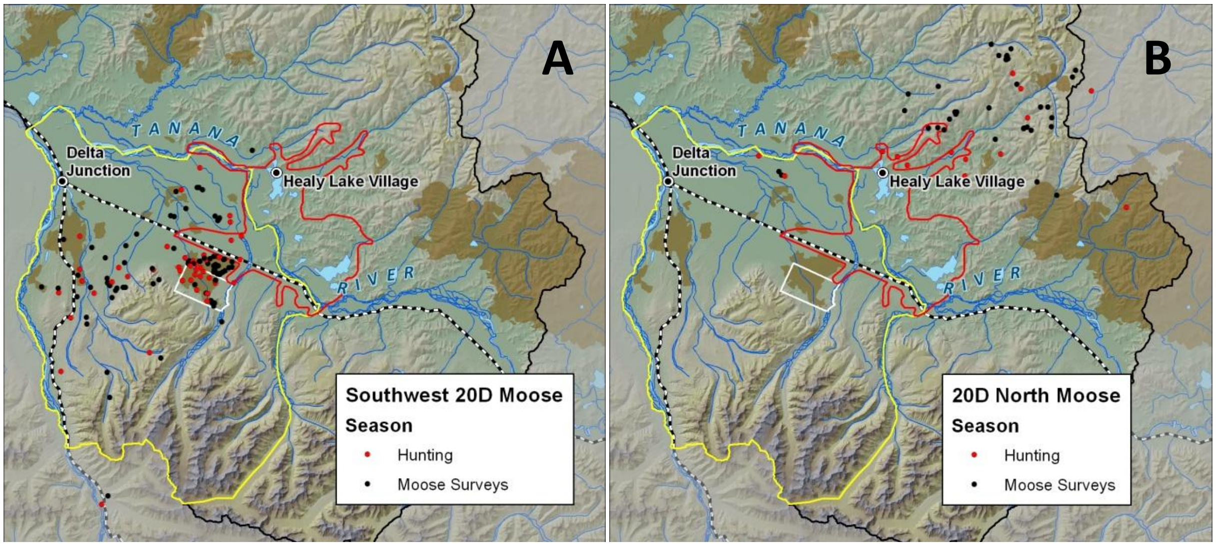


Figure 23. Comparison of the distribution collared moose during hunting season (September) and moose survey season (November) for moose captured in Southwest 20D (A) and 20D North (B) in October 2009. One male moose from Southwest 20D (outlined in yellow) moved North across the Tanana River in late November 2009. One 20D North moose captured along the Tanana River remained in Southwest 20D throughout hunting and survey seasons but moved to 20D North after November and remained in 20D North for the rest of the winter.



Tables

Table 1. Mean body measurements and standard errors for male moose in 20D North and for male, female adult and female calf moose in Southwest 20D. Body measurements are in cm, age is in decimal years. We excluded human-caused mortality from estimates of survival during first year of monitoring.

Sex/Age	n	Area	Total Body Length (se)	Metatarsus (se)	Neck (se)	Age (range)	Survival to Yr 1 (*n*)
Male Adults	15	N	287.9 (10.9)	61.7 (1.8)	109.3 (11.3)	6.3 (4 – 10)	93.3% (15)
	27	SW	278.2 (15.0)	60.8 (1.6)	102.8 (10.1)	4.6 (3 – 8)	93.3% (15)
Female Adults	18	SW	284.5 (13.0)	60.9 (2.4)	76.1 (6.3)	8.1 (4 – 13)	94.1% (17)
Female Calves	31	SW	204.7 (10.8)	53.9 (3.6)	61.6 (5.5)	0.75	NA

Table 2. Short-yearling body mass (lbs), population density (moose/mi^2), % browse removal and twinning rates for moose in 20D Southwest in comparison with similar populations along the Interior road system. Data were collected under Federal Aid Project 1.67 unless otherwise noted.

Population	Moose/mi^2 (Survey Yr)	% Browse Removal (range) Survey Yr	3-Yr Average Twinning Rate (Yrs Incl.)	Short-yearling Body Mass (se)
Southwest GMU 20D	2.3§ (2010)	15.3%‡ (14.0 – 16.6%) 2010	12.9%§ (2008-2010)	340.2 (8.8) 2010
Central GMU 20A	2.5^ (2008)	20.0%† (16.6 – 23%) 2007	7%* (2007-2009)	345.9 (4.4) 2009-2010
Minto Flats: GMU 20B	3.1^ (2008)	29.5%‡ (24.7 – 32.9%) 2010	23%* (2008-2010)	363.5 (6.1) 2010
Central GMU 20B	1.9^ (2008)	25.5%‡ (17.1 – 37.3%) 2007	5.3%* (2008-2010)	369.4 (7.2) 2009
Northern GMU 20C	0.25^ (estimated)	19.2%£ (6.8 – 30.5%) 2011	38%* (2010)	442 (7.5)* 2010

‡ Paragi and Kellie 2011.
§ Steve Dubois, ADF&G Delta, pers. comm.
† Paragi et al. 2008.
£ Paragi and Kellie Fed Aid Project 5.20, in prep.
* Don Young, ADF&G Fairbanks, pers. comm.
^ ADF&G 2010 Moose Management Report of Survey-Inventory Activities.