FEDERAL AID FINAL RESEARCH PERFORMANCE REPORT

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

Alaska Department of Fish and Game
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PROJECT NUMBER: 1.69

PROJECT TITLE: Movements and sightability of moose in Game Management Unit 21E

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WORK LOCATION: Interior Alaska

STATE: Alaska

PERIOD: 1 July 2009–30 June 2015

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

Residents of the lower Innoko River and middle Yukon River primarily from the communities of Anvik, Grayling, Holy Cross, and Shageluk rely on a moose (*Alces alces*) for subsistence, and guiding of nonlocal moose hunters in fall provides seasonal employment to local residents. In 1994 the intensive management (IM) of moose populations to produce a high yield for consumptive use was defined and mandated in Alaska Statute, Title 16, Sections 05.255(e)–(g) and (k). Objectives were set for Unit 21E moose in 2000 by the Alaska Board of Game for a population of 9,000–11,000 and a harvest of 550–1,100 (Alaska Administrative Code, Title 5, Section 92.108).

The 2006 *Yukon-Innoko Moose Management Plan* (page i) described the intent of local residents to "establish a proactive management program that will help to maintain an abundant moose population to provide for high levels of human consumptive uses. This approach is designed to help prevent a decline in the moose population to a low level that would be very difficult to reverse." In 2009 the Alaska Board of Game authorized an IM plan for Unit 21E moose (5 AAC 92.124) with a decision framework to implement wolf control if the abundance of observable moose (not corrected for sightability) declined to $<1/mi^2$ in a 5,070 mi^2 survey area that bounded the Yukon-Innoko floodplain and adjacent hills. The Division of Wildlife Conservation recognized a need for biological information about moose in Unit 21E to better understand moose seasonal movements and sightability for design of aerial surveys, moose nutritional condition as a possible factor limiting abundance, and the potential to manage moose population growth through harvest if wolf control allowed the population to increase. This information would aid creation of the first IM operational plan (ADF&G 2011) for Unit 21E moose when the IM plan is submitted to the Alaska Board of Game for reauthorization in spring 2017.

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

Land managers and local residents have perceived large-scale seasonal movements of moose to riparian winter habitat, particularly south of Anvik (*Yukon-Innoko Moose Management Plan,* p. 10). An unpublished study of moose movements in Unit 21E by ADF&G and the U.S. Fish and Wildlife Service (USFWS) during the late 1980s was based on limited VHF relocations but indicated common seasonal movements of 60 km and extreme movements of 100 km (male) and 225 km (female) in opposite directions from the study area (whether these were migration or dispersal movements is unknown due to limitations of data collection). Local residents perceived a decline in moose abundance during the fall hunting season that was not reflected by late-winter abundance estimates that are necessary because early-winter surveys are infeasible due to frequent poor flying weather and unreliable snow conditions. Managers sought to verify whether the current sampling boundary for the geospatial population estimator (GSPE) used to estimate late winter abundance is large enough and appropriately shaped to contain most of the moose available in the area during moose hunting season in early fall. We were constrained from collaring moose in early fall because of animal welfare consideration due to the potential for drowning or overheating during chemical immobilization. Thus, our study could not sample the fall population for estimating sustained yield of the September bull harvest. Nonetheless, sampling moose on their late winter range ensured our ability to determine whether moose surveyed in late winter left the area during the hunting season, which could have potentially biased harvest quotas higher than those required for sustainable yield.

In 2009 the biological data available for design of an IM program in Unit 21E consisted of 3 abundance estimates without sightability correction (range: 0.9–1.2/mi^2) from late winter since 2000 (Kellie Seaton 2014:Appendix A), 3 estimates of November age-sex composition and 7 estimates of twinning rate since 1998 (Peirce and Seavoy 2010), and 1 browse survey from 2006 (Paragi et al. 2008). In this research we sought to better understand facets of moose ecology in Unit 21E that would aid with planning surveys and managing for sustainable moose harvest. First, we estimated a sightability correction factor with associated precision for late-winter estimates of moose abundance as the primary metric to implement or suspend wolf control. Second, we increased sample size and estimated precision of twinning rate as an index to nutritional condition of adult females. If predator control led to moose population growth, twinning rate can guide recommendations for antlerless harvest to maintain productivity and reduce risk of excessive browsing pressure on winter range (Boertje et al. 2007). Finally, we sought to describe seasonal movements and dispersion of moose for optimal design of aerial surveys to estimate population-level parameters (abundance, composition, etc.).

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

OBJECTIVE 1: Determine seasonal movements of moose that overwinter in the Yukon and Innoko River floodplains to assist managers in defining winter range, spring calving areas, and moose distribution during hunting season and periods of aerial surveys in autumn (age-sex composition) and late winter (abundance).

JOB/ACTIVITY 1A: Capture and radiomark at least 30 and up to 45 moose (approximately 50% female) >2 years old with GPS collars and radiomark 10 additional female moose with VHF only collars in March 2010.

Moose were collared over a broad north-south expanse of the joint floodplains of the Innoko and Yukon Rivers to ensure that marked individuals were likely to be present for March sightability trials.

We deployed 44 GPS collars (24M, 20F) and VHF collars (10F) manufactured by Telonics, Inc. (Mesa, AZ) on adult (>1 yr old) moose during 14–18 March 2010 (Peirce 2012:Fig. 1). Male collars incorporated a 7.5 cm wide expandable butyl belting to accommodate 50% increase in neck circumference during the rut and return to the normal circumference outside the rut. One VHF collar apparently failed upon deployment, and we redeployed 2 GPS collars from natural mortalities (1M, 1F) early in the study for a total of 55 marked individuals yielding location data by April 2011.

JOB/ACTIVITY 1B: Obtain GPS relocations of moose by satellite upload and find additional VHF only collars as feasible from aircraft during March 2010 through February 2014.

Our USFWS partners evaluated GPS accuracy on collars in McGrath between deployments, and estimated positional error averaging 7 m for 1 female collar and 9 and 12 m for 2 male collars (n = 68 trials for each collar). We obtained weekly downloads of GPS data from the ARGOS satellite system until November 2012. We then contracted with ABR, Inc. of Fairbanks to create a program that automatically downloaded ARGOS data weekly and coded it by animal ID (to reduce potential manual data entry error of IDs) into a Microsoft Access database maintained on the ABR server. We kept a copy of the database on our agency server and periodically downloaded only new records from the ABR database over the internet. We flew VHF telemetry flights that included GPS collars in early summer to observe adult females and determine presence and number of calves. These were augmented by transect flights to observed random individuals during twinning surveys, often in concert with federal cooperators, to estimate twinning rate (Appendix A, this report). Telemetry flights were conducted again in fall and in late winter to confirm calf survival. We also used VHF telemetry to retrieve collars from mortalities and recapture moose in March 2014 to remove 23 of the remaining 24 GPS collars for direct download of telemetry data stored in the collar (1 bull was not captured due to unsafe capture conditions from erratic winds). We regularly distributed location data to federal cooperators during the acquisition phase. A total of 286,733 GPS locations were verified as suitable for spatial analyses after being subjected to position error filters (Dettki and Ericsson 2008), and we collected an additional 203 VHF locations.

JOB/ACTIVITY 1C: Define seasonal ranges of moose for planning survey and inventory activities and to aid management decisions.

We plotted GPS locations of male and female moose for March and November within a context of all moose locations and the boundaries of the fall composition surveys and late winter GSPE surveys. The 5,070 mi^2 sampling area for late winter abundance estimates included 99% of March locations over 4 winters and 95% of September locations (97% female and 94% male). The November composition area in the joint floodplain of the Innoko and Yukon Rivers (526 mi^2) was positioned and scaled for 2 planes to survey in 1 day including ferry time from McGrath. The composition area included 34% of November locations (46% of female and 25% of male locations, 2010–2013) and 36% of September locations (48% female and 25% male).

A winter hunt for moose in Unit 21E currently occurs only on federal lands (15 February–15 March) with the restriction that moose may not be taken within ½ mile either side of the Innoko and Yukon Rivers. To assess whether winter hunts could feasibly achieve greater harvest if the moose population increased following wolf control, we calculated the proportions of male and female locations that were within 0.8 and 1.6 km (0.5 and 1.0 mi) of rivers and sloughs judged by local residents to be navigable to motor boats. We did this for each month from September to March to assess moose vulnerability to harvest by boat and snowmachine access. Open water that allowed boat access existed in September and October and some years into until November, but may occur later in the future given current warming trends. Rivers were frozen and allowed snowmachine access from November through March; this period may likewise be shortened given current warming trends in the region. For moose occurring within 0.8 km of rivers when accessible by boats, the percentage of locations for both sexes was slightly higher in October (52%) than either September (50%) or November (45%). Locations within 1.6 km of rivers (Sep-Nov) increased by about 15% for males and 11% for females. When we considered potential winter moose hunts by snowmachine on females and predominantly antlerless males, we found a slight increase in the locations of males (25–34%) and females (20–29%) in areas open to hunting from November to March. Females were substantially more common (39–47%) than males (17–31%) in areas closed to hunting during winter. This finding supported regulatory protection along the Innoko and Yukon Rivers during winter hunts.

JOB/ACTIVITY 1D: Define periods of rapid range shift to develop guidelines for frequency of VHF telemetry flights to aid survey and inventory activities and range definition.

Net squared displacement measures the straight line distances between the starting location and the subsequent locations for the movement path of a given individual. We calculated this metric for individual moose relative to their starting location on 19 March (the date all moose were collared in 2010 and also the date just prior to collar removal in 2014) over the 4 years of study initially to discern spatial movement patterns that indicated migratory behavior (Bunnefeld et al. 2011). Mean change in weekly displacement ranged 1.7–11.4 km for females and 2.6–16.3 km for males (Appendix B, this document).

JOB/ACTIVITY 1E: Verify fit of new expandable GPS collar design for male moose.

We recaptured 5 male moose and examined a recent mortality of a collared bull on 12 October 2010 to examine their necks for signs of collar abrasion from neck swelling during the rut. Four (including the mortality) had no rubbing or only broken hair, whereas 2 had skin abrasions because the collar had expanded to only half the full extent of intended travel.

OBJECTIVE 2: Use radiomarked moose to develop a sightability correction factor (SCF) for late winter surveys to estimate moose abundance in Unit 21E. This objective was performed as a case study in the associated research project 1.66 (Evaluating options for improving GSPE performance and developing a sightability correction factor).

JOB/ACTIVITY 2A: Estimate a SCF by intensively searching a randomly-located quarter of randomly sub-sampled GSPE cells during a population survey in Unit 19A (late winter 2011).

We conducted a GSPE survey (Kellie and DeLong 2006) during 1–6 March, 2011. An experienced pilot-observer team was dedicated to flying intensive searches of units recently surveyed by the other 4 teams. Crews surveyed 153 sample units, and 42 intensive surveys were flown (17 in high stratum and 25 in low stratum). The SCF was 1.89 (SE = 0.40) in the high stratum and 1.24 (SE = 0.37) in the low stratum. The estimate for total moose, which includes the intensive SCF estimate of moose missed during the survey, was 1,666 moose (SE = 348) with a relative precision of 36.2% at the 90% confidence level; this did not meet our precision objective of ≤25%. We provided preliminary results in spring 2011 for the survey and inventory memo by McGrath Area staff and detailed results in a research memo (Kellie Seaton 2014:Appendix B).

JOB/ACTIVITY 2B: Estimate an SCF by intensive searches (job 2a) and by detection of radiomarked moose during a population survey in Unit 21E (late winter 2012).

We conducted a GSPE abundance estimate with McGrath Area staff and federal cooperators during 12–16 March 2012. We used VHF telemetry to confirm moose presence in survey blocks for sightability trials during the GSPE survey of abundance in March 2012. We completed 47 sightability trials (successful observations of 27/30 in high stratum and 11/17 in low stratum) and estimated SCF (~inverse of proportion seen) for the high stratum as 1.11 (SE = 0.069) and for the low stratum as 1.49 (SE = 0.285). Concurrent intensive searches were not done because of concerns by area managers with logistical complications in a remote area that could jeopardize survey completion if poor flying weather developed. The estimate of total moose abundance was 5,953 with 21% relative precision at the 95% CL, which met our research objective of ≤25%. The corresponding estimate of density with SCF was 1.17 moose/mi^2, comprised of 4.11 moose/mi^2 in the high stratum and 0.48 moose/mi^2 in the low stratum. We provided preliminary results in spring 2012 for the survey and inventory memo by McGrath Area staff and detailed results in a research memo (Kellie Seaton 2014:Appendix A).

OBJECTIVE 3: Database of moose relocations.

JOB/ACTIVITY 3A: Create an electronic archive as a GIS shapefile of moose relocations with associated attributes and metadata.

We created an Access geodatabase for archive and ArcGIS projects for display of some analysis results. Numeric results and graphics derived from analyses were stored on the shared drive of the regional data server.

OBJECTIVE 4: Reports, publications, and presentations at scientific forums.

JOB/ACTIVITY 4A: Write annual progress reports and a final technical report. Give presentations at scientific forums, particularly in Alaska. Publish results in peer-reviewed journals for jobs where results have utility outside Region III.

Aside from writing annual performance reports, we incorporated research memos on the sightability trials (jobs 2a and 2b) into appendices of the final performance report on project 1.66 (Kellie Seaton 2014). Paragi gave an oral presentation on preliminary analysis of movements and dispersion (job 1C) at the April 2015 annual meeting of the Alaska Chapter of *The Wildlife Society* in Juneau. We are drafting a wildlife research report on detailed analyses related to jobs 1C and 1D plus the analyses of behavioral change points to estimate parturition rate and correlation between ambient temperature and fall movement rates of bulls (see Section VI).

IV. MANAGEMENT IMPLICATIONS

The 2012 late-winter survey area included almost all (99%) of March locations of moose we monitored during 2010–2014, validating the survey boundary on winter range as including most moose in this population. It also included most (94%) of male locations in September, suggesting that few male moose migrate out of the March survey area. In the absence of being able to collar moose in fall, it seems reasonable to use late-winter abundance to set fall harvest quotas for males on the basis of our research.

The fall composition survey area included roughly half of female and one-quarter of male locations in November, which provides context for the proportion of population on which inference from age-sex ratios is made. Because collar deployment was not focused on areas of high density within the study area, these percentages likely are an underestimate of proportional moose occupancy in the November composition area based on our general knowledge of late-winter moose concentration in the composition area (Kellie Seaton 2014:Appendix A). Thus, the November survey boundary seems reasonable for inference on age-sex composition.

Based on monthly dispersion of moose in primary hunting corridors along navigable rivers, winter harvest of (antlerless) males and females should allow adequate harvest to manage population growth if wolf control is conducted. This strategy can prevent a decline in moose nutritional condition or degradation of forage plant at higher densities (Boertje et al. 2007, Young and Boertje 2011, Paragi et al. 2015).

Male and female moose exhibited nearly a 6-fold range in average weekly movements over an annual period as inferred from net squared displacement (Appendix B, this document). The plotted pattern provides managers with an indication of how frequently VHF telemetry frequency might be needed to answer questions on moose dispersion or movements at specified times of the year.

Intensive searches on a portion of the surveyed sample units in Unit 19A were feasible for estimating a sightability correction factor for the observable component based on standard and high intensity searches (SCF_o). However, sightability trials with radiomarked moose in Unit 21E allowed for an improved sightability correction by also incorporating animals missed in intensive searches (SCF_c). Estimation of a survey-specific SCF is warranted in Interior Alaska (Kellie Seaton 2014), particularly for late-winter surveys where SCF may be greater or more variable compared with early-winter surveys (Gasaway et al. 1986:31). The abundance estimate with SCF better informs the decision framework in the IM Plan for Unit 21E. This will first occur for the decision to implement wolf control when the estimated abundance of observable moose in the survey area is below the threshold density. If wolf control is implemented, it will again occur in the decision to suspend wolf control when observable moose in the survey area again exceeds the threshold density, presumably because of a numeric response. The level of information deemed necessary for decisions to implement IM will vary among members of the public and scientific community based on a perceived requirement to adequately balance uncertainty (a tolerance for risk of potential consequences of a management action) against specified outcomes (ADF&G 2011:Appendix I). For the decision framework in Unit 21E, an estimate of moose abundance with SCF and a precision that incorporates SCF variance better informs the risk of 2 undesirable scenarios: 1) implementing wolf control unnecessarily by inferring moose density is below the threshold when it is actually above the threshold (Type I error, false positive), or 2) failing to implement wolf control by inferring moose density is above the threshold when it actually is below the threshold (Type II error, false negative). Once wolf control is implemented, similar risks exist for using a given survey result in a decision to suspend wolf control.

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

JOB/ACTIVITIES 1C AND 1D: Warren conducted spatial analyses and estimated movement rates for these jobs and for topics described in Section VI.

JOB/ACTIVITY 3A: Warren created geodatabases that can be manipulated and displayed in ArcGIS.

JOB/ACTIVITY 4A: Paragi wrote this final performance report and began drafting a wildlife research report.

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

A) With assistance from ADF&G Research Biologist Kerry Nicholson, we used behavioral change point analysis (BCPA; Gurarie et al. 2009) to identify periods of substantially reduced movements by adult females as a means of estimating the proportion of parturient females in a population. We applied BCPA for estimating the proportion of parturient adult female moose based on constrained movements in May and June when females attend ≥1 neonatal calf (Rostan 2014). Our observations of ≥1 calf at heel from 4 years of VHF telemetry during twinning surveys conducted around 1 June and subsequent observations in November and March (47 female-years) validated 36 female-years for which there existed a corresponding pattern of constrained movements during suspected peak of calving (20–24 May). In 5 female-years where ≥1 calf was not observed we did not see a corresponding pattern of constrained female movement. However, in 6 female-years we observed no calf yet the female exhibited constrained movements, indicating that twinning surveys a week after parturition may fail to detect neonatal mortality events. Thus, the proportion of parturient females may be overestimated by 14% (6/42).

A single VHF telemetry flight was conducted ~1 week after the expected median parturition date to estimate twinning rate. We did this to maximize samples size before neonatal mortality from predation may occur (Boertje et al. 2007). We were unable to determine whether females that lost 1 of 2 calves would have a different movement pattern than females that lost a single calf to mortality because we did not do multiple calf observations. Although the twinning flights were not intended to estimate parturition, we used them to validate the BCPA outcomes.

B) McNeeley and Shulski (2011) and McNeeley (2012) described hunter concerns that warmer fall temperatures in recent years may have reduced or delayed rut-related movements by moose, potentially reducing harvest success in the Koyukuk drainage. Hunters perceive that warm temperatures during fall reduce moose hunting success by decreasing male movement rates, possibly as they seek shade to thermoregulate. This behavior may reduce the ability of hunters to visually detect moose. We sought to address this issue for the current dates of the fall hunting season in Unit 21E (5–25 September, as well as 25 August–30 September on federal lands) by testing for an inverse relationship between fall ambient temperature and movement rates of male moose. We first examined whether 4-hr movement rates of moose were negatively correlated to ambient temperatures recorded hourly at the Anvik airport (west-central portion of study area). We estimated Pearson's correlation coefficient (r) between airport temperature and movement rate during 15 August to 15 October and found it to be significant ($P < 0.05$) for 36 of 67 male-years (5 positive and 31 negative; 25 individuals over 1–4 years, 2010–2013). However, the correlations were variable and overall not strongly negative ($\bar{x}_r = -0.093$, SD = 0.146, range: −0.408 to 0.457).

In a separate analysis related to fall weather, we compared movement rates to temperatures recorded on GPS collars for 60 male-years with complete data records. Our

USFWS partners evaluated variation in temperature recorded on 3 undeployed collars with temperature data from the nearby (0.5 km) National Weather Service station in McGrath during April 2011. During 30 trials, the collars were found to report ambient temperatures within 2 degrees Centigrade 49% of the time with 6 trials averaging 5–13 degrees higher than corresponding ambient temperatures. We found significant correlation for 38 of 60 male-years (4 positive and 34 negative), but again, correlations were variable and overall not strongly negative ($\bar{x}_r = -0.140$, S.D. = 0.143, range: −0.387 to 0.243). Although our study was not designed to address this question, we did not find strong evidence of an inverse relationship between male movement rates in fall (immediately before and during the hunting season and into the rut) and ambient temperatures as inferred from the Anvik airport (for the entire study area) or a sensor on individual GPS collars. Delayed leaf drop during warmer weather may reduce visibility of moose and could explain lower harvest rate during periods of unseasonably warm weather. In addition, hunters may avoid hunting when warmer conditions may complicate meat care (McNeeley and Shulski 2011, McNeeley 2012).

VII. PUBLICATIONS

None.

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VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

This work was designed to address practical management issues for validating current techniques used in survey and inventory and to provide site-specific information for drafting an IM operational plan in the near future. McGrath Area staff re-deployed VHF collars on moose when GPS collars were removed in March 2014 to permit estimates of sightability correction in future late-winter abundance surveys and to aid future estimates of twinning rate. Our federal cooperators sought to estimate habitat selection using GPS data and collected cover type information to validate accuracy of an earlier vegetative classification. However, the refuge office closed in June 2014, effectively ending further work on that federal objective for the time being. The 2010–2014 GPS data could be used to further evaluate movements, habitat selection, and other facets of spatial use by moose in this area.

BCPA allows use of relatively frequent GPS relocations to describe animal behavioral patterns. Cost and accuracy of GPS telemetry continues to decrease with advances in hardware and data handling automation. With the labor and fixed-wing costs required for VHF telemetry in remote areas, GPS technology may be more cost efficient in the future. BCPA has also been applied to ungulates that give birth to single calves, such as caribou (DeMars et al. 2013). Our initial findings are encouraging, but we recommend further validation of BCPA based on GPS telemetry of moose where frequent VHF telemetry is feasible (i.e., probably not Unit 21E) for estimating parturition, number of calves born, and individual neonate mortality by simultaneous direct observation. An important question for moose is whether movement patterns can be discerned for females losing only 1 of 2 calves that might allow estimates of mortality for individual neonates.

IX. APPENDICES

APPENDIX A.

Table 1. Counts of parturient female moose with 1 or 2 calves used to estimate twinning rate during 2010–2013 in Unit 21E, western Interior Alaska. In most years telemetry was used to observe marked females in addition to random females.

Year	Date	No. with single calf	No. with twin calves	Twinning rate	Lower 95% CL[a]	Upper 95% CL[a]
2010	26–28 May	15	18	0.545	0.375	0.715
2011	2 & 6 June	32	22[b]	0.407	0.276	0.538
2012[c]						
2013[d]	29–30 May	38	18	0.321	0.199	0.443
2014	29–30 May	35	16	0.314	0.186	0.441

[a] Binomial confidence limits (CL).
[b] Two of these cows had 3 calves.
[c] Attempts at survey flights were aborted because of extended poor weather.
[d] Estimates based on observations of random animals only because aircraft mechanical and electrical problems developed in-flight that precluded telemetry.

APPENDIX B.

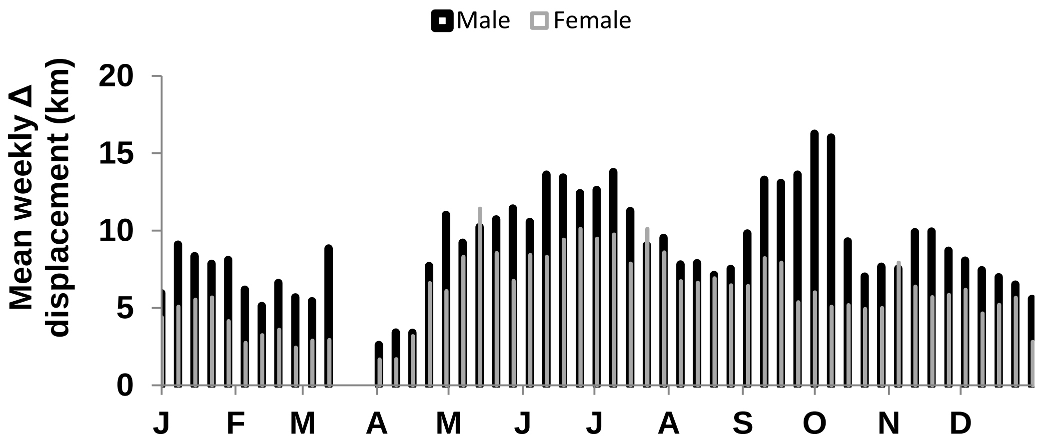

Figure 1. Seasonal movement patterns of male and female moose as inferred from weekly change in net squared displacement during 4 years (2010–2013) based on an annual spatial origin of 19 March, Unit 21E, western Interior Alaska.

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