AERIAL MOOSE SURVEY
on, and around,
KANUTI NATIONAL WILDLIFE REFUGE,
November, 2010

Tim Craig
US Fish and Wildlife Service

and

Glenn W. Stout
Alaska Department of Fish and Game

February 2011

DATA SUMMARY

Survey Dates:	12-16 November 2010 (Stratification) 15-19 November 2010 (Intensive survey)
Total area covered by survey:	Kanuti National Wildlife Refuge (NWR) Survey Area: 2,714 mi^2 (7,029 km^2); Total Survey Area: 3,736 mi^2 (9676 km^2)
Total survey units	Kanuti NWR Survey Area: 508; Total Survey Area: 701
Number of units surveyed:	Kanuti NWR Survey Area: 164; Total Survey Area: 213
Total moose observed:	Kanuti NWR Survey Area: 409 moose (181 cows, 151 bulls, and 77 calves); Total Survey Area: 446 moose (196 cows, 167 bulls, 83 calves)
November population estimate:	Kanuti NWR Survey Area: 1068 moose (90% confidence interval = 946 - 1191) comprised of 569 cows, 293 bulls, and 187 calves*; Total Survey Area: 1331 moose (90% confidence interval = 1165 – 1497) comprised of 704 cows, 373 bulls, 235 calves*. *Subtotals by class do not equal the total population because of accumulated error associated with each estimate.
Estimated total density:	Kanuti NWR Survey Area: 0.39 moose/mi^2 (0.20 moose/km^2); Total Survey Area: 0.36 moose/mi^2 (0.14 moose/km^2)
Estimated ratios:	Kanuti NWR survey area: 33 calves:100 cows, 7 yearling bulls:100 cows, 24 large bulls:100 cows, 51 total bulls:100 cows; Total Survey Area: 33 calves:100 cows, 8 yearling bulls:100 cows, 24 large bulls:100 cows, 53 total bulls:100 cows

INTRODUCTION

Kanuti National Wildlife Refuge (NWR), the Alaska Department of Fish and Game (ADF&G) and the Bureau of Land Management cooperatively conducted a moose (*Alces alces*) population survey 12 - 19 November 2010 on and around Kanuti NWR. Moose surveys have been conducted on Kanuti NWR since 1989 using two different methods. The Gasaway method (Gasaway et al. 1986) was employed in 1989 and 1993 and the Geo-Spatial Population Estimator (GSPE) (Ver Hoef 2002 and 2008, Kellie and Delong 2006) was used in 1999, 2004, 2005, 2007 and 2008. GSPE surveys done since 1999 have shown that the moose density in the survey area remains low, and, while not stable, has reached a low-density dynamic equilibrium (Gasaway et al. 1992)

Moose are an important subsistence resource for the residents of four villages which are located near the survey area: Bettles, Evansville, Alatna, and Allakaket. Estimated average harvest of moose in these villages, as measured during household surveys from 1997 through 2002, was 37 moose per year (Brown et al. 2004). Non-local hunting pressure is light in the area, both because most of the Refuge is closed to moose hunting by non-local hunters, and because the remaining open hunting areas are difficult, and expensive, to access. The low moose density in the area is a further disincentive for non-rural hunters. Nonetheless, the low moose density and local resident perception that subsistence harvest is declining have led to concerns about allocation of moose between local and non-local hunters. Other issues related to moose management in the area are the effect of predation on the moose population and the carrying capacity of the Refuge, particularly given the active fire history in the area.

The three objectives for the 2010 moose survey were to: 1) continue monitoring the moose population on Kanuti NWR; 2) increase the precision of the population estimate by surveying a larger number of sample units than has been surveyed previously; and 3) determine a sightability correction factor (SCF) for the survey.

STUDY AREA

The survey occurred over a large part of Game Management Unit 24B in north-central Alaska (Figure 1). Most of the terrain in the survey area is relatively flat, but there are rolling hills around the periphery of Kanuti NWR. Vegetation types include black and white spruce (*Picea mariana* and *P. glauca*, respectively) forest, black spruce woodland, paper birch (*Betula papyrifera*) forest, mixed spruce/birch forest, tall and low shrub communities, tussock tundra dominated by tussock cottongrass (*Eriophorum vaginatum*), and riparian and wetland areas dominated by willows (*Salix* spp.) and other deciduous vegetation. The types and ages of plant communities are strongly influenced by fire history; over 70% of the refuge has burned since 1940.

Although the survey was conducted seamlessly, the survey area was treated as two entities for analysis: the Kanuti NWR Survey Area (2,714 mi^2 [7,029 km^2]) and the Total Survey Area (3,736 mi^2 [9676 km^2]). The 2010 Kanuti NWR Survey Area boundaries and sample units were the same used since 1999, which allowed comparisons with those surveys. The Total Survey Area included both the Kanuti NWR Survey Area and additional survey units west of the Refuge proper.

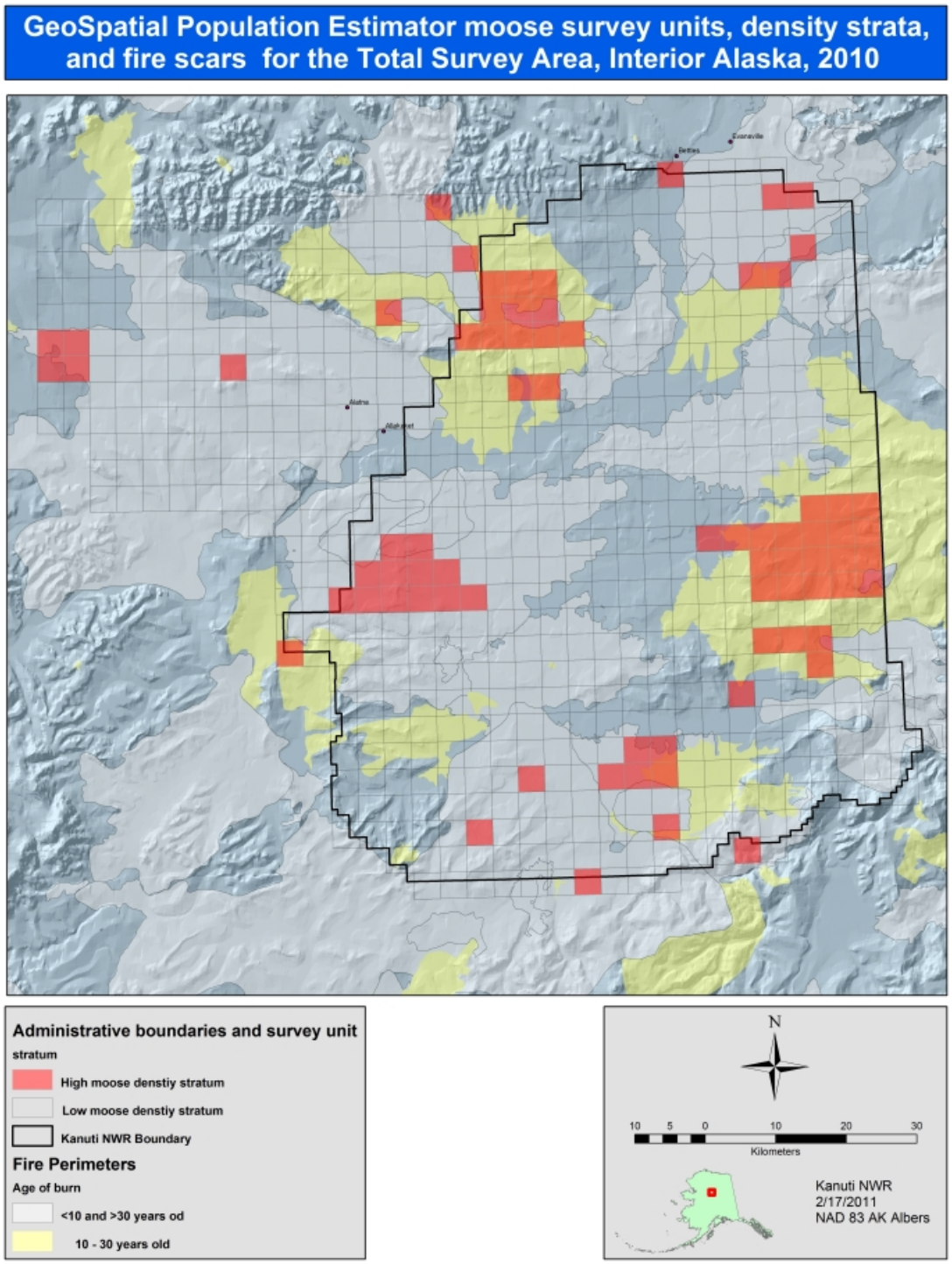

Figure 1. Survey units for a moose survey conducted in November, 2010, Game Management Unit 24B, Alaska. Kanuti National Wildlife Refuge boundary, fire perimeters for burns of two different age allocations (burns 10 – 30 years old are preferred by moose), and moose density stratum are displayed.

METHODS

The moose population survey was conducted using the GSPE method, a modification of a technique initially developed by Gasaway et al. (1986) and used on Kanuti NWR in 1989 and 1993. The GSPE method is widely used in Alaska which allows comparison between survey areas. Methods for the GSPE method are discussed in detail in Kellie and DeLong (2006) but will be summarized here.

The Total Survey Area was delineated using a geographical information system (GIS) layer developed by ADF&G that divides the state into a grid of sample units that measure 2 minutes latitude by 5 minutes longitude on a side. Sample units in our survey area averaged about 5.3 mi^2 (13.7 km^2) in size. The 2010 Total Survey Area consisted of 701 units and included State, Bureau of Land Management administered lands, and private land west of the Refuge that had not been included in past surveys. The boundaries of the Total Survey Area incorporated the 508 survey units that comprised the Kanuti NWR Survey Area surveyed 5 times in the past decade using GSPE methods.

Moose GSPE surveys have two components: stratification and intensive surveys. Stratification flights are conducted initially to improve the precision of population estimates by identifying the survey units that have similar moose density, and differentially allocating survey effort between these separate strata. During stratification, each survey unit is assigned to either a "High" or "Low" moose density stratum by direct observation. We also subjectively assigned each unit to either a High or Low stratum based solely on habitat quality. Stratification flights were conducted in a Cessna 206 by two back-seat observers. A front-seat navigator/observer recorded data while the pilot concentrated on maintaining course. Contiguous units were flown in an east-west orientation. Each unit was crossed at midsection and at a relatively high speed (200 km/hr) about 600 ft (183m) above ground level. During the density stratification, units were classified immediately after a unit was overflown based on both the actual number of moose observed, or suspected, and by habitat characteristics. If three or more moose are seen in a unit, or suspected to be present based on fresh tracks but where no moose were seen, the unit was classified as a High moose density stratum. If fewer than three moose were seen, but a unit was considered to be very good moose habitat (contained abundant, accessible willows and birch, and/or good riparian habitat), and some tracks, it was also assigned to the High moose density stratum. Units that contained fewer than three moose, or that were covered with poor habitat (e.g. black spruce with little understory vegetation) were classified as Low moose density strata.

Sample units for the survey were randomly selected from the density strata (Kellie and DeLong 2006). Approximately 10 – 20% of the units were withheld from the random selection and subjectively used to fill in between blocks of units because the GSPE has a spatial component whose results are improved if there are no gaps among surveyed units.

Following stratification, tandem-seated aircraft (e.g., Super Cub, Scout, and Husky) were used to intensively survey individual units for moose. These aircraft held a backseat observer who also recorded data, and a pilot/observer who used a Global Positioning System (GPS) receiver to identify the boundaries of sample units and keep track of

portions of units they had already surveyed. Search intensity varied with habitat. Greater effort was spent in areas with higher canopy cover (e.g., forests versus muskeg) or where fresh moose tracks indicated the potential presence of moose. Latitude/longitude coordinates of lone or grouped moose were recorded using the aircraft GPS receivers or hand-held GPS units operated by the back-seat observer. Each moose observed was categorized as: cow, calf, yearling bull (spike or forked antlers), medium bull (a bull with antlers that were larger than spike or fork but whose antler spread was <50 inches [127 cm]), or large bull (antler spread ≥50 inches). Moose population estimates within the survey area were made using a web-based GSPE analysis program developed by ADF&G (Ver Hoef 2002, 2008; Kellie and DeLong 2006; www.winfonet.alaska.gov).

The GSPE survey methodology assumes 100% sightability of moose. However, this assumption is not often met (Boertje, ADF&G, unpublished data). Therefore, simultaneous with the 2010 GSPE survey, we determined the sightability of moose during our survey period. Fortunately, the population of moose we surveyed contained animals that were outfitted with radio-collars during an unrelated study. We determined the sightabililty of moose during our survey by locating collared moose prior to intensively surveying a unit, and establishing if the observers in the survey plane had spotted the radio-collared moose. A strategy that avoided biasing observers was developed so that tested individuals did not know when, or if, they were being tested.

RESULTS

Survey conditions

The survey was conducted 12 - 19 November 2010. Stratification flights were conducted 12 – 16 November and intensive surveys of individual units began on 15 November. Survey conditions were generally classified as “excellent” to “good” except for a few units that were categorized as “fair” and one as “poor”; both of the later classifications due to turbulence encountered on the southern end of the study area. Snow conditions during the survey period were good with complete snow cover and frost often occurring on overgrowth. Temperatures ranged between -32˚ and + 25˚F (-16 and -1 ˚C). Light conditions ranged from flat to bright light and medium to high intensity. All intensive survey pilots were experienced in survey techniques, as had all observers except two who were paired with experienced pilots. Weather conditions deteriorated throughout Interior Alaska on 19 November when low clouds, accompanied by freezing rain, moved into the region. This effectively terminated the survey. Unfortunately, the storm did not abate quickly, and the entire survey crew was marooned in Bettles for nearly a week after the survey concluded, greatly increasing survey costs.

Stratification Results

During stratification flights we found that over half of the SUs in the Total Survey Area were considered High quality moose *habitat* (Table 1; Figure 2). However, only 11% of the SUs were classified as having a High *density* of moose.

Survey area	*# High moose density SUs (% of area)*	*# Low moose density SUs (% of area)*	*#High moose habitat SUs (% of area)*	*# Low moose habitat SUs (% of area)*	*Mean # moose observed, High density SUs*	*Mean # moose observed, Low density SUs*
Total Survey Area	*75 (11)*	*626 (89)*	*375 (54)*	*326 (46)*	*4.97 (SE=0.51)*	*1.44 (SE=0.19)*

Table 1. Moose survey unit (SU) classification by density and habitat quality and number of moose observed in each during stratification flights in November, 2010 in the Total Survey Area, Game Management Unit 24B, Alaska.

Of the moose we observed during intensive surveys, 77% (341) and 81% (331) were located in the units designated as High density SUs in the Total Survey Area, and the Kanuti NWR Survey Area, respectively. Further, the mean number of moose observed in High density SUs during the surveys was 3 times the number of moose detected in Low Density strata. These data indicate that the stratification classifications were accurate.

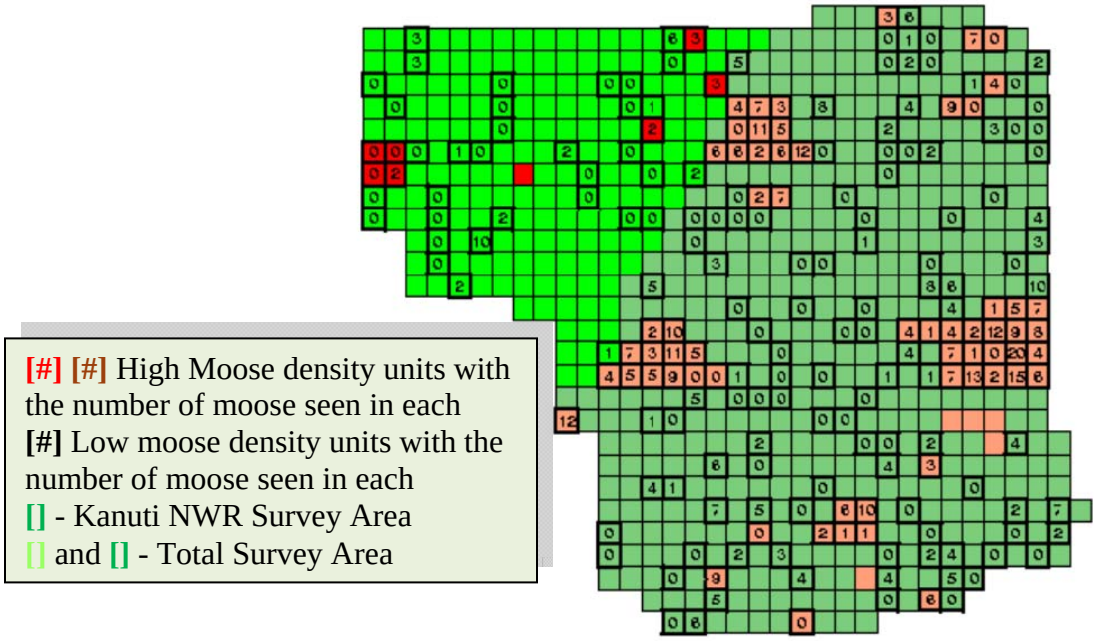

Figure 2. Moose counted in survey units in November, 2010 relative to moose density stratum. Kanuti NWR, and Total Survey Area, Game Management Unit 24B, Alaska.

Population survey results

Of the 508 sample units within the Kanuti NWR Surveyed Area, 164 (32%) were surveyed for moose (Table 2). A total of 62 High density units (38%) and 102 Low density units (62%) were intensively surveyed. Of the 701 sample units within the Total Survey Area 213 (30%) were surveyed for moose. A total of 69 High density units (32%)

and 144 Low density units (68%) were surveyed in this area. Survey time per unit ranged from 8 – 57 minutes with a mean of 29.5 (±6.5SE) min. spent in survey units. The number of survey planes used (excluding stratification plane) ranged from 1 – 7 airplanes per day. In the final days of the survey, patchy ice fog in parts of the survey area influenced the number of units that were surveyed each day. As a result, the total number of units surveyed by all planes during single days ranged from 1 – 55. Typically, each plane surveyed around 9 units on days when weather was fair. Variation in the number of units surveyed on fair weather days depended on their distance from Bettles, light conditions, fuel needs, number of moose in a unit, and habitat complexity of survey units (e.g. units with closed tree canopy required more time to survey).

Table 2. Summary Statistics for 8 moose population estimates (90% Confidence Interval), in the Kanuti NWR Survey Area, Game Management Unit 24B, Alaska. Surveys conducted in 1989 and 1993 employed the Gasaway method while subsequent surveys were conducted using the GeoSpatial Population Estimator method.

	1989	***1993***	***1999***	***2004***	***2005***	***2007***	***2008***	***2010***
Survey Area (sq. miles)[1]	2,615	2,644	2,715	2,710	2,710	2,714	2,715	2,714
Units Surveyed	Not applicable[2]	Not applicable[2]	108	103	82	150	80	164
Population Estimate (Range of Estimate)	1,172 (867 - 1,476)	2,010 (1,567 - 2,453)	1,003 (794 – 1,211)	842 (602 – 1,083)	1,025 (581 – 1,470)	588 (463- 714)	872 (669 – 1,075)	1,068 (946- 1,191)
Standard Error	Not available	Not available	127	146	270	76	124	74.5
Moose Density (moose/sq. mi)	0.45	0.76	0.37	0.31	0.38	0.22	0.32	0.39
Estimated Cows	Not Available	Not Available	542	403	471	276	432	569
Estimated Bulls	Not Available	Not Available	320	252	331	167	199	293
Bulls:100 Cows	64	61	59	62	70	60	46	51
Yearling Bulls:100 Cows	4	8	4	9	20	13	14	7
Calves:100 Cows	17	33	30	46	43	53	58	33

[1]Survey areas vary among years depending on how survey units were delineated
[2]Survey units varied in shape and size and are not comparable to units used in subsequent surveys

Observers classified 409 moose within the 164 units surveyed in the Kanuti NWR Survey Area with a range of 0 – 18 moose counted in single units. This yielded an average count of about 2.5 moose per surveyed unit. Of these moose, 181 were cows, 151 bulls and 77 calves. In the Total Survey Area, which included the Kanuti NWR Survey Area, 446 moose were classified, including 196 cows, 167 bulls and 83 calves. Only 4 sets of twins were counted in the Total Survey Area and all were located in units that were in the Kanuti NWR Survey Area.

The GSPE population estimate for the Kanuti NWR Survey Area was 1068 moose (± 122; 90% CI), resulting in a density of 0.39 moose/mi^2 (0.15 moose/km$^{2)}$). The narrow 90% confidence interval (it is standard practice to compare 90% CI among GSPE surveys in Alaska) for the 2010 population estimate confirms that this is the most precise estimate of the moose population on the Kanuti NWR Survey Area to date (Figure 3)

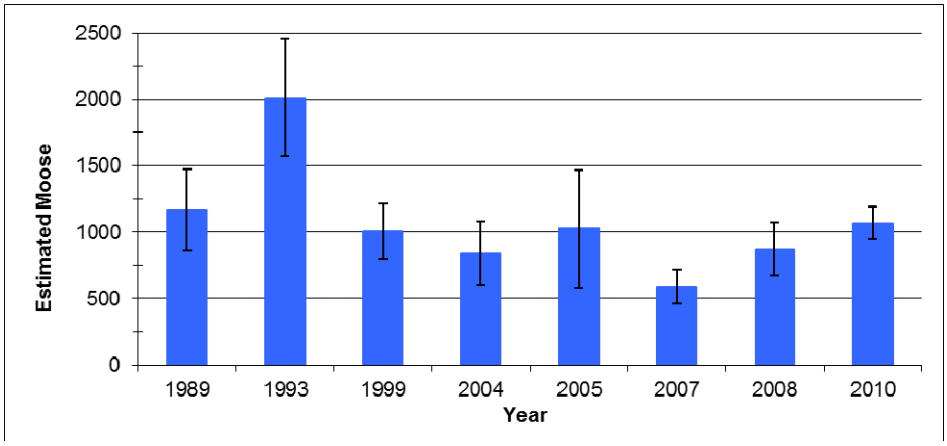

Figure 3. Moose population estimates on Kanuti NWR, Game Management Unit 24B, Alaska. Error bars represent the 90% confidence interval for each year.

Estimated moose densities by sex and age class in the Kanuti NWR Survey area were 0.08 bulls/mi^2, 0.15 cows/mi^2, and 0.05 calves/mi^2 (0.03/km^2, 0.06/km^2, and 0.02/km^2, respectively). Population estimates and ratios (indexed to 100 cows) for bulls by age class for the Total Survey Area are presented in Table 3. Note that all Large bulls in the survey were located in the Kanuti NWR Survey Area.

Table 3. Estimated bull moose population and age ratios in November, 2010 indexed to 100 cows in the Kanuti NWR and Total Survey Area, Game Management Unit 24B, Alaska.

	All bulls	Yearling bulls[b]	Large bulls
Population estimate			
Kanuti NWR Survey Area	293	43	136
Total Survey Area	373	53	136
Ratio estimate: 100 cows			
Kanuti NWR Survey Area	51:100	7:100	24:100
Total Survey Area	53:100	8:100	24:100
90%CI[a]			
Kanuti NWR Survey Area	240-346	27-58	103-169
Total Survey Area	302–445	32–74	103–169

[a] Upper and lower estimate of confidence intervals (CI).
[b] Assuming a 50:50 sex ratio for yearlings, total yearling density in the survey area is expected to be twice that of yearling bulls

Costs by agency for the 2010 GSPE survey are found in Appendix 1. Complete survey results for the entire 2010 survey are archived in, and can be retrieved from, the Alaska Department of Fish and Game's WINFONET database (http://winfonet.alaska.gov/; accessed 1 December 2010). An example of output from WINFONET is found in Appendix 2.

Sightability index
We found the sightability of moose by intensive survey planes during the 2010 GSPE survey to be very high *vis a' vis* the 30% SCF determined for the 2008 moose survey, the only other survey when a SCF was determined. Of 23 trials observed in 2010, pilot/observer teams detected known-location radio-collared moose 22 times. This resulted in a sightability correction factor (SCF) of 4.5%.

DISCUSSION

The Kanuti NWR Survey Area has been surveyed five times using GSPE techniques since 1999. However, we acquired the most precise (low CIs) and accurate (low SCF) moose survey of all these surveys in 2010. This resulted from several reasons. First, the precision of a population estimate of a subset of SUs is improved in the geospatial analysis by surveying a contiguous, larger area. Therefore, surveying units in the Total Survey Area improved the precision of the estimates in the smaller Kanuti NWR Survey Area. In addition, during the 2010 survey we used experienced survey pilots, completed an accurate stratification, and had good survey conditions, all of which improved the results of the survey.

Moose population densities determined for the Kanuti NWR Survey Area using GSPE methodology have ranged from 0.31 to 0.39 moose/mi^2 with the exception of 2007 when the estimated population was even lower (0.22 moose/mi^2). Except for the 2007 estimate, the Confidence Intervals for all of these other estimates overlap. From these data, we

conclude that while moose numbers probably do fluctuate somewhat in the survey area, the moose density remains low, and has changed very little over the past decade. This is not atypical for Interior Alaska moose populations where hunting and trapping pressure on predators is low. Gasaway et al. (1992) report a mean density of 0.38 moose/mi^2 (0.15 moose/km^2) for 20 moose populations in Alaska and the Yukon Territory where predation was thought to be a limiting factor. Where predation was not thought to be limiting, the mean density of 16 populations was 1.7 moose/mi^2 (0.66 moose/km^2). The current moose density on KNWR Survey Area is 0.39 moose/mi^2 while the average over the past 6 years when GSPE methods were used is 0.33 moose/mi^2 ($\pm$0.06).

The Kanuti NWR Survey Area population has maintained a relatively high bull/cow ratio (46 – 70 bulls/100 cows) throughout the last decade. This is probably resultant of the low human harvest on the Refuge due to past management strategies. A minimum of 20 bulls:100 cows in the fall is considered adequate to maintain moose numbers, except in low density areas like the Kanuti NWR, where cows are more widely dispersed. There, a ratio of 30 – 40 bulls:100 cows (ADF&G 2001) may be required.

Browse condition is often used as a measure of moose habitat quality (Franzmann and Schwartz 1998, Paragi et al. 2008). Stout (2008) report that there were very low levels of browse removal in GMU 24B during a study in late winter in 2007. Similarly, twinning rates are a good index of the nutritional status of moose, (Franzmann and Schwartz 1985, Paragi et al. 2008). Twinning rates have been found to be high (35 – 60%) in portions of GMU 24 A&B in the last three years, including in the Kanuti NWR Survey Area. Saperstein (2009) reported that almost half of the Kanuti NWR survey area was classified as high quality habitat for moose during the 2007 GSPE survey and we found similar results during our habitat stratification of the Total Survey Area in 2010 (only 46% of the area was considered low quality habitat). In contrast to the habitat stratification, we found that units with High moose density only occurred in 11% of the Total Survey Areas in 2010. The browse removal and twining data, coupled with these habitat and density stratification results, suggest that while moose occur at low density in the survey area, habitat does not appear to be a factor limiting the population.

If we assume a pregnancy rate of 96% as determined in a radio telemetry study in GMU 24 A&B (Saperstein et al. 2009) and a twining rate of 51%, the average over the past three years (T. Hollis, unpublished ADF&G memoranda 2010), 149 calves/100 cows were potentially born in spring 2010 on our study area. However, in the November GSPE survey we estimated there to be only 33 calves/100 cows. While we do not know the fate of moose calves between birth and November on the Kanuti NWR Survey Area, it is clear that recruitment into the population is low. In nearby Koyukuk NWR, Osborne et al. (1991) found that black bears (*Ursus americanus*) were responsible for 40% of the calf mortalities, while brown bears (*Ursus arctos*) (3%) and wolves (*Canis lupus*) (9%) accounted for far fewer mortalities. Similarly, Bertram and Vivion (2002) found that even though moose on Yukon Flats National Wildlife Refuge, another nearby Refuge, had high pregnancy and twining rates, predation by black bears (45%), and grizzly bears (39%) were responsible for low (28%) neonate survival during the first 14 weeks after parturition. Calf ratios of 20 - 30 calves:100 cows are suggested necessary to maintain a

stable moose population and ratios exceeding that are needed for moose populations to grow (ADF&G 2001). The 2010 estimates for both yearling bulls (7/100 cows) and calves (33/100 cows) indicate there will not be much change in moose densities on Kanuti NWR Survey Area in the near future.

Moose habitat quality in Interior Alaska is often related to ecological succession in areas that have burned and subsequently change through time. The Kanuti NWR Survey Area is largely a fire dominated ecosystem that has experienced several large fires since 1990. Research elsewhere in Interior Alaska indicated that burns between 10 – 30 years old are preferred over younger burns by moose (Maier et al. 2005). This was supported by observations on Kanuti NWR in past moose surveys, and during the 2010 survey, as well. Many of the High moose density units in both the Total Survey Area and the Kanuti NWR Survey Area were in burns that were more than 10 but fewer than 30 years old. One exception occurred in the west-central portion of the study area, about 20 km south of Allakaket. There, a 1972 burn hosted a high number of moose, perhaps because the varied topography and concomitant environmental conditions in this hilly area retarded secession in places. Climate change models predict an increased incidence of fire in Interior Alaska (Rupp 2009) concurrent with a drying trend (SNAP 2009). While one of these trends may increase habitat for moose in areas over time, the other will likely degrade habitat in others. As a result, predicting the availability of moose habitat in the survey area in the future will be very difficult.

ACKNOWLEDGEMENTS

Funding was provided by U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game and the Bureau of Land Management. Expert aircraft support was provided by R. Cebulski, E. Finch, A. Greenblatt, D. Rippitoe, D. Saylors, M. Spindler, M. Webb and P. Zaczkowski. Observers that contributed to the success of this survey included: A. Gabriel, T. Hollis, E. Juliannus, N. Pamperin, G. Stout, and Jessica Vanduyn. T. Paragi conducted the stratification tests. Analyses were conducted using the Alaska Department of Fish and Game automated analysis program. Peter Butteri provided fire mapping help.

REFERENCES

ADF&G. 2001. Koyukuk River moose management plan, 2000 – 2005. Unit 24 and the northern portion of Unit 21D. In cooperation with the Koyukuk River Moose Hunters' Working Group. Fairbanks, Alaska. 37 pp.

Bertram, M. R. and M. T. Vivion. 2002. Moose mortality in eastern interior Alaska. J. Wildl. Management. 66:747-756

Brown, C. L., R. J. Walker, and S. B. Vanek. 2004. The 2002 – 2003 harvest of moose, caribou, and bear in Middle Yukon and Koyukuk River communities. Technical Paper No. 280, Alaska Department of Fish and Game, Juneau, Alaska.

Franzmann, A. W. and C.C. Schwartz. 1985. Moose Twinning Rates: A Possible Population Condition Assessment. J. of Wildl. Manag. 49: 394-396

Franzmann, A. W. and C. C. Schwartz. 1998. Ecology and management of North American moose. Smithsonian Institution Press, Washington, D.C. 733 pp.

Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biol. Pap. 22. U. of Alaska, 108 pp.

Gasaway, W. C., R. D. Boertje, D. V. Grandgard, K. G. Kellyhouse, R. O. Stephenson and D. G. Larsen. 1992. The role of predation in limiting moose as low densities in Alaska and the Yukon and implications for conservation. Wildl. Monogr. 120. 59 pp.

Kellie, K. A. and R. A. DeLong. 2006. Geospatial survey operations manual. Alaska Department of Fish and Game. Fairbanks, AK. 55 pp.

Maier, J. A. K., J. M. Ver Hoef, A. D. McGuire, R. T. Bowyer, L. Saperstein, and H. A. Maier. 2005. Distribution and density of moose in relation to landscape characteristics: Effects of scale. Can. J. For. Res. 35:2233–2243.

Osborne, T.O., T. F. Paragi, J. L. Bodkin, A. J. Loranger, and W. N. Johnson. 1991. Extent, cause, and timing of moose calf mortality in western Interior Alaska. Alces 27:24–30.

Paragi, T. F., C. T. Seaton, and K. A. Kellie. 2008. Identifying and evaluating techniques for wildlife habitat management in interior Alaska: Moose range assessment. ADF&G, Division of Wildlife Conservation. Final Research Technical Report. Grants W-33-4, 5, 6, & 7. Project 5.10. Juneau, AK. 76 pp.

Rupp, T.S and A. Springsteen. 2009. Summary Report for Kanuti National Wildlife Refuge: Projected Vegetation and Fire Regime Response to Future Climate Change in Alaska. May 15th 2009.

Saperstein, L. 2009. Aerial moose survey on Kanuti National Wildlife Refuge, November 2007. Final Report, FY 09-01. Kanuti NWR, Fairbanks Ak. 14 pp.

Saperstein, L. B., K Joly, T Craig, A. Hollis, and G. W. Stout. 2009. Distribution and Movements of moose (Alces alces) in the upper Koyukuk River Drainage, Alaska. American Society of Mammalogists, annual meeting, University of Alaska, Fairbanks, Fairbanks, Alaska.

SNAP [Scenarios Network for Alaska Planning]. 2009. Climate change impacts on water availability in Alaska. University of Alaska, School of Natural Resources and Agriculture Sciences. http://www.snap.uaf.edu/projects/climate-change-impacts-water-availability-alaska

Stout, G. W. 2008. Unit 24 moose. Pages 579-616 *in* P. Harper, editor. Moose management report of survey and inventory activities 1 July 2005-30 June 2007. Alaska Department of Fish and Game. Project 1.0 Juneau, Alaska, USA.

Ver Hoef, J. M. 2002. Sampling and geostatistics for spatial data. Ecoscience 9(2):152–161.

Ver Hoef, J. M. 2008. Spatial methods for plot-based sampling of wildlife populations. Environ. Ecol. Stat. 15:3– 13.

APPENDIX 1

Cost by Agency

Kanuti National Wildlife Refuge moose survey costs for the Total Survey Area, Alaska, November 2010

Vendor	Description	Flight hours	Cost
OAS (Greenblatt)	PA18	38.10	9,142.80
OAS (Rippeto)	Cessna 206	20	3,500.00
OAS (Cebulski)	PA 18	24.8	3,100.50
OAS (Spindler)	Scout	27.2	3,400.00
Bettles Lodge	Fuel		7,191.00
Fuel (Greenblatt)	Fuel		877.79 78.80
Fuel (Cebulski)	Fuel		960.33 1,997.5
Fuel (Spindler)	Fuel		781.12
Wright Air	Travel		418.00
Wright Air	Travel		358.5
Food	+Freight		1,442.31
Food	+Freight		161.72
Food	+Freight		39.58
Propane			185.00
Hazard pay (AG)			135.52
Travel (Rippeto)			144.00
Salary (Rippeto)			2,535.84
Travel (Spindler)			85.00
Travel (Craig)			70.00
Travel (Gabriel)			38.00
Overtime (Spindler)			1,197.72
Total			$37,840.53

Bureau of Land Management moose survey cost for the Total Survey Area, Alaska, November 2010.

Bettles Lodge	**Fuel**	**3000.00**
Total		$3000.00

Alaska Department of Fish and Game moose survey costs for the Total Survey Area, Alaska, November 2010

Vendor	Description	Costs
	Food	**342.04**
	Travel	**611.53**
	Fuel	**2,999.25**
Ak. Wildife Safaris (Ernie Finch)	Air charter	**4,515.00**
Shadow Aviation (Andy Greenblat)	Air charter	**4,951.00**
Tundra Air (Marty Webb)	Air charter	6,494.00
Papa Zulu Air (Paul Zaczkowski)	Air charter	5, 831.00
Husky Air (Dan Sailors)	Air charter	3958.00
Total		**$29,701.82**

Appendix 2

WinfoNet

Moose Surveys - Population/Ratio Estimates

Main Menu | Add/Edit | Retrieve | Estimates | Documents | Data Security

Home -> Survey and Inventory Tools -> Moose Surveys -> **Moose Surveys - Population/Ratio Estimates**

Do A Ratio Estimate | Do Another Population Estimate

Moose Population Estimate--Geo Technique

Survey: 24B KANUTI
Year: 2010
Season: Fall

REQUEST PARAMETERS	
Analysis Column:	[TotalMoose]
Analysis Area:	KANUTI
Strata Column:	StratName
Counted Column:	Counted
Unit Area Column:	AreaMi

Right click to download data used to calculate estimate.

Right click to download RCode used to calculate estimate.

RESULTS

Estimate		Confidence Intervals		
		Confidence	Interval (moose)	Interval (proportion of the mean)
Population Estimate:	1068.42	80%	973.0038 1163.8362	0.0893059
Standard Error:	74.45366	90%	945.9546 1190.8854	0.1146229
		95%	922.4935 1214.3465	0.1365816

SAMPLE DETAILS

Total Samples

	Stratum	N
1	HIGH	75
2	LOW	626
3	TOTAL	701

Total Area

	Stratum	Area
1	HIGH	399.957
2	LOW	3335.676
3	TOTAL	3735.633

Sample Sizes

	Stratum	n
1	HIGH	69
2	LOW	144
3	TOTAL	213

Area Sampled

	Stratum	Area
1	HIGH	367.757
2	LOW	767.820
3	TOTAL	1135.577

Moose Counted

	Stratum	Counted
1	HIGH	343
2	LOW	207
3	TOTAL	550

ESTIMATE DETAILS

Stratum: HIGH

Empirical Semi-Variogram

	distance	gamma	np
1	4.362876	0.7966074	242
2	9.356056	0.6941222	372
3	15.538219	0.5042839	188
4	21.484636	0.5925733	108
5	28.397474	0.5405398	84
6	35.051756	0.5237789	334
7	40.827889	0.5818215	476
8	46.871219	0.5009119	574

Parameter Estimates

	nugget	parsil	range
1	0.5826255	0.06303368	26.14857

Stratum: LOW

Empirical Semi-Variogram

	distance	gamma	np
1	4.417786	0.1166998	240
2	9.854737	0.1431758	726
3	16.022714	0.1472750	1036
4	21.991047	0.1719670	1282
5	28.164571	0.1823230	1434
6	34.437246	0.2202690	1586
7	40.709696	0.1854775	1606
8	46.890771	0.1873843	1786

Parameter Estimates

	nugget	parsil	range
1	3.22453e-07	0.1882415	3.741249