AERIAL MOOSE SURVEY IN UPPER GAME MANAGEMENT UNIT 24, ALASKA, FALL 2004, INCLUDING STATE LAND, AND LANDS ADMINISTERED BY THE BUREAU OF LAND MANAGEMENT, GATES OF THE ARCTIC NATIONAL PARK AND PRESERVE, AND KANUTI NATIONAL WILDLIFE REFUGE

Project Report:

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Photo: G. Stout

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DATA SUMMARY

Entire Survey Area:
Survey Dates: 25 October – 7 November, 2004
Total area covered by survey: 11,494 mi^2 (29,769 km^2)
Total moose observed: 653 moose (341 cows, 211 bulls and 101 calves)
November population estimate: 2,805 (90% confidence interval = 2,176 – 3,434) moose
Estimated total density: 0.24 moose/mi^2 (0.09 moose km^2)
Estimated ratios: 35 calves:100 cows; 8.6 yearling bulls:100 cows; 65 bulls:100 cows

Gates of the Arctic National Park and Preserve Block:
Survey Dates: 26 October – 2 November, 2004
Total area covered by survey: 5,106 mi^2 (13,225 km^2)
Total moose observed*: 164 moose (87 cows, 61 bulls and 16 calves)
November population estimate: 968 (90% confidence interval = 737 – 1,199) moose
Estimated total density: 0.19 moose/mi^2 (0.07 moose km^2)
Estimated ratios: 25 calves:100 cows; 7 yearling bulls: 100 cows; 71 bulls:100 cows
*Does not include moose counted as part of Middle Fork Koyukuk Trend Count.

Kanuti National Wildlife Refuge Block:
Survey Dates: 30 October – 7 November, 2004
Total area covered by survey: 2,709 mi^2 (7,016 km^2)
Total moose observed: 292 moose (145 cows, 96 bulls and 51 calves):
November population estimate: 842 (90% confidence interval = 602 – 1,083) moose
Estimated total density: 0.31 moose/mi^2 (0.12 moose km^2)
Estimated ratios: 46 calves:100 cows; 9 yearling bulls: 100 cows; 62 bulls:100 cows

"Remainder GMU 24" Block:
Survey Dates: 30 October – 7 November, 2004
Total area covered by survey: 3,678 mi^2 (9,527 km^2)
Total moose observed: 89 (42 cows, 28 bulls, and 19 calves)
November population estimate: 749 (90% confidence interval = 369 – 1,128) moose
Estimated total density: 0.21 moose/mi^2 (0.08 moose/km^2)
Estimated ratios: 43 calves:100 cows; 10 yearling bulls:100 cows; 67 bulls:100 cows

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G), Bureau of Land Management (BLM), United States Fish and Wildlife Service (FWS), and the National Park Service (NPS) cooperatively conducted a moose population survey in the upper portion of Game Management Unit (GMU) 24 in 2004 (Fig. 1). The survey included Kanuti National Wildlife Refuge (Kanuti NWR) in its entirety, and portions of Gates of the Arctic National Park and Preserve (GAAR), including the Alatna, John, and the North Fork Koyukuk rivers. Three annual Trend Count Areas (TCA) were also surveyed as part of the greater population survey (Fig. 2). The Kanuti Canyon and Henshaw Creek TCAs are within the Kanuti NWR and the Middle Fork Koyukuk TCA is on lands managed by the BLM and the State of Alaska. This report includes population estimates for the entire survey area and for the GAAR and Kanuti NWR blocks, and trend data from the three TCAs. These population parameters are intended to aid managers from all participating agencies in making informed decisions regarding management of moose in the northern part of GMU 24.

It is problematic to evaluate the relative population dynamics of a moose population based solely on density due to the lack of information for carrying capacity of the habitat. Gasaway et al. (1992) calculated 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 limiting. Mean density of 16 populations within the same general area was 1.7 moose/mi^2 (0.66 moose/km^2) where predation was thought not to be limiting. Ballard et al. (1991) reported a range of 0.13 – 3.2 moose/mi^2 (0.05 – 1.2 moose/km^2) for 29 moose populations in Alaska.

In addition to density, bull:cow and calf:cow ratios are often estimated to evaluate the hunting pressure and recruitment in a moose population, respectively. As with density values, these ratios depend on a number of factors including population trends, habitat quality, and predation pressure. A minimum of 20 bulls:100 cows in the fall is often considered adequate to maintain a moose population. Minimum calf:cow ratios for maintaining a moose population depend on adult mortality rates of the population. Van Ballenberghe and Ballard (1997) reported the early winter proportion of calves in a population can vary between 7% where predation is intense (Van Ballenberghe 1987) and 44% for populations where hunting (and presumably predation) is negligible (Rolley and Keith 1980).

Population surveys conducted on Kanuti NWR documented a decline in the moose population between 1993 and 1999 (Saperstein 2002) that corresponded with hunter reports of fewer moose in northern GMU 24 (Glenn Stout, ADF&G, personal observation). Kanuti NWR was scheduled for its 5-year population survey in 2004, but the lack of recent information from the GAAR portion of GMU 24 made it difficult to assess the moose population for the upper Koyukuk River area. Moose are an important subsistence resource for the residents of Bettles, Evansville, Alatna, Allakaket, Wiseman, and Coldfoot. In addition, many hunters from outside these villages enjoy hunting in this area. In recent years, with the perception of a decline in the local moose population, questions have been raised concerning the allocation of moose between local and non-

local hunters. The issue of subsistence versus sport hunting is controversial throughout the state of Alaska and this conflict will likely intensify as competition increases for limited wildlife resources.

The availability of historical data within the survey area varies. Kanuti NWR conducts population surveys at approximately 5-year intervals in cooperation with ADF&G. Previous population estimates were obtained for the refuge using the Gasaway method (Gasaway et al. 1986) in 1989 and 1993, and the Geo-Spatial Population Estimator method (GSPE) in 1999 (Ver Hoef 2001, 2002). The 1999 survey included portions of GMU 24 outside of the refuge, enabling separate estimates for the entire survey area, the refuge alone, and for the area outside of the refuge. Between these population surveys, annual trend surveys were consistently conducted in two TCAs within the refuge from 1989 – 1992 and 2000 – present to monitor age and sex ratios. The BLM and the ADF&G have conducted surveys in the Middle Fork Koyukuk River TCA each year since 1999. The TCA units border GAAR's eastern boundary between Coldfoot and Wiseman.

Some historical data exist for portions of the area surveyed in GAAR in 2004, including portions of the Alatna River drainage (Dale et al. 1994) and a portion of the Middle Fork Koyukuk River (ADF&G and the Koyukuk River Moose Hunters' Working Group 2001, Saperstein 2002). A population survey was conducted along the Dalton Highway corridor 25 - 30 October 1991 following the Gasaway method and analyzed using MOOSEPOP software (D. Reed 1989), resulting in an estimate of 1,416 (± 311; 90% CI) moose for a 3,373 mi^2 (8,736 km^2) survey area. Osborne (1995) estimated the moose population at 6,000 – 8,000 moose in an area roughly comparable to the 2004 total survey area based on results of the 1991 Dalton Highway corridor survey, the 1993 Kanuti NWR survey (Martin and Zirkle 1996), and data from surrounding areas. Although a portion of GAAR was included in some of these past studies, most of the area surveyed in GAAR in 2004 was not. Therefore, this is the first statistical estimate of moose population parameters for the GAAR survey block.

The objective for the 2004 moose survey was to document changes in the moose population on Kanuti NWR and adjacent areas in upper GMU 24 and to increase the understanding of the moose population in GAAR in the Alatna, John, and North Fork Koyukuk river drainages.

STUDY AREA

The study area is roughly bounded by the crest of the Brooks Range to the north (67° 58'N), the Alatna River (155° 26'W) or the Mentanontli River (153° 20'W) to the west, the South Fork Koyukuk River (149° 54'W) or Dalton Highway (150° 20'W) to the east, and by the foothills of the Ray Mountains to the south (65° 56' N) (Fig. 1). Principal land managers in this area are the State of Alaska, BLM, FWS, NPS, and Native corporations and villages. Vegetation types include spruce and deciduous forest and woodland, tall shrub, low shrub, prostrate shrub, mesic herbaceous, sparsely vegetated areas, and aquatic habitat. Survey units that were entirely alpine or water were intentionally excluded from the survey because those habitats are not typically utilized by moose.

METHODS

Moose population surveys were conducted following guidelines outlined by Gasaway et al. (1986) and modified by Ver Hoef (2001, 2002). These survey methods were developed by ADF&G and are used statewide and in parts of Canada, allowing for comparison between survey areas. Our survey area was delineated using a geographical information system developed by ADF&G and divided into a grid of rectangular sample units of 2 degrees latitude and 5 degrees longitude, resulting in units ranging in size from 5.0 mi^2 – 5.4 mi^2 (12.9 – 14.0 km^2) depending on how far north the unit is (i.e., units decrease in area to the north as longitude lines converge approaching the pole). For example, average unit size is about 5.1 mi^2 (13.2 km^2) in the GAAR block and 5.3 mi^2 (13.7 km^2) in the Kanuti NWR block. The GAAR survey block covered approximately 5,106 mi^2 (13,225 km^2) and contained a total of 1,001 units (Fig. 1). The Kanuti NWR survey block covered the entire refuge and was approximately 2,710 mi^2 (7,019 km^2) in size and included 507 survey units (Figure 1). The remaining area ("Remainder GMU 24"), consisting of State, BLM, and private lands, covered 3,678 mi^2 (9,527 km^2) and included 696 survey units.

Three TCAs within the survey area (Kanuti Canyon, Henshaw Creek, and Middle Fork Koyukuk) were included in the larger population survey to maintain consistency of annual age and sex composition trend information (Fig. 2). The Kanuti Canyon and Henshaw Creek TCAs are within the Kanuti NWR and were considered part of the Kanuti block. The units within the Middle Fork Koyukuk TCA was considered part of the GAAR block. Data from all units in the Henshaw Creek and Kanuti Canyon TCAs were used for calculating population estimates for the Kanuti NWR block. Only data from those units in the Middle Fork Koyukuk TCA that were randomly selected as survey units for the GAAR block were used in the calculation of GAAR population estimates. All TCA data were used to calculate population estimates for the entire survey area.

Precision in moose surveys can be improved by stratifying survey units as high ("H") or low ("L") moose density and allocating survey effort between these separate strata. However, because there are little historic moose density data for GAAR, and because almost none of the habitat within the GAAR block was considered to be prime moose habitat, the entire block was classified as "L". The Kanuti NWR block and the "Remainder GMU 24" block were stratified into "H" and "L" units prior to surveying. Stratification flights were conducted using a Cessna 206 sequentially flying over the center of each unit on an east-west transect. The stratification crew consisted of two back-seat observers, a front-seat navigator/observer, and the pilot. Each unit was evaluated and then classified as "H" or "L" based on habitat characteristics, the number of moose observed, the number of moose tracks, and/or information from previous surveys.

The GAAR portion of the survey utilized five planes, each with a pilot and 1 observer. Planes included 3 Piper Supercubs (Arctic Air Alaska, Caribou Air Service and Alaska State Troopers), a Husky (National Park Service) and a Maule M-7 (Yukon Eagle Air). Participants in the survey were housed in Bettles or Coldfoot, Alaska. With the exception

of one observer, all pilots and all observers had previous experience in aerial moose surveys. The Kanuti NWR portion of the survey also utilized 5 planes: a Cessna 206 for stratification (FWS), 3 Piper Supercubs (FWS, Arctic Air Alaska), and a Maule (Yukon Eagle Air). The BLM chartered one Scout (Tundra Air) to survey the Middle Fork Koyukuk TCA and also assisted with the population survey. ADF&G chartered Yukon Eagle Air, Tundra Air, and utilized assistance from Alaska State Troopers. Nine observers were involved in the portion of the survey that occurred outside of GAAR. Three of the observers had no moose survey experience prior to this survey; one of these observers participated only on stratification flights.

Survey aircraft used Global Positioning System (GPS) receivers to identify the boundaries of sample units. 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 were observed. Moose observed were assigned a group number and the coordinates of the group were recorded using the aircraft GPS receivers. Survey methodology assumes 100% sightability of moose (although this assumption is not always met; Boertje, ADF&G, unpublished data). Numbers of moose in each group were recorded. Moose were 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 2001, 2002; winfonet.alaska.gov).

Kanuti NWR is the only survey block with previous population estimates to enable multi-year comparison. Direct statistical comparison is only appropriate for the 1999 and 2004 surveys because the same methodology was used. As previously mentioned, earlier surveys followed the Gasaway method (Gasaway et al. 1986) rather than the GSPE method. A one-tailed t-test was used to compare the population estimate from the 1999 and 2004 surveys. Although the analysis was only for the Kanuti NWR block, degrees of freedom employed in the analysis were based on the total number of survey units for all blocks because all units were used to calculate the variance for GSPE statistics. Prior to the analysis, the 1999 data were reanalyzed with the ADF&G GSPE program. This was necessary to provide consistency between the 1999 and 2004 estimates because the original 1999 analysis employed a least-squares method to estimate autocorrelation, but subsequent surveys used, and will continue to use, a restricted maximum likelihood method (J.M. Ver Hoef, personal communication, December 2005). This analytical change resulted in slightly different population estimates from what has been previously reported (Stout 2000, Office of Subsistence Management 2005, page 156).

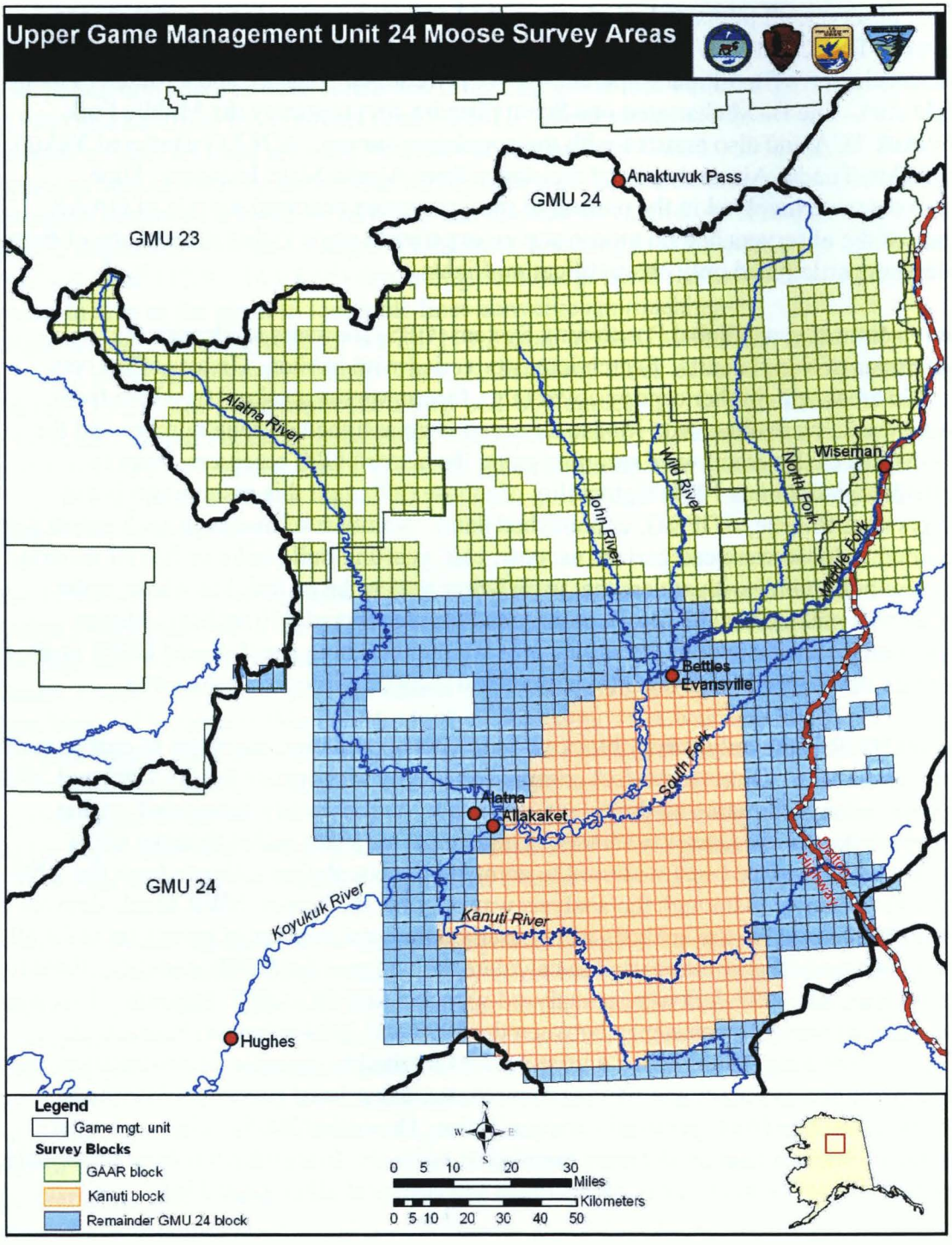

Figure 1. Survey units delineated for a moose survey in Northern GMU 24, Fall 2004.

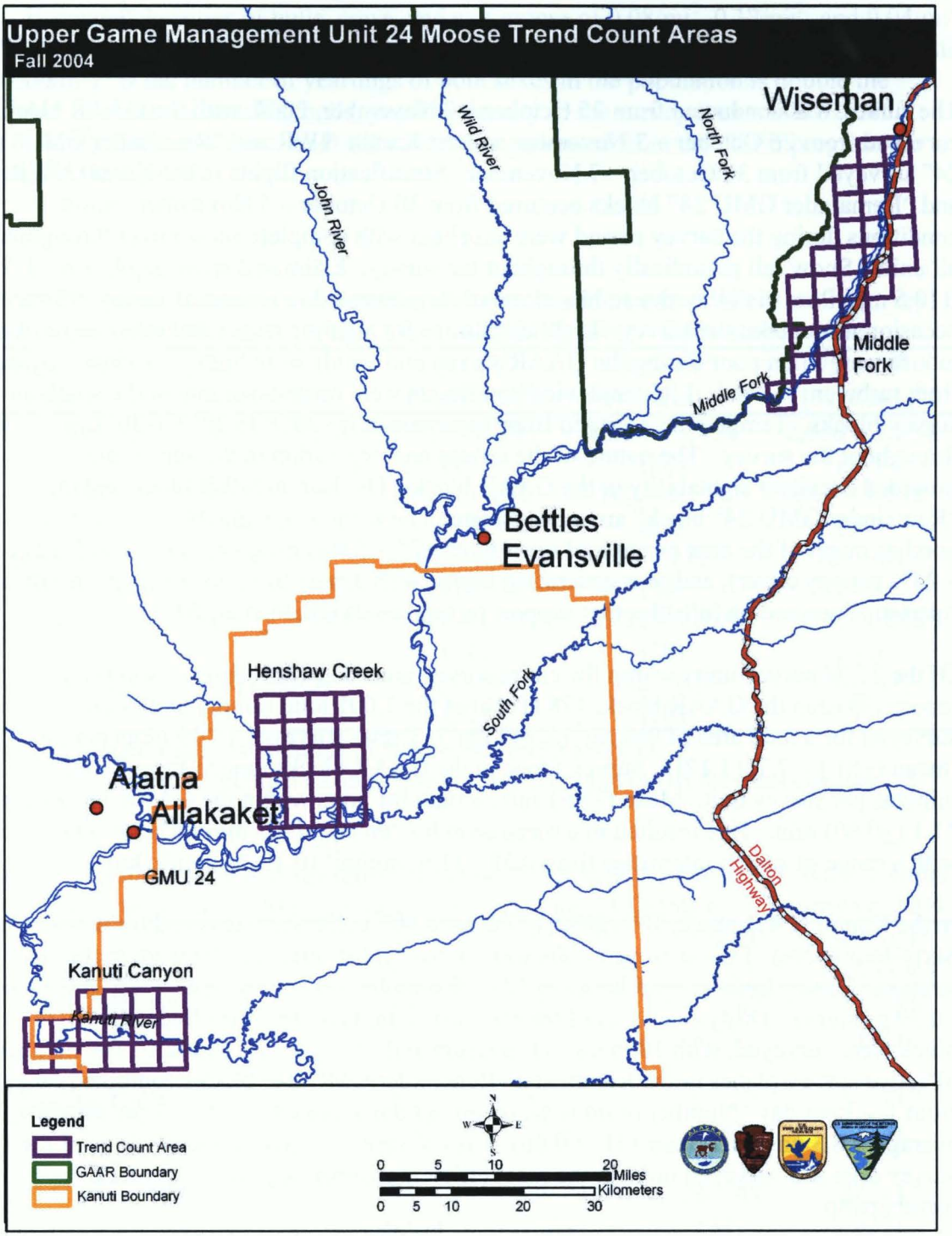

Figure 2. Location of Trend Count Areas showing individual survey units, in Northern GMU 24, fall 2004.

RESULTS

Survey conditions

The survey was conducted from 25 October – 7 November, 2004, with the GAAR block surveyed from 26 October – 2 November and the Kanuti NWR and "Remainder GMU 24" surveyed from 30 October – 7 November. Stratification flights in the Kanuti NWR and "Remainder GMU 24" blocks occurred from 30 October – 5 November. Snow conditions during the survey period were excellent with complete snow cover throughout all units. Snow fell periodically throughout the survey. Estimated snow depth was ~1.5 ft (0.5 m). Poor visibility due to low cloud cover prevented or restricted survey efforts on occasion throughout the survey. Light conditions for sighting tracks and other signs of moose were often poor during the GAAR survey and winds were highly variable ranging from turbulent to calm. Light and wind conditions were more favorable in the southern survey blocks. Temperatures ranged from approximately -20° F to 20° F (-30° C to -7° C) throughout the survey. The nature of the terrain and vegetation in the survey area provided excellent sightability in the GAAR block. The Kanuti NWR block and the "Remainder GMU 24" block" are more forested. Nonetheless, sightability remained good as much of the area consists of open forest (25 – 59% canopy cover), woodland (10 – 24% canopy cover), and/or regenerating burns, with denser trees occurring primarily in riparian zones and on hillsides that support mixed stands (BLM et al. 2002).

Of the 2,204 survey units within the entire survey area, 331 (15%) were surveyed for moose. Within the GAAR block, 178 (18%) of the 1,001 total sample units were surveyed for a total area of 907 mi^2 (2,349 km^2). Crews surveyed 1 - 19 units per day (mean [$\pm$SE] = 7.7[$\pm$1.17]). Survey times in the GAAR blocks ranged from 2 – 62 minutes per survey unit. Mean ($\pm$SE) survey time for units within the GAAR blocks was 21.1 ($\pm$0.90) min. This resulted in a mean search intensity of 4.1 min/mi^2 (1.6 min/km^2) with a range of search intensities from 0.38 - 11.9 min/mi^2 (0.15 - .4.6 min/km^2)

In the Kanuti NWR block, 103 (20%) of the total 507 units were surveyed for moose. Sixty-four (62%) of the surveyed units were in the "H" stratum and 39 were in the "L" stratum. Survey times ranged between 17 – 59 minutes per survey unit (mean $\pm$SE = 26 $\pm$0.79 minutes). Thirty-one (4%) of the 696 survey units in the "Remainder GMU 24" block were surveyed, with 18 in the "H" stratum and 13 in the "L" stratum. The number of active survey planes in the Kanuti and "Remainder GMU 24" blocks combined ranged from 1 – 3 per day. Number of units surveyed per day ranged from 4 – 13 per airplane, averaging 8.3 units per plane (SE = 0.86). Crews were sent to different sections of the survey area and surveyed units in the most efficient manner, regardless of block membership.

Moose observations and population estimates

Total area results

Observers counted 653 moose within the 331 units surveyed of the 11,494 mi^2 (29,769 km^2) total survey area. The GSPE population estimate for the total survey area was 2,805

moose (± 629; 90% CI), resulting in a density of 0.24 moose/mi^2 (0.09 moose/km^2, Table 1). Estimated densities of bulls, cows, and calf moose of 0.08/mi^2, 0.12/mi^2, and 0.04/mi^2 (0.03/km^2, 0.05/km^2, and 0.01/km^2), respectively. Yearling bull densities were 0.01/ mi^2 (0.00/km^2). If the number of yearlings of both sexes in the population is double the number of observed yearling bulls, yearling density in the survey area was 0.02/mi^2 (0.01/km^2). Bull:cow ratios and calf:cow ratios generated from the GSPE program are presented in Table 2.

Table 1. Estimated numbers of moose at different confidence intervals in entire survey area, upper Game Management Unit 24, Alaska, 24 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
Total Moose	2,805 (±382.3)	2,315 – 3,295 (17)	2,176 – 3,434 (22)	2,056 – 3,554 (27)
Total Bulls	928 (±137)	752 – 1,104 (19)	702 – 1,154 (24)	659 – 1,198 (29)
Yearling Bulls	126 (±27.9)	91 – 162 (28)	80 – 172 (36)	72 – 181 (43)
Total Cows	1,426 (±239.4)	1,119 – 1,733 (21)	1,032 – 1,820 (28)	957 – 1,896 (33)
Total Calves	490 (±83.5)	383 – 597 (22)	352 – 627 (28)	326 – 653 (33)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Table 2. Estimated sex and age ratios of moose at different confidence intervals in entire survey area, upper Game Management Unit 24, Alaska, 24 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
All Bulls:100 Cows	65 (±0.11)	51 – 78 (21)	47 – 82 (27)	44 – 85 (32)
Yearling Bulls:100 Cows	8.6 (±1.87)	6 – 11 (28)	6 – 12 (36)	5 – 712 (43)
Calves:100 Cows	35 (±0.07)	26 – 43 (24)	24 – 45 (31)	22 – 47 (37)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

GAAR block results

A total of 164 moose were observed during the fall 2004 survey in the GAAR block (Table 3). The majority of cows did not have calves (> 84%). We only observed >1 calf with a cow during the survey two times, and in both instances, 2 calves were observed with 1 cow. Large, medium, and yearling bulls made up approximately 60%, 30%, and 10%, respectively, of all bulls observed. No single-antlered bulls were observed during the survey. We observed ratios of 62 mature bulls:100 cows (large and medium bulls), 8 yearling bulls:100 cows, and 18 calves:100 cows. Moose were found most commonly in the eastern portion of the NPS survey area (Fig 2).

Results from the GSPE program (Table 4) indicate a moose density of 0.19 moose/mi^2 (0.07 moose/km^2) over the entire 5,106 mi^2 (13,224 km^2) survey area, with estimated densities of bulls, cows, and calf moose of 0.07/mi^2, 0.10/mi^2, and 0.03/mi^2 (0.03/km^2, 0.04/km^2, and 0.01/km^2), respectively. Yearling bull densities were < 0.01/ mi^2. If the number of yearlings of both sexes in the population is double the number of observed yearling bulls, yearling density in the survey area was 0.01/mi^2 (0.00/km^2). Bull:cow ratios and calf:cow ratios generated from the GSPE program are presented in Table 5.

Table 3. Summary of moose observed in GAAR during a population survey conducted from 26 October – 2 November 2004 in the upper Koyukuk River drainage, Alaska.

	# observed	Observed density (# moose/mi^2)
Large Bulls[a]	36	0.04
Medium Bulls[a]	18	0.02
Yearling Bulls[a]	7	0.01
Cows	87	0.10
Calves	16	0.02
Total	164	0.18

[a] Bulls were classified as large if their antler spread was estimated to be ≥ 50 inches, medium if their antler spread was estimated to be < 50 inches but greater than a spike or fork, and a yearling if their antler conformation was either a spike or a fork.

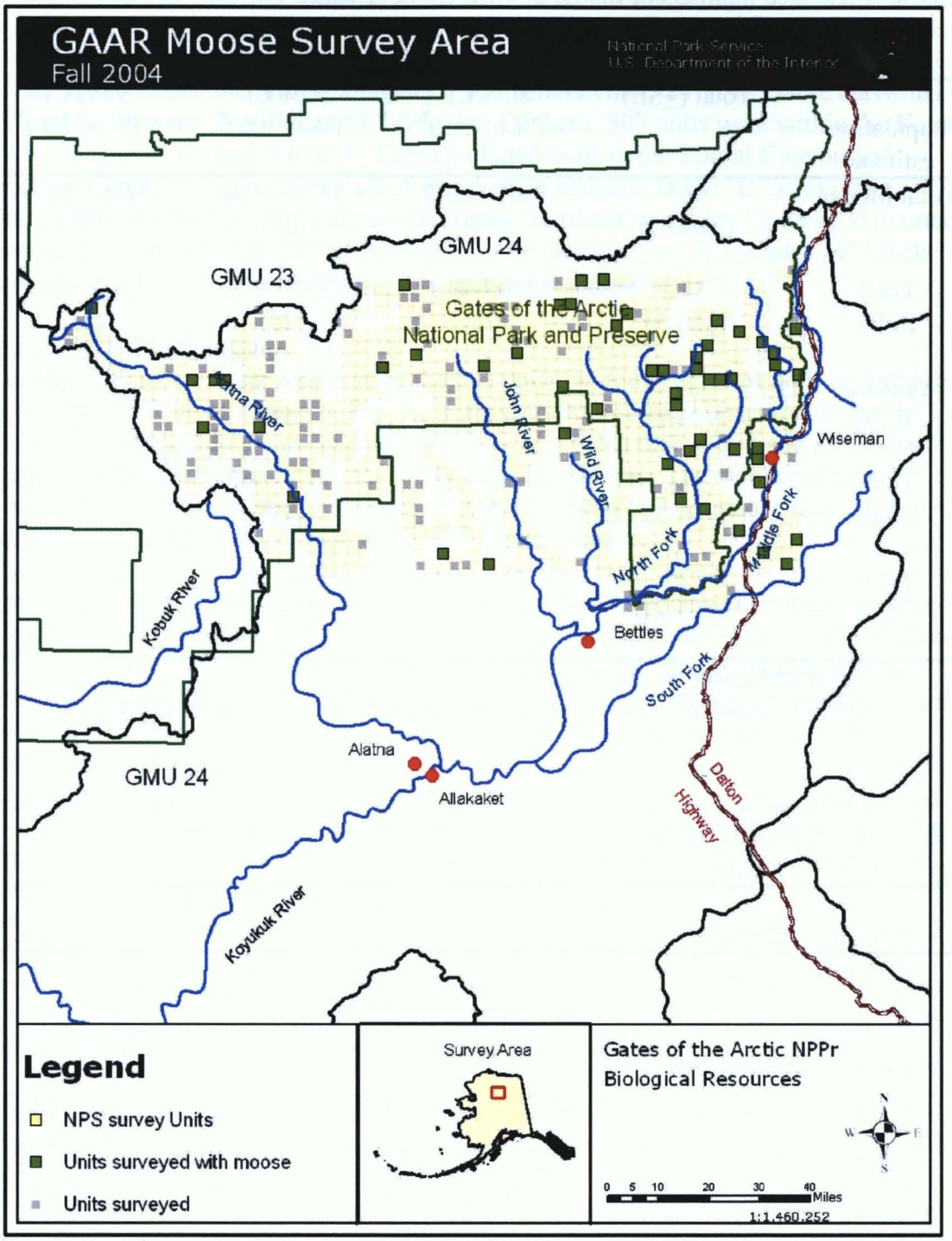

Figure 3. Survey units delineated for a moose census in GAAR in Northern GMU 24, Fall 2004. Randomly selected units that were actually surveyed are indicated on the map, including those units that were found to contain moose.

Table 4. Estimated numbers of moose at different confidence intervals in Gates of the Arctic National Park and Preserve including the Alatna, John and North Fork Koyukuk rivers, Alaska, 26 October – 2 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
Total Moose	968 (±140.5)	787 – 1148 (19)	737 – 1199 (24)	692 – 1243 (28)
Total Bulls	349 (±54.5)	280 – 419 (20)	260 – 439 (26)	243 – 456 (31)
Yearling Bulls	37 (±11.8)	21 – 52 (41)	17 – 56 (53)	14 – 60 (63)
Total Cows	511 (±91.5)	394 – 629 (23)	361 – 662 (29)	332 – 691 (35)
Total Calves	129 (±31.2)	89 – 169 (31)	77 – 180 (40)	68 – 190 (47)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Table 5. Estimated sex and age ratios of moose at different confidence intervals in Gates of the Arctic National Park and Preserve, including the Alatna, John and North Fork Koyukuk rivers, Alaska, 26 October – 2 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
All Bulls:100 Cows	71 (±0.13)	54 – 88 (24)	49 – 93 (31)	44 – 97 (37)
Yearling Bulls:100 Cows	7 (±0.02)	5 – 10 (40)	4 – 11 (50)	3 – 12 (59)
Calves:100 Cows	25 (±0.08)	15 – 35 (39)	13 – 38 (50)	10 – 40 (59)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Stratification Flight Results for Kanuti NWR and "Remainder GMU 24" (not including GAAR)

A total of 1,203 units were stratified in the Kanuti NWR block and nearby State and private lands outside the refuge boundary ("Remainder GMU 24"); 123 were classified as "H" and 1,080 were classified as "L" (Fig. 4). Of these, 507 units were within the Kanuti NWR block (81 "H" and 426"L"). These included units in the Kanuti Canyon and Henshaw Creek TCAs (36 units), all of which were assigned to the "H" stratum regardless of the moose density observed during stratification flights (done so to maintain consistency with previous years). Forty-two of the units in the "Remainder 24" block were classified as "H"; the remaining 654 units were classified as "L."

Kanuti NWR Block Results

A total of 292 moose were observed in the 103 units randomly selected and surveyed in the Kanuti NWR block (Table 6, Fig. 5). Fifty-three moose were observed in the "L" stratum (n = 39) yielding a mean count of 1.36 (SE = 0.36) moose/unit and an observed density of 0.26 moose/mi^2 (0.10 moose/km^2) for the stratum. The number of moose counted in the "H" stratum (n = 64) was 239, with a mean of 3.73 moose/unit (SE = 0.47) and a stratum density of 0.70 moose/mi^2 (0.27 moose/km^2).

Most of the 145 cows (71%) observed in the Kanuti NWR Block were not accompanied by calves, while 23% had a single calf and just over 5% had twins. One unaccompanied calf was observed. Large, medium, and yearling bulls made up approximately 52%, 32%, and 16%, respectively, of all bulls observed. The observed sex and age ratios in the Kanuti NWR Block were 56 mature bulls:100 cows (large and medium bulls), 10 yearling bulls:100 cows, and 35 calves:100 cows.

Results from the GSPE analysis program (Table 7) for the Kanuti NWR Block provided a population estimate of 842 moose (SE = 146.1) and a density of 0.31 moose/mi^2 (0.12 moose/km^2). The estimated densities by sex and age were 0.09 bulls/mi^2 (0.03 bulls/km^2), 0.15 cows/mi^2 (0.06 cows/km^2), and 0.06 calves/mi^2 (0.02 calves/km^2). Yearling bull densities were 0.01 moose/mi^2 (0.0 moose/km^2). Assuming a 50/50 sex ratio for yearlings, total yearling density in the survey area is expected to be twice that of yearling bulls, or 0.02 yearlings/mi^2 (0.01 yearlings/km^2). Bull:cow ratios and calf:cow ratios generated from the GSPE program are presented in Table 8.

Results of previous moose population surveys conducted on Kanuti NWR in 1989, 1993 (Martin and Zirkle 1996), and 1999 (Stout 2000) are displayed with the 2004 estimate in Table 9 and Fig. 6. Sightability correction factors (SCFs, Gasaway et al. 1986) were calculated for the 1989 and 1993 surveys, resulting in SCFs of 1.0 and 1.14, respectively. The 1993 population estimate without the SCF was 1,759 moose (±321; 90% CI). A one-tailed t-test comparing the 1999 and 2004 survey results indicated that there was not a statistically significant decline in total moose numbers between years (t = 0.05, df = 514, p = 0.48; degrees of freedom employed in calculations in 2004 used total number of survey units for all blocks because all units were used to calculate the variance for GSPE statistics).

"Remainder GMU" Block Results

Thirty-one of the 696 units were surveyed in the "Remainder GMU" block. Eighteen of the surveyed units were in the "H" stratum. A total of 89 moose were observed with a composition of 42 cows, 28 bulls, and 19 calves. Twenty-four (57%) of the cows were not accompanied by calves, 17 (40%) had a single calf, and 1 (2%) had twins. Population estimates for the "Remainder 24" block were associated with high variability because of the small sample size relative to the entire block. An estimated 749 moose occupied the block, for a density of 0.21 moose/mi^2 (0.08 moose/km^2). Bull, cow, and calf estimates are in Table 10 and ratio estimates can be found in Table 11.

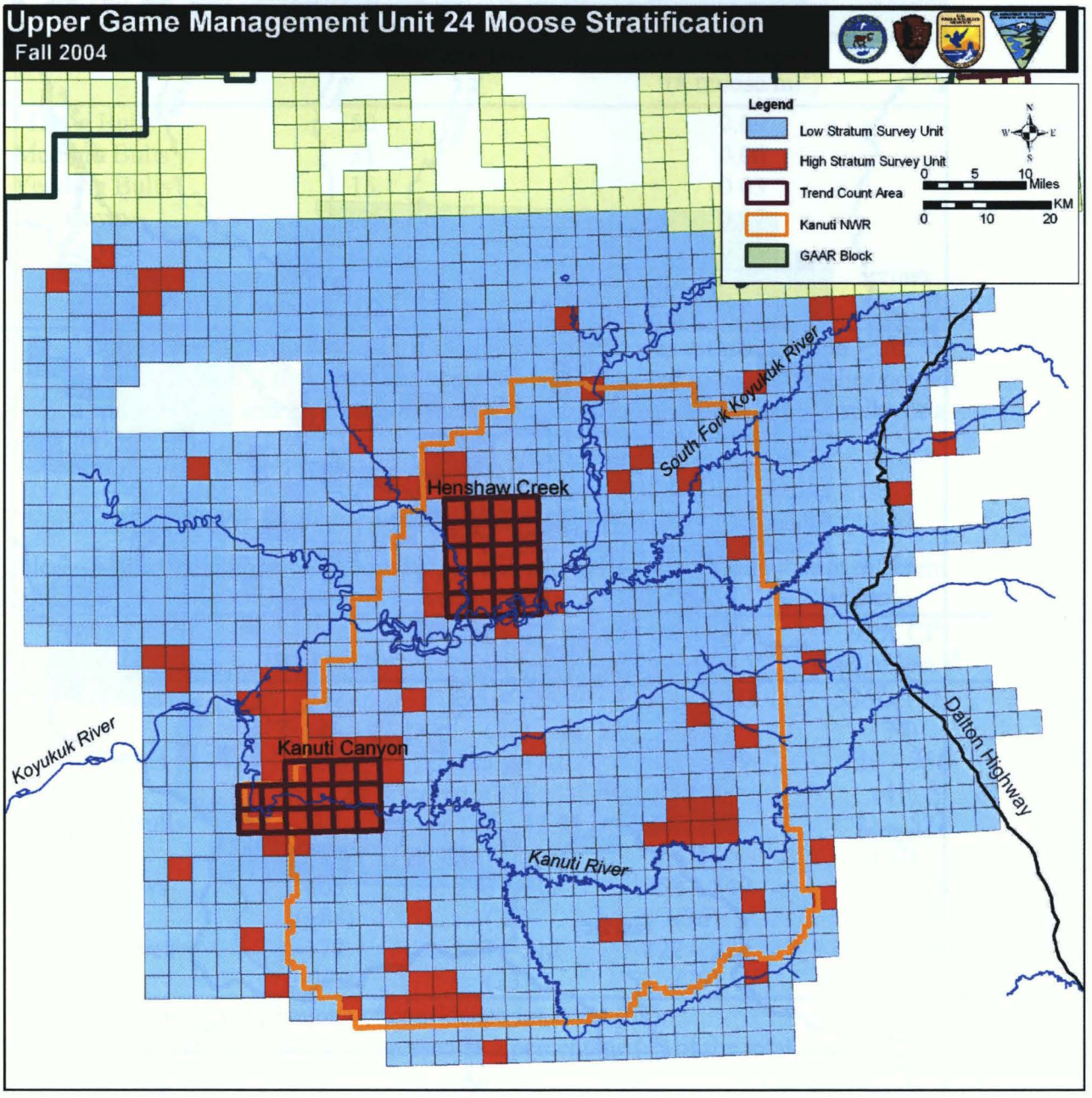

Figure 4. Stratification of survey units in the Kanuti and "Remainder GMU 24" survey blocks, Northern GMU 24 moose survey, Fall 2004. Units within the GAAR block were all placed in the low density stratum.

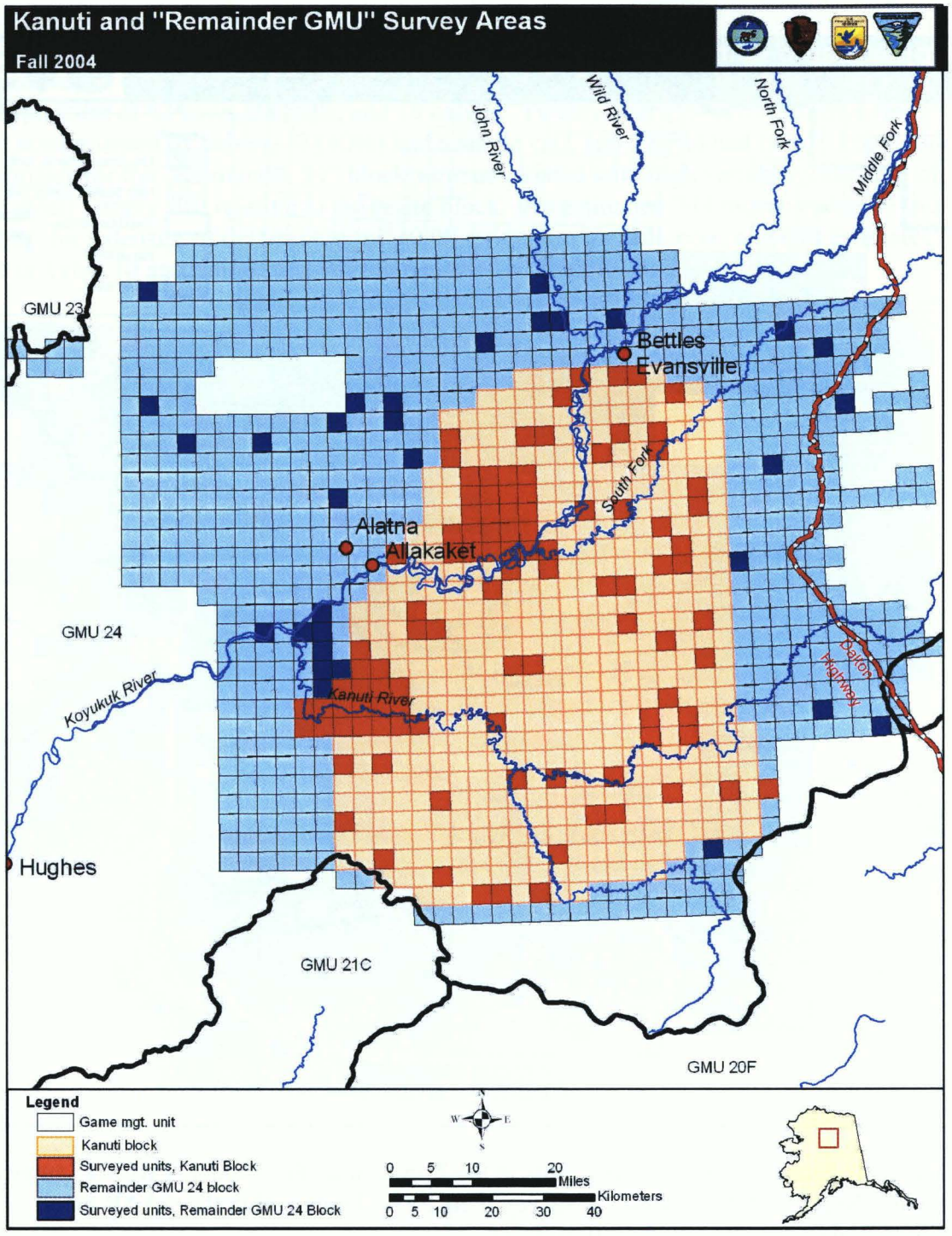

Figure 5. Randomly selected and surveyed units in the Kanuti and Remainder GMU survey blocks, Northern GMU 24 moose survey, Fall 2004.

Table 6. Summary of moose observed on the Kanuti NWR, Alaska, during a population survey conducted from 30 October – 7 November, 2004.

	# observed	Observed density[b] (# moose/mi^2)
Large Bulls[a]	50	0.09
Medium Bulls[a]	31	0.06
Yearling Bulls[a]	15	0.03
Cows	145	0.27
Calves	51	0.09
Total	292	0.53

[a] Bulls were classified as large if their antler spread was estimated to be ≥ 50 inches, medium if they their antler spread was estimated to be < 50 inches but not a spike or fork, and a yearling if their antler conformation was either a spike or a fork.

[b] Based on 546 mi^2 (103 surveyed units, 5.3mi^2 average unit area)

Table 7. Estimated number of moose by sex and age in Kanuti NWR moose at different confidence intervals, 30 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
Total Moose	842 (±146.1)	655 – 1030 (22)	602 – 1083 (29)	556 – 1129 (34)
Total Bulls	252 (±52.8)	185 – 320 (27)	165 – 339 (34)	149 – 356 (41)
Yearling Bulls	37 (±7.8)	27 – 47 (27)	24 – 49 (35)	21 – 52 (42)
Total Cows	403 (±88)	290 – 517 (28)	258 – 549 (36)	230 – 576 (43)
Total Calves	172 (±30.8)	133 – 212 (23)	122 – 223 (29)	112 – 233 (35)

[a] Upper and lower bounds of confidence intervals (CI).

[b] The confidence interval expressed as a percentage (±) of the total estimate.

Table 8. Estimated ratios of moose at different confidence intervals in Kanuti NWR, Alaska, 30 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
All Bulls:100 Cows	62 (±14)	44 – 80 (29)	39 – 85 (37)	35 – 90 (44)
Yearling Bulls:100 Cows	9 (±2)	6 – 11 (32)	5 – 12 (41)	4 – 13 (49)
Calves:100 Cows	46 (±11)	32 – 61 (31)	28 – 65 (39)	25 – 68 (47)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Table 9. Summary of moose population estimates for the Kanuti National Wildlife Refuge, 1989, 1993, 1999, and 2004.

	2004	**1999**	**1993**	**1989**
Survey Area (miles^2)[a]	2,710	2,715	2,644	2,615
Population Estimate	842	1,003	2,010	1,172
Range of Estimate[b]	602 – 1,083	794 – 1,211	1,567 - 2,453	867 - 1,476
Moose Density (moose/mile^2)	0.31	0.37	0.76	0.45
Bulls:100 Cows	62	59	61	64
Yearling Bulls:100 Cows	9	4	8	4
Calves:100 Cows	46	30	33	17

[a] Survey areas vary among years depending on how survey units were delineated and how units intersected the refuge boundary. Units extending beyond the boundary were considered "in" the refuge, even if much of the unit was outside the boundary.
[b] 90% confidence interval

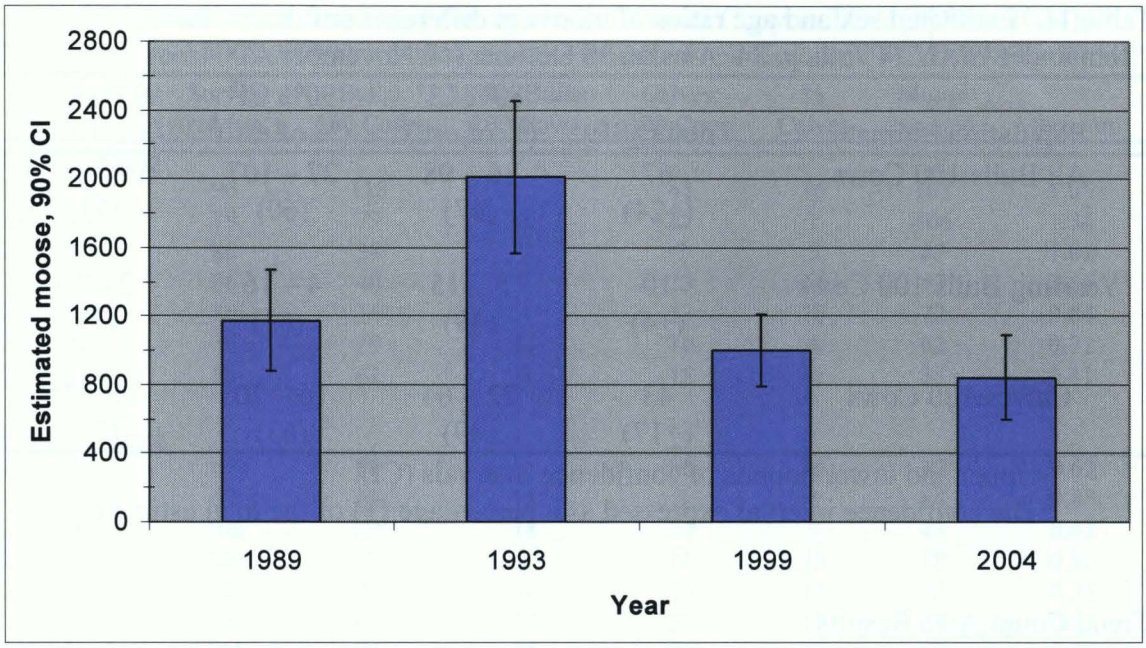

Figure 6. Moose population estimates for Kanuti NWR, Alaska 1989 - 2004. Error bars represent the range of the 90% CI. Methods differed among years, with standard Gasaway surveys conducted in 1989 and 1993 and modified Gasaway-VerHoef surveys conducted in 1999 and 2004.

Table 10. Estimated numbers of moose at different confidence intervals in "Remainder GMU 24" block, upper Game Management Unit 24, Alaska, 30 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
Total Moose	749 (±230.6)	453 – 1,044 (39)	369 – 1,128 (51)	297 – 1,201 (60)
Total Bulls	259 (±74.7)	163 – 354 (37)	136 – 381 (47)	112 – 405 (57)
Yearling Bulls	40 (±11.6)	25 – 55 (37)	21 – 59 (47)	17 – 63 (57)
Total Cows	375 (±140.4)	195 – 555 (48)	144 – 606 (61)	100 – 650 (73)
Total Calves	162 (±43.7)	106 – 218 (35)	90 – 234 (44)	76 – 247 (53)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Table 11. Estimated sex and age ratios of moose at different confidence intervals in "Remainder GMU 24" block, 24, Alaska, 30 October – 7 November, 2004.

Population estimate	Total (±SE)	80% CI[a] (% of est.)[b]	90% CI[a] (% of est.)[b]	95% CI[a] (% of est.)[b]
All Bulls:100 Cows	67 (±24)	36 – 98 (47)	27 – 107 (60)	19 – 115 (71)
Yearling Bulls:100 Cows	10 (±4)	5 – 15 (49)	4 – 16 (63)	2 – 18 (75)
Calves:100 Cows	43 (±17)	22 – 64 (49)	16 – 70 (63)	11 – 75 (75)

[a] Upper and lower bounds of confidence intervals (CI).
[b] The confidence interval expressed as a percentage (±) of the total estimate.

Trend Count Area Results

The Kanuti Canyon TCA was surveyed on 1 and 4 November, and the Henshaw Creek and Middle Fork Koyukuk TCAs were surveyed 30 October – 1 November. Results for 2004 and earlier surveys are presented in Table 12. Number of moose counted, density, and all ratios were higher in the Henshaw Creek TCA than in the Kanuti Canyon TCA. More moose were observed in the Middle Fork Koyukuk TCA compared to the other two TCAs, but ratios were similar and generally fell between those calculated for Kanuti Canyon and Henshaw Creek. The one exception was that the bull:cow ratio in the Middle Fork Koyukuk TCA (38 bulls:100 cows) was lower than ratios seen in the Kanuti Canyon TCA (41 bulls:100 cows) or Henshaw Creek TCA (76 bulls:100 cows).

The bull:cow ratio in the Kanuti Canyon TCA was lower than the estimated refuge-wide ratio in 2004, while the bull:cow ratio in the Henshaw Creek TCA was higher than the refuge-wide estimate. A similar relationship existed for the yearling bull ratio in these TCAs compared to the refuge estimate. The calf:cow ratios in both TCAs were lower than that estimated for the entire refuge.

Table 12. Results of moose trend surveys in the Kanuti Canyon TCA (1988 – 2004), the Henshaw Creek TCA (1991 – 2004), and the Middle Fork Koyukuk TCA (1987 – 2004).

Regulatory year	Survey Area (mi^2)	Bulls: 100 Cows	Yrlg. Bulls: 100 Cows	Calves: 100 Cows	% Calves	Moose counted	Moose/mi^2
Kanuti Canyon							
1988-1989	96	118		41	16	101	1.05
1992-1993	79	77	8	27	1	106	1.34
2000-2001	86	38	7	7	5	87	1.01
2001-2002	86	40	9	23	14	57	0.66
2002-2003	86	16	4	13	10	72	0.84
2003-2004	86	29	11	10	6	62	0.72
2004-2005	86	41	0	18	11	35	0.41
Henshaw Creek							
1991-1992	67	80		30	14	42	0.62
1992-1993	67	58	11	5	3	64	0.85
2000-2001	106	129	18	24	9	43	0.41
2001-2002	106	106	0	31	13	38	0.36
2002-2003	106	72	6	28	14	36	0.34
2003-2004	106	68	15	29	15	67	0.63
2004-2005	106	76	15	33	16	69	0.65
Middle Fork Koyukuk River							
1987-1988	78	49	5	21	13	104	2.16
2000-2001	77	13	0	43	27	62	0.81
2001-2002	77	36	9	18	12	34	0.44
2002-2003	77	0	0	33	25	24	0.31
2003-2004	113	23	9	24	16	104	0.92
2004-2005	113	38	6	22	14	110	0.97

DISCUSSION

Total area

Composition data summarized at the beginning of this report for the total area are not remarkably different from the separate survey blocks of the GAAR or the Kanuti NWR, and interpretation of the results is no different. The high bull:cow ratios reported are consistent with low levels of exploitation of bulls by hunters. Moderate calf:cow ratios in the range of 25 - 45 calves:100 cows are not remarkable, but the estimated calf:cow ratios were considerably higher than those observed in the 1999 survey and suggest productivity was higher for the 2004 cohort. High productivity in the spring of 2004 was corroborated by spring twinning surveys, fall calf:cow ratios observed in surveys conducted in the lower Koyukuk River drainage in 2004 (Stout 2004*a*, 2004*b*), and twinning surveys conducted regionally (pers. comm. M. Keech and D. Young [ADF&G]).

The Kanuti NWR block and the remainder of the total area surveyed in 2004 (not including the GAAR block) are roughly comparable to the total area surveyed in 1999, (6,388 mi^2 [16,545 km^2] in 2004 versus 8,390 mi^2 [21,730 km^2] in 1999; Stout 2004*a*). This combination of the Kanuti and "Remainder GMU 24" blocks is referred to as the

Bettles Block. Much of the decrease in survey area size between the 1999 and 2004 surveys was due to the non-inclusion of habitat that was considered to be "non/poor habitat" for moose (e.g., bare ground, steep rocky slopes). Moose density declined from 0.32 moose/mi^2 (0.12 moose/km^2) in 1999 to 0.25 moose/mi^2 (0.10 moose/km^2) in 2004 in the Bettles Block (Appendix 1). One could argue that the effect of removing ~2,000 mi^2 (5,180 km^2) of relatively poor habitat from the survey area would bias the density data upward, if any direction at all. The ~22% decline in the moose population density estimate (1999 versus 2004) for the Bettles Block was a greater relative decline than what was observed within the Kanuti Block (~16% decline); however, sample size was reduced in the Bettles Block in 2004, particularly in the "Remainder GMU 24" portion. In 1999, 194 units were surveyed (108 in the Kanuti Block and 86 in "Remainder GMU 24"), and in 2004, 134 units were surveyed (103 in the Kanuti Block and 31 in "Remainder GMU 24"). The high variance associated with the small sample size in the "Remainder GMU 24" block is evidenced in the wide confidence intervals displayed in Tables 10 and 11. This could account for the smaller decline that was observed in the Kanuti Block, where sample size only differed by 5 units between surveys and habitat may be of higher quality given the numerous riparian areas and wetlands on the refuge. From a regional perspective, the decline in the upper Koyukuk River drainage since the early to mid-1990s (30% – 50%; Martin and Zirkle 1996, Stout 2000, Woollington 1998, Osborne 1995, Stout 2004*a*), was greater than the decline (15% – 20%) that was observed in the higher moose density areas of the lower Koyukuk River drainage (below Hughes) during that same time.

GAAR block

This was the first large-scale survey in this portion of GAAR. Based on personal observations of participating biologists and historical observations, we anticipated this entire area to have low moose density. Information from this survey will be invaluable in guiding future survey efforts and variance in future surveys should be reduced as a result. Even so, given the low density of moose in the area, stratification will still be a problem because of the combination of moose movement and the low number of survey units that contain moose. This will likely result in a large variance in the number of moose in units classified as "H". Additionally, some variance was, and will be, caused by the clumped distribution of moose, as is evidenced by our results in 2004 when the majority of units within GAAR contained 0 moose while one unit contained 18.

Bull:cow ratios (71 bulls:100cows) were high during the 2004 survey, though not surprisingly so for a largely unhunted population of moose (Rausch et al. 1974). Calf:cow ratios (25 calf:100 cows) were midway between levels expected in a stable (20 calves:100 cows) and a growing moose population (30 calves:100 cows; ADF&G and the Koyukuk River Moose Hunters' Working Group 2001).

It is difficult to evaluate the moose population in the NPS survey area because there are little statistical data from the area with which to compare population levels or sex and age composition. Nonetheless, relative to moose populations in other regions of Alaska, the moose densities observed in the GAAR survey area (0.19 moose/mi^2 [0.07 moose/km^2])

are very low. The nearest historical population surveys occurred on the Kanuti NWR, just to the south of the GAAR survey area, results of which are included in this report. The 1999 moose density there was found to be nearly twice (0.37 moose/mi^2 [0.14 moose/km^2]) that found in the GAAR survey area in 2004.

Kanuti NWR block

This was the fourth population survey on the Kanuti NWR, and results indicate a decline in the moose population since its peak in 1993. However, variability around the estimates has been high, resulting in overlapping 90% CIs for all years except 1993. This indicates that only during 1993 can we be 90% certain that there is a difference in the moose population. The 1993 peak may be related to greater than normal numbers of caribou on the refuge during the winter of 1992 – 1993, which provided an alternate prey source for wolves and relieved the predation pressure on moose. Refuge records indicate that about 60,000 Western Arctic Herd caribou moved onto the western Kanuti Flats in November 1992 for about two weeks, and 1,200 – 2,000 remained on the refuge until late April. Favorable winter conditions during the winter of 1991 – 1992 may also have contributed to improved survival and increased recruitment, resulting in higher moose numbers in 1993. Snow depth in Bettles in March 1992 was only 16.8 inches (42.7 cm; http://climate.gi.alaska.edu/climate/Location/TimeSeries/Data/bttSd), considerably lower than the average long-term early March snow depth of 30 inches (76.2 cm) recorded in Bettles for the years 1971 – 2000 (Natural Resources Conservation Service 2005).

Observed densities of moose in sampled units were lower in both strata in 2004 than in 1999, but the decline was more pronounced in the "L" stratum. The observed density in the "H" stratum declined from 0.79 moose/mi^2 (0.31 moose/km^2) in 1999 to 0.70 moose/mi^2 (0.27 moose/km^2) in 2004 (11% decline), while the observed density in the "L" stratum declined from 0.39 moose/mi^2 (0.15 moose/km^2) in 1999 to 0.26 moose/mi^2 (0.10 moose/km^2) in 2004 (33% decline). The estimated moose density for Kanuti NWR declined by 0.08 moose/mi^2 (0.03 moose/km^2) between the two surveys. The ratios of bulls, yearling bulls, and calves increased in 2004 (Table 9).

The 2004 survey bull:cow ratio (62 bulls:100 cows) achieved the objective of at least 30 - 40 bulls:100 cows in the upper Koyukuk region (ADF&G and the Koyukuk River Moose Hunters' Working Group 2001). In addition, the 2004 calf:cow ratio (46 calves:100 cows) was the highest ever observed during population surveys on the refuge, and is above the level considered sufficient to support population growth (30 – 40 calves:100 cows; ADF&G and the Koyukuk River Moose Hunters' Working Group 2001). However, snow conditions during the winter of 2004 – 2005 may have resulted in high over-winter mortality of calves. The Natural Resources Conservation Service and local area residents reported unusually high snow depths and snow water content in 2004, sometimes breaking records, throughout the winter (McClure 2005).

Trend Count Areas

The number of moose observed and the bull:cow and calf:cow ratios in the Kanuti Canyon TCA generally declined since the late 1980s, while the number of moose observed and population ratios in the Henshaw Creek TCA generally increased since trend surveys were reinitiated in 2000. Bull:cow ratios have been consistently high in the Kanuti Canyon and Henshaw Creek TCAs, indicating a low level of exploitation by hunters. Bull:cow ratios remaining above 50 bulls:100 cows for all years, and the highest calf:cow ratio was observed in 2004.

Relatively few moose (<100) are typically counted in these two TCAs, making it difficult to interpret results since the ratios are based on a small number of moose. Results are also influenced by local habitat characteristics; the Kanuti Canyon TCA burned in 1972 and the Henshaw Creek TCA burned in 1991, resulting in very different seral stages, and potentially the attractiveness of the two areas to moose. Maier et al. (2005) modeled moose density in Alaska relative to landscape characteristics and found that the density of moose was positively correlated with burns between 11 – 30 years old. The burn in the Henshaw Creek TCA was 13 years old in 2004, and was just entering the period when moose density would be expected to increase. In contrast, the Kanuti Canyon TCA burned > 30 years prior to the 2004 survey, exhibiting an age after which old burns cease to attract a disproportionate number of moose.

The confounding influences of fire history in the TCAs, and the inability to statistically analyze TCA trend data, indicate that it may be better to spend resources surveying randomly selected units on an annual basis to gather sex and age ratio and population estimates for the refuge. Surveying 50 random units allocated between the two strata, rather than 36 units subjectively located in TCAs, would likely provide more valuable information than the existing trend data even if variance around the estimate was high due to small sample size.

The results of the Middle Fork Koyukuk TCA are more difficult to interpret than the other two TCAs. Moose density and bull:cow ratios were substantially greater in 1987 - 1988 in comparison to later years. Moose density and bull:cow ratios were lowest in 2002-2003 but have since increased (Table 10). No trend is apparent for the cow: calf ratio in the Middle Fork Koyukuk TCA. While a downward trend in moose numbers from 1987 – 2004 is apparent, yearly data from 2000 – 2004 fluctuate widely. These data suggest that either the small sample sizes obtained do not provide a complete picture of population dynamics in the TCA or that local, transitory environmental parameters radically affect moose occupancy of the area. The TCA is located in the Middle Fork Koyukuk River valley which is deep, wide, and bordered by precipitous, high mountains. Although no studies of moose movements have been conducted in the area, it is likely that moose in the area are greatly influenced by snow depth. We speculate that as snow depth increases, moose are driven to lower elevations where taller browse species are still available above the snow. The effects of this movement may have far-reaching consequences for the population since moose are probably more vulnerable to predation when they are concentrated, and accessibility to them by human and wildlife predators is

enhanced. Results from TCA surveys support this theory, since the lowest moose densities reported occurred in the winters of 2001 – 2002 and 2002 – 2003, when the accumulated fall snow depth was comparatively low, and the highest in 2004 when snow was deepest. A study of moose movements in the area will be necessary to understand the effects of snow depth on moose habitat use in the TCA and associated risks incurred as animals move to less secure habitats.

One historical study of moose populations in the vicinity of the Middle Fork Koyukuk TCA was completed in 1987, following the Gasaway method (Gasaway et al. 1986). All trend counts conducted since then used the methodology modified by VerHoef (2001, 2002). Although comparisons of data collected using these two techniques are problematic, trend data indicate that the moose density and the bull:cow ratio in the Middle Fork Koyukyk TCA declined since surveys were initiated. Interestingly, it appears that the calf:cow ratio has remained relatively constant during these years.

MANAGEMENT IMPLICATIONS

User group conflicts and declining moose densities in the Koyukuk River drainage prompted the ADF&G to organize an advisory planning group to address moose hunter concerns within the Koyukuk River drainage (ADF&G and the Koyukuk River Moose Hunters' Working Group 2001). Several major hunting regulation changes were adopted by the State Board of Game and the Federal Subsistence Board in 2002 and 2004 in the Koyukuk drainage that addressed user conflicts, over-harvest of cows, and declining bull:cow ratios. However, the regulatory changes were never expected to increase moose numbers. Moose population increases will only be achieved if calf survival and/or yearling recruitment exceed adult mortality. Regulation changes included implementation of several limited-drawing permit-hunt areas, stringent meat salvage requirements, and shortening (with the potential for emergency closure) the fall and winter antlerless moose seasons (Office of Subsistence Management 2003, 2004). Resource user concerns, as well as the overall low density of moose in the survey area, suggest that a conservative approach to moose management in the upper Koyukuk region is warranted.

Because moose in GMU 24 are an important resource, land and wildlife managers will require up-to-date estimates of moose population size and trends to best address demands for this resource. Given current funding, this can be best achieved by conducting periodic aerial surveys following a statistically rigorous protocol, such as those presented by Gasaway et al. (1986) or Ver Hoef (2001, 2002). Data from these surveys provide a defensible base upon which to build management decisions. Ideally, surveys would be conducted annually, but due to the high costs of aerial surveys, this schedule may be difficult to maintain. One reasonable alternative would be a 2 - 3 year survey schedule. Cooperation between State and Federal agencies in conducting these surveys will allow sharing of resources, thereby making surveys more feasible.

Similarly, coordinating aerial moose surveys among Federal and State agencies will provide valuable insight into moose population dynamics in a much broader area then

could be achieved by a single agency. This concerted effort will allow comparison of population trends among adjacent areas to gain insight into region-wide moose population dynamics and distribution. Coordinated surveys will also help to standardize survey methodology and simplify interpretation of results.

Additional research such as studies on mortality, movement, reproductive status, and habitat availability and quality would further our understanding and improve management of moose in the upper Koyukuk River drainage. Moose movement in GMU 24 is not quantifiable by aerial population surveys. In other parts of Alaska and northwest Canada, moose have been found to be either migratory or resident, with migratory components traveling average distances ranging between 22 – 76 miles (35 – 123 km) between seasonal ranges (Mauer 1998, Keech et al. 2000). The distance moose move in GMU 24 is unknown, but would be useful in evaluating localized changes in population levels. Information on moose movements, particularly in response to weather, would also be useful in delineating populations, evaluating harvest, and ultimately in proposing harvest regulations.

COSTS

The costs of the survey in the northern portion of upper GMU unit 24E were shared by the NPS, ADF&G, FWS, and BLM. Survey costs in Gates of the Arctic National Park and Preserve including the Alatna, John and North Fork Koyukuk rivers were provided by the NPS (Table 13). Flight times to complete the survey are presented in Table 14. Costs incurred by Kanuti NWR and ADF&G are in Tables 15 and 16, respectively.

Table 13. Costs of an aerial survey to estimate moose sex and age composition and population level in Gates of the Arctic National Park and Preserve including the Alatna, John and North Fork Koyukuk rivers during October and November 2004.

Item Description	Cost
Avgas provided by Bettles Lodge (1500 gal@$4.49/gal)	$6700
Groceries for moose survey (10 people for 10 days)	$1194
Fuel for truck in Bettles	$122
Park plane (Cessna 185)	$504
Park plane (Husky)	$3727
Charter time (Maule M-7) Yukon Eagle Air	$1512
Charter time (Supercub) Arctic Air Alaska	$9109
Charter time (Supercub) Caribou Air Service	$2695
OAS administrative costs	$1755
Satellite Phone Bill	$88
Software for Garmins (Moving map)	$214
TOTAL	$27620
GRAND TOTAL	$27620

Table 14. Flight times of survey planes in Gates of the Arctic National Park and Preserve including the Alatna, John and North Fork Koyukuk rivers during October and November 2004.

Plane	Survey Time
Sample unit survey	
PA-18	46.8
PA-18	16.13
PA-18	~ 4.0
Husky	44.9
Maule M-7	7.2
Misc.	
C-185	3.6 (Shuttle gear and personnel between Coldfoot and Bettles)

Table 15. Costs and flight time incurred by Kanuti NWR during the 2004 moose population survey. Cost does not include groceries present in the Kanuti NWR bunkhouse prior to the survey or 341 gallons of aviation provided by the NPS. Flight hours include shuttle time between Fairbanks and Bettles.

Item Description	Cost	Flight hours
Contract Scout	$2,191	12.3
Contract Maule M-7	$3,780	18.0
USFWS SuperCubs	$4,797	57.8
USFWS Cessna 206	$4,611	31.8
Fuel cost	$4,249	NA
Groceries	$ 397	NA
TOTAL	$20,025	

Table 16. ADFG expenses including funds from a Challenge Cost Share grant from BLM – Aerial moose population estimation and classification survey in GMU 24 during October and November 2004.

Item Description	Cost
Avgas provided by Bettles Lodge	$180
Groceries for moose survey	$369
Charter time (Maule M-7) Yukon Eagle Air	$3770
Charter time (Supercub) Tundra Air	$2166
G. Kuhn - Commercial Air Transit, Wright Air Service	$270
TOTAL	$6755
GRAND TOTAL	$6755

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REFERENCES

Alaska Department of Fish and Game and the Koyukuk River Moose Hunters' Working Group 2001. Koyukuk River Moose management plan 2000-2005. Unit 24 and the northern portion of Unit 21D. 37 pp.

Ballard, W., J.S. Whitman, and D.J. Reed. 1991. Population dynamics of moose in south-central Alaska. Wildl. Monogr. 114. 49 pp.

BLM, USFWS, and Ducks Unlimited, Inc. 2002. Kanuti/Ray Mountains/Hogatza River earth cover classification. BLM-Alaska Technical Report 28. BLM/AK/ST-02/009+6500+931. Anchorage, AK. 85 pp.

Dale, B.W., L.G. Adams, and R.T. Bowyer. 1994. Winter wolf predation in a multiple ungulate prey system, Gates of the Arctic National Park, Alaska. Pages 223-230 *in* L. Carbyn, S. Fritts and D.R. Seip, editors., Ecology and conservation of wolves in a changing world. Proceedings of the 2nd international symposium on wolves. Edmonton, Alberta.

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.

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

Keech, M.A., R.T. Bowyer, J.M. Ver Hoef, R.D. Boertje, B.W. Dale and T.R. Stephenson. 2000. Life-history consequences of maternal condition in Alaska moose. Journal of Wildlife Management 64: 450-462.

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.

Martin, P.A. and A.H. Zirkle 1996. Moose population estimate: Kanuti National Wildlife Refuge, November 1993. Unpublished FWS report, Fairbanks, AK. 10 pp.

Mauer, F.J. 1998. Moose migration: northeastern Alaska to northwestern Yukon Territory, Canada. Alces 34(1): 75-81.

McClure, R. 2005. Alaska snow survey report: May 1, 2005. Unpublished NRCS report, Anchorage, AK. 34 pp.

Natural Resources Conservation Service 2005. Alaska snow survey report, March 1, 2005. USDA NRCS report, Anchorage, AK. 30 pp.

Osborn, T. 1992. Summary and analysis of the moose census data collected along the Dalton Highway Corridor in 1991. Unpublished report. Alaska Department of Fish and Game. Fairbanks, Alaska. 5 pp.

Osborne, T.O. 1995. Unit 24 moose management progress report of survey–inventory activities. Pages 453–463 *in* M.V. Hicks, editor. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-23-5, W-24-1 and W-24-2. Study 1.0. Juneau, Alaska.

Office of Subsistence Management. 2003. Management regulations for the harvest of wildlife on federal public lands in Alaska. 163 pp.

_____. 2004. Management regulations for the harvest of wildlife on federal public lands in Alaska. 132 pp.

_____. 2005. Western Interior Alaska Regional Advisory Council, Fisheries meeting materials, October 4-5, McGrath, Alaska. 165 pp.

Rausch, R.A., R.J. Sommerville, and R.H. Bishop. 1974. Moose management in Alaska. Nat. Can. 101: pp. 705-721.

Rolley, R.E. and L.B. Keith. 1980. Moose population dynamics and winter habitat use at Rochester, Alberta, 1965-1969. Can. Field-Nat. 94:9-18.

Saperstein, L. 2002. Moose trend surveys in the upper Koyukuk River drainage 2001: Kaunti Canyon, Henshaw Creek, Wild River, and Middle Fork Koyukuk Trend Areas: progress report FY03-01. Unpubl. USFWS report, Fairbanks, AK. 15 pp.

_____. 2005. Kanuti National Wildlife Refuge 2005 wolf survey results: March 23-27. Unpubl. USFWS report, Fairbanks, AK. 5 pp.

Stephenson, R.O. 1978. Characteristics of exploited wolf populations. Alaska Department of Fish and Game Final Report, Federal Aid in Wildlife Restoration. Projects W-17-3 through W-17-8, Job 14.3R. Juneau, AK. 21 pp.

Stout, G.W. 2000. ADF&G Memorandum to David James, Wildlife Management Coodinator, summarizing results of the 1999 moose survey in GMU 24. May 12, 2000, Fairbanks, AK, 26 pp.

_____. 2003. Unit 24 wolf management report. Pages 223-231 in C. Healy, editor, *Wolf management report of survey and inventory activities 1 July 1999-30 June 2002*. Alaska Department of Fish and Game. Juneau, AK.

_____. 2004*a*. Unit 24 moose management report. Pages 542–565 *in* C. Healy, editor. Moose management report of survey and inventory activities 1 July 2001–30 June 2003. Alaska Department of Fish and Game. Project 1.0. Juneau, Alaska.

_____. 2004*b*. Unit 21D moose management report. Pages 462–495 *in* C. Healy, editor. Moose management report of survey and inventory activities 1 July 2001–30 June 2003. Alaska Department of Fish and Game. Project 1.0. Juneau, Alaska.

Van Ballenberghe, V. 1987. Effect of predation on moose numbers: A review of recent North American studies. Swed. Wildl. Res. (Suppl.) 1:431-460.

Van Ballenberghe, V., and W.B. Ballard. 1997. Population dynamics. Pages 223-245 *in* A. W. Franzmann and C.C. Schwartz, editors., Ecology and management of the North American Moose. Wildlife Management Institute. Smithsonian Institution Press, Washington, D.C.

VerHoef, J.M. 2001 Predicting finite populations from spatially correlated data. 2000 Proceedings of the Section on Statistics and the Environment of the American Statistical Association, pp. 93-98.

VerHoef, J.M. 2002. Sampling and geostatistics for spatial data. Ecoscience 9(2):152-161.

Woolington, J.D. 1998. Unit 24 moose management progress report of survey–inventory activities. Pages 421–433 *in* M.V. Hicks, editor. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-24-4 and W-24-5. Study 1.0. Juneau, Alaska.

APPENDIX 1.

GMU - 24 Upper Koyukuk River Drainage population estimation surveys.

Regulatory year	Survey area (mi^2)	Bulls: 100 cows	Yearling bulls:100 cows	Calves:100 cows	Twins/100 cows with calves	Percent calves	Moose	Moose/mi^2
1989–1990[a] Kanuti NWR	2615	64	4.1	16.5	n/a	9.2	1172 (878–1467)	0.45
1993–1994[a] Kanuti NWR	2644	61	8.0	33.0	n/a	17.0	2010 (1716–2304)	0.76
1999–2000 Kanuti NWR	2714	59	4.4	30.2	n/a	16.7	1003 (794-1211)	0.37
1999-2000 Bettles block	8390	65	4.9	27	n/a	14.7	2662 (2012-3313)	0.32
2004–2005 Kanuti NWR	2710	62	8.6	46	n/a	20.7	842 (602–1083)	0.31
2004-2005 GAAR block	5106	71	7.8	25	n/a	13.3	1072 (816–1328)	0.21
2004-2005 Bettles block	6388	65	9.3	45	n/a	21.4	1596 (1071–2121)	0.25
2004-2005 Total block	11494	65	8.6	35	n/a	17.8	2810 (2178–3441)	0.24

[a] Martin and Zirkle 1996.