FEDERAL AID FINAL
RESEARCH PERFORMANCE REPORT

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
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Alaska Department of Fish and Game
Wildlife Restoration Grant

PROJECT TITLE: Evaluating options for improving GSPE performance and developing a sightability correction factor

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I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

The geospatial population estimator (GSPE) uses finite population block kriging (Ver Hoef 2001) to estimate the abundance of moose. GSPE does not employ a sightability correction factor (SCF) for moose that are undetected in surveyed units (Kellie and DeLong 2006). Instead, based on the relationship between sightability with search intensity established in Gasaway et al. (1986), GSPE minimizes sightability error through high search intensity (8–10 minutes/mi^2) and focuses estimation on observed moose. Thus, GSPE estimates of population abundance are often referenced as estimates of "observable" moose abundance.

In practice, the GSPE technique is rarely conducted at the search intensity for which it was designed. A review of GSPE surveys in Interior Alaska indicated that most conscientious pilot-observer teams apply a maximum average search intensity of 6.5–7 minutes/mi^2 (Kellie and DeLong 2006), but some GSPE surveys conducted in Interior Alaska reported search intensities as low as 3.8 minutes/mi^2 (Fig. 1). Thus, it is likely that GSPE surveys conducted at a search intensity <8–10 minutes/mi^2 are underestimating abundance. Further, at low search intensity, different survey conditions can lead to substantial variation sightability among surveys (Gasaway et al. 1986), creating a nontrivial source of bias in population trends. Ultimately, accurate estimation of population abundance and trend is needed when population estimates are near thresholds for management action (e.g., intensive management population objectives). Consequently, the development and documentation of techniques to measure and combine SCFs with GSPE is a high priority for the Alaska Department of Fish and Game (ADF&G).

Prior to this study, almost all sightability-corrected GSPE estimates in Interior Alaska applied “fixed,” or static, SCFs developed during other moose surveys. These fixed SCFs were multi-year SCF composites measured in Game Management Unit (GMU) 19D (Keech 2012) or GMU 20A (Boertje et al. 2009). However, surveys in these 2 areas were conducted at high search intensity by very experienced pilot-observer teams (Fig. 1). Extrapolation of those SCFs to abundance estimates from other survey areas, or survey years, assumes similar search intensity, habitat, wind, light, frost, and snow conditions as well as consistent pilot-observer expertise. Thus, this assumption was violated routinely and it is questionable whether applying fixed SCFs improved the accuracy of population estimates.

A review of SCF studies across Interior Alaska suggests that sightability for winter moose surveys can range from 1.0 to 1.8 (Table 1), depending on search intensity, survey conditions, habitat, and pilot-observer experience. Search intensity, snow conditions, and vegetation cover were the major factors affecting SCF in prior studies with radiocollared moose (Gasaway 1977, 1978; Gasaway et al. 1979, 1986). Those studies clearly showed that SCFs of 1.0 to 1.1 (i.e., high sightability) were only achieved when experienced pilot-observer teams searched at 10–12 minutes/mi^2 in early winter with moderate to good snow conditions and forest-shrub mixtures indicative of Interior Alaska.

Ideally, SCF estimation should 1) be based on survey-specific information, 2) minimize additional survey cost, and 3) be easily integrated with the GSPE survey methodology. Survey-specific sightability correction is vital to accurate estimation of abundance at search intensities <8 minutes/mi^2 because conditions vary among survey areas and years. Survey-specific SCF estimation using both radio collars (Boertje et al. 2009, Keech 2012) and intensive search areas (Kellie and DeLong 2006:Appendix A) have been described and implemented in a few surveys. However, no comprehensive documentation on these techniques is available to standardize field methods. Further, no attempt to model survey-specific sightability based on covariates (e.g., search intensity, canopy cover) has been attempted. Modeled SCFs may be a low-cost alternative to radio collar and intensive searches if SCF estimation is within acceptable levels of accuracy and precision.

Finally, incorporation of SCF into GSPE estimates of population abundance improves the accuracy of estimates, but also reflects the actual, but lower, precision resulting from error in both SCF and GSPE estimation. GSPE precision has not been reviewed since the method was first applied in 1997. There are now enough GSPE surveys available to review GSPE estimate precision under a range of sample sizes, stratification approaches, and survey area sizes. Understanding the relative impact of sample size, survey area, stratification error, and moose density on GSPE precision may assist biologists and biometricians fine-tuning the performance of SCF and GSPE in combination.

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

ADF&G has conducted research on sightability in the past, but field-tested solutions for practical integration of SCF with the current GSPE method are not available. During the development of the Gasaway survey technique (Gasaway et al. 1986), the relationship between sightability and survey conditions was evaluated to develop recommendations for minimum survey conditions. They also evaluated differences in sightability between fall and spring surveys, and recommended avoiding spring surveys because of the low and variable sightability associated with bright sunlight (Gasaway et al. 1981). Finally, they examined sightability during the summer (i.e., May and June) and determined that abundance and composition estimation during this season was not practicable (Gasaway et al. 1985).

More recently, sightability correction specific to GSPE has been conducted on several fronts. Radiocollared moose were used in GMUs 19D and 20A to develop survey-specific (Keech et al. 2011) and "composite" SCFs (Boertje et al. 2009) that were calculated from trials conducted over several survey years (Table 2). As discussed above, these trials were conducted at high search intensity by very experienced observer-pilot teams (Fig. 1), making it difficult to extrapolate SCF results to the majority of other survey areas in the Interior. In cooperation with federal aid project 1.69, additional field and statistical methodology for conducting radio collar SCF estimates were documented for the 2012 GSPE survey in GMU 21E (Appendix A).

In addition to SCF estimation using only trials with radiocollared moose, the equations to calculate an intensive SCF were adapted from Gasaway et al. (1986) for use with the GSPE survey technique (Kellie and DeLong 2006:Appendix A). To our knowledge, this technique has not been used in Interior Alaska, but has been applied in western Alaska near Bethel (E. Wald, USFWS, unpublished data) and Nome (T. Gorn, ADF&G, unpublished data) and Palmer, Alaska (T. Peltier, ADF&G, unpublished data). Further, specific field methodology vital to consistent and correct application of the intensive SCF method has not been published. In cooperation with federal aid project 1.69, field and statistical methods for conducting an SCF estimate using intensive searches was performed in the 2009 GSPE survey in GMU 19A and thoroughly documented (Appendix B).

Concurrent, but separate, SCF modeling research was conducted in GMUs 16A and 16B to model sightability relative to various survey covariates during late winter GSPE surveys (Christ 2011). Christ (2011) determined that group size and percent vegetation cover provided more precise estimates than "fixed" SCFs currently employed in the region. The findings from this project, Christ (2011) and federal aid project 1.69 should be integrated to provide a single protocol manual for SCF estimation using the GSPE method.

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

OBJECTIVE 1: Evaluate the effects of search intensity on sightability.

I used a Microsoft Access® database to enter, analyze and archive data collected during sightability trials in Interior Alaska. There were 1,137 trials, as well as associated covariates and spatial polygons, entered from datasheets and maps crated during sightability trials conducted from 1976 to 1979 (Gasaway et al. 1981). I also gathered and entered sightability and covariate data from 491 trials conducted during GSPE surveys. This included trials conducted in GMUs 20A and 19D prior to this project and new trial data collected as part of this project from GMUs 20D, 24B, 19D and 21E (Table 2, Appendices A and C). The trials collected in GMU 21E were the first late winter GSPE sightability trials collected in the Interior Alaska.

The relationship between search intensity and sightability has been referenced in the handbook for conducting Gasaway moose surveys (Gasaway et al. 1986), and was pivotal to the GSPE survey design (see Section I). I examined this relationship among the original Gasaway sightability trials and among recent GSPE sightability trials using a general linear model with a binomial distribution. I included covariates for survey season (early or late winter) and moose density during both the Gasaway sightability trial period and the more recent GSPE sightability trials. I used group size from Gasaway units and moose density within the survey unit for an equivalent measure during the GSPE trials, understanding that these 2 metrics measure somewhat different dynamics related to sightability. Search intensity was normally distributed for both periods and did not require a transformation. I excluded trials where snow conditions were poor or where I did not have all available data (i.e., search area, search time or season).

There were 737 Gasaway trials (626 moose seen and 111 moose missed) and 442 GSPE trials (364 moose seen and 78 moose missed) available for analysis. Mean search intensity was 9.49 minutes/mi^2 (SE = 0.17) among Gasaway sightability trials and 8.60 minutes/mi^2 (SE = 0.10) among GSPE trials. There was no difference in the proportion of moose seen between Gasaway trials (84.9%) and GSPE trials (82.4%, P = 0.2479, z = 1.1555). Sightability (1/proportion seen) was 1.177 among Gasaway trials and 1.214 among GSPE trials. Sightability among the Gasaway trials was significantly related to both search intensity (P > 0.00001; z = 6.69) and season (P = 0.0037, z = -2.90) as well as marginally related to group size (P = 0.0645, z = 1.85). However, among GSPE trials, sightability was not related to either search intensity (P = 0.68, z = 0.41) or season (P = 0.68, z = 0.41) but was related to moose density in the unit (P = 0.02, z = 2.32). From these results, I conclude that search intensity and seasonal survey conditions are far less related to sightability using the current GSPE method than when using the Gasaway method.

OBJECTIVE 2: Evaluate the sensitivity of GSPE precision to different characteristics of survey design.

I worked with Brian Taras (ADF&G, DWC Region III) to examine how GSPE precision is affected by stratification and associated error, sampling ratio (high stratum units: low stratum units), moose density, sample size and survey area size. In general, the power of

GSPE to detect trends in population abundance is greater in areas with higher moose density and higher rates of population change. Based on the analysis of 3 survey areas selected to represent relatively high, moderate, and low moose densities, areas surveyed annually at current resource levels were able to detect moderate trends (4% change per year) with power = 0.80 and $\alpha = 0.05$ on the order of 7–10 years in high density areas (Fig. 2), 10–13 years when density was moderate (Fig. 3), and ~15 years where moose density was low (Fig. 4). Less time is needed to detect more dramatic trends. For example, an 8% change in moose abundance per year may be detectable in 5–7 years in areas of high moose density, 6–8 years in moderate densities and 9–10 years in low densities. In addition, monitoring smaller areas may offer some advantages for detecting trend because estimate precision improves when a much a higher proportion of the area is sampled. Further, in some survey areas where moose distribution is somewhat unpredictable (e.g., Unit 25D East) misclassification rates when stratifying can be high. Where this occurs, a simple random sample may yield an abundance estimate with higher precision than one from a stratified random sample (Fig. 5). Finally, we learned that confidence intervals associated with estimates of moose abundance in low density areas can, under some conditions, be biased low (i.e., estimated confidence intervals are tighter than they should be). Ultimately, specific recommendations for stratification, sampling and area delineation are too complex to provide general guidance and we recommend consulting with a biometrician when designing a specific monitoring program.

I have compiled a table of GSPE surveys in Interior and western Alaska across a gradient of survey variables to provide realistic expectations of precision under a variety of survey designs (Table 3). These values may be used by biologists and biometricians to design new surveys or modify existing surveys. Specifically, observed precision at given levels of sampling, moose density and survey area sizes may provide quantifiable sidebars when attempting to achieve a specific precision level in a new or existing GSPE survey area.

OBJECTIVE 3: <u>Develop a spatial sightability model using percent canopy cover generated from satellite imagery</u>.

I worked with Dr. Jay Ver Hoef (Ver Hoef Statistical Consulting Services) to develop a spatial SCF model using all Unit 20A and McGrath EMMA sightability trials conducted from 2001 to 2007. For our habitat covariate, I used the 2001 National Land Cover Data set (Homer et al. 2007) because it provided a 30 m-resolution vegetation classification for all of Alaska. I summarized vegetation using 2 classification systems (% spruce and % mature forest) where percentages were calculated as the number of 30-m pixels of that vegetation class within a GSPE sample unit divided by the total number of pixels in that sample unit. Jay Ver Hoef evaluated the effectiveness of these 2 classification systems as a covariate for sightability and chose percent forest to include in the model, using it in a nonlinear function:

$$1-\exp(-x/\alpha)$$

where x is % mature forest. After trying various values for α, Ver Hoef obtained the “best fit” for the nonlinear function, as determined by the smallest P-value, with $\alpha = 0.23$ ($P = 0.258$, $t = -2.24$) in a logistic regression that modeled sightability as a function of average search intensity during the survey, % mature forest in individual surveyed units, including random effects for year and UnitID to create correlation among observations within year for multiple measurements of the same UnitID within or among years (Fig. 6). The regression model estimates the relationship between probability of detection and the covariates search intensity (minutes/mi^2) and % mature forest (Fig. 7). The correction factor is:

$$f_c(\hat{\boldsymbol{\beta}}) = (1+\exp(\mathbf{x}_0'\hat{\boldsymbol{\beta}}))/\exp(\mathbf{x}_0'\hat{\boldsymbol{\beta}})$$

Where $\mathbf{x}_0$ is a vector of specified covariate values and $\widehat{\boldsymbol{\beta}}$ are the estimated regression coefficients. Then

$$\frac{\partial f_c}{\partial \hat{\boldsymbol{\beta}}} = \frac{1}{\exp(\mathbf{x}_0'\hat{\boldsymbol{\beta}})}\mathbf{x}_0$$

and:

$$\operatorname{var}[f_c(\hat{\boldsymbol{\beta}})] = \left(\frac{1}{\exp(\mathbf{x}_0'\hat{\boldsymbol{\beta}})}\right)^2 \mathbf{x}_0'\mathbf{C}\mathbf{x}_0$$

The development of a spatial SCF model was completed at the beginning of FY10. The spatial SCF has many merits including application to any GSPE survey area (covariates are available statewide), application to earlier GSPE surveys, and straightforward incorporation of SCF equations and covariate data into the existing WinfoNet computational framework and interface. However, the spatial SCF provides only a broad, generalized estimate of sightability for each survey area and does not reflect annual variation in sightability stemming from weather conditions or pilot experience. As a result, the spatial SCF model is likely least accurate when SCF correction is most necessary: during years when sightability is unusually high or low. At best, in situations where an intensive or radio collar SCF was not performed, the spatial SCF is a preferred alternative to the “fixed” SCFs, especially when examining long-term trends, because it can be applied to previous surveys and incorporate some survey-specific information (i.e., habitat and search intensity among surveyed units). Field application of alternative, survey-specific methods for estimating sightability were conducted and documented in Interior Alaska under federal aid project 1.69 (Appendices A and B).

OBJECTIVE 4: Writing reports.

Annual progress on this project was documented in federal aid progress reports and in the form of memos to area staff. I have included with this final report 4 memos.
Appendices A and B outline spring surveys conducted in cooperation with federal aid project 1.69 and describe the pre-survey, survey, and post-survey logistical and statistical considerations for conducting a radio collar SCF (Appendix A) and an intensive SCF (Appendix B) for a late winter survey. Appendix C summarizes the collection of radio collar sightability trials from 2008 to 2010 and provides datasheets that may be useful in radio collar SCF data collection. Finally, Appendix D describes a GSPE + SCF survey

conducted in a small survey area with one stratification level during early winter in GMU 19D.

IV. MANAGEMENT IMPLICATIONS

Based on the results of this project, it is clear that estimates of population abundance calculated using the GSPE should be accompanied by a survey-specific correction for sightability, including sightability precision. The relationship between search intensity and sightability, on which the GSPE approach is predicated, is not strong using the GPSE survey technique. As a result, even adherence to the recommended search intensity of 8–10 minutes/mi^2 may not result in a high rate of moose detection. In short, sightability must be remeasured for each combination of survey-specific conditions (i.e., weather, pilot-observer performance and habitat) if we desire to use GSPE abundance estimates for the management of moose populations.

I recommend that all future GSPE moose surveys apply either an intensive (Appendix B, Kellie and DeLong 2006) or radio collar (Boertje et al. 2009, Keech 2011, Appendices A and C) SCF and ensure adequate sampling to avoid spurious estimates of sightability. Application of a “fixed” SCF or reporting “observable moose” results in a nonsensical approximation of population abundance that is undermined by large, unmeasured error. For example, a “fixed” SCF of 1.21 is currently applied to most early winter GSPE estimates (without associated precision), but survey-specific SCFs within a single survey area ranged from 1.0 to 1.5 over 4 consecutive survey years (GMU 20A, Table 2). Application of a fixed SCF to all years elevates estimates of abundance but fails to correct for variation among estimates due to variable sightability among surveys. Failure to correct for variation in sightability can hinder trend detection or, worse, generate spurious results caused by trending detection rates rather than trending moose abundance. Further, accurate estimation of population abundance is needed for effective moose management. For example, the 2004 GSPE estimate in GMU 20A was 13, 566, 16,414 or 20,349 moose, depending on whether no SCF (i.e., perfect sightability), a fixed SCF (1.21), or a survey-specific, but under-sampled, SCF (1.50, n = 21) was applied. More importantly, the corresponding 4% harvest rate could be anywhere from 542 to 814 moose, greatly hampering our ability to inform management decisions. At a minimum, where survey-specific SCF is not measured, biologists should discuss their GSPE estimates and associated management applications in the context of the potential range of sightability (Table 2) and its effect on estimates of abundance and related management decisions.

Obtaining survey-specific SCFs in the field increases survey cost by about 20% (Appendix B and C). Both biologists and regional coordinators should be aware that accurate population estimation will require a higher cost than previously budgeted. Ultimately, incorporating SCF with the GSPE may result in fewer surveys to maintain accurate population estimation in the remaining surveys. To avoid unreasonably poor precision and spurious estimates of sightability, it is vital to use power analyses (Figs. 2–4) and existing SCF and survey information (Tables 2–3) a priori to ensure sufficient sampling for both GSPE and SCF estimation. GSPE and SCF performance can also be monitored during the survey to ensure that expected levels of precision are being achieved (Appendix B and C).

In this report, I compile statistical and logistical documentation for obtaining survey-specific SCFs using 3 different methods: radio collar, intensive, and spatial SCFs. However, for the spatial SCF, which models sightability based on search intensity and % mature forest, I recommend limiting its use to the areas where modeled data were collected (i.e., GMUs 19D and 20A). Modeled SCFs are especially appealing when they use common covariates and are capable of estimating sightability among previous surveys. Eventually, the spatial SCF model should be informed and tested by a biometrician using sightability trials conducted in a wider range of habitats, pilot experience levels and moose densities. Results from Christ (2011) and our own model results (see Objective 1) suggest that some measure of moose group size or local density may be a useful third covariate in sightability models.

Finally, the application of survey-specific SCFs to population estimation will result in less precise, but more accurate, estimates. Biologists should evaluate GSPE survey design, including SCF sampling, in their areas to optimize estimates of abundance relative to management objectives and desired level of precision. In some cases, to increase precision without increasing sampling effort, it may be necessary to reduce the size of the survey area. Monitoring population abundance is most useful in areas where moose density is likely to change over time (e.g., areas accessible to hunters), provided that these smaller areas include the entire winter range (e.g., areas used during severe winter conditions).

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

During this segment I reviewed SCF research conducted by ADF&G in Regions II, III, and V and incorporated that review into the final report. I also assisted with final review of 2 memos detailing field protocols for the radio collar (Appendix A) and intensive search (Appendix B) methods for obtaining a survey-specific SCF.

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

None.

VII. PUBLICATIONS

None.

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VIII. RESEARCH EVALUATION AND RECOMMENDATIONS

This research project, along with federal aid project 1.69 and work conducted by Christ (2011) provide a rich resource for the practical application of SCFs to GSPE estimates. At this point, ADF&G should prioritize biometrician and biologist staff to coauthor a department manual detailing planning, field and analysis methods for obtaining accurate estimates of moose population abundance. The following topics should be considered for this effort:

1) Approaches for conducting power analyses to optimize sampling for both the GSPE survey units and sightability trials.
2) Discussion of stratum-specific sightability estimation and alternative methods to conducting sightability trials in areas of extremely low moose density.
3) Discussion of the tradeoffs between intensive and radio collar approaches for SCF estimation.
4) Further examination and field testing of a modeled SCF.
5) Incorporation of up to 3 different formats and statistical SCF calculations into the WinfoNet interface currently used to calculate GSPE estimates.
6) Examples for all datasheets, spreadsheets, and calculations used in SCF/GSPE surveys, including an internet-based source for digital files.

TABLES

Table 1. SCF measured at different search intensities during early winter studies of sightability using radio collar trials in Interior Alaska from 1976 to 1979 (Units 20A/20B: Gasaway et al. 1986) and from 2001 to 2006 (EMMA: Keech et al. 2011, central Unit 20A: Boertje et al. 2009).

Search intensity (minutes/mi^2)	4–6	7–9		10–12
Survey area	20A/20B	EMMA	Central 20A	20A/20B
SCF	1.40	1.23	1.21	1.06
SCF range	1.26–1.80	1.17–1.33	1.00–1.50	1.05–1.07

Table 2. Measured sightability correction factors (SCFs) obtained in Interior Alaska from 2001–2012 using the GSPE survey technique. Sample sizes (*n*) reflect the number of opportunities for an observer-pilot team to detect a radiocollared moose using standard GSPE survey techniques. Detection rate represents the number of times a moose was detected divided by the sample size. SCF was calculated as 1/detection probability. Search intensity is for all GSPE survey units searched during the survey, except in southern Unit 20D (*) where it is the mean search intensity among GSPE units used in sightability tirals. Fall surveys were conducted from October through December and spring surveys were conducted from February through April. SCF for Unit 21E was estimated separately for GSPE stratification for high and low moose density. See Appendix A for details. Methods for obtaining SCF for the Unit 19D EMMA in 2012 are available in Appendix D.

Study area	Year	*n*	Detection rate (%)	SCF	se	Search intensity (min/mi^2)	Moose density (moose/mi^2)	Season
19D EMMA	2001	38	84.2	1.18	0.085	7.8	1.0	Fall
19D EMMA	2003	28	75.0	1.32	0.148	10.0	1.1	Fall
19D EMMA	2005	49	77.6	1.28	0.100	8.7	1.2	Fall
19D EMMA	2006	49	85.7	1.16	0.069	7.9	1.3	Fall
19D EMMA	2007	41	75.6	1.31	0.119	9.0	1.6	Fall
19D EMMA	2008	20	80.0	1.23	0.143	8.2	1.4	Fall
19D EMMA	2012	30	76.7	1.30	0.133	8.4	1.2	Fall
Central 20A	2003	18	83.3	1.13	0.130	9.0	3.5	Fall
Central 20A	2004	21	66.7	1.50	0.237	8.8	3.3	Fall
Central 20A	2005	17	82.6	1.21	0.139	8.7	3.2	Fall
Central 20A	2006	13	100.0	1.00	0.000	9.0	3.1	Fall
Southern 20D	2009	13	92.3	1.08	0.090	9.9*	2.5	Fall
Southern 20D	2010	21	90.0	1.11	0.083	9.7*	2.4	Fall
21E Low	2012	17	64.7	1.49	0.285	5.6	0.4	Spring
21E High	2012	30	90.0	1.11	0.069	7.3	4.1	Spring
Kanuti 24B	2008	27	77.8	1.29	0.135	7.1	0.3	Fall
Kanuti 24B	2010	21	95.2	1.05	0.053	6.6	0.4	Fall

Table 3. A collection of GSPE surveys conducted from 1997 through 2009. Survey areas are divided into 2 types: small (<1,000 mi^2) and large (>1,000 mi^2). Fall surveys were conducted from October through December and spring surveys were conducted from February through April. A fixed sightability correction factor (SCF) of 1.21 was assigned to fall surveys and 1.25 to spring surveys for comparisons with biological thresholds for moose density. Survey-specific SCFs (measured during survey) were used in Unit 19D and a composite (multi-year) area-specific SCF was used in Unit 20A.

Unit	Year	Survey name	Survey area (mi^2)	Area type	Season	No. units surveyed	Total units in survey area	% Surveyed	Estimated observable moose	90% CI as proportion of the mean	SCF used for total	Estimated total moose density (moose/mi^2)
12	2000	12 Northwest	2846	Lg	fall	60	473	12.7%	2,475	0.23	1.21	1.13
12	2001	12 Northwest	2865	Lg	fall	79	476	16.6%	2,204	0.15	1.21	0.96
12	2003	12 Northwest	2845	Lg	fall	69	473	14.6%	3,064	0.35	1.21	1.35
12	2005	12 Northwest	2845	Lg	fall	48	473	10.1%	2,129	0.15	1.21	0.94
12	2006	12 Northwest	2702	Lg	fall	89	449	19.8%	2,317	0.18	1.21	1.07
12	2008	12 Northwest	2702	Lg	fall	92	449	20.5%	3,225	0.18	1.21	1.44
12	2000	Tetlin	2973	Lg	fall	80	485	16.5%	844	0.20	1.21	0.34
12	2001	Tetlin	2954	Lg	fall	80	482	16.6%	1,443	0.20	1.21	0.59
12	2003	Tetlin	2954	Lg	fall	80	482	16.6%	1,317	0.19	1.21	0.54
12	2008	Tetlin	2954	Lg	fall	80	482	16.6%	1,843	0.20	1.21	0.75
19A	2001	19A Aniak	1731	Lg	spring	65	270	24.1%	1,197	0.21	1.25	0.86
19A	2005	19A SE	3874	Lg	spring	100	607	16.5%	1,083	0.17	1.25	0.35
19A	2008	19A SE	3874	Lg	spring	75	607	12.4%	1,703	0.28	1.25	0.55
19D	2004	19D East	4195	Lg	fall	99	695	14.2%	1,224	0.32	1.27	0.37
19D	2008	19D East	4195	Lg	fall	89	695	12.8%	1,715	0.28	1.27	0.52
19D	2001	19D EMMA	528	Sm	fall	87	87	100.0%	440	0.00	1.19	0.99
19D	2003	19D EMMA	528	Sm	fall	45	87	51.7%	424	0.19	1.35	1.09
19D	2004	19D EMMA	528	Sm	fall	87	87	100.0%	531	0.00	1.27	1.28
19D	2005	19D EMMA	528	Sm	fall	87	87	100.0%	479	0.00	1.30	1.18
19D	2006	19D EMMA	528	Sm	fall	87	87	100.0%	591	0.00	1.17	1.31
19D	2007	19D EMMA	528	Sm	fall	87	87	100.0%	662	0.00	1.33	1.67
19D	2008	19D EMMA	528	Sm	fall	43	87	49.4%	599	0.17	1.27	1.44
20A	1999	20A	5747	Lg	fall	86	987	8.7%	11,340	0.14	1.21	2.39
20A	2000	20A	5747	Lg	fall	114	987	11.6%	11,211	0.18	1.21	2.36
20A	2001	20A	5747	Lg	fall	78	987	7.9%	11,511	0.15	1.21	2.42
20A	2003	20A	5747	Lg	fall	112	987	11.3%	14,684	0.13	1.21	3.09
20A	2004	20A	5747	Lg	fall	129	987	13.1%	13,566	0.15	1.21	2.86

Unit	Year	Survey name	Survey area (mi^2)	Area type	Season	No. units surveyed	Total units in survey area	% Surveyed	Estimated observable moose	90% CI as proportion of the mean	SCF used for total	Estimated total moose density ($moose/mi^2$)
20A	2005	20A	5747	Lg	fall	123	987	12.5%	13,348	0.15	1.21	2.81
20A	2006	20A	5747	Lg	fall	115	987	11.7%	12,773	0.16	1.21	2.69
20A	2008	20A	5747	Lg	fall	158	987	16.0%	10,361	0.11	1.21	2.18
20B	2001	20B	9196	Lg	fall	138	1628	8.5%	10,261	0.17	1.21	1.35
20B	2003	20B	9196	Lg	fall	60	1628	3.7%	13,400	0.23	1.21	1.76
20B	2004	20B	9196	Lg	fall	73	1628	4.5%	13,810	0.28	1.21	1.82
20B	2006	20B	9196	Lg	fall	127	1628	7.8%	13,321	0.21	1.21	1.75
20B	2008	20B	9196	Lg	fall	127	1628	7.8%	14,838	0.16	1.21	1.95
20B	2008	FMA	315	Sm	fall	56	56	100.0%	417	0.00	1.21	1.60
20D	1999	20D North	3174	Lg	fall	96	540	17.8%	2,395	0.14	1.21	0.91
20D	2004	20D North	3174	Lg	fall	60	540	11.1%	1,929	0.25	1.21	0.74
20D	1998	20D South	1890	Lg	fall	40	319	12.5%	3,630	0.30	1.21	2.32
20D	2000	20D South	1890	Lg	fall	38	320	11.9%	3,932	0.17	1.21	2.52
20D	2001	20D South	1890	Lg	fall	39	320	12.2%	3,435	0.23	1.21	2.20
20D	2003	20D South	1890	Lg	fall	47	320	14.7%	5,493	0.29	1.21	3.52
20D	2005	20D South	1890	Lg	fall	59	320	18.4%	5,553	0.19	1.21	3.56
20D	2006	20D South	1890	Lg	fall	51	320	15.9%	7,243	0.22	1.21	4.64
20D	2008	20D South	1890	Lg	fall	59	320	18.4%	5,006	0.21	1.21	3.20
20D	2009	20D South	1890	Lg	fall	60	320	18.8%	4,633	0.17	1.21	2.97
20E	2004	20E Central	2178	Lg	fall	53	366	14.5%	802	0.19	1.21	0.45
20E	2005	20E Central	2178	Lg	fall	62	366	16.9%	1,097	0.19	1.21	0.61
20E	2006	20E Central	2178	Lg	fall	80	366	21.9%	979	0.19	1.21	0.54
20E	2000	20E West	1932	Lg	fall	72	333	21.6%	1,115	0.12	1.21	0.70
20E	2001	20E West	1932	Lg	fall	87	333	26.1%	915	0.17	1.21	0.57
20E	2003	20E West	1944	Lg	fall	78	333	23.4%	1,128	0.25	1.21	0.70
20E	2004	20E West	2452	Lg	fall	55	419	13.1%	1,435	0.22	1.21	0.71
20E	2005	20E West	2452	Lg	fall	80	419	19.1%	1,801	0.17	1.21	0.89
20E	2006	20E West	2452	Lg	fall	80	419	19.1%	2,399	0.19	1.21	1.18
20E	2007	20E West	2452	Lg	fall	82	419	19.6%	2,098	0.18	1.21	1.04
20E	2008	20E West	2452	Lg	fall	81	419	19.3%	2,040	0.15	1.21	1.01
21D	2001	21D Total	5526	Lg	fall	291	986	29.5%	8,922	0.13	1.21	1.95
21D	2004	21D Total	5526	Lg	fall	452	986	45.8%	7,967	0.04	1.21	1.61

Unit	Year	Survey name	Survey area (mi^2)	Area type	Season	No. units surveyed	Total units in survey area	% Surveyed	Estimated observable moose	90% CI as proportion of the mean	SCF used for total	Estimated total moose density ($moose/mi^2$)
21E	2000	21E East	5070	Lg	spring	100	822	12.2%	8,394	0.26	1.25	2.07
21E	2005	21E East	5070	Lg	spring	150	822	18.2%	4,673	0.17	1.25	1.15
21E	2009	21E East	5070	Lg	spring	150	822	18.2%	6,218	0.17	1.25	1.53
24B	1999	24 Kanuti	2714	Lg	fall	108	507	21.3%	1,188	0.26	1.21	0.53
24B	2004	24 Kanuti	2710	Lg	fall	103	507	20.3%	842	0.29	1.21	0.38
24B	2005	24 Kanuti	2710	Lg	fall	82	507	16.2%	1,025	0.43	1.21	0.46
24B	2007	24 Kanuti	2715	Lg	fall	150	508	29.5%	588	0.21	1.21	0.26
24B	2008	24 Kanuti	2715	Lg	fall	80	508	15.7%	872	0.23	1.21	0.39
25C	1997	25C	4643	Lg	fall	110	699	15.7%	2,270	0.15	1.21	0.59
25C	2007	25C	4643	Lg	fall	104	699	14.9%	3,019	0.24	1.21	0.79
25D	1999	25DE	2936	Lg	fall	102	553	18.4%	829	0.20	1.21	0.34
25D	2000	25DE	2936	Lg	fall	111	553	20.1%	740	0.27	1.21	0.30
25D	2001	25DE	2936	Lg	fall	114	553	20.6%	514	0.27	1.21	0.21
25D	2004	25DE	2936	Lg	fall	113	553	20.4%	943	0.20	1.21	0.39
25D	2005	25DE	2936	Lg	fall	121	553	21.9%	1,008	0.20	1.21	0.42
25D	2006	25DE	2936	Lg	fall	117	553	21.2%	799	0.17	1.21	0.33
25D	2007	25DE	2936	Lg	fall	110	553	19.9%	585	0.23	1.21	0.24
25D	1999	25DW	2269	Lg	fall	93	421	22.1%	862	0.19	1.21	0.46
25D	2000	25DW	2269	Lg	fall	92	421	21.9%	666	0.24	1.21	0.36
25D	2001	25DW	2269	Lg	fall	99	421	23.5%	651	0.24	1.21	0.35
25D	2004	25DW	2269	Lg	fall	93	421	22.1%	511	0.25	1.21	0.27
25D	2006	25DW	2269	Lg	fall	97	421	23.0%	417	0.21	1.21	0.22
25D	2008	BMA	530	Sm	fall	50	100	50.0%	175	0.13	1.21	0.40
25D	2009	BMA	530	Sm	fall	50	100	50.0%	221	0.16	1.21	0.50
25D	2008	BMA Ctrl	530	Sm	fall	51	100	51.0%	76	0.25	1.21	0.17

FIGURES

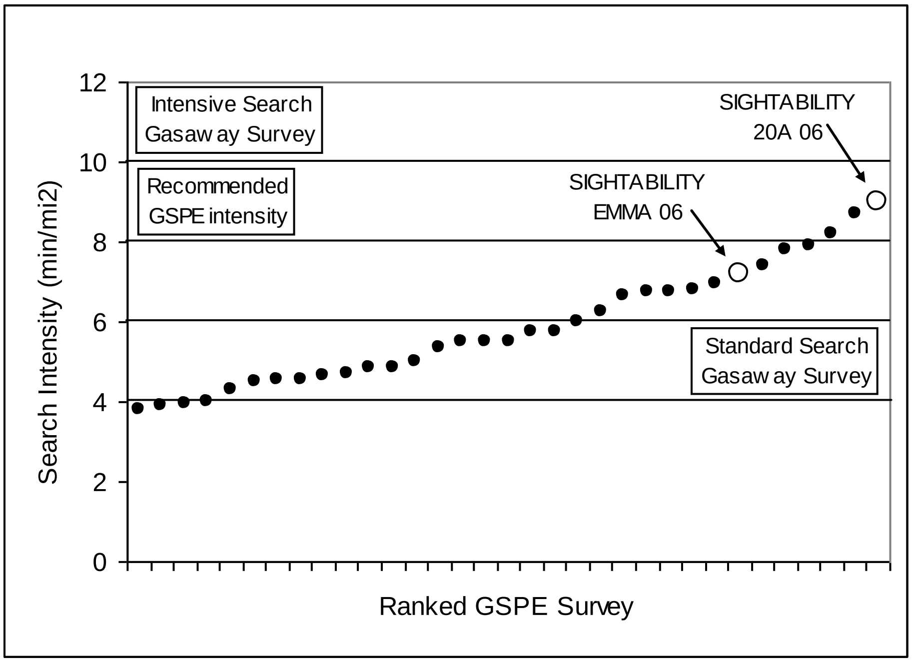

Figure 1. Average search intensity for 31 GSPE surveys conducted throughout Interior Alaska prior to 2006 (black) and for two 2006 surveys where SCFs were measured using radioed moose (white). Surveys with the highest search intensities were conducted in Units 19D (EMMA), 20A, and 20D. Recommended search intensities for Gasaway et al. (1986) surveys were 4–6 minutes/mi^2 for standard searches 10–12 minutes/mi^2 while a search intensity of 8–10 minutes/mi^2 was recommended for GSPE surveys (Kellie and DeLong 2006).

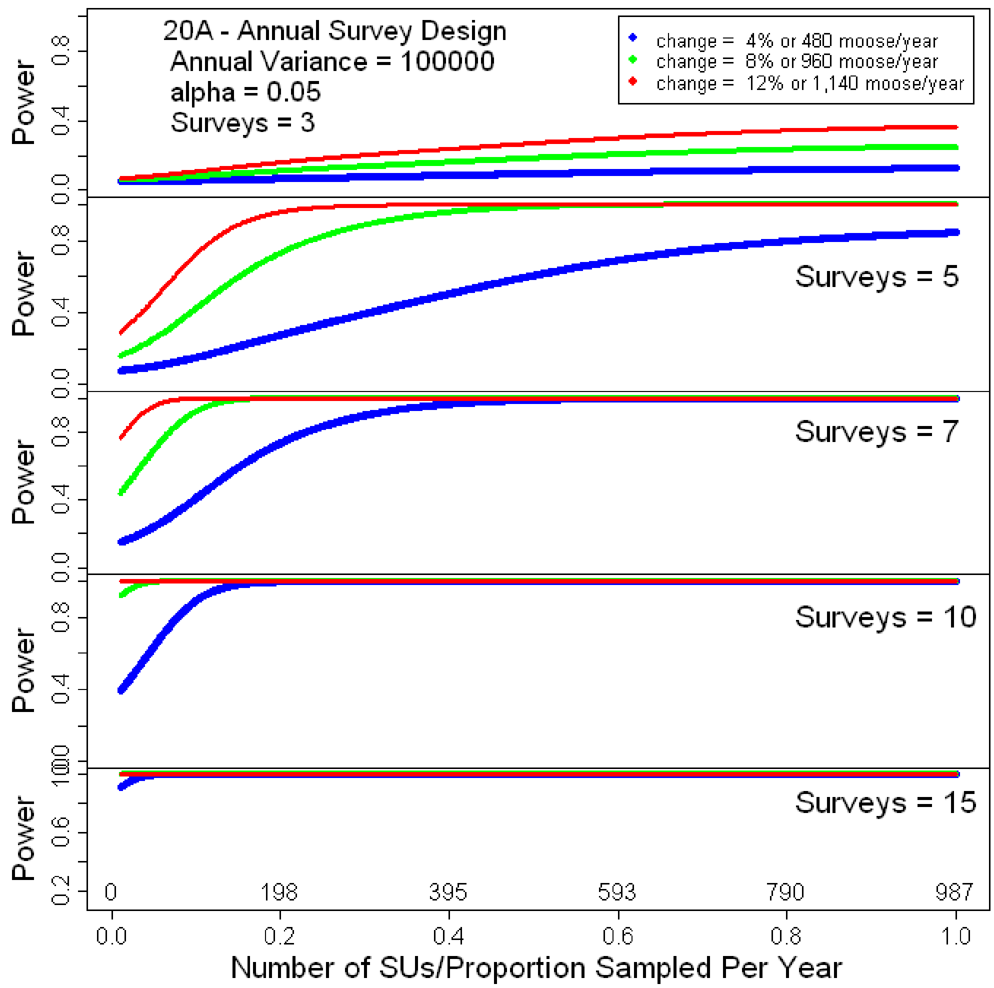

Figure 2. Estimated power to detect a trend in moose population abundance at high moose density (Game Management Unit 20A). Estimates vary based on the magnitude of trend (colored lines), the number of surveys conducted over the time period, and the proportion of sample units sampled during each survey. The horizontal axis is labeled with both the number of units sampled (upper number) and the proportion of units sampled (lower number).

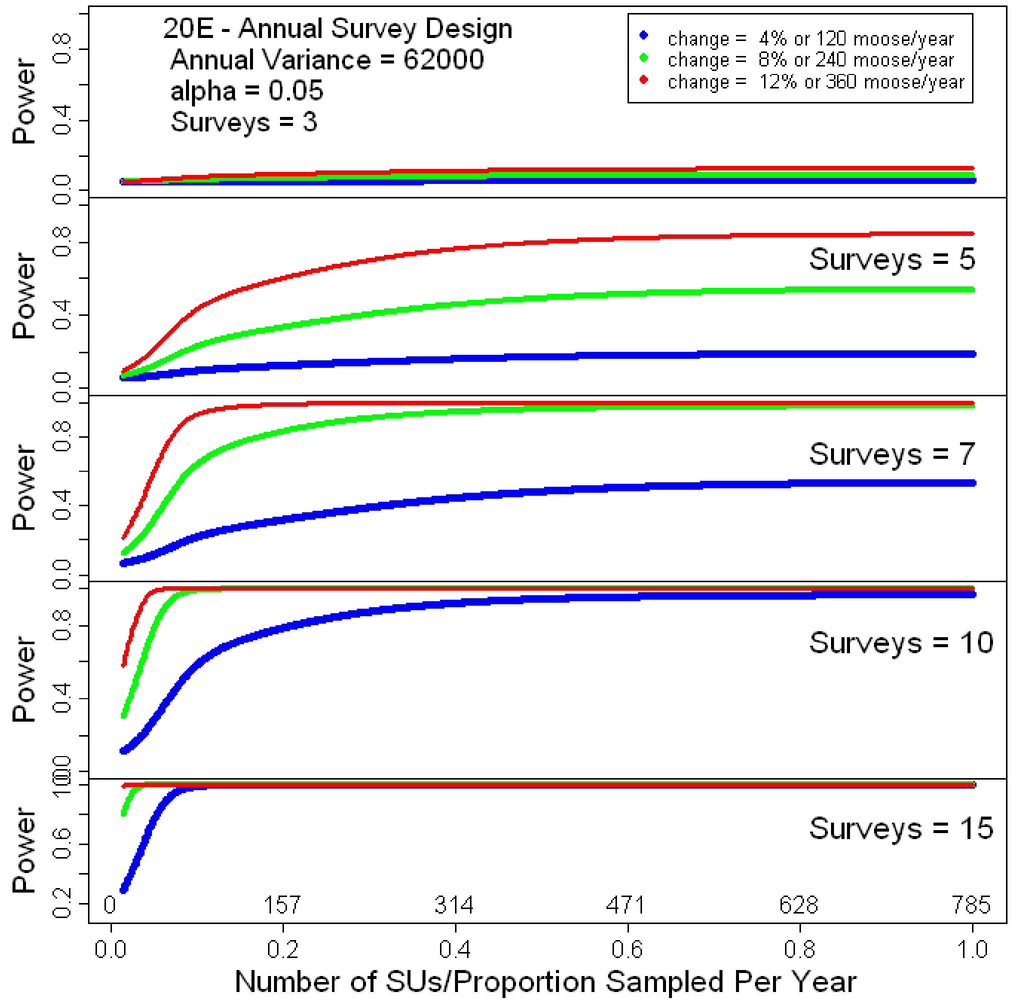

Figure 3. Estimated power to detect a trend in moose population abundance at moderate moose density (Game Management Unit 20E). Estimates vary based on the magnitude of trend (colored lines), the number of surveys conducted over the time period, and the proportion of sample units sampled during each survey. The horizontal axis is labeled with both the number of units sampled (upper number) and the proportion of units sampled (lower number).

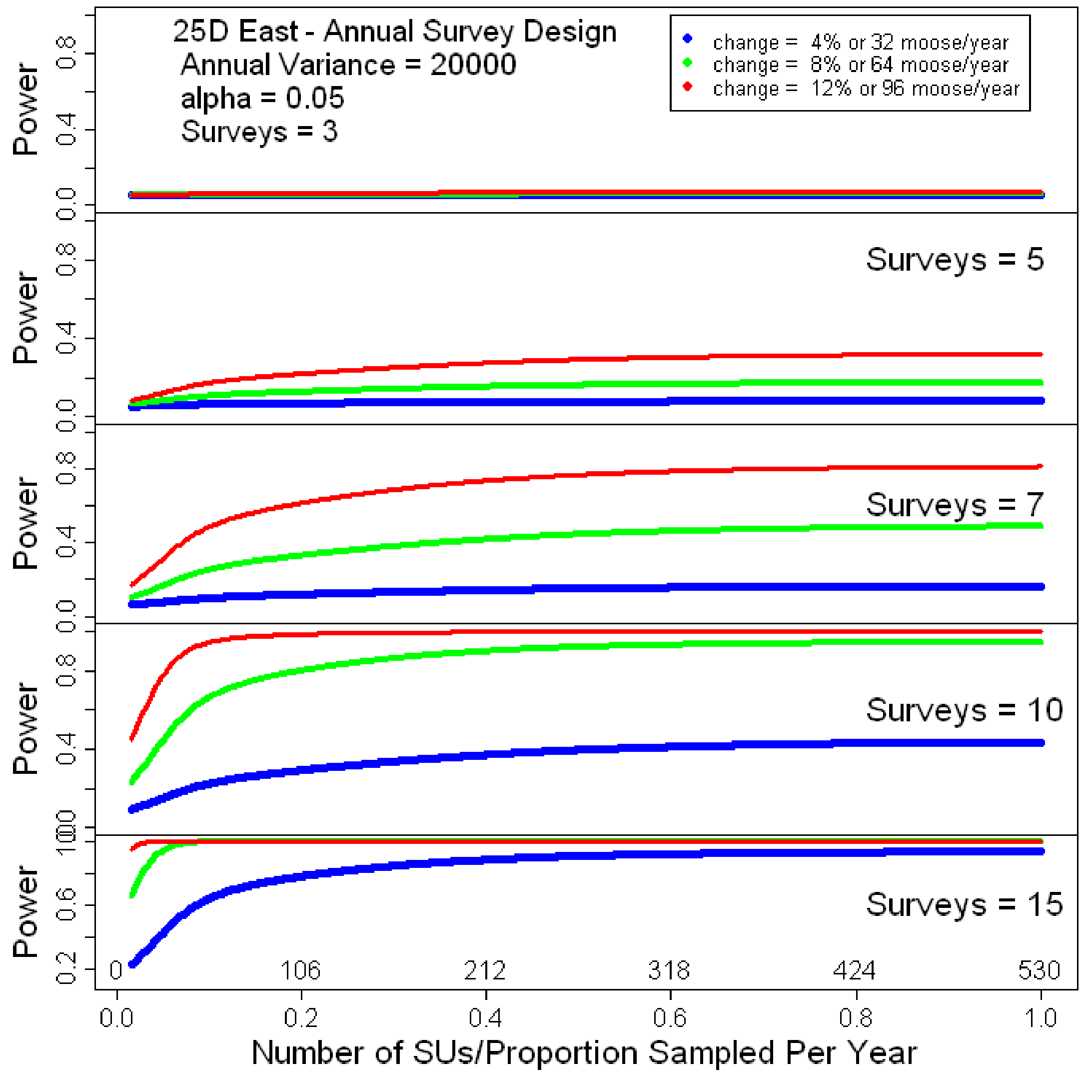

Figure 4. Estimated power to detect a trend in moose population abundance at low moose density (Game Management Unit 25D). Estimates vary based on the magnitude of trend (colored lines), the number of surveys conducted over the time period, and the proportion of sample units sampled during each survey. The horizontal axis is labeled with both the number of units sampled (upper number) and the proportion of units sampled (lower number).

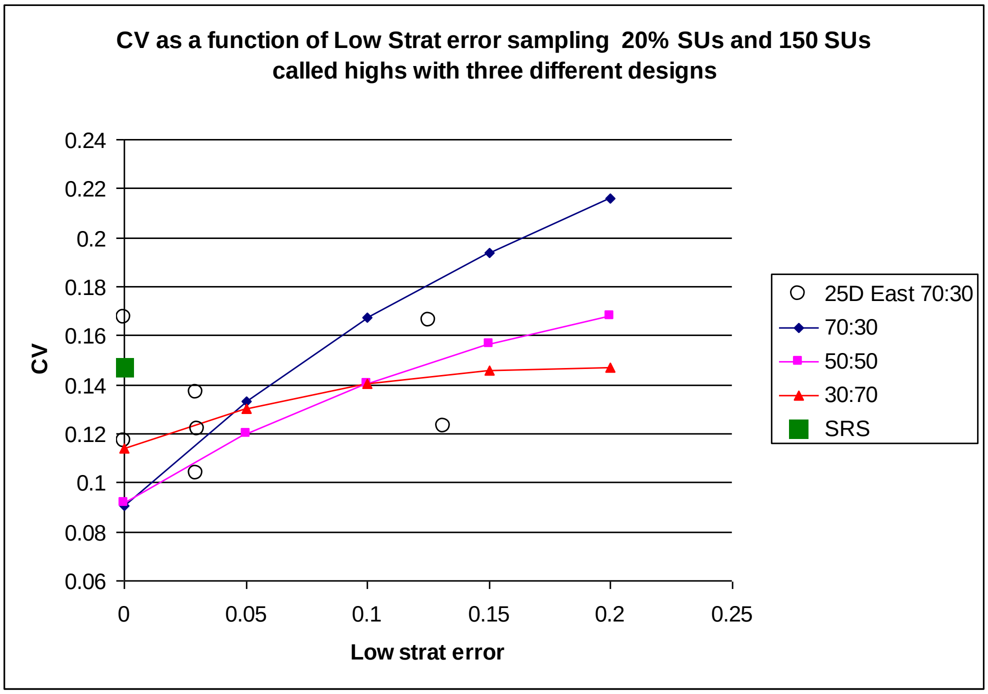

Figure 5. Simulated variation (CV) associated with estimates of moose population abundance at different percentages of stratification error in the low stratum. Three different sampling ratios of high stratum: low stratum GSPE units are illustrated (colored lines) as well as random sampling without stratification (green squares) using simulated data. Real survey data from Unit 25D East (open circles) are overlaid for context. In this example, 150 units are sampled, representing sampling 20% of a 530-unit survey area.

Solutions for Fixed Effects

Effect	Estimate	Standard Error	DF	t Value	Pr > |t|
Intercept	2.9715	1.6158	270	1.84	0.0670
EstSI	0.1308	0.09980	270	1.31	0.1910
funMatFor	-3.1296	1.3958	270	-2.24	0.0258

Solution for Random Effects

Effect	UnitID	Year	Estimate	Std Err Pred	DF	t Value	Pr > |t|
Year		2001	0.2756	0.3637	270	0.76	0.4491
Year		2003	-0.1601	0.3642	270	-0.44	0.6607
Year		2004	-0.5780	0.3965	270	-1.46	0.1460
Year		2005	-0.02397	0.3252	270	-0.07	0.9413
Year		2006	0.5594	0.3467	270	1.61	0.1078
Year		2007	-0.07292	0.3452	270	-0.21	0.8328

Figure 6. Model results from a general linear mixed model explaining the relationship between the probability of detecting a moose and covariates (Effect) during a standard GSPE survey. EstSI is the search intensity (minutes/mi^2) spent conducting the survey of the GSPE unit. FunMatFor is a nonlinear function (1-exp(−1* % mature forest/0.23) of the % mature forest within the GSPE unit. Year was included as a random effect. There were no survey units (UnitID) that were repeated within a year.

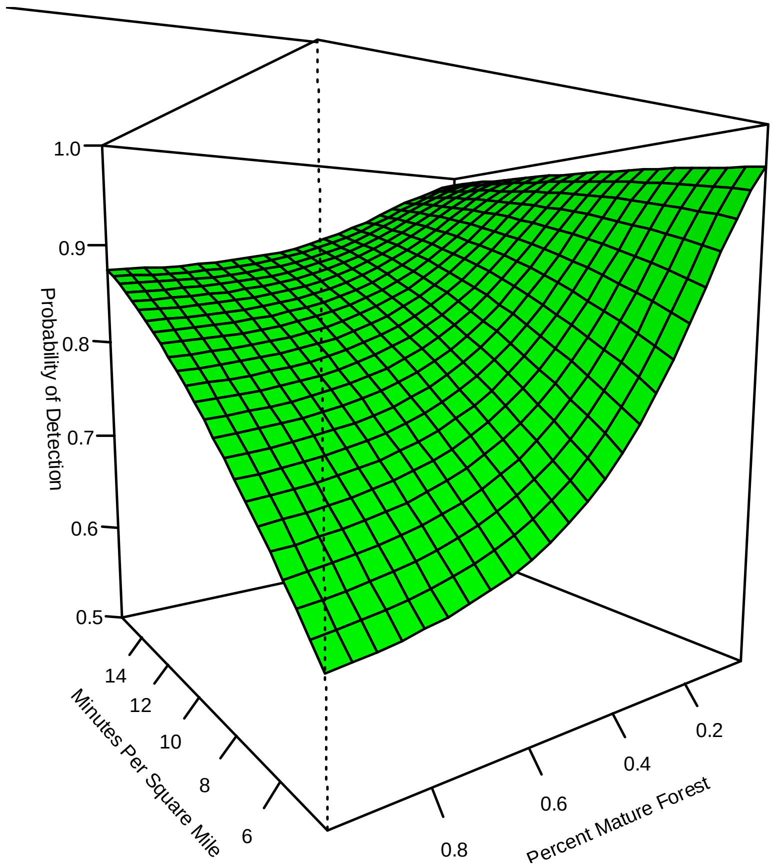

Figure 7. The modeled relationship between probability of detecting a moose using standard GSPE survey methods as a function of the % mature forest in the survey unit and the search intensity (minutes of survey per square mile surveyed).

IX. APPENDICES

APPENDIX A. Late Winter GMU 21E moose population estimate and sightability correction.

MEMORANDUM State of Alaska

Department of Fish and Game
Interior/Northeast Region, Fairbanks

TO:	Doreen I. Parker McNeill Management Coordinator Roger J. Seavoy McGrath Area Biologist Joshua M. Peirce McGrath Assistant Area Biologist	DATE:	September 10, 2014
THRU:	Scott M. Brainerd Research Coordinator	TELEPHONE:	459-7327
FROM:	Tom F. Paragi Wildlife Biologist Kalin A. Kellie Seaton Wildlife Biologist Brian D. Taras Biometrician Division of Wildlife Conservation Fairbanks	SUBJECT:	Unit 21E moose population estimate with sightability correction, March 2012

This memo includes the background, sampling strategy, logistics, survey-specific conditions, results, and discussion of the 2012 geospatial population estimator (GSPE) survey in the Grayling-Anvik-Shageluk-Holy Cross moose survey area of Game Management Unit 21E. As part of federal aid research project 1.69, we used radiocollared moose to estimate a sightability correction factor (SCF) for a late winter survey of a typically low-density (<1.1 moose/mi^2; Gasaway et al. 1992) moose population in western Interior Alaska. SCF estimates the proportion of moose not seen by observers during the standard aerial survey by means of radiomarked moose in randomly-selected and non-randomly assigned sample units (SU). The estimate of observed moose in Unit 21E from the GSPE was then corrected using a SCF to yield an estimate of total moose in the survey area and a variance that includes sampling and SCF components. Costs, list of people participating, and other population metrics were summarized by J. Peirce (memorandum 27 June 2012).

BACKGROUND

Moose surveys in Unit 21E have been used to estimate population size for calculating sustained yield (harvest) as a percentage of population. After a Unit 21E intensive management plan was established in 2010, moose surveys were also used to evaluate whether the population has declined below a density threshold (1.0 moose/mi^2 in the 5070 mi^2 survey area), which would activate wolf predation control to increase the moose population and its sustainable harvest (section 4B of the regulation 5 AAC 92.124). GSPE abundance estimates in Unit 21E have occurred in late February or early March 2000, 2005, and 2009. The 2000 survey used GSPE cells with a Gasaway et al. (1986) technique and 3 density strata, whereas the subsequent surveys used the GSPE technique (Kellie and DeLong 2006) and 2 strata.

Gasaway et al. (1986:31) partitioned the correction factor for sightability of moose into an observable component (SCF_0) estimated from standard and high intensity searches of selected plots and a "constant" component (SCF_c) as the remainder not seen from the air during high intensity searches. SCF_c was then estimated from radiomarked (uniquely identifiable) animals. This allowed estimates of observable moose to be corrected to the true population size. The GSPE is also based on observable moose but was predicated on the search intensity being high enough (8–12 min/mi^2; Ver Hoef 2000) that the number of moose not observed is negligible.

In practice, pilot-observer teams typically achieve <7 min/mi^2 during late winter surveys and the effect on sightability at low moose density is unknown. Gasaway et al. (1986:31) had estimated SCF_c for late winter surveys in the central Interior, but no estimate of late winter sightability in a GSPE using radio collars has been attempted in the sparsely forested habitats of western Interior Alaska. In March 2011 we used intensive searches on a random sample of SUs to estimate SCF_0 at low density in Unit 19A (Paragi et al. 2013), where moose winter range is primarily riparian habitat interspersed with sparse conifer forest and tundra.

Our study objective was to use radiocollared moose to estimate SCF in the western Interior during a late winter GSPE survey to estimate total moose abundance and the associated variance, with a desired relative precision of ≤25% of the mean at the 95% confidence level. We had deployed 54 radio collars on 24 males and 30 females in the Yukon-Innoko floodplain (Fig. 1) during March 2010 as part of a larger study on moose seasonal movements.

METHODS

Sampling for Stratification, Abundance Survey, and Sightability Trials

We used the 2009 stratification of SUs between high (≥3 moose expected) and low (0-2 moose expected) strata because no large burns or other obvious changes to habitat occurred in the survey area since then, with the exception that SUs 56, 67, 165, 167, 758, 880 and 910 were changed from lows in 2009 to highs in 2012 based on observations of >8 moose in 2005 or 2009 surveys. Although the depth and distribution of snow can influence moose distribution (e.g., Coady 1974), we did not measure snow depth during previous GSPE surveys and are unable to assess its influence on moose distribution among survey years. The rectangular SUs in the study area averaged 6.17 mi^2 (range due to longitudinal lines narrowing with increasing latitude: 5.99–6.35 mi^2).

To determine sample allocation for the 2012 GSPE survey, we used sample variances estimated from 2005 and 2009 moose surveys in Unit 21E with equations provided by Cochran (1977:106) and Gasaway et al. (1986:47–48) to optimally allocate sampled SUs between strata and estimate a sample size sufficient for attaining an estimate of observable moose with relative precision (RP) equal to $RP_{@95\%\ \text{confidence level}} = 0.15$ for, where:

$$RP_{@95\%} = \frac{SE}{Observable\ Moose\ Abundance} \times 1.96.$$

Using data from the 2005 survey, a sample size of 149 SUs was estimated as necessary to attain $RP_{@95\%} = 0.15$ at an optimal allocation of 63% H: 37% L. Using data from the 2009 survey, a sample size of 149 SUs was estimated as necessary to attain $RP_{@95\%} = 0.15$ at an optimal allocation of 85% H: 15% L. Funds existed to sample 150 SUs.

We chose a 75:25 sampling allocation because it is intermediate between 2005 and 2009 survey results; it is close to optimal (sample size difference of 2 SUs) if the more recent 2009 data reflect current moose counts from aircraft (Fig. 2), and it allocates a more than adequate number of SUs (n = 45) to the low stratum. We withheld 15 SUs (10% of sample) to fill spatial gaps remaining after selecting randomly136 SUs (erroneously 1 more than intended). Contrary to the optimal allocation, these non-random samples were allocated based on approximately a 20: 80 prevalence of H: L units in the survey area (3 H and 11 L]) because more spatial gaps were anticipated in the low stratum. Low-stratum units that share a boundary with high-stratum units are likely to produce above-average counts of moose. To avoid over-sampling edge units during non-random selection and potentially biasing high the population estimate, we used the ratios of edge: interior low-stratum units found in the study area (164 of 672, 24%) to guide our spatial selection (3 of 12, 25%) in the low stratum. To attain the overall 75:25 allocation we randomly sampled 110 high stratum SUs and 25 low stratum SUs; therefore, the 150 sampled SUs included 110 random highs, 3 non-random highs, 26 random lows, and 11 non-random lows for a 3:1 ratio (113 H: 37 L). Two randomly-chosen high SUs included the villages of Anvik (SU 669; H) and Shageluk (SU 704; H). Because conducting moose surveys directly over villages is both a safety hazard and irritating to the public, we chose to omit these two SUs from the selection and choose the next two SUs in the random sequence of high-stratum units (SUs 930 and 165). Because airports can be some distance from villages, aerial photos should be consulted when excluding SUs.

A minimum of 15 sightability trials per stratum were planned. Each radiocollared moose in a surveyed SU constituted one trial with 2 possible outcomes: the survey plane saw the moose (success) or missed it (failure). We assessed the need for additional trials in the field by comparing the precision of the most recent estimate of total moose with our precision objective. We used Program R to run the GSPE code (no internet access to WinfoNet at field camp) to obtain estimates of observable moose and their variance for each stratum. We used a template in a Microsoft Excel® spreadsheet with a Solver function to calculate the estimates of SCF and their variance for each stratum, entering the GSPE abundance estimate and SE to the reported decimal precision (e.g., no rounding during intermediate steps). The template calculated estimates of total moose abundance for each stratum as the product of SCF and the estimate of observable moose. Goodman's formula for the exact variance of a product (Goodman 1960) was used to account for the variance in both factors when calculating the variance for these stratum estimates of total moose. The template added the stratum estimates of total moose abundance and their variance to estimate total moose abundance and its variance. If more trials were needed, the template was used to estimate the number needed by simulating the effect of collecting additional data on precision under a variety of scenarios (i.e., number of trails and their allocation between strata).

Logistics and Protocols

Five pilot-observer teams (survey crews) were used for the survey plus a pilot-observer team for telemetry that directed sightability trials and occasionally surveyed a SU. The survey teams were composed of 3 charter pilots highly experienced in moose surveys, 3 experienced ADF&G pilots (including telemetry plane), 3 experienced observers (including telemetry observer), and 3 relatively inexperienced observers (2 flew with charter pilots). We anticipated that each survey team would complete 7–10 SUs daily, and that the entire survey would require 4-5 days including trials. Sightability trials were conducted throughout the survey and across all survey teams to ensure sampling of all survey conditions (e.g., light intensity, wind, and team combinations). We used radiomarked adult (>2 yr old) males (n = 17), lone adult females (n = 10), and females with 1–2 calves (n = 15) for trials that were distributed mostly in or near the floodplain of the Innoko and Yukon rivers. The telemetry crew would monitor location of collared moose daily to derive blind assignments for survey crews in the same day or the following morning. Typically each survey crew was assigned 2–3 SUs to start for a rough geographic separation in the study area that positioned them for ≥1 SCF trial assignment(s) that day. The telemetry crew launched 30-60 minutes before the survey crews to verify location of moose for SCF trial assignments (given over the radio) and to assess weather conditions that might hinder trials (e.g., lingering fog, turbulence over hills) and warrant a change in strategy.

Pilot-observer teams followed the GSPE protocol (Kellie and DeLong 2006). Teams were instructed to keep their search times close to the average search times in high and low strata from 2009 (Table 1). Pilots were instructed to collect a waypoint of all circled moose and record waypoint number and habitat cover type (meadow, shrub, forest), cover class (a diagram illustrated increments of 10% cover), and whether collared moose were standing or bedded. Typically for SCF trials the survey plane would contact the telemetry plane by radio upon completing a SU. The crew of telemetry plan would use their knowledge of the locations of radiocollared moose to decide whether they needed to fly to that SU to determine the outcome of a SCF trial. GPS flight tracks were downloaded each night so we could use the information to rectify discrepancies in whether teams observed collared moose (i.e., circling in GPS flight path could be matched against locations of collared moose). This was used on rare occasions where telemetry plane overflight directly following survey unit completion was not practical because of distance and work on simultaneous trials. In those instances the survey teams were directed to confirm presence of collared moose. Only the telemetry crew viewed the master map showing high and low strata and which SUs were completed so other crews could be assigned to SUs with collared moose (additional trials) without knowing that they were being tested. Each day the telemetry plane would have an updated map (color coded by use of a small portable printer to reduce error with manual methods) to indicate high and low strata and which SUs were completed, plus manual entry of collared moose locations for assigning new trials. We reviewed data sheets each evening to ensure all parts of the form were completed and that moose missed during SCF trials were not added to the survey observations.

We began estimating total moose abundance after day 3 (94 SUs surveyed) to define current variances and identify whether change in sampling allocation for SCF trials (low vs. high) was warranted. Knowing the predominance of radiomarked animals would be in high density strata based on past grouping in late winter, we recognized the need to focus on trials in low density strata early in the survey, repeating the trials with different pilot-observer teams unaware they were being tested. The master survey map used by the telemetry team to assign SUs daily and modify assignments as warranted in the air was kept confidential from survey teams so they would be largely unaware of being tested in a particular SU.

We compared search intensity between the 2009 and 2012 surveys and between high and low strata in the 2012 survey using a Mann-Whitney U statistic because data were non-normally distributed (Lilliefors test, P <0.05). We think that search effort was essentially independent among teams and among SUs for each team (i.e., not a learned behavior that changed search intensity over time to induce a correlation) and sought to examine *post hoc* the relationships of search intensity to covariates of density stratum, forest canopy cover, and survey team judgment of survey conditions. Because degree of forest canopy cover can obscure sighting of moose and influence search patterns and search intensity (Gasaway et al. 1986), we estimated proportion of forest cover (trees ≥6 m tall, ≥25% canopy cover) for each SU from 2001 imagery classified in the National Land Cover Database (30 m pixels) to evaluate how search intensity in this survey related to winter canopy cover. The NLCD imagery was from the growing season and represented greater cover in deciduous forest than present during winter but provides an objective context. Deciduous forest occurs in portions of the floodplain (balsam poplar) and on hills (Alaska birch and quaking aspen) but is often mixed with coniferous forest (neither ≥75% canopy cover), which is relatively predominant in mixed and pure (≥75%) stands in this study area. Willow shrub is often typed as young deciduous forest due to spectral signature, but most is <6 m tall. We present summary statistics of search intensity among teams to describe variation in this survey. Valid statistical comparisons among teams would have required a study design that included a strategy for randomly assigning survey teams (experimental units) with replication to treatments consisting of combinations of factors such as canopy cover, different habitat types, day (weather condition), etc., to prevent confounding through chance assignment of SUs.

RESULTS

Survey Conditions

The GSPE survey was based out of a commercial camp at Reindeer Lake, Alaska (Fig. 1) from 12–16 March 2012. The telemetry plane began locating radiomarked moose on 11 March so arriving survey planes could be assigned SUs. The most recent snowfall of about 12 inches ended on 6 March. On 12 March it was −35° F, clear, and calm in the morning with shadows and glare. Four of 5 survey crews arrived, and 3 were operating by early afternoon (1 pilot on federal contract had duty time restrictions). On 13 March it was 0° F, light turbulence, and broken-overcast (surrounding hills obscured) at 09:30 but increased turbulence and winds 20–30 mph by 11:00, with blowing snow at ground level obscuring fresh moose tracks in open terrain. The remaining survey crew arrived and all 5 were operating by early afternoon of the 13th. However, most crews had to be shifted to the southern portion of the survey area because of turbulence and denser forest to the north (harder to circle plane for observations beneath spruce canopy), which disrupted planned SCF trials. On 14 March it was 0^{o} F with scattered clouds and calm or lights winds, generally excellent survey conditions. On 15 March there were similar conditions except light to moderate turbulence to the north in the morning that moderated by afternoon. Finally, on 16 March it was −10° F, clear, and calm with ground fog in the south part of the study area until late morning. Overall survey rating was reported on only 89% of data sheets despite all sheets having search condition factors (snow, light, habitat) noted on the data form checklist. The only factor checked in “additional conditions” list was “windy/turbulent.” Teams judged overall survey rating as excellent for 30% of sample units, good for 65%, and fair for 5% fair (n = 133, reporting rate 89%). There was low variation in reported survey ratings among days once all teams had arrived on the 13th but substantial variation among teams for all days combined (Table 2). We assumed missed reporting was accidental (2 teams accounted for 76% of 17 blanks) and not a function of survey condition (blanks were spread among all days).

Survey Intensity and Abundance Estimation

Search intensity in the 2012 survey averaged 7.3 min/mi^2 for the high stratum and 5.6 min/mi^2 for the low stratum (Table 1). The average search intensity for strata combined was 6.9 min/mi^2 with a standard error of the sample mean (SE = sample standard deviation/$n^{0.5}$) = 0.2. For descriptive purposes, search intensity in the 2012 survey was greater than in the 2009 survey for both the high stratum (U = 3981, P = 0.008) and low stratum (U = 775, P = 0.013), possibly because we emphasized a minimum intensity during the pre-survey briefing in 2012. In the low stratum of the 2012 survey, there was no difference (U = 181, P = 0.75) in search intensity between SUs with no moose ($\bar{x}$ = 5.7, SE = 0.3, n = 20) and SUs with 1–15 moose ($\bar{x}$ = 5.4, SE = 0.4, n = 17). In the high stratum, SUs with 1–15 moose ($\bar{x}$ = 7.4, SE = 0.3, n = 108) were had greater search intensity (U = 82, P = 0.008) than SUs with no moose ($\bar{x}$ = 5.0, SE = 0.4, n = 5). Variability in the mean number of moose observed in 2012 as expressed by the coefficient of variation (CV = SE/$\bar{x}$) was lower in the high stratum compared with the 2005 and 2009 surveys of similar method, sampling effort, and stratification, whereas it was higher in the low stratum compared with the 2 prior surveys and twice the variability of the high stratum in 2012 (Table 1). Allocation of SUs by stratum was uneven among survey teams, and search intensity varied more in the high stratum than in the low stratum (Table 3).

There were 2687 moose observed in the survey, and the estimate of observable moose was 4914 with a relative error of 11% of mean at the 90% confidence level (or 13% at 95% CL), which was more precise than prior surveys using a similar stratification (Table 4). The observable moose abundance corresponds to a density of 0.97 moose/mi^2. Counts suggested 26 SUs were misclassified by stratum (17% of sampled units: 9 Lows >2 moose and 17 Highs <3 moose; Figs. 1 and 3). A notable exception was an extra SCF trial (not part of GSPE) where Team 1 counted 144 moose in a Low (SU 270) that included the Yukon River.

Sightability Trials

We completed 47 sightability trials (successful observations of 27/30 in high strata and 11/17 in low strata) among 5 crews (Table 3). We estimated SCF (~inverse of proportion seen) for the high stratum as 1.11 (SE = 0.069) and for the low stratum as 1.49 (SE = 0.285). The estimate of total moose abundance was 5953 with 21% relative precision at the 95% CL, which met our research objective of $\leq$25%. The corresponding estimate of density with SCF was 1.17 moose/mi^2, comprised of 4.11 moose/mi^2 in the high stratum and 0.48 moose/mi^2 in the low stratum.

Each team completed 5–12 SCF trials. Trials were performed in 17 randomly-chosen SUs and in 1 non-random SU that contained a radiocollared moose and were used in the GSPE. Only 5 low SUs near the northern extent of the survey area (i.e., greatest distance from field camp) reliably contained collared moose for trials. To increase the number of SCF trials, especially for achieving at least 15 trials in the low stratum, we repeated team assignments 2–3 times in 5 SUs used for the GSPE (2 random Lows, 3 random Highs) for 6 additional trials. We also conducted trials 1 time in 3 extra SUs not included in the GSPE (3 Highs) and 2–4 times in 7 extra SUs not included in the GSPE (4 Lows, 3 Highs), including 1 where there were 2 collared moose, for 21 additional radio trials. Where repeated trials occurred in an SU chosen for the GSPE, only the initial moose count was included in the estimate of observable moose. To avoid bias, the extra SUs were selected independently of the original design based on logistic efficiency (weather, proximity of teams, safety of flight separation) with care taken to spread them among various habitats, survey teams, and days of the survey (e.g., weather conditions).

In addition to the 45 radio trials described above, we utilized 2 additional trials possible by fortuitous observation of a uniquely identifiable non-collared individual in an extra trial SU not included in the GSPE. These trials were on separate teams several hours apart on the same day from a single non-collared moose associated with a collared animal that remained bedded in a low SU with poor habitat (neither moose was observed during either trial). We assumed this time difference between trials was sufficient to allow moose movement, thus was not biased. Additionally, we had 5 potential trials we could not use in our calculations. Three involved observations of collars that were not located prior to trials. At the time of the survey there were 2 collars of unknown status in the study area, likely not functioning (1 of each sex). One of the 3 observations was subsequently confirmed to be collared male #37 mistakenly not on our search list (its GPS location on that day corresponded to the observation that was judged to be a male moose by an experienced pilot) and 1 was a compromised VHF collar observed by a survey crew that was missed initially by telemetry team but subsequently detectable by telemetry only within ¼ mile. Collars not known to the telemetry team but observed during the survey are unsuitable for trials because their binary complement (non-functioning collars that are not observed) can never be confirmed, thus no chance for "failure" trials and a resulting low bias for SCF. In addition to these 3 situations, on 1 occasion a collared moose near a SU border moved out by the time a survey occurred, and another attempted trial was excluded because it was compromised by an accidental communication with the survey pilot regarding flight safety near a village.

SCF trials began with a partial survey day on 12 March and were disrupted by weather on the 13th, so most trials occurred in the last 3 days of the survey (Table 2). SCF trial coverage by stratum was also unevenly distributed among survey teams (Table 3). Further, we also learned upon data summary that SCF trials were proportionately distributed unevenly with respect to frequency of moose counts per SU (Fig. 3), which would be difficult to address during survey planning beyond trial coverage by stratum. Coefficient of variation in mean search intensity differed substantially among teams in both low and high density strata (Table 3). In most instances the mean search intensity and mean number of moose observed within teams was greater for SCF trials than non-trial searches of SUs for each stratum (Fig. 3, Table 3), raising the question of potential bias if teams suspected they were being tested.

There was an expected positive relationship between search intensity and observed moose (Fig. 4). We noted more often greater search intensity for >1 moose observed under "good" survey conditions than under "excellent" conditions in low-density SUs (Fig. 4a). High-density SUs appeared to have had a similar relationship but with substantial overlap between "excellent" and "good" and stronger outliers (Fig. 4b). The relationship between proportional forest cover and search intensity by density stratum and observer judgment of survey conditions showed a greater positive association of search time with forest cover under "excellent" conditions compared with "good" conditions for both density strata (too few "fair" examples for inference) (Fig. 5). Collared moose were observed bedded under dense conifer canopy by the telemetry crew even with temperatures to -30F or cloudy conditions (i.e., unlikely high thermal stress), with snow depth averaging 32 inches (Appendix). This was a moderate depth likely causing some hindrance to movements and potentially selection for habitat with shallower snow to reduce energy expenditure (Coady 1974) in a landscape risk context that includes access to forage and wolf predation risk.

The total cost of the survey including federal contributions was approximately $57,500 (Peirce memo) of which the SCF trials cost about $10,600 (18%). The extra cost of the state-owned research plane was $2436 for fuel to support 30.0 hours telemetry and 8.0 hours ferry, assuming $9.16/gal and consumption rate of 7 gallons per hour. We assigned 27 extra SUs for SCF trials that were not part of the estimate of observable moose; these trials took 20.6 hours to survey, not including extra travel within the study area outside of randomly-assigned SUs (comparatively small amount of time). The 2090 gallons of aviation fuel barged to Holy Cross in 38 poly drums and transported by boat to the field camp equated to $9.16/gal, including backhaul to Holy Cross of 22 empty drums that represented 1200 gallons of fuel used during the survey. The 6 days lodging expenses for the telemetry crew plus the equivalent of 3 survey crews for an extra day to complete the extra SCF trials at $140/day/person was $2520. Thus the cost of the SCF trials was $10,597: $3757 for fuel (58.6 hrs), $4320 for aircraft charter (assuming 8 hours/day at $180/hr dry for rounded cost), and $2520 for lodging. If the telemetry plane was a charter instead of a state plane it would have added $6840 for SCF trials. The telemetry crew also surveyed 10% (4 high and 11 low) of the total SUs between conducting trials for 8.2 hours not included in the research estimate.

DISCUSSION AND RECOMMENDATIONS

The 2012 GSPE in Unit 21E demonstrated the value of research staff and biometric assistance with survey planning for area managers to maximize the gains in accuracy and precision within empirical field constraints. Planning assistance helped specify sample size and optimal allocation between low and high density strata to efficiently achieve our precision criteria for our estimate of observable moose. A spreadsheet to estimate effect of SCF sample size based on number of binary trials illustrated beforehand that at least 15 trails in the low stratum were likely necessary to estimate the detection parameter with sufficient accuracy. This tool gave us confidence that we were proceeding correctly with the survey as we reviewed daily results in the field and allowed us to make real time adjustments to sample size and allocation between strata.

In 2012 we focused on achieving minimum sample sizes in SCF trials because this was the first attempt using radios in a spring survey for a GSPE in the Interior. We were conscious of rotating teams among habitats of the study area but could have done a more proportional allocation of teams between strata (Table 3) so SCF for each stratum would better represent the combination of habitats and survey team skills used in the standard survey. Ideally the SCF trials are spread among the survey crews in the same proportion as SCF trials are distributed between strata (30H: 17L or ~2:1 in this survey). Daily team assignments to ensure progress with SCF trials included factors of safety (aircraft separation) plus geographic efficiency to ensure a population estimate will be possible in the event weather terminates a survey before all sampling occurs. The telemetry crew must be flexible to reassign the entire daily workload contingent on survey conditions, as occurred on the 13th. This balance of considerations will remain a challenge, but awareness of issues will inform decisions. The telemetry team should review assignment of crews among strata each evening to ensure the trials best represent the stratification, survey area, and survey conditions.

We recommend survey-specific SCFs continue to be measured and applied to late winter surveys in Unit 21E until the variability of SCF in this study area is better documented. Although beyond the scope of our research since we have only 1 data point, we believe a brief discussion of SCF application in late winter surveys is warranted. Managers seek the option of applying SCF surveys performed in the same or “similar” nearby study areas in previous years (sometimes referred to as “composite” SCFs if resulting from multiple surveys) because the extra expense and effort of survey-specific SCF is often not feasible outside of associated research projects. A “composite” SCF may be appropriate when multiple survey-specific SCFs demonstrate repeatability in the *same* study area within the expected range of survey conditions among years (snow cover, flying weather, skill of pilot/observer teams, etc.), such as for early winter surveys described by Boertje et al. (2009:316) and Keech (2012:13). However, caution is advised in using SCF data from prior years for late winter surveys until more data can be evaluated. Gasaway et al. (1986:31) provided site-specific examples of moose not seen during intensive surveys in the central Interior being substantially higher in late winter (SCF_c = 1.13) compared with early winter (SCF_c = 1.02). Gasaway et al. (1986:31) simply stated that estimating a SCF in late winter is difficult. We further expect the higher SCF_c for late winter may have an associated higher variability among years. Our original intent was to begin to address this concern by conducting the first survey with both intensive searches and radio-mark SCF trials in Unit 21E to separately estimate SCF_0 and SCF_c, respectively, but it was logistically infeasible in this remote study area. The infrequency of surveys in Unit 21E and difficulty of logistics in this remote area will hinder future efforts at documenting the variability of SCF, particularly since this research project is ending.

We do not think greater search intensity in SCF trials compared with non-trial searches reflected bias from knowledge of being tested. The greater mean search intensity and mean number of moose observed within teams and strata for SCF trials compared with GSPE cells was also observed in SCF trials using radiomarked moose conducted near McGrath, Alaska where track logs were examined (Kellie Seaton, unpublished). Higher search times in SCF trial units resulted from circling and classifying more moose, not because the teams recognized they were being tested and intensified their search. SUs used for SCF trials are expected to contained more moose on average than randomly selected units (Fig. 3) because they are chosen based on the presence of a radiocollared moose (i.e., exclude zero counts). This effect would likely be minimal for high stratum SUs as relatively few have no moose.

Deploying radio collars allows an estimate of the proportion of moose that will not be seen at a given survey intensity (*p* ~ 1/SCF) and thus SCF_c (Gasaway et al. 1986:31), but it has a fixed cost for collar deployment not feasible in all situations. Sightability correction where a subsample of SUs is searched at high intensity (Gasaway et al. 1986:31) can be used anywhere but requires an assumption of a relatively small SCF_c and incurs additional risk associated with flying low and slow in tight circles. For both methods, sample sizes required to meet precision objectives can be estimated prior to the survey and, in both cases, depend on SCF value (i.e., a fixed sample size results in a lower precision for a larger SCF). That said, predicting the number of moose in each SU selected is an additional step in planning for the intensively flown SCF making it possible that, by chance, fewer moose may be encountered than anticipated on average, leading to larger number of samples than planned to attain precision goals. However, the opposite is also true by chance. The radio SCF in Unit 21E cost about 25% more based on effort (excluding ca. $15,000 for collar deployment plus cost of collars) than the intensive SCF_0 conducted in Unit 19A during March 2011. However, radio SCF includes SCF_c for the total estimate of SCF. Intensive trials are also affected by survey-specific conditions that affect the ability of the intensive search team to spot animals missed by survey teams. The intensive survey pilot in the 2011 trials in Unit 19A (Marty Webb, Tundra Air, Fairbanks, Alaska) noted that his ability to spot moose missed by other teams was facilitated by good tracking conditions during the survey, which were contingent on appropriate light for visual detection and lack of snow drifting over fresh tracks. These survey-specific conditions change the percent of moose that remain unseen at the high search intensity (SCF_c) resulting in additional and unmeasured variation in the population estimate compared with using radio collars. This is a further caution against applying a composite SCF instead of a survey-specific SCF until adequate information exists.

Survey-specific conditions include weather (light quality and turbulence), habitat type (vegetation and snow depth), and pilot-observer team (experience and physical comfort with aerial survey maneuvers). These conditions affect probability of detecting moose and accurately classifying age and sex. Weather conditions and other factors affecting survey quality should be recorded daily by the telemetry team and archived in the survey memo to supplement observer reports of conditions on data sheets that are subjective (not directly relatable among observers) and may vary over time for a given team. Consistent reporting of conditions among surveys may help explain unexpected results and provide guidance where minimum standards may need adjusting for certain conditions in a specific survey area. Effect on sightability trials of daily movement rate of male and female moose during the 2012 GSPE survey (VHF observations and GPS locations) and moose use of cover type will be further examined for the final report. Duplicate surveys of the same SU for SCF purposes afforded an opportunity to examine variability in counts among teams, although the comparison is confounded by time (moose movement in or out of SU or vegetative cover, changes in light conditions). Once moose movement rates during this survey are quantified, the 11 instances of 2-4 surveys of the same SU could be examined to see the effect of survey team and search intensity on moose counts.

Our general observation in prior reviews of GSPE data sheets is an inconsistency in recording of survey conditions and habitat type/density by teams for each SU. Our post hoc evaluations of the relationship by density stratum between survey intensity and moose observed (Fig. 4) and between forest canopy cover and survey intensity (Fig. 5) showed evidence of greater search intensity when conditions were judged to be compromised (“good” or greater vegetation concealment) compared with ideal (“excellent” or lesser concealment). This suggests teams actually search harder in compromised conditions or denser habitat and lends credibility to use of survey team assessment of conditions in judging overall quality of survey from the composite of SU quality scores. We encourage biologists to explain the value of condition quality scoring to observer teams during pre-survey briefings and practice quality control on GSPE surveys by diligent review of data sheets each evening while memories of daily events are fresh.

We used 42 collared moose for SCF trials in this survey. Despite redeployment of 4 collars in 2010 and 2011 from early mortalities to maintain the starting sample size of 54, the number of live moose with functioning collars was down to 41 by June 2012. At this rate of mortality and collar failure, we assumed <30 collars would be functional by the next moose survey scheduled for late winter 2015, particularly because the aging cohort and shortening battery life were likely result in a higher attrition rate. In March 2014, the remaining 18 live moose with GPS collars were recaptured for data recovery and fitted with VHF collars. Additional VHF collars were deployed on new individuals for a total of 19 females and 9 males now marked in Unit 21E for future SCF trials. Minimum sample size for SCF trials depends on dispersion of moose among density strata (ideally proportional), size of survey area (travel time for telemetry plane among trial locations), and other logistical considerations. Twenty-eight collars are minimal for SCF trials in Unit 21E, particularly to conduct at least 15 trials in the low stratum, but this sample reflects current budget constraints.

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Table 1. Intensity of aerial searches (min/mi^2) and number of moose observed by density stratum (high and low) during 4 surveys in Unit 21E. Approximately 12% of the 5,070 mi^2 survey area was sampled in 2000 and 18% in subsequent years.

			Search intensity (min/mi^2)								Moose observed per sample unit							
	Sample size		High stratum				Low stratum				High stratum				Low stratum			
Year	High	Low	$\bar{x}$	SE[a]	CV[b]	Range	$\bar{x}$	SE	CV	Range	$\bar{x}$	SE	CV	Range	$\bar{x}$	SE	CV	Range
2000[c]	52	48	--	--	--	--	--	--	--	--	45.8	8.5	19	0–264	1.9	0.4	19	0–13
2005[d]	98	52	--	--	--	--	--	--	--	--	16.7	2.9	17	0–195	2.5	0.7	26	0–21
2009[e]	90	60	6.3	0.2	3	2.2–11.2	4.8	5	5	1.4–9.2	35.4	7.1	20	0–394	1.9	0.4	22	0–13
2012	113	37	7.3	0.3	4	3.3–18.5	5.6	0.2	4	1.9–8.2	23.1	2.7	12	0–157	2.0	0.5	28	0–15

[a] SE = standard error of the mean (sample standard deviation/$n^{0.5}$).
[b] CV = coefficient of variation ([SE/ $\bar{x}$]*100).
[c] A medium stratum of moose density was also defined for this survey. The moose observed per sample unit for 31 medium units (mean = 12.7, SE = 2.4, range 0–58, CV = 19.1) and 21 high units (mean = 94.7, SE = 15.6, range 9–264, CV = 16.4) were combined into the high stratum in this table. Search intensity for 2000 was not in the digital archive, and the original data sheets were destroyed in the 2006 office fire in McGrath. The survey memo noted that poor conditions delayed the 4-day stratification for 2 days and scattered snow showers and fog occurred during the subsequent 4 days of the survey (T. Boudreau, 28 April 2000). An overall rating of survey condition was not reported.
[d] Survey intensity for 2005 was not in the digital archive, and the original data sheets were destroyed in the 2006 office fire in McGrath. However, the range of survey intensity for strata combined (12-88 min/SU ~ 1.9–14.3 min/mi^2) was reported in a memo (E. Lenart, 9 May 2005). The survey memo reported conditions of 0º F to 20º F, calm except for the last day when it was very turbulent, and mostly flat to medium light intensity that made detecting moose difficult; particularly in forested areas. Sightability in forest was considered poor to fair, whereas sightability along the riparian zones and island willow bars was considered good to excellent. The overall rating for survey conditions was good.
[e] Snow was deep during the 2009 survey, with adults in many places dragging their bellies and movements apparently restricted (memo, J. Peirce, February 23–March 4, 2009). The deep snow may have contributed to moose congregating in high density wintering areas. Weather during the stratification and survey was “extremely challenging” but an overall rating of survey condition was not reported.

Table 2. Reported rating (*n* = 133 sample units) for search conditions by team and by date during an aerial survey of moose in Unit 21E, March 2012.

		Date					
Team	Rating	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	All dates (%)
1	Excellent	3	3	4	5	2	77
	Good	--	2	2	--	--	18
	Fair	--	1	--	--	--	5
2	Excellent	3	3	--	1	--	25
	Good	2	4	7	7	1	75
	Fair	--	--	--	--	--	0
3	Excellent	3	--	1	--	--	16
	Good	1	6	5	4	5	84
	Fair	--	--	--		--	0
4	Excellent	--	--	2	1	--	47
	Good	--	3	4	3	5	47
	Fair	--	3	1	--	--	7
5	Excellent	--	2	--	--	--	14
	Good	--	4	5	8	2	68
	Fair	--	--	2	1	--	18
6	Excellent	--	--	3	3	1	10
	Good	--	3	1	--	3	90
	Fair	--	1	--	--	--	0
All teams (%)	Excellent	75	23	29	31	16	
	Good	25	63	69	69	84	
	Fair	0	14	3	0	0	
n SCF trials		2	2	14	17	10	45

Table 3. Intensity of aerial searches (min/mi^{2}) and number of moose observed by density stratum (high and low) among 4 survey teams for the 2012 Geospatial Population Estimator (GSPE) survey in Unit 21E. The sightability correction factor (SCF) trials include the 17 random samples and 1 non-random sample that were used in the GSPE calculations; only data from first SCF trial in a sample unit (SU) was used for the abundance estimate if multiple trials occurred in that SU.

		Search intensity (min/mi^{2})										Moose observed per sample unit							
		SUs surveyed					SUs surveyed with SCF trials					SUs surveyed				SUs surveyed SCF trials			
Team	Strat	n[a]	$\bar{x}$	SE[b]	CV[c]	range	n	$\bar{x}$	SE	CV	range	$\bar{x}$	SE	CV	range	$\bar{x}$	SE	CV	range
1	High	23	8.0	0.6	7	4.5–18.5	7[d]	10.5	1.4	14	7.0–18.5	29.9	7.6	25	2–157	46	14.7	32	8–157
	Low	3	3.2	1.0	32	1.9–5.2	1	10.0	--	--	--	3.7	2.2	60	1–8	144	--	--	--
2	High	14	9.3	0.7	8	5.5–14.5	4[d]	11.4	2.1	18	8.1–17.5	30.6	5.8	19	0–78	49	9.3	19	17–106
	Low	15	6.2	0.3	5	3.7–8.2	4	7.1	0.4	6	6.1–7.8	1.1	0.6	53	0–9	2	0.8	42	1–5
3	High	29	6.8	0.6	9	3.6–18.4	7	9.0	1.8	20	4.4–18.4	16.8	4.7	28	0–106	35	7.6	22	9–90
	Low	5	6.9	0.0	<1	6.8–7.0	4	6.6	0.3	4	5.9–7.1	0.0	0.0	--	0–0	4	1.2	34	2–7
4	High	21	7.1	0.4	6	4.0–11.1	3	7.5	1.1	15	5.3–9.2	31.9	7.2	23	0–108	38	9.6	25	8–80
	Low	2	6.2	0.6	10	5.6–6.8	2	7.1	0.3	5	6.8–7.5	5.0	2.0	40	3–7	4	1.6	46	1–6
5	High	22	6.3	0.4	6	3.3–11.5	8	7.1	0.4	6	5.7–9.4	14.4	4.8	34	0–105	18	4.8	28	5–44
	Low	1	4.6	--	--	--	4	6.3	0.1	2	6.1–6.6	0	--	--	0–0	2	1.9	85	0–6

[a] The telemetry crew surveyed an additional 15 sample units, thus $n = 135$ in this table.
[b] SE = standard error of the mean (sample standard deviation/$n^{0.5}$).
[c] CV = coefficient of variation ([SE/ $\bar{x}$]*100).
[d] There was 1 sample unit that contained 2 collars.

Table 4. Estimates of moose abundance in Unit 21E based on the geospatial population estimator (GSPE)[a] and observed abundance with a sightability correction factor (SCF) applied for moose not seen during the survey. Variance is shown as relative precision for the 90% confidence level for comparison of 2012 with prior surveys.

	Observed moose		Observed moose with SCF	
Year	Estimate (no./mi^2)	Relative precision	Estimate (no./mi^2)	Relative precision
2000	5151 (1.0)	13%	--	--
2005	4673 (0.9)	17%	--	--
2009	6218 (1.2)	17%	--	--
2012	4914 (1.0)	11%	5953 (1.2)	21%

[a] The 2000 survey was a Gasaway technique based on 100 GSPE cells with 3 density strata (low, medium, high) whereas the other surveys were the GSPE technique based on 150 cells with 2 strata (low, high).

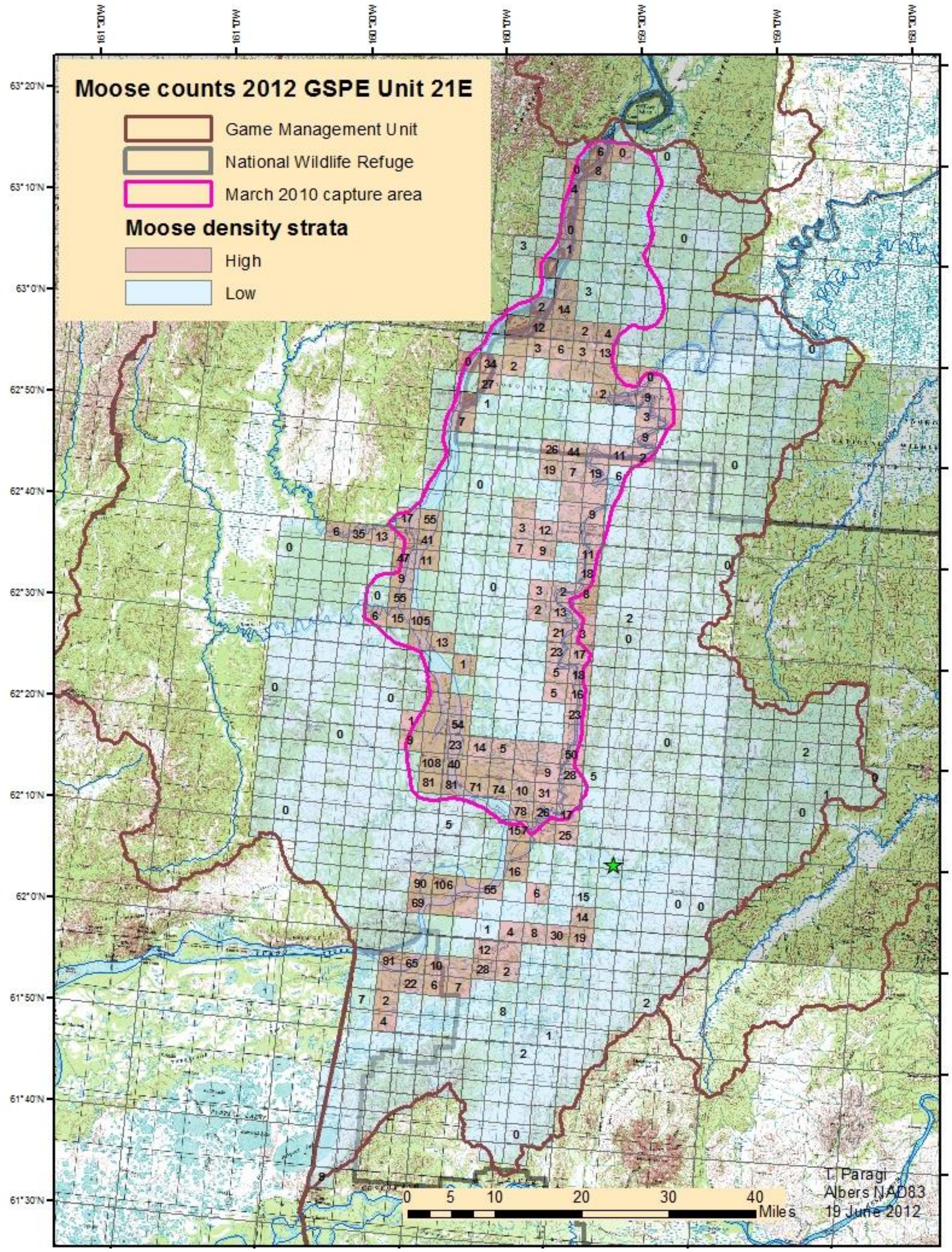


Figure 1. Map of 2012 GSPE survey area (defined by density strata as rectangular sample units), counts of moose in 150 sampled units, and location of moose capture area in March 2010, Unit 21E, western Interior Alaska. Field camp at Reindeer Lake is noted by the star.

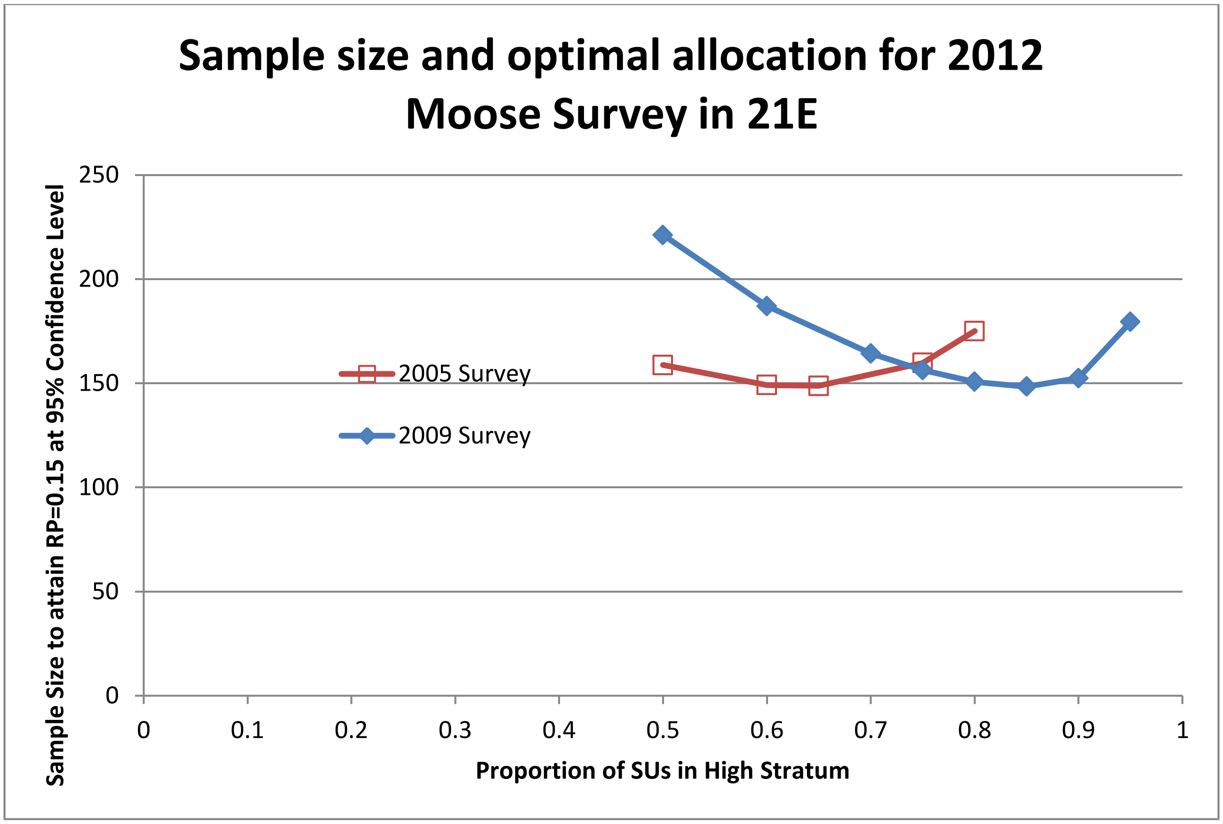


Figure 2. Optimization curves to define the minimum number of sample units allocated between low and high strata to achieve a desired precision at the 95% confidence level in a GSPE survey based on two prior surveys in the study area.

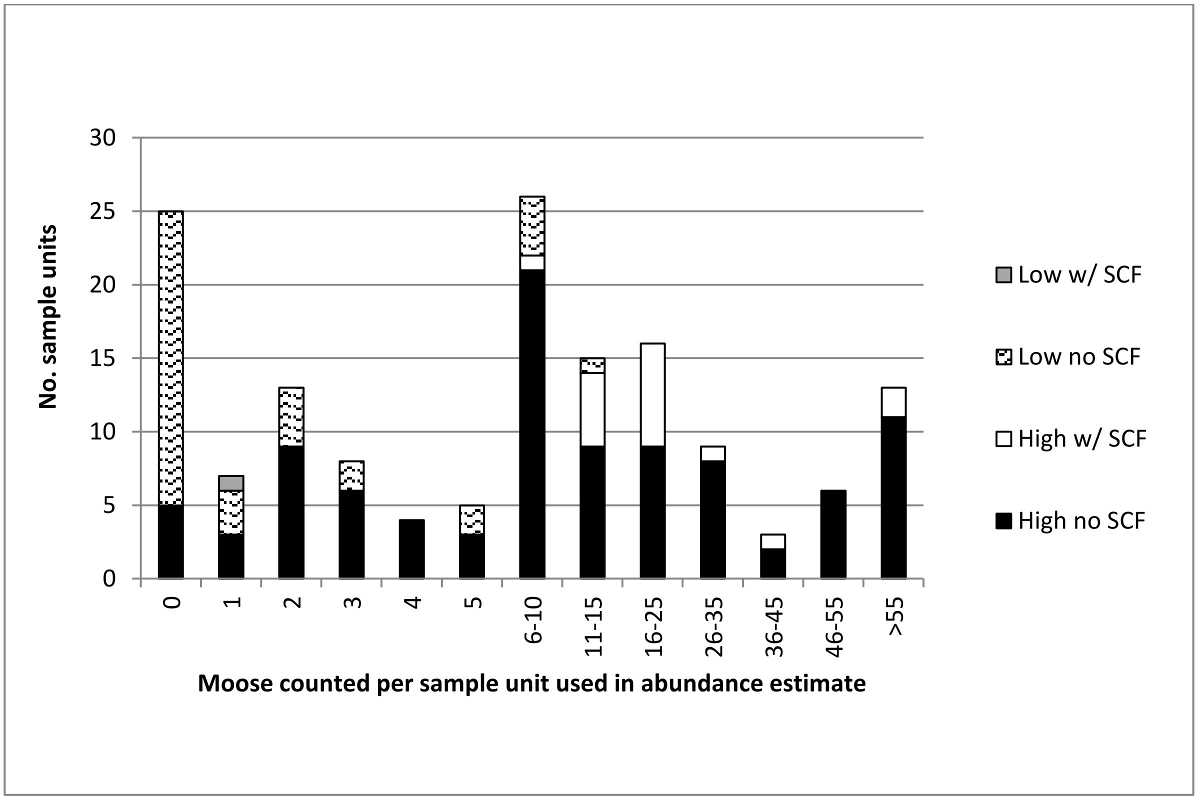
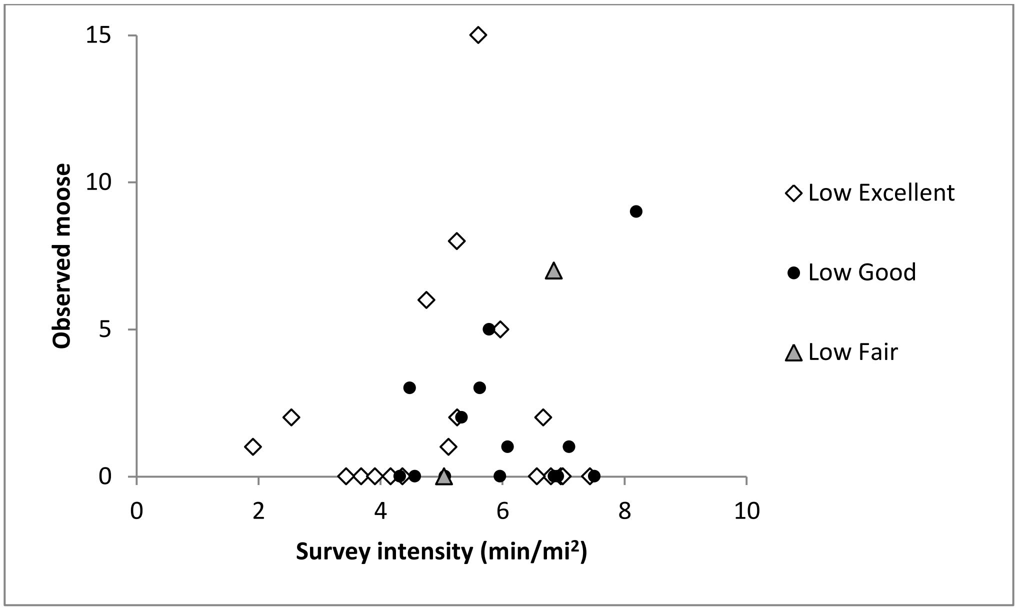


Figure 3. Histogram of moose counted in 150 sample units binned by count size and stratified by density (Low, High) during the March 2012 GSPE survey in GMU 21E. Bars include proportional coverage by sightability correction factor (SCF) trials in 18 sample units used in the abundance estimate (excludes an additional 26 SCF trials where counts were not used in the abundance estimate because 1 random trial had 2 collared moose).

a



b

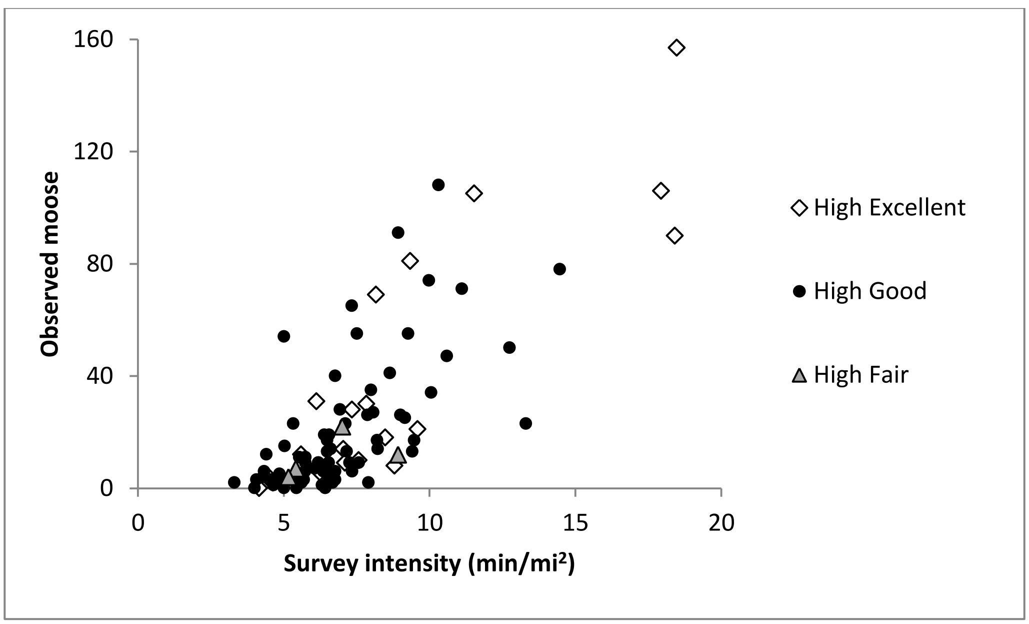
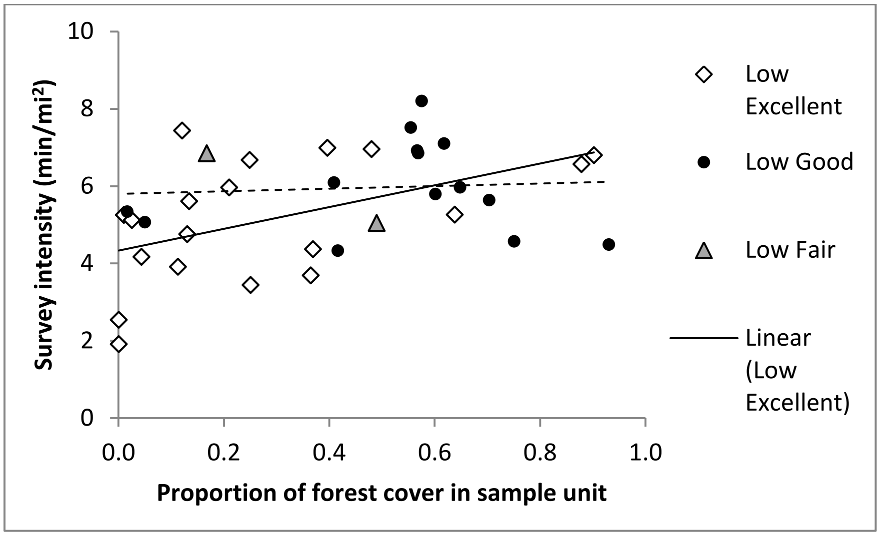


Figure 4. Relationship of survey intensity to number of moose counted where survey conditions (excellent, good, fair) were rated by observers in 6 teams in (a) 37 low density sample units and (b) 113 high density sample units in Unit 21E, March 2012. Note differences in scale of both axes.

a



b

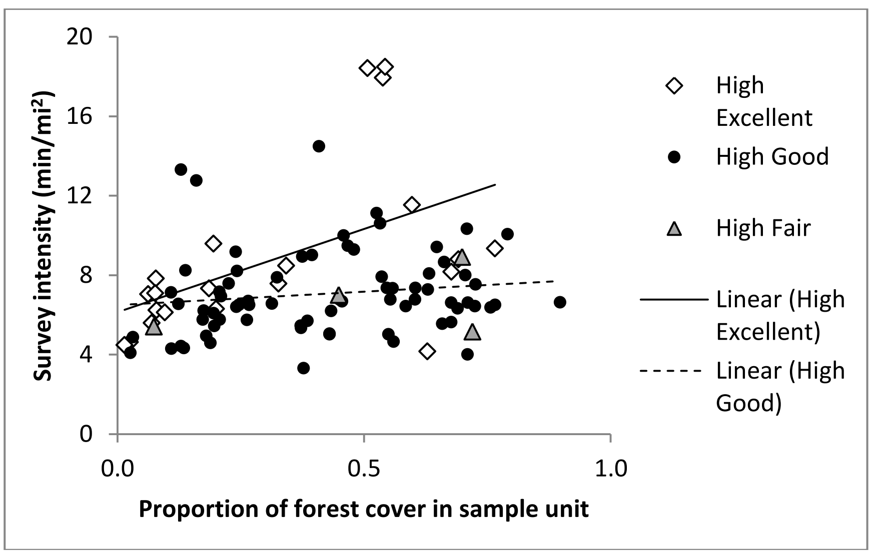


Figure 5. Relationship of forest cover (trees ≥6 m tall, ≥25% canopy cover) to survey intensity where survey conditions (excellent, good, fair) were rated by observers in 6 teams in (a) 37 low density sample units and (b) 113 high density sample units in Unit 21E, March 2012. Linear trend is indicated, but note differences in vertical axis scale.

Appendix. Snow depths during March 2012 moose survey in Unit 21E.

The telemetry plane obtained snow depths at opportunistic landing spots to gauge conditions relative to other surveys. Overall this year appeared similar to slightly less snow depth than locations of moose captures during mid-March 2010, which averaged 27.9 inches (range: 18.0–40.0, *n* = 49; T. Paragi and K. Kellie memo, 6 May 2010).

Cover type	Lat	Long	Depth (in)
On ice 50 m from shore	62°56.238′	159°35.164′	29
On ice 50 m from shore	63°04.148′	159°38.006′	37
On ice 100 m from shore	62°14.792′	159°50.680′	15
Old feltleaf willow forest off river	62°19.738′	159°32.919′	35
Poplar forest off river	63°00.148′	159°50.821′	43
Average			31.8

APPENDIX B. Department memo detailing late winter GMU 19A moose population estimate and sightability correction.

MEMORANDUM State of Alaska

Department of Fish and Game
Interior/Northeast Region, Fairbanks

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Management Coordinator
Roger J. Seavoy
McGrath Area Biologist
Joshua M. Peirce
McGrath Assistant Area Biologist

DATE: April 24, 2013

THRU: Scott M. Brainerd
Research Coordinator

TELEPHONE: 459-7327

FROM: Tom F. Paragi
Wildlife Biologist
Kalin A. Kellie Seaton
Wildlife Biologist
Brian D. Taras
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SUBJECT: Unit 19A moose population estimate with sightability, correction, March 2011

This memo presents the background, sampling strategy, logistics, and results for the 2011 geospatial population estimator (GSPE) survey in the Central Kuskokwim Moose Management Area of eastern Game Management Unit 19A. Discussion and recommendations are also provided. As part of federal aid research project 1.69, we evaluated the use of intensive aerial searches for estimating a sightability correction factor (SCF) for a late winter survey of a low-density moose population in Interior Alaska. The intensive SCF is based on a minimum estimate of the proportion of moose missed by observers during the standard survey (SCF_0) by resurveying a random sample of sampled units with substantially greater search intensity. The estimate of observed moose in Unit 19A from the GSPE and its variance were then corrected using SCF_0 to yield an estimate of total moose in the survey area. Costs, list of people participating, and other population metrics were summarized by J. Peirce (memo 15 March 2011).

BACKGROUND

Surveys

The first abundance estimate in Unit 19A was in early March 1998 for the Holitna and Hoholitna drainages using methods of Gasaway et al. (1986) that included estimating SCF_0. Gasaway et al.

(1986:27–30) cautioned that late winter surveys were likely to have a more variable and generally higher proportion of moose not observed during standard survey intensity and recommended against surveys at this seasonal period. Gasaway et al. (1986:31) also noted that the proportion of moose not seen during intensive surveys (SCF_c) from later winter surveys (estimated 1.13 using radiomarked moose) was substantially higher than SCF_c from fall surveys (1.02). However, estimates of abundance in the western subunits of the McGrath Area have been conducted in late winter because early winter snow cover and weather conditions are irregular, hindering completion of surveys in locations remote from the area office (Units 19A and 21E). The 1998 Gasaway SCF for Unit 19A was 1.18 (SE = 0.09) for the high stratum and 1.36 (SE = 0.15) for the low stratum, and the density estimate was 1.26 moose/mi^2 with the 80% CI = 14.4%. Subsequent surveys in 2005 and 2008 in the same vicinity were GSPE estimates of observable moose without SCF (point estimates of 0.28 and 0.44 moose/mi^2, respectively), thus did not account for unobserved moose and variation in population estimates caused by variation in sightability (Table 1). No estimates of late winter sightability in a GSPE are available for Interior Alaska. Further, Gasaway (1986:34) had noted the greater cost of estimating sightability when density is low (e.g., <1 moose/mi^2).

Federal aid project 1.69 began in July 2009 and included a research objective to estimate SCF for moose in Unit 21E by use of radio collars, a method that also accounts for moose missed by intensive searches (Gasaway et al. 1986:31). We had modified the research work plan to conduct intensive surveys to estimate SCF_0 in Unit 19A during the late winter GSPE survey 2011 to better inform the research design and logistics of estimating SCF_c (currently part of study design) and SCF_0 (proposed additional work) for the GSPE survey in Unit 21E that was planned for late winter 2012. Results of the 1998 Gasaway survey and the 2005 and 2008 GSPE surveys in Unit 19A helped inform the design of the 2011 GSPE survey with intensive sightability correction in Unit 19A. The survey area in 2011 was composed of 607 GSPE survey units (SU) or cells that encompass the Holitna, Hoholitna, and Stony River drainages within 3,853 mi^2 of eastern Unit 19A (Fig. 1).

Study Objectives

1) Evaluate practicality of using standard and intensive search intensities for moose in the western Interior during late winter GSPE surveys.

2) Estimate SCF and use it to estimate total moose abundance and the associated variance, with a desired relative precision of $\leq$25% of the mean at the 90% confidence level.

METHODS

Sampling for Stratification, Surveys, and Intensive Calculations

In the 2008 survey, there were 163 high-stratum and 444 low-stratum units of which 40 highs and 35 lows were surveyed. The same stratification was used for the 2011 survey. Approximately 10,000 acres burned in the Big Lake and Hoholitna fires in summer 2009. This encompassed 7 GSPE cells (Fig. 2) that were examined during the 2011 survey but not re-stratified because of minimal change in habitat or moose presence. Additional funding was made available to increase the sample size in 2011 to 150 units and improve estimate precision. Based on 2005 and 2008 surveys and variance-to-sample size relationships from other surveys areas with similar moose density, sampling 150 SUs was expected to yield an estimate of observable moose with relative precision at the 90% confidence level in the 0.14-0.19 range. Ninety percent of the 150 SUs were chosen randomly and another 10% were chosen to fill in spatial gaps in the sampling. Methods described in Gasaway et al. (1986) along with data from the 2005 and 2008 surveys were used to optimally allocate sampling effort between strata. A 70:30 split was expected to be close to optimal and also ensure a sufficient number of SUs were sampled in the low stratum. Therefore, we selected 135 random units (95 highs, 40 lows) and used 14 of the 15 nonrandom units in the low stratum to fill in gaps around the predominantly low-density periphery of the survey area (Fig.1). Fifty-nine percent of the high-stratum SUs were selected for sampling whereas 12% of the low-stratum SUs were selected.

The Geospatial Survey Operations Manual (Kellie and DeLong 2006; ADF&G) recommends intensively sampling 15 SUs from each stratum to estimate an SCF; however, no explanation is provided for that sample size. Therefore, we adapted the single stratum methods to determine the optimal number of SUs to intensively search (Gasaway et al. 1986) to account for stratum-specific SCFs to estimate the number and allocation of intensively searched SUs. Using these methods and data from past 19A surveys (including the 1998 Gasaway survey) as well as the results from efforts to estimate SCF using intensive surveys done in fall surveys in southcentral Alaska (Units 14A and 16B), we planned to intensively search 35-40 SUs. These SUs were randomly chosen from sampled units, with 15 in the high-stratum and 20-25 in the low stratum. This allocation was to be re-examined for estimator performance approximately half way through the survey.

Simulations performed to evaluate the performance of this sampling design indicated that the estimate of total moose abundance (SCF_0 * GSPE estimate) would likely have a relative precision 2–5 percentage points greater than that for observable moose (GSPE estimate) at the 90% confidence interval. Data from the 2008 survey were used to simulate the number of moose observed by the survey planes. A wide range of SCFs (1.1-1.8; even greater retrospectively) was used to simulate the number of moose observed during the intensive searches. Stratum abundances were assumed equal to those in 2008, and the relative precision of the overall estimate of observable moose was varied between 0.15 and 0.20.

Previous survey data used in simulations when planning this survey contained a high proportion of null counts during the regular searches, so we set sample sizes accordingly. Becker and Reed (1990) noted that drawing all (or all but one) null counts during intensive searches that follow null counts during the regular survey results in nonsensical estimates of SCF and its variance. Therefore, ≥2 SUs with moose observed are preferred (Becker and Reed 1990). Null values in both regular and intensive surveys of a sample unit are valid SCF trials as it informs the observer that no moose were missed during the regular search. In addition, these null:null result also improve precision as each contributes 1 sampling degree of freedom to the SCF estimate. That said, for a given value of SCF, SUs with moose have a larger effect on variance reduction. Therefore, to guard against having <2 sample units with no moose observed during the intensive search and to increase our chances of seeing moose in general, we increasing the size of the search area from one-quarter (as recommended in Kellie and DeLong 2006) to one-half of a GSPE SU. This increased the area searched intensively from ~1.6 mi^2 to ~3.2 mi^2 and was more consistent with earlier recommendations of 4 mi^2 when density is low (Gasaway et al. 1986:34-

36). The sightability correction factors for the simulations and survey were calculated using equations in Appendix A from (Kellie and DeLong 2006).

Logistics

Five pilot-observer teams were used for the survey. One team (commercial charter pilot experienced in moose surveys and experienced observer) was dedicated to flying intensive searches of units recently surveyed by the other teams. Compared with the Gasaway protocol where each survey team conducts intensive surveys of their own samples, a single intensive team would provide a consistent detection standard and avoid inexperienced pilots doing prolonged circling at a steep angle while trying to see tracks or classify moose straight down in dense spruce with shadows. The disadvantage of a single team is sorting out which individual moose were seen by teams, which is why GPS flight tracks (showing circles around points investigated) and waypoints of moose groups near borders were collected by survey and intensive search teams. We anticipated that each of the other 4 teams would complete 7-10 SUs daily, and that the entire survey would require 4-6 survey days. The teams contained a mixture of experience: 2 commercial charter pilots, one experienced in moose surveys; 2 ADF&G pilots, both with some experience in moose surveys; 3 experienced observers, and 2 inexperienced observers (both flew with same ADF&G pilot). We attempted to pair experienced pilots with inexperienced observers or vice versa. North and south half-sections of GSPE cells (1 minute of latitude × 5 minutes of longitude) were chosen randomly from the sampled units prior to the survey. To minimize moose movement across unit boundaries or between N-S halves of a unit, intensives were intended to occur within two hours after the regular search was concluded. The firing order for each survey team was assigned at the beginning of the day with the intent of temporally spacing SUs chosen for intensives. This prevented a backlog of intensive surveys that could create large time delays between the initial survey and the intensive search. Intensive searches were conducted throughout the survey to ensure adequate sampling of all survey conditions (e.g., light intensity and pilot-observer combinations).

The four pilot-observer teams conducting the regular GSPE survey followed the GSPE protocol used during the 2008 survey. Survey teams were instructed to keep their search times close to the average search times from 2008. Units in the survey area average 6.38 mi^2. In 2008, the average search intensity was 36 minutes (5.64 min/mi^2) in the low stratum and 42 minutes (7.45 min/mi^2) in the high stratum. The minimum and maximum search times were 13 and 57 minutes. In addition to standard survey activities, the four survey planes also recorded whether moose fell within the northern or southern half on the unit. If a group was half-in and half-out, the moose were recorded as one group and notes were kept on which of the moose were in which half. In addition, moose groups that were close to or spanning any of the borders (outer or N/S boundary) were given a waypoint so that they could be later referenced with GPS locations from the intensive search team.

The pilot-observer team conducting intensives surveyed their half-unit areas (3.19 mi^2) intensively enough to observe every moose in the area. Because the goal of the intensive search was to find every moose, we did not limit this search to a specific range of search intensities. SUs with more suitable habitat (e.g., presence of browse species) and thicker canopies were searched with greater intensity. In addition, moose tracks were used to track in on specific animals and alternatively the lack of tracks used as an indicator that moose are likely not present.

Gasaway et al. (1986:29) recommended search intensity ≥30 min/mi^2 for intensives during late winter surveys in semi-open coniferous canopy and a search intensity of 12 min/mi^2 for intensives in open canopy. For practical considerations we chose a target range of 9-12 minutes/mi^2 for intensives (~25 to 34 minutes). Intensives would be searched to the extent needed to see all the moose in a habitat type. In addition, moose tracks could be used to track specific animals in some low-density areas and the lack of tracks used as an indicator that moose were not likely present.

This was the first field test where a separate crew conducted the intensive surveys. Some coordination was necessary to match up moose seen during the regular search and during the intensive. Each survey plane was equipped with a GPS that was removed and downloaded each evening. We used the GPS track and waypoints of moose groups to match up the intensive and regular searches, calculate exact search times, and observe search styles in various habitat types. GPS tracks were downloaded each night so that organizers could use the information to rectify discrepancies between regular and intensive searches while the pilot-observer teams could still recall the details. The intensive crew did not conduct any regular searches to minimize their response time when a trial was available to begin.

RESULTS

Survey Conditions

The survey was based out of Sleetmute, Alaska during 1–6 March 2011. No surveys were conducted on 3 March because of strong and gusting winds. Snow coverage was complete, but conditions were difficult for detecting fresh tracks because snow was >4 days old at the beginning of the survey. The wind event on 3 March scoured moose tracks in open habitats, but old tracks in sheltered areas remained intact and hindered efforts to discern fresh tracks. In addition, small groups (e.g., 50) of caribou from the Mulchatna herd created numerous tracks and foraging craters that hindered observation of moose tracks in several low-density SUs in the southeast portion of the moose survey area. The weather conditions were primarily clear and sunny causing glare especially in wind-blown areas where an earlier icing crust was exposed. Shadows from vegetation were common on clear days, even in relatively open habitats like riparian stands of willow. Light turbulence occurred the first 2 days, resulting in airsickness for some observers, but relatively calm or light winds prevailed after the wind event.

Pilots attempted to follow moose tracks encountered during standard transect search patterns to determine freshness (no drifting by snow) or confirm movement out of the GSPE cell by directional tracking. Tracking was difficult in shadows, particularly in taller spruce forest. Pilots concentrating on tracks in taller vegetation would communicate to observers to watch for moose standing or bedded adjacent to visible tracks. Bedded moose under spruce canopy or in burned forest where dark windfall stumps were exposed were particularly challenging to discern, often only confirmed after 2 or more passes.

Sampling and Population Estimation

Crews surveyed 153 SUs with roughly a 35:65 split between units surveyed in the low and high stratum (Fig. 1). Forty-two intensive surveys were flown: 25 in the low stratum and 17 in the high stratum. Eleven intensive surveys were conducted on units not originally chosen for intensive searches. These “filler” intensives (Figs. 1 and 3) were conducted on the next available unit whenever the intensive plane was waiting on the completion of a randomly-chosen intensive and had adequate time to add another intensive. Delay between end of regular and start of intensive searches averaged 35 minutes (median = 25, range 0–122) with slight recording error due to watches not being synchronized among crews. This is the minimum delay; the location of starting and ending points for searches could have meant longer delays for specific animals depending on their location in a trial area. In addition, 10 randomly-chosen intensive searches were not completed. In most instances this was because survey conditions (e.g., daylight or wind) changed markedly between the initial survey and the intensive survey. This usually occurred at the end of the day, or if the length of time became too great (>2 hr) between the initial survey and potential intensive search. Finally, one survey plane with experienced pilot and observer switched from regular to intensive searches for the last 0.5 days to increase the sample size. Allocation of intensive trials was reexamined after 2.5 days of surveying. At that point it was determined that the maximum number of 25 SUs in the low stratum should be sampled intensively to meet precision objectives.

Mean search intensity for the survey was 6.4 min/mi^2 (range: 3.3 to 11.0 min/mi^2) and was higher in the high stratum for all search types (Table 2). Null moose counts were prevalent in the survey (56% of sampled units; Table 2 and Fig. 4), and moose were seen in only 13 of the 42 SUs chosen for intensive searches (Table 3). SUs sampled by each of the 4 survey teams were intensively searched (6–17 per team; Table 3). Intensive searches found 0 moose in 90% of the units where 0 moose were counted during the regular searches. The single trial most affecting the SCF point estimate and variance was SU 72 where 8 moose were observed in the standard search and 22 in the intensive. This demonstrates the potential for a single trial to greatly influence the SCF estimate in low density areas with a majority of intensively flown SUs having zero moose counted. In 3 units, more moose were observed during regular searches than intensive searches. In 2 of these instances, GPS tracks were used to determine post-hoc that moose had moved out of the unit between regular and intensive searches (time delays between regular and intensive searches: SU 392 = 85 min and SU 532 = 0 min). In one instance (SU 411, 0 min between searches) the survey team saw a moose that was not observed by the intensive team, which is evidence that SCF_0 is a minimum estimate. For purposes of estimating SCF, we set the intensive result equal to the regular result for SUs 392, 411, and 532; thus, on average 1.9 (64/34) more moose were seen during the intensive than during the regular survey (Table 2). Across survey teams, increased search time did not appear to be consistently related to the percentage of moose seen during regular searches (Table 3).

The GSPE population estimate for observable moose following the Unit 19A 2011 survey was 962 moose (SE = 106) with a 90% CI = 787 to 1,136 moose. The 18% relative precision at the 90% confidence level met our precision objective. SCF in the high stratum was 1.89 (SE = 0.40) and was 1.24 (SE = 0.37) in the low stratum. The estimate for total moose, which includes the intensive SCF estimate of moose missed during the survey, was 1,666 moose (SE = 348) with a 90% CI = 1,063 to 2,269. Relative precision of 36.2% at the 90% confidence level did not meet our precision objective.

Additional Cost of Intensive Searches

A single crew was used daily for most intensive searches, with the exception of the final day when a second crew was used for 4 searches to achieve desired sample size. Total fixed-wing time for intensive searches (exclusive of ferry time among sampled units) was 23.0 hours compared with 103.5 hours for regular searches. Thus, intensive searches required an additional 18% effort at $180/hr dry charter rate and $6.57/gal avgas assuming a rounded 7 gal/hr consumption rate (fuel $1056 + dry charter $4,140), $125/day/person for crew of 2 × 5 days = $1,500, and $180/hr × 10 hr = $1,800 ferry for extra plane from Fairbanks. Thus the total cost of the intensive searches for SCF was $8,496. This represented 19% of the total survey cost (J. Peirce memo, 15 March 2011).

DISCUSSION AND RECOMMENDATIONS

The purpose of moose surveys in Unit 19A has been to estimate population size for calculating sustained yield (harvest as a percentage of population) and to evaluate response of the population to management treatments, including wolf predation control since 2004 and moose harvest closure since 2006. Final decisions on harvest changes will hinge on several factors, including a desired harvest rate that will allow for continued population growth, discussions with local advisory committees, the precision of the 2011 estimate, and the timing of a renewed harvest in eastern Unit 19A in the larger context of moose harvest along the Kuskokwim River.

It is unlikely that area biologists will be able to use previous surveys in conjunction with the 2011 survey to determine if population growth has occurred as a result of Intensive Management treatments since 2004. Several factors hindered comparisons with earlier estimates, including low population density in all surveys (which contributes to poor precision), especially poor precision for observed moose in the 2008 survey, and no estimate of sightability in 2005 or 2008 (Table 1). Further, the precision of our SCF-corrected estimate of abundance in 2011 was lower than desired. The 2011 survey was the first GSPE survey in Unit 19A to include sightability correction with the population estimate and its variance, thus providing a benchmark for future comparison to subsequent estimates or to a threshold (yet to be determined). We recommend designing a monitoring program with specified precision criteria for Unit 19A that includes sampling protocols capable of detecting the expected level of change in abundance, or change in other response parameters (e.g., age-sex composition or calf survival), with respect to management treatments. For estimating abundance with GSPE, it may be advantageous to identify a smaller survey area (e.g., where high density cells are clustered) so the overall sampling proportion is higher with 150 cells (fixed cost for planning). Sampling to estimate composition from fixed areas of high density should include evaluation of required survey area and sample size to address the defined management question.

The field logistics for the intensive SCF are an important consideration for planning future estimates of intensive SCF. In Unit 19A, the lag time between when a regular team finished and the single intensive team started increased the chance for moose movement across a boundary. Despite daily planning to separate trials in space (for aircraft safety) and time (finish sequentially so intensive team goes from 1 trial to another efficiently), having only 1 intensive team was inefficient at times, hence the “filler” trials. We recommend that survey planes collect a GPS waypoint for all groups of moose, not just moose close to borders. This would have helped with clarification in some instances where groups of moose moved around within the unit between regular and intensive searches. We also recommend that survey organizers strive daily to ensure that intensives are allocated proportionately among pilot-observer teams to ensure that detection probability by all pilot-observer teams is adequately represented in SCF across daily variation in weather during the survey. In practice, weather often disrupts intended search patterns in portions of a survey area (e.g, topography dependent), so achieving adequate representation among teams by the end of the survey becomes the substitute objective. Constraints of fuel and pilot availability are less for surveys closer to logistic bases, where return to the survey area to finish remaining sample units is less problematic. We chose not to perform intensive SCFs along with the radio collar trials in Unit 21E in 2012 because the logistical complexity of the intensive SCFs would have risked completion of that remote survey, which typically has a short weather window.

Overall these logistic constraints would be mitigated if teams did their own intensive trials per Gasaway et al. (1986), which permits teams to immediately learn where they missed moose and possibly improve their search image. However, flight safety should remain the overriding concern for intensive SCF because low, slow flight and tight turns increase the risk for stall-spin accidents due to self-generated wake turbulence. The primary reason we chose a single experienced team to fly the intensive SCFs was because some of the other teams may have lacked sufficient experience to safely fly as needed to search intensively. Other drawbacks of the having teams perform their own intensive trials include: 1) the team may not improve their search image and repeatedly miss the same moose; 2) teams will be correcting to their own SCFc, thus introducing variability in the proportion of moose not seen even during the intensive surveys; and 3) due to the competitive nature of spotting moose, some teams may not be as motivated to find their own “mistakes” (i.e., the moose they missed). The decision on which method to use ultimately resides with the biologist conducting the survey (with concurrence by the Management Coordinator) based on the survey area and experience of all pilots.

The conditions that yielded high SCF in Unit 19A during 2011 may occur in other areas that include conifer forest and other vegetation inducing shadows in Interior Alaska during late winter. These preliminary results support estimation of survey-specific sightability during late winter surveys because sightability can be quite poor and likely variable among years (Gasaway et al. 1986:31) as a function of survey conditions (e.g., light characteristics, snow conditions, and pilot-observer experience). Sightability during late winter surveys should be compared with sightability during the typically poor survey conditions of early winter to determine whether late winter surveys in the Interior are truly a better estimate of population size.

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Table 1B. Estimates of abundance of observed moose and observed corrected for sightability (Confidence Interval, CI; Relative Precision, RP) in Game Management Unit 19A. Estimated number of observed moose in 1998 was based on Gasaway et al. (1986) with intensive searches of randomly sampled survey units to estimate sightability correction factor (SCF_0) whereas other surveys were geospatial population estimator.

		Observed moose			Observed moose with SCF_0		
Year	Area (mi^2)	Estimate	90% CI	RP at 90%	Estimate	90% CI	RP at 90%
1998	1,733[a]	--	--	--	2180	1,777, 2,583	18.5
2005	3,874[b]	1,085	897, 1,270	17.2	--	--	--
2008	3,874[c]	1,703	1,225, 2,181	28.0	--	--	--
2011	3,874	962	787, 1,136	18.1	1666	1,063, 2,269	36.2

[a] Holitna and Hoholitna drainages (62 of 158 sample units surveyed); survey conditions described as excellent (J. Whitman memo, 9 March 1998; survey data not in WinfoNet).

[b] Holitna and Stony rivers portion of larger survey area (7,156 mi^2); survey conditions not reported, no memo found (likely lost when McGrath office burned in December 2006).

[c] Stratification done in office for 2008 survey based on 2005 stratification; survey conditions not described (R. Seavoy memo, 11–14 March 2008).

Table 2B. Search intensity and counts for moose by survey type and density stratum in 6.38 mi^2 GSPE sample units (SUs), Stolitna study area, eastern Game Management Unit 19A, Alaska, 1–6 March 2011.

				Search intensity (min/mi^2)[a]		Moose counted			
Survey type	Sample type	Strat	SUs (*n*)	mean	range	*n*	mean	median	% SUs w/ 0 moose
Standard	All SUs	L	54	5.7	2.0 - 9.4	26	0.5	0	80
Standard	All SUs	H	99	6.7	3.3 - 11.0	440	4.4	2	43
Standard	Intensively searched SUs	L	25	5.5	2.8 - 9.4	2	0.5	0	80
Standard	Intensively searched SUs	H	17	6.6	4.7 - 8.5	29[b]	2.6	0	53
Intensive	All SUs	L	25	9.4	2.8 - 29.5	3	0.1	0	92
Intensive	All SUs	H	17	11.6	4.7 - 21.3	55	3.2	1	47

[a] Calculated from data forms, not directly from GPS track data. Search intensities based on average unit sizes for the survey area (6.38 mi^2 for whole units and 3.19 mi^2 for intensive areas).
[b] Excludes SU 411 where 1 moose was seen by survey team that was missed during intensive search.

Table 3B. Search intensity and proportion of moose observed during regular searches by survey team for sample units (SUs) that were also selected for intensive searches on half-cells.

Survey team	No. intensive units	Mean search intensity all SUs (min/mi^2)	Searches where moose observed (regular or intensive)	Mean search intensity SUs with moose (min/mi^2)	Moose seen on standard searches / moose seen on intensive searches (%)	Mean search intensity SUs without moose (min/mi^2)
1	8	6.00	0	--	--	6.00
2	6	6.14	3	6.17	60	6.11
3	14	6.66	5	7.55	78	6.17
4	14	5.22	3	6.48	93	4.87

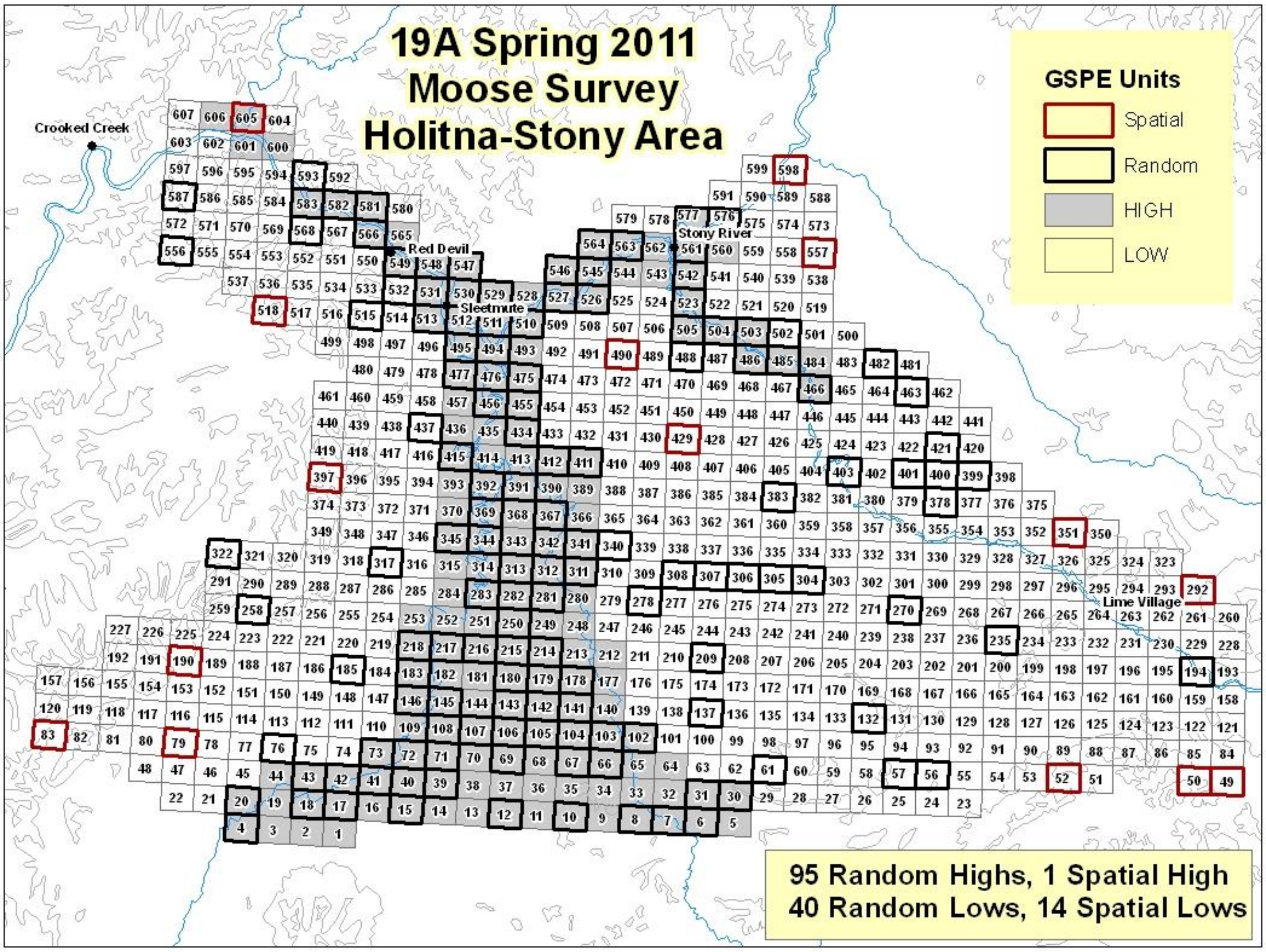

Figure 1B. Sampling design for the moose survey in eastern Game Management Unit 19A, 1-6 March 2011. This area composes most of the Central Kuskokwim Moose Management Area. Spatial and random units (n = 150) chosen for the survey are outlined in bold, and high-stratum units are shaded. Spatial pattern of these survey unit strata differed greatly from those in earlier surveys used to design the 2011 survey. Numbers in cells are the sample unit IDs.

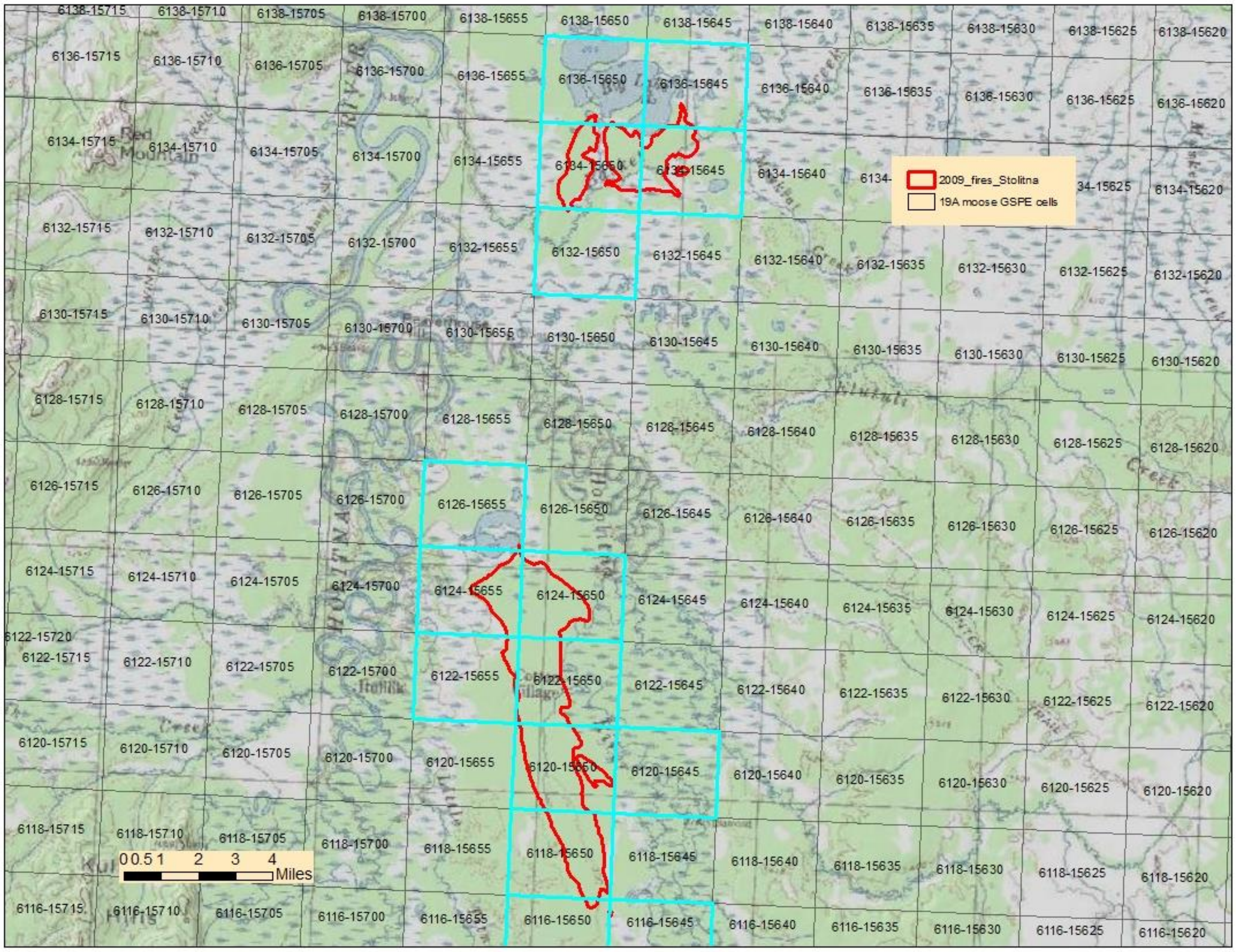

Figure 2B. GSPE cells that composed most of three 2009 burn areas in the Unit 19A survey area.

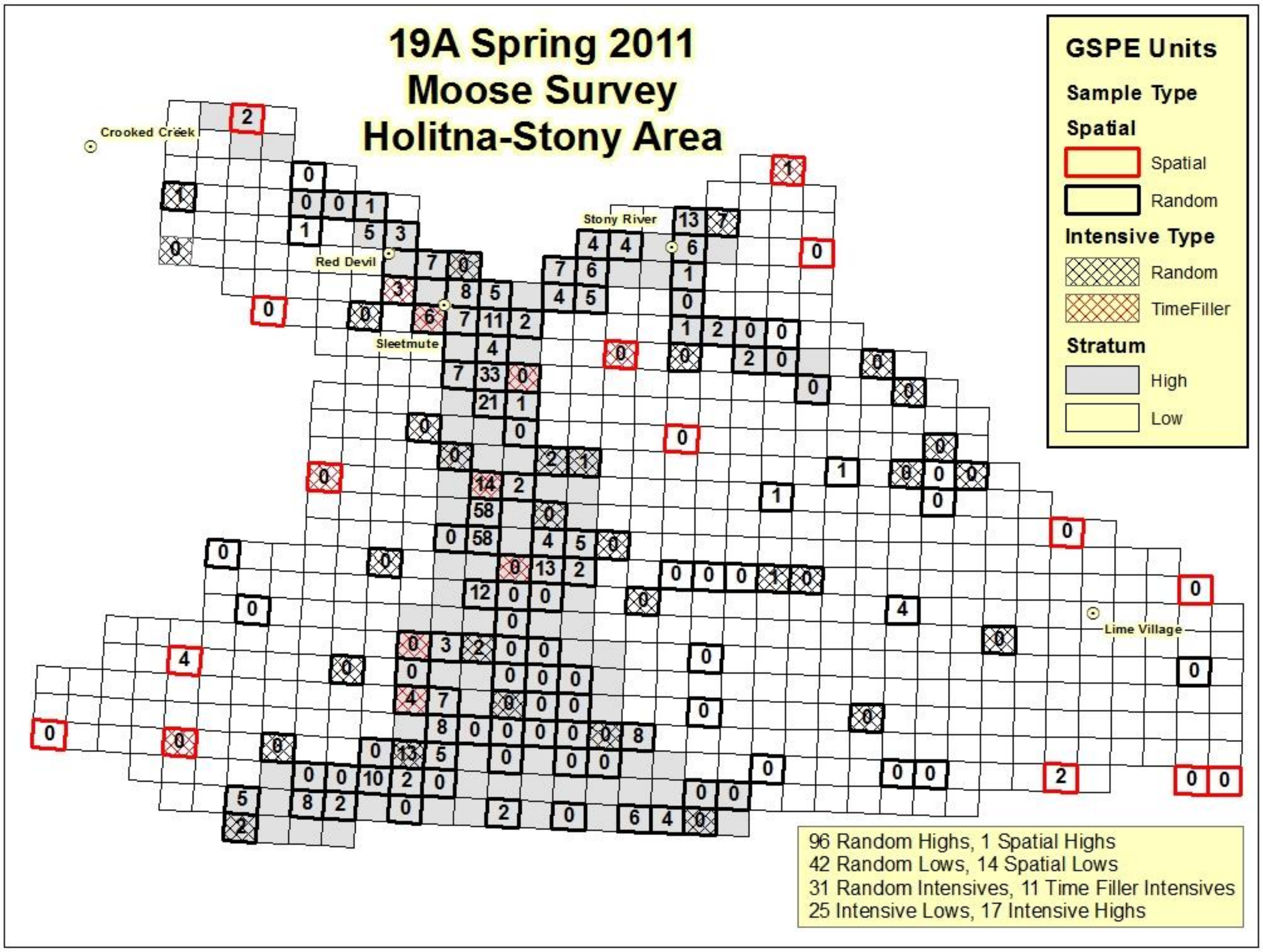

Figure 3B. Moose counts by cell sampled in the March 2011 moose survey in eastern Game Management Unit 19A. Sampling strata are described in Figure 1, and intensive searches actually conducted are depicted with cross hatching.

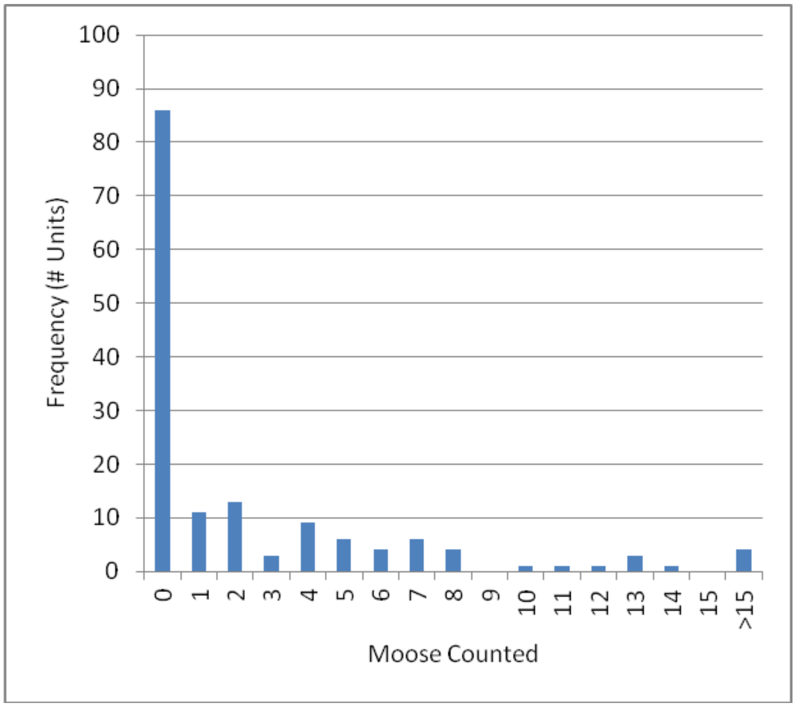

Figure 4B. Histogram of moose counted during the late winter 2011 GSPE survey in GMU 19A.

APPENDIX C. Department memo summarizing early winter radio collar sightability trials conducted during 2008–2010 and providing a first draft of associated field methods.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

DIVISION OF WILDLIFE CONSERVATION

SEAN PARNELL, GOVERNOR

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MEMORANDUM

TO: Distribution

FROM: Kalin Kellie, Wildlife Biologist
Tom Paragi, Wildlife Biologist

DATE: 9 December 2010

SUBJECT: GSPE Sightability Trials 2008–2010

Background

Sightability trials are binary tests of whether or not individual collared moose were observed during a GSPE survey. These data are used to determine the percentage of moose that are missed during GSPE surveys and provide us with a correction factor used to correct GSPE survey estimates of observable moose to estimates of total moose in a survey area (Gasaway et al. 1986, Boertje et al. 2007).

From 1999 to 2008, sightability trials were conducted to develop GSPE sightability correction factors (SCFs) for survey areas in McGrath and GMU 20A as part of on-going research projects (federal aid projects 1.58, 1.62, and 1.57). In federal aid project 1.66, these sightability trial data were used to develop a spatial SCF model that uses search intensity and % forest in surveyed GSPE units to estimate a survey-specific sightability correction factor. The spatial SCF model was developed using a 1999 vegetation classification of evaluated accuracy (National Land Cover Database, 30 m resolution) and is designed to be applicable to surveys throughout Interior Alaska. The model can be applied retrospectively to any prior GSPE surveys where search times were recorded and entered into WinfoNet. The spatial SCF model now requires testing in areas outside the 20A and McGrath areas where the model was trained.

From 2008 to 2010, we worked with area biologists Glenn Stout and Steve DuBois, as well as cooperators from the Kanuti NWR, to conduct sightability trials in 2 new areas. These data were used to develop area-specific SCFs. In addition, we documented the field methods for conducting sightability trials to encourage standardized methods for conducting sightability trials in the future. We will evaluate the performance of the spatial SCF model by comparing the area-specific SCFs to SCF predicted by the spatial SCF model. The methods, evaluation and implementation plan for the spatial SCF model and will be documented in a technical report due in August 2011.

Methods and Area Descriptions

We summarized previously-developed methods for conducting sightability trials in a short document that focuses on field logistics. This provides biologists with a practical reference for conducting sightability trials as part of their GSPE surveys. This working document is appended to the memo for reference, but biologists are cautioned to contact the authors for the most recent version prior to conducting the trials.

GMU 24B

The survey area included the Kanuti National Wildlife Refuge. It is located in the upper Koykuk River basin, west of the Dalton Highway. The survey area contained a forested mosaic of recent productive burns, riparian corridors, upland hills, and poorly-drained lowlands. The moose population in the area is low (0.22 moose/mi^2 in 2007) and declining (Stout 2008). Radiocollared moose used for the sightability trials are part of an on-going cooperative study between ADF&G, USFWS, BLM and NPS to examine movements and nutrition of GMU 24 moose.

All survey and sightability operations were based out of Bettles, Alaska. Bulls, lone cows and cows with calves were used in both trials. From 10-14 December 2008, 27 sightability trials were conducted using 5 different survey teams. Tom Seaton (Fairbanks Assistant Area Biologist, ADF&G) piloted the radiotracking plane, assisted by observer Kalin Kellie. During 15–19 December 2010, 21 sightability trials were conducted using 5 different survey teams. Mike Spindler (Kanuti NWR, USFWS) piloted the radiotracking plane, assisted by observer Tom Paragi. Survey costs associated with sightability trials in 2008 and 2010 were paid by USFWS and the ADF&G moose management budget for Galena. Details and results for the 2008 and 2010 GSPE moose surveys, including description of survey-specific conditions, will be available in the ADF&G moose management reports covering those years.

GMU 20D Southwest

The survey area is bounded on the west by the Delta River, by the Tanana River to the North, the Johnson River to the East and the Alaska Range to the South. The habitat in the generally forested survey area includes riparian corridors along the major rivers, recent productive burns, low-scrub uplands into subalpine with productive willow bands along creeks, and large tracts of agricultural land between the Alaska Highway and the Tanana River. The moose population in this area is at high density (4.7 moose/mi^2 in 2007) and increasing (DuBois 2008).

All survey and sightability operations were based out of Delta Junction, Alaska. On 13 December 2009, 13 sightability trials were conducted using 2 different survey teams. Only bull moose were available for sightability trials. Andy Greenblatt (Shadow Aviation) piloted the radiotracking plane, assisted by observer Kalin Kellie. From 17 to 21 December 2010, 21 sightability trials were conducted using 6 pilot-observer combinations of survey teams. Bulls, lone cows and cows with calves were used in these trials. Kalin Kellie piloted the radiotracking plane without an observer. Survey costs associated with sightability trials were paid for using U.S. Army special project money. Details and results for the 2009 and 2010 GSPE moose surveys will be available in the ADF&G moose management reports covering those years.

SCF Estimates

In GMU 24B, 20 additional GSPE units were surveyed in 2008 and 8 additional GSPE units in 2010 specifically to conduct sightability trials. Collared moose were seen in 21 out of 27 trials in 2008 (SCF = 1.286) and in 20 out of 21 trials in 2010 (SCF = 1.05). Single-year samples are small and a composite SCF from 2 years represents a better approximation of the range of conditions across both surveys (41 out of 48 trials, SCF = 1.171).

In GMU 20D Southwest, 4 additional GPSE units were surveyed in 2009 and 7 additional GSPE units in 2010 specifically to conduct sightability trials. Collared moose were seen in 12 out of 13 trials in 2009 (SCF = 1.083) and in 19 out of 21 trials in 2010 (SCF = 1.105). Again, because single-year samples are small, we present a 2-year composite SCF (31 out of 34 trials, SCF = 1.097).

Discussion

Sightability trial data are important for two reasons. First, radio collar SCFs developed in GMU 20A and the McGrath area may not be applicable to other fall survey areas. Thus, wherever radiocollared moose are available, we recommend developing a composite SCF over several years that is specific to the habitat of a survey area. Second, accumulating fall sightability trial data in Interior Alaska is desired for building a long-term, diverse dataset of sightability trials needed to further refine the spatial SCF.

The SCF trials conducted in GMU 24B are the first trials conducted in a low-density moose population. The majority of sightability trial data collected are from high-density moose populations. Because a large portion of the moose populations in Interior Alaska are at low density, we are especially interested in collecting more trial data in low-density areas. Biologists with radiocollared moose should consider including additional funding for sightability trials in their requests for GSPE survey funds. We currently have no on-going research project with a budget for fall sightability trials, but are willing to assist with logistics.

Finally, sightability trials have not been conducted anywhere in the Interior with sufficient sample sizes to distinguish among annual SCFs. According to a power analysis conducted by B. Taras (ADF&G Biometrician) for 2012 spring SCF trials in GMU 21E (federal aid project 1.69), over 100 trials annually are needed to statistically differentiate among annual SCFs in a survey area. Because of this, we recommend applying multi-year composite SCFs and associated variance to GSPE estimates. Further, we recommend collecting an additional year of sightability trial data before applying composite SCFs in GMU 24B and GMU 20 Southwest. In GMU 24B, there was a large difference in between the 2008 and the 2010 SCF estimates, and another year of trials may provide a better overall composite of the variation in sightability. In GMU 20D Southwest, SCF estimates are fairly similar between years, but slightly lower than expected given the habitat type and conditions. We recommend another year of sightability trials to verify that this SCF estimate is accurate.

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Conducting Sightability Trials

by Kalin Kellie and Tom Paragi, ADF&G

last modified: 9 December 2010

Overview

The GSPE method for estimating population size is based on counts of moose observed during the survey. However, an unknown portion of moose are missed when surveying sample units. To estimate this portion, and correct GSPE estimates of observable moose to total moose, biologists have employed sightability trials of collared moose during the survey. Sightability trials are binary information collected whenever a pilot/observer team (survey team) is presented with the opportunity to observe a collared moose during a survey. To correct estimates of observable moose to total moose, the GSPE estimate is multiplied by the ratio of total trials over the number of trials where a moose was seen. The variation surrounding this ratio should also be combined with the variance of the GSPE estimate. Estimates corrected to total moose will have less precision, but provide a more accurate estimation of population size and comprehensive estimate of precision to evaluate harvest rates and management decisions.

Ideally, sightability correction factors represent the unique combination of conditions encountered during that survey (e.g., observers, weather, snow cover). However, because it is logistically difficult to obtain sightability trial data, biologists commonly pool several years of sightability data and use the composite sightability correction factor to correct all GSPE survey estimates for that area. Thus, most sightability correction factors obtained through sightability trials represent sightability conditions specific to an area, but averaged across survey years and associated conditions.

The precision surrounding a correction factor increases with sample size, but we cannot recommend a target sample size for two reasons. First, the biologist needs to first determine what level of precision is desired to meet management objectives. Secondly, the precision surrounding a correction factor is dependent on the magnitude of correction. Estimates of poor sightability require more sampling than good sightability to achieve similar estimate precision. Prior to trials, we recommend that biologists conduct a power analysis where they input their standards for precision and provide a rough estimate of sightability based on habitat and search intensity in their survey area.

Methods

Sightability trials should be conducted under normal survey conditions (e.g., normal search times, typical survey team members). Survey teams tend to increase search effort when they know they are being tested, so to ensure normal survey conditions, biologists must attempt to keep survey teams somewhat unaware that they are being tested until after the trial is completed. There are two different scenarios currently employed to conduct trials: 1) random trials conducted during the survey, and 2) nonrandom trials conducted during the survey. Random trials are conducted only when a collared moose occurs within a sample unit randomly chosen for the GSPE survey. Where collared moose and randomly selected units are sparse on the landscape, random trials are difficult to obtain and should be augmented by nonrandom trials to achieve the target sample size.

Nonrandom trials conducted during a survey are collected by directing survey teams to survey in units that were not sampled for GSPE estimation. These units are usually included covertly along with random GSPE sample units so that survey teams are unaware that they are being tested. Nonrandom units can be chosen dynamically during the survey. Further, if the number of collared moose is limiting, nonrandom trials can be conducted in the same unit multiple times by rotating survey teams.

Units selected for nonrandom trials are based on the knowledge that the unit contains collared moose. Thus, on average, units chosen for nonrandom trials contain a higher moose density than units chosen randomly or based on their spatial position. Because of this bias, nonrandom units added to the survey to augment sightability trials should not be used for population estimation. Thus, nonrandom units should be considered an additional survey cost specific to sightability estimation.

Logistics

Acquiring blind sightability trials requires daily, real-time field coordination. It is most efficient to have a plane dedicated to radiotracking collared moose and organizing the sampling dynamically each day based on collared moose locations (the radiotracking crew). The passenger (or pilot where a passenger is unavailable) in the radiotracking crew is responsible for directing survey teams to survey both random and nonrandom units seamlessly so that it is not readily apparent to the teams when they are conducting a sightability trial. Usually, the radiotracking crew assigns 2 to 3 units to each survey team at the start of the day, requesting that they check in after completing each unit to find out if there was a collared moose in that unit. Throughout the day, the radiotracking crew will assign additional random and nonrandom units to each survey team based on current collared moose locations, minimizing the chance that collared moose move out of the units before they can be observed. Toward the end of the day, the radiotracking crew will decrease the number of on-going trials so there is adequate time to verify trials upon completion (if necessary) and confirm locations of collared moose for initial assignments the next day. Because the radiotracking crew does not need adequate survey light to begin locating moose, they can usually launch 30–60 minutes prior to survey teams each day and verify whether collared moose are still in the chosen units. Different collared moose are used each day to eventually cover the entire study area. To increase sample size, multiple survey teams can be cycled through a unit to achieve multiple trials using the same collared moose. However, random units surveyed twice for sightability trials can only be used once in GSPE estimation.

The minimum data required for sightability trials are 1) whether or not the moose was seen during the trial, 2) the survey unit number, and 3) the frequency of the radiocollared moose. Additional information can be recorded during sightability trials that can help the biologist determine why moose are being missed (see last page). The data desired for sightability trials should be determined prior to the survey and should be recorded by the radiotracking crew at the conclusion of each sightability trial. It is not necessary for the radiotracking crew to record this information each time they relocate a collared moose, because the parameters are only useful as they relate to moose sightability during the trial. It also should be noted by the radiotracking crew if a collared moose has clearly moved between the time it was initially available for observation and the time when the moose was subsequently relocated by radiotracking.

Survey teams should not deviate from the normal GSPE survey methods used for a survey area. To ensure normal methods, average search times can be calculated from previous surveys and used as a standard. This ensures that sightability trial data are representative of normal survey conditions. When involved in sightability trials, a survey team also does two things. First, survey teams should note whether or not an animal in the group was collared on the standard GSPE survey forms during a survey. They can also use the form (see below) to record additional information for collared moose. It is important that the survey teams know ahead of time that they are required to record this information during the survey for collared moose they observe. Second, whenever a survey team completes a unit, they will make radio contact with the radiotracking crew and report whether they saw a collared moose and relay other related data they recorded about the collared moose. If the survey team and radiotracking crew can agree that the collared moose was seen, then the radiotracking crew can record the information and move forward. If the survey team failed to see the moose, the radiotracking crew must return to that unit and point out the moose to the survey team by circling it. Sometimes collars are not visible from the air. To determine whether this is the case, once the moose has been pointed out, the survey team can use their GPS track to determine whether the moose was seen.

As a final step to ensure blind sightability trials, specific information concerning the remaining random sample units should be kept confidential. Mark off each day the completed units on a map of the survey area, but do not indicate on that map which random units remain to be surveyed (best to keep the master survey map hidden from the survey teams). In addition, the survey teams should not keep a running tally of completed units on their clipboards because some units may be reused for sightability trials. When units are reused, the radiotracking crew should attempt to blend these in with assigned units, rather than leaving them until the end of the survey when it will be more noticeable. The radiotracking crew can keep track of daily progress on a separate map, recording the number of random and nonrandom units each day in the context of what needs to be completed for the GSPE survey. They will also track the number of sightability trials conducted and, if necessary, keep a running calculation of the correction factor to determine if it is meeting expectations of precision at the targeted sample size. Each evening, the radiotracking crew should present each survey team with a list of 2-3 “starter” units for the next day; these could be random or nonrandom units based on distribution of collared moose and the critical need to maintain separation of survey aircraft for safety. Each evening the covariates for observed collars should be recorded from each survey team clipboard onto a master sheet by the radiotracking crew.

The radiotracking crew can decide to use only a subset of the survey teams for trials each day if there are a large number of survey teams or they are distributed over such a an area that is too large to maintain radio contact with all of the planes. If a survey team is likely to be out of radio contact in an area with no collared moose, they can be given their full unit list for the day and should be made aware do not need to check in after each unit.

Suggested materials for SCF trials:

- Cord(s) for downloading GPS devices each night to archive tracks and waypoints from

each survey plane (clarify the intent to download at start of survey)
- Compact color printer for daily updates of survey progress by density strata (reduces errors in using color pencils in large surveys by connecting directly to GIS program)

Pilot/Observer: ____

Date	Survey pilot/obs	GSPE SU	Surv wpt	Freq	Sex	Group Size	Stand/ Bed	Veg* /burn?	% cover	Seen?

* within 10 m of moose: conifer forest, mixed forest, deciduous forest, shrub, meadow, water

Figure 1C. Radiotracking plane observations of radiocollared moose during GSPE survey.

Pilot/Observer: ____

Date	GSPE UnitID	Time	Wpt	Sex	Group Size	Standing/ Bedded	Veg*/burn?	% cover class (see flyer)

* within 10 m of moose: conifer forest, mixed forest, deciduous forest, shrub, meadow, water

Figure 2C. Survey team observations of radiocollared moose during GSPE survey.

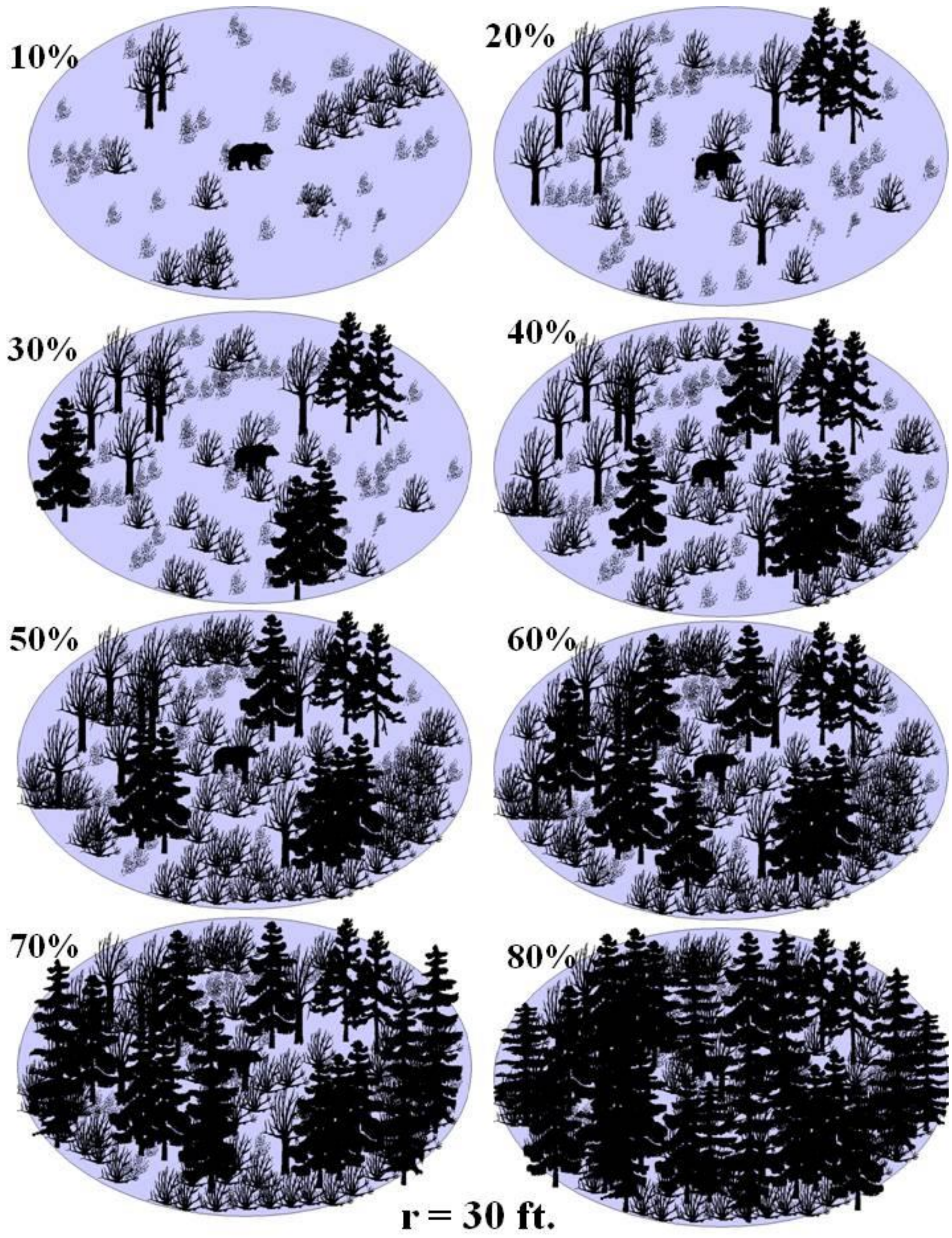

Figure 3C. Cover classification within 30 feet of the radiocollared moose. Cover classification courtesy of Earl Becker, ADF&G Anchorage.

APPENDIX D. Department memo summarizing an early winter GSPE survey conducted in 2012 that used a single stratification level and applied survey-specific radio collar SCF.

MEMORANDUM State of Alaska

Department of Fish and Game
Interior/Northeast Region, Fairbanks

TO: Doreen Parker McNeill
Management Coordinator
Roger J. Seavoy
McGrath Area Biologist

DATE: September 10, 2014

THRU: Scott M. Brainerd
Research Coordinator

TELEPHONE: 459-7327

FROM: Tom F. Paragi
Wildlife Biologist
C. Tom Seaton
Wildlife Biologist
Division of Wildlife Conservation
Fairbanks

SUBJECT: 2012 Moose management area survey, Unit 19D

Background and sampling design

The department conducted a moose survey in a 1,118 mi^2 area composed of the experimental micromanagement area (EMMA, 528 mi^2) containing McGrath and a surrounding buffer during 16–19 November 2012. Moose population and composition estimates in eastern Unit 19D East are priority for the department because of an ongoing intensive management program designed to increase moose harvest and a concurrent research program designed to document and identify causes for changes in moose population size. The research objective during 2001–2009 was to document rate of increase in the population following reduced predation (Keech et al. 2011).

In recent years moose surveys in this area have been conducted within a range of sampling intensity and spatial scales (Keech et al., memo 28 January 2009). During the present absence of a research biologist to design the next phase of monitoring, research and management staff discussed the current priority for information needs in the McGrath area office in early October 2012. Until the objectives of the new research effort are clarified, a relatively precise estimate with sightability correction was warranted for options to detect future change in abundance. Brian Taras, Wildlife Biometrician, assisted with planning advice.

The decision was to reallocate sampling effort from the remaining portion (99 sample units [SUs]) of a larger survey area outside the EMMA buffer (Keech et al., memo 28 January 2009) into other areas in winter 2012–2013. We chose to reallocate 25 of the 99 to the present survey (originally 92 units) to increase the 50% sampling intensity of recent years to 64% (92 + 25 = 117 of 184 total) for greater power to detect change. The rationale was that moose population growth has slowed or stalled in recent years, so detection of further increase or decrease will be more difficult. Until managers define the desired power to detect change in a decision framework to suspend or re-implement predation control, we took a conservative approach to enable a more precise estimate of abundance. We randomly chose 110 cells and selectively chose 7 additional cells to fill spatial gaps based only on layout (no prior information or ecological factors), optimizing those which had the lowest number of adjacent selected cells.

As with past surveys in this area, we utilized radio-collared adult females (n = 48 potentially in or near the survey area) to conduct trials for estimating a sightability correction factor (SCF) for moose not seen during the geospatial population estimator (GSPE) technique. We used random selection, rather than the systematic, checkerboard selection applied in recent years, to allocate the 50% sampling intensity. Our concern in part was that a systematic selection would compromise our ability to test pilots in blind trials, where some trials must be assigned outside the selected GSPE units. We were also concerned that a checkerboard spatial pattern might introduce variance into trend analysis if moose tendency to move between adjacent units was low in fall because of habitat patterns.

Radio tracking of collared adult females began on 15 November 2012. We initiated the survey on 16 November with ~ 8 inches of snow 2 days after about 4 inches had fallen. No additional snowfall occurred after the start of the survey, so the snow surface appeared rough. Substantial wind prior to and during the survey resulted in even low-elevation turbulence in some flat areas and removed snow from conifer branches even in thick forest and scoured snow from open vegetation, exposing low vegetation such as grass and tussocks. Overall we rated survey conditions as adequate.

Methods

Three Department of Fish and Game aircraft/pilots and 3 private charter aircraft/pilots conducted the 2012 survey with a single observer in each aircraft. Pilots and aircraft for surveys were Ernie Finch and Mark Keech (Piper PA-18), Joshua Peirce and Roger Seavoy (state Piper PA-18), Tom Seaton (state Bellanca Scout, primarily telemetry), and Dan Sailors (Husky). Observers were Mark Cox (volunteer), Tom Paragi (ADF&G, primarily telemetry), Doreen Parker McNeill, Rita St. Louis, Louise Standish (ADF&G), and Kevin Whitworth (MTNT, Inc.). Survey teams were given written instructions to apply at least the same approximate survey effort as the 2011 survey, which averaged 42 minutes per SU with a maximum of 62 minutes.

As in past years, we used the geospatial population estimator (GSPE) technique (Kellie and DeLong 2006). Due to the homogeneous distribution of moose in the MMA, we used a single (high density) stratum for the entire area. For sightability calculations, the telemetry crew located radio-collared moose in SUs prior to survey crews entering the unit. In addition to their normal survey duties, survey crews took note of all radio collars seen on moose. After completion of survey flying in each SU, survey crews reported their findings of collared moose to the telemetry plane. The telemetry crew would then begin the process of making a determination if the collared moose were seen or not seen by the survey crew. The telemetry crew relocated radiocollared moose and with the survey crew's assistance, would determine whether or not the radio-collared moose had been sighted during the survey. Observers and pilots were given written instructions on protocols that included noting on the data sheet when collared moose were seen and the GPS waypoint. Survey teams were reminded to not include on data sheet tallies those collared and associated moose that were not seen during a survey but subsequently pointed out by the telemetry team. Each evening at the office the completed survey units were entered into a spreadsheet that was joined to the survey unit shapefile in the GIS for printing a map that showed which selected units were completed for ease of tracking team assignments and radio collar locations the following day. We attempted to spread trials among survey teams and over the period of the survey to reflect conditions.

Population estimates for the EMMA and the EMMA + buffer areas were calculated using GSPE software in WinfoNet. To estimate population abundance for these single-stratum areas, analysis areas were defined for each survey area and 20 low-stratum "dummy" cells outside the area (Fig. 1) were appended to the data before uploading into WinfoNet. The "dummy cells" were entered as sampled units with a count of zero moose. Population estimates were then calculated using analysis areas for the two survey area (DeLong 2006). We calculated a sightability correction factor (SCF) and its variance using the Delta method (Rice 1995) to account for nonlinearity in its expected value. Thus, SCF differs slightly from simply dividing available collared moose by observed collared moose. We calculated variances for the SCF corrected population estimates and for age-sex ratios to infer population composition using Goodman's formula for a product of random variables (Goodman 1960) and present 90% confidence intervals. Ratio estimates and variance calculations for abundance and ratios using WinfoNet output and estimated SCF were facilitated by formulas entered into spreadsheets courtesy of Brian Taras.

Results and Discussion

Sky conditions throughout the survey were clear with a fairly persistent northeast wind and temperatures 0° F to −20° F. Light to moderate turbulence existed in the hills on all days and in portions of the flats on most days. Surveys were attempted but not completed in 4 SUs in the hills (82, 375, 412 twice, 5001 twice). Thus, we completed 113 of 117 high stratum SUs in the EMMA + buffer survey area (Fig. 1). The telemetry team completed 9 of the 113 survey units between radio-tracking duties. The average search intensity was 7.8 min/mi^2 (SE = 0.1) or 47.1 minutes per unit (range: 23–69 min), which was closer to the minimum recommended for GSPE (8–10 min/mi^2; Kellie and DeLong 2006:32) than the 2011 survey. Survey teams observed 23 of 30 (76.7%) radiocollared moose within selected SUs plus 8 extra SUs not selected for the GSPE, which produced an SCF of 1.29 (SE = 0.13). Counts from SCF trials in SUs not chosen for the GSPE do not apply to the population estimate (biased positive by presence of at least 1 moose) but are valid for an estimate of age-sex composition.

During the fall 2012 survey we observed 650 moose in the survey area. The moose population estimate from these observed animals was 1,036 (0.9 moose/mi^2), whereas the estimate with SCF applied was 1,337 (1.2/mi^2) with a relative precision of 19% at the 90% confidence level (Table 1). Composition (rate per 100 cows, no SCF applied) including data from the 8 extra SCF trials was 37 bulls, 35 calves, and 7 yearling bulls (n = 734). The abundance estimate for the EMMA only was 474 observed moose and 612 with SCF (1.2/mi^2) with a relative precision of 22% at the 90% confidence level (Table 2). Using the GSPE software to estimate ratios of sex and age classes and incorporating variance in SCF to define precision (Tables 1 and 2) provides greater inference over uncorrected ratios without variance.

Moose abundance is a primary metric for monitoring the continued implementation of an intensive management program in Unit 19D East. The relatively precise, SCF corrected estimates from fall 2012 should provide options for evaluating trend in moose abundance and demography relative to management actions in coming years.

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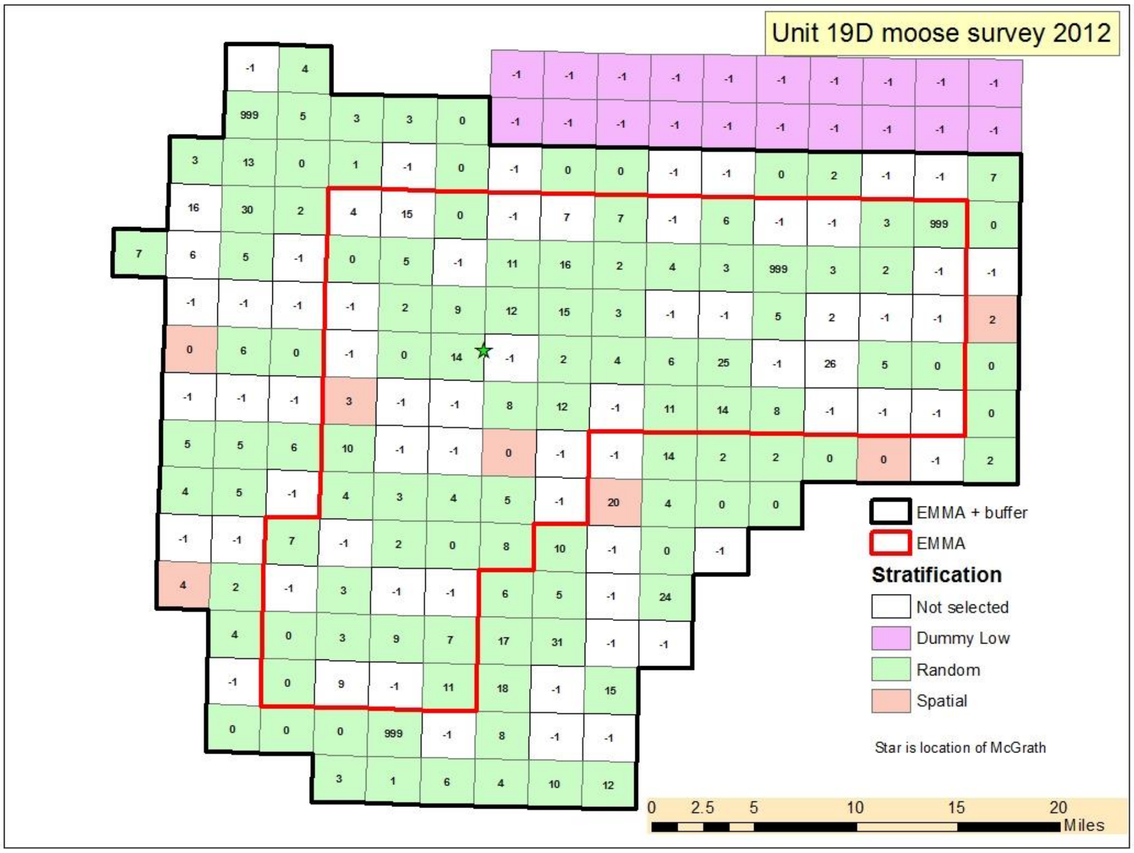

Figure 1. Sampling and stratification used to estimate moose numbers within the Unit 19D EMMA + buffer during 16–19 November 2012. Numbers indicate actual moose observed, with 999 indicating failed attempts to conduct sightability trials in selected SUs. White squares are non-selected SUs where −1 indicates no sampling and positive numbers are extra sightability trials that contribute toward uncorrected age-sex composition but not the GSPE. Pink SUs were appended post-hoc and given a count of zero moose in WinfoNet to fulfill the requirement for 2 strata in WinfoNet calculations. These units were ignored in abundance estimation through the use of analysis areas. Experimental micromanagement area (EMMA) is also shown in red.

Table 1. Estimates from fall moose surveys in the experimental moose management area + buffer (1,118 mi^2), Unit 19D, 2001–2012.

Year	Number of moose observed	Estimate of observable moose (90% CI)	SCF ($n_{observed}$, $n_{available}$)	Estimate with SCF applied (90% CI)	Calves: 100 cows (90% CI)	Bulls:100 cows (90% CI)	Yearling bulls:100 cows (90% CI)	Total moose/mi^2
2001	455	727 (±89)	1.19 (32, 38)	868 (±147)	36 (±10)	21 (±6)	8 (±3)	0.8
2004	578	940 (±107)	1.27	1192 (±228)	66 (±18)	18 (±6)	8 (±4)	1.1
2006	762	1117 (±102)	1.17 (42, 49)	1308 (±174)	55 (±10)	30 (±8)	12 (±3)	1.2
2007	844	1290 (±131)	1.33 (31, 41)	1720 (±306)	53 (±14)	36 (±10)	15 (±4)	1.5
2008	678	1356 (±116)	1.27 (16, 20)	1718 (±352)	44 (±12)	40 (±11)	14 (±5)	1.5
2009	711	1435 (±127)	1.27	1820 (±323)	38 (±10)	40 (±11)	11 (±4)	1.6
2010	712	1416 (±114)	1.27	1796 (±312)	43 (±11)	49 (±13)	16 (±5)	1.6
2011	639	1298 (±121)	1.27	1647 (±295)	42 (±11)	33 (±10)	10 (±3)	1.5
2012	650	1036 (±91)	1.29 (23, 30)	1337 (±256)	36 (±10)	39 (±12)	8 (±3)	1.2

Table 2. Estimates from fall moose surveys in the experimental micromanagement area (528 mi^2), Unit 19D, 2001–2012.

Year	Number of moose observed	Estimates of observable moose (90% CI)[a]	SCF ($n_{observed}$, $n_{available}$)	Estimate with SCF applied (90% CI)	Calves: 100 cows (90% CI)	Bulls:100 cows (90% CI)	Yearling bulls:100 cows (90% CI)	Total moose/mi^2
2001	440	440 (±0)	1.19 (32,38)	525 (±61)	34 (±6)	18 (±3)	8 (±1)	1.0
2003	237	424 (±79)	1.35 (21,28)	573[a](±138)	56 (±20)	18 (±8)	5 (±3)	1.1
2004	531	531 (±0)	1.27	674 (±104)	63 (±14)	13 (±3)	6 (±1)	1.3
2005	479	479 (±0)	1.30 (38,49)	621 (±79)	51 (±9)	18 (±3)	9 (±2)	1.2
2006	591	591 (±0)	1.17 (42,49)	692 (±67)	58 (±8)	25 (±3)	14 (±2)	1.3
2007	662	662 (±0)	1.33 (31,41)	883 (±129)	56 (±12)	39 (±8)	16 (±3)	1.7
2008	296	599 (±103)	1.27 (16,20)	758 (±191)	43 (±14)	33 (±12)	14 (±7)	1.4
2009	331	654 (±93)	1.27	830 (±174)	44 (±14)	31 (±11)	7 (±3)	1.6
2010	311	625 (±74)	1.27	793 (±154)	43 (±13)	38 (±13)	15 (±5)	1.5
2011	335	658 (±90)	1.27	835 (±170)	49 (±14)	31 (±14)	12 (±5)	1.6
2012	308	474 (±62)	1.29 (23,30)	612 (±131)	48 (±15)	29 (±11)	6 (±3)	1.2

[a] All SUs were sampled during 2001 and 2004–2007, thus counts of observable moose have no variance or CIs.

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