Final Report
Alaska Moose Monitoring Workshop
Anchorage, Alaska
April 24 & 25, 2018

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Executive Summary

Moose are vitally important to Alaska's subsistence and recreational hunters, wildlife viewers and economy. Both the State of Alaska and federal government are mandated to manage moose populations. Specific information needs vary across the state, but the ability to monitor the size, trend, and composition of moose populations is fundamental to sound, scientific management.

Moose population monitoring (including measures of abundance, composition, and trend) in Alaska has routinely involved aerial surveys flown in the fall and early winter, prior to antler drop, when sexes can be distinguished. These surveys rely on complete snow cover to optimize sightability. Over the past decade, delayed onset of snowfall has crippled biologists' ability to monitor moose populations using existing protocols, especially in coastal regions.

Two additional factors create challenges for moose population monitoring. First, changes in Alaska's human population, moose harvest patterns, and agency legal mandates have altered the types and amounts of information managers need to inform decisions regarding hunting seasons, bag limits, allocation among user groups, and predator management. Second, state and federal agency budgets for monitoring moose populations are static or declining.

To address these challenges, the Wildlife Management Institute (WMI) collaborated with the Alaska Department of Fish and Game (ADF&G), the U.S. Fish and Wildlife Service (FWS), and the National Park Service (NPS) to convene the Alaska Moose Monitoring Workshop in Anchorage on April 24 and 25, 2018. The workshop brought together over 70 managers, researchers, and biometricians from the sponsoring agencies, as well as invited speakers from the National Marine Fisheries Service (NMFS), Mount Holyoke College, and Environment Yukon to address challenges to monitoring moose populations. Major financial support for the workshop was provided by the U.S. Fish and Wildlife Service through the Western Alaska Landscape Conservation Cooperative. Additional support was provided by the Alaska Department of Fish and Game and Wildlife Management Institute.

Prior to the workshop, the organizers conducted a series of focus group discussions, individual interviews, and an online survey of moose biologists in Alaska and Yukon to gather information on issues and challenges related to monitoring moose populations. Results helped formulate the objectives of the workshop which were:

- To examine the nature and frequency of challenges to monitoring moose populations.
- To identify actions that can be taken now to improve achievement of survey objectives.
- To examine potential alternatives to increase monitoring efficiency and effectiveness.
- To identify and prioritize research needs to improve moose monitoring in Alaska.

The first day of the workshop consisted of a series of presentations and discussions about results of the pre-workshop survey, monitoring information needs, ways to improve the most commonly used method for estimating abundance (Geospatial Population Estimation or GSPE), and alternative ways to monitor moose populations, including use of infrared-based surveys.

For the morning of April 25th, participants were divided into two working groups that focused on 1.) optimizing application of GSPE, and 2.) exploring alternatives to GSPE. In relation to optimizing application of GSPE, group 1 identified the following needs:

- Developing a common sightability model that can be applied across the state. Although this may be less accurate than survey-specific measures of sighability, it could significantly reduce cost associated with collecting sightability information and promote more consistent, widespread, and well-documented inclusion of sightability error into estimates of abundance;
- Automate existing, common methods for incorporating sightability estimates into WINFONET, including the ability to archive sightability data;
- Make stratification more efficient by reducing the number of units that you need to stratify, targeting areas of highest uncertainty. This may be facilitated by using the statewide archive for GSPE survey and stratification data to develop a multi-year model for "desk-top" stratification;
- Increase efficiency by committing additional biometrician time in support of the design and implementation of GSPE, to 1) evaluate existing monitoring programs on a case-by-case basis, and 2) support the automation of common statistical tools to evaluate GSPE performance;
- Evaluate the potential of increasing the number of strata from 2 to 3 in WinfoNet to increase estimate precision;
- Update the GSPE User Manual with lessons learned and improvements.

A team consisting initially of **Joel Holyoak, Charlotte Westing, Graham Frye,** and **Kim Jones** agreed to take the lead for further developing these "need statements" and formulating a proposal to take to the ADF&G Division of Wildlife Conservation Division Management Team for consideration. Biologists from the FWS and NPS will be engaged, as well, and encouraged to advance consideration of ways to address these needs through those agencies.

With respect to the need for alternatives to address the impacts of changing climate on managers' ability to apply GSPE (e.g., lack of adequate snowcover, lack of adequate flying weather, and difficulty gathering composition data due to timing of antler drop), group 2 identified a range of needs and actions. Time constraints limited the group's ability to discuss the full range of needs and actions, but the top three needs selected via a simple majority vote to explore in depth were:

- Developing a “Decision Framework” tool to help biologists evaluate the pros and cons of various monitoring techniques and select a method addressing particular information needs (e.g. relative importance of abundance vs composition data) and circumstances (e.g. moose density, and distribution, habitat variables, population size, magnitude of harvest). Scott Brainerd referenced an existing framework developed by Tom Paragi for use in intensive management areas that can serve as a starting point for this work. **Bill Dunker** and **Carmen Daggett** agreed to take the lead on follow-through on this topic.
- Exploring a range of remote sensing techniques, including sensors using other spectral bands (e.g., thermal imaging, LiDAR), to supplement strictly visual observations. **Todd Rinaldi** agreed to take the lead on follow-through on this topic.
- Improving sightability models. This overlapped with one of the needs identified by group 1. However, group 2’s discussion focused on the specific research directions needed and opportunities available to develop improved models. **McCrea Cobb** agreed to take the lead on follow-through on this topic, which will need to be closely coordinated with the group 1 team identified above.

During the discussion following report-outs from the working groups, questions arose regarding how the additional needs/opportunities identified by group 2 could be further explored and, ultimately incorporated into the Decision Framework. These needs span a range of topics including CKMR[1], engaging hunters/communities in gathering data, utilizing browse surveys and other indirect measures of condition, etc. **Scott Brainerd** agreed to take the lead on follow-through on this topic.

All four objectives for the workshop were successfully accomplished. The magnitude and spatial scale of the problems in completing surveys were well documented through the pre-workshop survey and are now broadly recognized. Personnel from the participating agencies are discussing the conditions under which different survey methods are most appropriate and the importance of considering modifications of survey methodologies as an adaptation strategy to the impacts of climate change in Alaska. Concrete “next steps” were identified and individuals volunteered to take responsibility for follow-through.

After the workshop, the planning team met to discuss how to ensure there was follow-through on the output and recommendations. The need for an individual who could commit time to this effort was identified; without that there is a high risk that results will not be implemented. The group recommended that ADF&G find a way to hire Kalin Seaton through a contract or part-time position to work on this. Bruce Dale concurred in that recommendation and Michael Guttery agreed to move forward in finding a way to engage Kalin.

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[1] Close-Kin Mark Recapture (Bravington, Skaug, and Anderson, *Statistical Science*, 2016).

<u>The Workshop</u>

The workshop began with opening remarks by Bruce Dale, Director of the ADF&G Division of Wildlife Conservation; Ryan Mollnow, Chief of Hunting and Fishing for the Alaska Region of the FWS; and Deb Cooper, Associate Regional Director of Resource-related Programs with the NPS. Each of the speakers emphasized the importance of moose to the economy, ecology, and culture of Alaska, the value of accurate information on the status of moose populations for decision-makers, and the need for their agencies to work collaboratively and leverage talent and resources. In view of ongoing changes in the climate and funding levels, these speakers also encouraged the participants to “think outside the box” to overcome the challenges of monitoring moose populations.

Moose Population Information Needs (What do we really need to know?)

The first segment of the workshop focused on moose population information needs. Joel Reynolds, with the NPS, started this off with a presentation on framing monitoring objectives. Key points in Joel’s presentation (Appendix 1) included:

1. Monitoring programs should be developed through a four step process that aligns with adaptive management:
    a. Problem Framing: defining what management decisions must be made and what data are needed to inform those decisions;
    b. Designing the monitoring;
    c. Implementing the monitoring
    d. Learn & Revise: analyzing results of monitoring and adapting the approach to continually improve the data.
2. Across Alaska, the type of management decisions and socio-biological contexts for management vary widely, so no “one size” solution to moose monitoring will “fit all.”

Next, Kalin Seaton, formerly with ADF&G, presented results of the pre-workshop survey related to monitoring objectives. Key elements of Kalin’s presentation (Appendix 2) included:

1. Moose monitoring in Alaska is being adversely affected by poor sightability, inadequate snow cover, inadequate flying weather, chronic cancellation of surveys, and low precision of estimates.
2. The impact of these factors varies from Southeast, to Southcentral, Eastern Interior, Western Interior, Coastal Subarctic, and Arctic/North Slope.
3. Biologists’ monitor moose populations for the following reasons, in descending order of importance:
    a. Inform harvest regulations

    b. Maintain specific goals for abundance and trend
    c. Understand effects of management
    d. Use direct observation to keep abreast of several factors
    e. Maintain public credibility
    f. Learn more about moose ecology
    g. Determine impacts of other human activities
    h. Manage opportunities for other uses
4. The most important metrics are composition, abundance, trend, and harvest.
5. Nearly a third of respondents indicated that composition data are their primary information source for management decisions and nearly half said they use composition when other sources are not available. This suggests careful consideration of how composition data are collected, analyzed, and used is important.
6. Biologists primarily use composition data to monitor adult sex:age ratios and calf recruitment rates.
7. In addition to quantitative results, biologists reported aerial surveys were important for maintaining credibility with the public, becoming acquainted with their area of management responsibility, job satisfaction, and to gather observations on other species.
8. Although two thirds of biologists agreed with the statement that their monitoring program is adequate to address their goals, 23% reported they disagreed with that statement.

Todd Rinaldi, with ADF&G, closed out this segment with a presentation on ADF&G Moose Operational Planning. Key elements in Todd's presentation (Appendix 3) included:

1. Moose operational plans are used to document the goals (general descriptions of desired outcomes of moose management, e.g. "Increase the harvestable surplus of bull moose in key hunting areas near local communities by reducing mortality from bear and wolf predation") and objectives (measurable targets and standards of performance, e.g. Manage for 25 fall calves: 100 cows in Subunit 13A). The plans provide guidance for management as well as survey and inventory programs.
2. The level of precision and the type of monitoring information needed varies widely across Alaska. In areas where the Intensive Management Law requires increasing moose numbers and harvests (e.g. GMU 20A), greater precision and frequent estimates of abundance are needed. In remote areas with relatively limited harvest pressure (e.g. GMU 25D) managers' decisions can be supported with less precise and less frequent estimates.

3. ADF&G is in the process of reviewing and updating operational plan goals and objectives to ensure that goals are consistent with public desires, as reflected in decisions of the Board of Game, and objectives are measurable.

Application and Challenges of Geospatial Population Estimation (GSPE)

The pre-workshop summary documented that Geospatial Population Estimation (GSPE) was the most frequently used method to monitor moose populations. GSPE was developed in the late 1990s and early 2000s as an improvement to an earlier method of stratified random sampling, commonly referred to as the "Gasaway" method. GSPE uses a fixed grid cell approach, rather than the variable-sized sample units of the Gasaway method, as well as additional statistical analysis to provide more precise estimates.

The effectiveness of both the GSPE and Gasaway methods, like all monitoring methods that rely on observations of moose from aircraft, depend on observers' ability to detect moose visually. This is referred to as "sightability." Although some work has been done recently to assess sightability during surveys without snow cover on the ground (see Aderman presentation in next section), biologists have relied on solid snow cover to enhance sightability when conducting GSPE surveys. This has become increasingly problematic as climate change has reduced the extent, frequency, and duration of complete snow cover in many parts of Alaska. This issue was a major motivating factor for this workshop.

In addition to issues related to lack of consistent snow cover, some biologists, researchers, and biometricians were concerned about other factors that influence the results of GSPE or other monitoring methods. To address these concerns, the pre-workshop survey included a range of question related to issues implementing survey techniques. The second section of the workshop focused on results of this part of the pre-workshop survey and a review of the history and application of GSPE.

Kassidy Colson, with ADF&G, started this section with a presentation on "Issues Implementing Survey Techniques" (see Appendix 4). Key points of the presentation included:

1. Across Alaska, composition, abundance, population trend, and harvest were the four most important parameters monitored (in that order, starting with most important).
2. Most biologists prefer to conduct surveys in early winter (Oct. – Dec.), although about one third indicated a preference for late winter (Jan. – Apr.). Most biologists reported being able to conduct surveys during their preferred time.
3. GSPE and trend counts were identified as the most important monitoring methods, although Gasaway census and population models were also used to some extent.

4. Fall/early winter count areas and GSPE were cited as the most important means to monitor sex and age composition.
5. For management contexts where a level of precision of ± 15% or less is desired, GSPE estimates are not meeting the desired level.
6. Most biologists use some form of sightability correction in monitoring, but approaches varied and lack of analytical tools hampers application.
7. Nearly half of the respondents reported being unsuccessful in conducting abundance surveys at least half the time, and over a third reported being unsuccessful in conducting composition surveys at least half the time.
8. The ability to detect population trend from surveys is related to population density. It is easier to detect changes in high density populations than in low density ones.

Next, Jay Ver Hoef, with NOAA Fisheries, who led development of the GSPE, reviewed this survey method. Key elements of Jay's presentation (see Appendix 5) included:

1. Major differences between GSPE and the Gasaway methods are that GSPE:
    a. Uses grid cells with straight line edges, making it easier and more efficient to sample the area, using modern GPS-aided flight patterns;
    b. Balances the size of plots with sample size;
    c. Is model-based, so sampling can be optimized rather than randomized;
    d. Uses two strata that can be applied using prior knowledge, rather than requiring aerial survey time and expense;
    e. Uniform survey effort of about 8 minutes/square mile (developed based on earlier studies in Interior Alaska suggesting this effort level would achieve detection rates of about 90-95%); and
    f. Allows sampling more often temporally and less dense spatially.
2. GSPE has been used over 450 times across Alaska, with over 24,000 sample units from 1997 to the present.
3. The accumulation of data over space and time allows for more efficient sampling and more precise estimation, especially for smaller areas.
4. Models can be used to push analysis further; several potential extension were discussed, including the potential for integrative analyses combining multiple information streams.

Improvements and Alternatives to GSPE

Given the problems associated with application of GSPE, the next segment of the workshop covered ways to improve application of GSPE as well as several alternative methods to monitor moose populations. To begin this segment, Kalin Seaton presented the final summary of the pre-workshop survey. Key elements of Kalin's presentation (Appendix 6) included:

1. The three main issues with monitoring moose are chronic cancellation of surveys due to a wide range of factors, having to conduct surveys during less-preferred times of the year, and inadequate precision of surveys to inform management decisions.
2. Reasons surveys fail or are canceled include inadequate snow cover, poor flying weather, and antler drop.
3. Inadequate snow cover is a moderately important problem in the Arctic and a very important factor in the rest of the state.
4. Poor flying weather is a factor in all the coastal areas. Often weather "windows" are too short to permit stratification flights, followed by surveys of GSPE cells or Gasaway sample units.
5. The timing of antler drop, and the fact that large bulls drop antlers earlier than smaller bulls, can greatly impact the ability to gather accurate composition data.
6. Biologists who reported having to conduct surveys at less-preferred times cited the following reasons in descending order of importance:
    a. Lack of adequate snow cover;
    b. Lack of flying weather;
    c. Lack of pilot/observer availability;
    d. Lack of daylight;
    e. Lack of funding; and
    f. Lack of adequate inter-agency coordination.
7. The need for greater precision in estimating abundance and composition supports the need for new techniques. New techniques should address:
    a. Snow cover
    b. Accuracy
    c. Precision
    d. Continuity with Old Method
    e. Flying Weather
    f. Dense Cover
    g. Similar Cost
    h. Documentation and Support
    i. Flexible Timing
8. At the same time, any new technique should avoid:
    a. Increase staff time required;
    b. Substantially increase cost;
    c. Require more staff/charters;
    d. Rely on ground observations;

    e. Require specimens from hunters; or
    f. Rely on helicopters for aerial surveys
9. There is a clear need for interagency coordination and commitment of resources to address the problems identified in the survey.

Andy Aderman, with Togiak National Wildlife Refuge, presented results of efforts to incorporate sightability into GSPE surveys on the refuge, under conditions where snow cover is lacking. Key elements of Andy's presentation (Appendix 7) included:

1. The Togiak NWR moose population has been expanding to the west since the 1980s and demonstrated the highest rates of productivity in Alaska over the past 2 decades.
2. Low intensity reconnaissance flights in the 1980s detected fewer than a dozen moose on average in GMU 17A, but by 2011, a Gasaway census estimated the population at over 1150.
3. Since 2012, surveys have been hampered by lack of snow cover.
4. The refuge set three objectives for monitoring:
    a. Estimate abundance of moose with 25% precision at the 90% confidence level and maximize accuracy using a Sightability Correction Factor (SCF).
    b. Develop a survey-specific SCF for moose surveys conducted during 4 sampling periods (Spring and Fall 2016- 2017) with 15% relative precision at the 95% confidence level.
    c. Develop a model for predicting sightability of moose on Togiak NWR using attributes known to affect sightability of moose (snow cover, search rate, habitat category) with 25% precision at the 90% confidence level.
5. The Refuge worked with a PhD student in statistics (Matt Higham) at Oregon State and Jay Ver Hoef to integrate a mark-resight sightability correction that considered survey unit level covariates into the GSPE. They conducted sightability trials over 4 sampling occasions in 2016 and 2017.
6. With that, they were able to estimate abundance of moose with <25% precision at the 90% confidence level under no snow conditions on Togiak, due in large part to the fact that most of the moose habitat is not forested. However, the precision of the estimate may be less than this because it does not include error surrounding the SCF estimate.

Sophie Czetwertynski, with Environment Yukon, presented on her work to apply modeling to optimize survey effort and precision in Yukon. Key elements of Sophie's presentation (Appendix 8) included:

1. Moose population monitoring in Yukon has not been affected by climate change to the same extent as coastal Alaska, but challenges there include:

    a. Low population densities leading to many empty sample units or grid cells for either the Gasaway or GSPE methods;
    b. High variation in "high" blocks leading to uncertainty in final population estimate;
    c. Low spatial autocorrelation;
    d. Crew/stakeholder frustrations of not counting moose in known very high blocks that are excluded from sampling due to randomization; and
    e. No opportunity to use expert (First Nations, outfitters, etc.) knowledge to influence sampling leading to lower public confidence in survey results.
2. To address these issues, Environment Yukon developed models to optimize survey effort. The models use a combination of landscape/habitat and local knowledge to optimize sampling based on reducing uncertainty of predictions for not-yet-sampled units.
3. The survey has three phases:
    a. Randomly select 30% of sample units (SU) anticipated to be sampled across predicted densities;
    b. Use data and observations to generate candidate models every evening. Select SU to fly the following day to meet model assumptions and reduce uncertainty in model predictions. This phase represents the majority of flying days; and
    c. Model validation – generate predictive map of unsampled SUs. Allow crew to select survey units where they feel the model is not predicting well. Recheck model(s).
4. Advantages of this approach include:
    a. Quantitative description of moose abundance-habitat/landscape relationships;
    b. No need for stratification flight;
    c. Accounts for patchy distributions of moose, particularly in low density areas;
    d. Active participation of stakeholders and crew throughout survey;
    e. Greater stakeholder confidence in survey results;
    f. Subsampling is area specific (similar to geospatial); and
    g. Composition can be estimated based on observed patterns as opposed to group size.
5. Limitations include:
    a. Requires availability of high quality GIS layers to develop predictive models;
    b. Requires "Expert" information;
    c. Requires staff experienced in modeling messy data that will catch unexpected issues; and
    d. A limited number of survey areas have been tested.
6. Next steps in development of this approach include:

   a. Finalizing updates to R-based GUI;
   b. Developing a spatial sightability correction (using available SCF data);
   c. Extrapolating to unsurveyed Moose Management Units using weighting in space and time;
   d. Detecting landscape-level influences (access) and quantifying risk; and
   e. Accounting for composition bias in recruitment surveys.

Adam Craig, with ADF&G, presented on his analysis of the potential for adaptive cluster sampling to improve efficiency and accuracy of moose surveys. Key points in Adam's presentation (Appendix 9) included:

1. Adaptive cluster sampling is most effective with smaller populations and where individuals tend to be clustered in space, rather than broadly distributed. It has been used in a broad range of fields, including biology, ecology and epidemiology.
2. Adaptive cluster sampling uses a grid, similar to GSPE, but sampling proceeds by initially surveying a number of grid cells, then sampling cells adjacent to any cells that are found to be occupied by a pre-determined number of individuals, etc. until the limits of the cluster are determined.
3. An adaptive cluster sample can provide efficient estimation with careful choice of design type, critical value, neighborhood, and initial sample size.
4. Advantages include:
   a. Potentially more efficient sampling design;
   b. Locating areas of high animal abundance;
   c. Flexible construction; and
   d. Potential cost savings
5. Disadvantages include:
   a. Less control of the final sample size and total cost of the survey; and
   b. Counts in edge units are not used unless part of the initial sample.
6. Although adaptive cluster sampling holds some promise for increasing the efficiency and accuracy of moose surveys, particularly in areas where habitat conditions contribute to patchy distribution of moose, it is too early to tell when and where the advantages outweigh the disadvantages.

John Merickel, with ADF&G, presented information on the potential to use close-kin mark-recapture (CKMR) methods to monitor moose. Key elements of John's presentation (Appendix 10) included:

1. CKMR can be used to estimate abundance and vital rates using only samples from harvested animals.

2. CKMR is analogous to the Lincoln-Peterson mark-recapture method, except that it uses genetics to identify parent-offspring pairs (POPs) and bases estimates on the ratio of POPs to total adults sampled.
3. CKMR works best in large populations that are sparsely sampled.
4. Hunter-harvested moose could provide an inexpensive source of samples.
5. Advantages of CKMR include:
    a. Only need samples from dead animals.
    b. Half-siblings permit study of adults without catching them.
    c. No confounding from tag-reporting.
    d. Less susceptible to bias from un-modelled heterogeneity of capture because no self-recaptures needed.
    e. CV is inverse to sample size not its square root, so precision improves rapidly with additional samples.
6. Potential applications in Alaska include:
    a. Harvested populations.
    b. Areas without reliable abundance and vital rate estimation techniques.
    c. Different from GSPE type estimates.
    d. May be more of a long term monitoring tool.

Thomas Millette, with the GeoProcessing Lab at Mount Holyoke College, presented information on the potential use of AIMS-based aerial thermal moose survey technology, techniques and results (AIMS). Key elements of Tom's presentation (Appendix 11) included:

1. AIMS has been used to census moose in Vermont and Nova Scotia;
2. The technique uses an aerial platform, flying designated transects, taking simultaneous color and infrared images that are subsequently analyzed via a computer program;
3. Images detected via infrared can be cross-checked with the color photos;
4. Results are subject to environmental variability related to temperature, time of day, sky conditions, snow/ no snow, canopy condition, and animal behavior;
5. Advantages include:
    a. Tight control on area metrics;
    b. All data is available in GIS formats;
    c. Results are available for scrutiny and reprocessing;
    d. Works without snow as long as ground is frozen;
    e. Imagery can be used to support additional analyses (eg. Habitat analysis, animal condition, composition).
6. Disadvantages include:
    a. More expensive per hectare;
    b. Longer turn-around times.

Optimizing and Exploring Alternatives to GSPE

On the morning of April 25th, participants were divided into two working groups. Group 1 focused on optimizing application of GSPE. Group 2 explored alternatives to GSPE.

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