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Challenges to Monitoring Moose in Alaska

Kalin A. Kellie, Kassidy E. Colson, and Joel H. Reynolds

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Alaska Department of Fish and Game **Division of Wildlife Conservation**

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Cover Photo: Two moose viewed from a Piper Super Cub during a February moose survey near Sleetmute, Alaska. ©2005 ADF&G, photo by Kalin Kellie.

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Abstract

Monitoring moose (*Alces alces*) populations is a key component of wildlife management in Alaska. In response to reports of recent difficulties implementing the existing techniques for monitoring moose, an interagency work group identified the monitoring techniques currently in use, characterized technique performance, and examined commonality and geographic patterns of problems encountered when applying techniques in the field. Field biologists engaged in monitoring moose in Alaska were emailed an online questionnaire designed to organize information about overall program satisfaction, population parameters monitored, techniques for estimating parameters, and current impediments to monitoring.

During 2007–2017, biologists failed to complete 42% of scheduled surveys to estimate abundance (n = 295 surveys, 42 respondents). Survey failure rates differed across ecoregions: failure rates were highest in the Kenai/Southcentral (57%), Eastern Interior (43%) and Coastal Subarctic (41%) ecoregions, but lower rates of survey failure were reported for Western Interior (20%) and Arctic Slope (15%) ecoregions of Alaska. Patterns of survey failure were similar for composition.

Lack of adequate snow cover and poor flying weather were the first and second most commonly cited reasons, respectively, for failure to complete scheduled surveys. Where surveys were successfully completed, estimates generally had less precision than desired, with only 50% of respondents achieving intended precision goals for abundance estimation. Biologists indicated a strong willingness to use a new method for monitoring moose if it 1) did not rely on complete snow cover, 2) was more accurate, 3) provided higher precision, 4) provided continuity with previous estimates, 5) could be used where inclement flying weather is frequent, 6) could be used in areas with dense vegetative cover, 7) was accompanied by technical assistance or a user manual, and 6) was similar in cost to existing methods. They indicated mild unwillingness to use a new method that 1) used ground observations, 2) required hunters to turn in specimens, 3) used helicopters for aerial observation, or 4) required more resources than current methods.

These results highlight the need to develop new survey and measurement techniques that can be conducted independently of problematic snow and weather conditions, or at least have far more flexibility in implementing survey protocols. Indeed, the problem of monitoring moose in areas with poor snow conditions is so challenging and pervasive that solutions may require a concentrated, cooperative effort among agencies, including practical feedback from field biologists. Precision of existing techniques may also be improved through better optimization of survey design, the integration of more historical population information in estimation, and perhaps by better clarifying precision requirements relative to program goals.

Key words: Moose, *Alces alces*, monitoring programs, moose management, aerial surveys, abundance, composition, survey protocols**.**

Introduction

Population monitoring is most useful to wildlife conservation if it effectively informs a decision-making process (Crowe 1983, Shea et al. 1998, Reynolds et al. 2016). Ideally, such monitoring programs first clearly identify the program goals, especially the management decisions to be informed and level of information quality they require. Later development steps usually include identifying major drivers of change, then designing the data collection and analysis activities to discern among causes to inform actions (Stoltenberg et al. 1970, Reynolds 2012, Williams and Brown 2013). In practice, many monitoring programs are reactive to public demand for information on short notice. Hence, at their conception, programs are often based on or adapted from existing methods without first clarifying program and information goals or thoroughly assessing applicability of the chosen methods to the new context. Such monitoring programs can easily extend into costly, indefinite surveillance efforts that fail to inform decisions (for any of a multitude of reasons—see summaries of causes and impacts in Nichols and Williams 2006, Field et al. 2007, Reynolds 2012, Reynolds et al. 2016). Regular evaluation is essential for program learning and improvement (e.g., adaptive monitoring sensu in Lindenmeyer and Likens 2009), and there is a growing emphasis on monitoring program evaluation and assessment (e.g., Lindenmeyer and Likens 2009, Reynolds et al. 2016), but it still remains a relatively rare undertaking. Rarer still is the simultaneous evaluation of multiple monitoring programs for a single species, including important species such as moose (*Alces alces*), to highlight common challenges, gain insight into regional drivers of those challenges, and identify potentially fruitful areas for broad improvement.

The importance of evaluating moose monitoring in Alaska is underscored by the priority placed on moose conservation and harvest opportunities by state and federal wildlife agencies. In 1994, the Alaska State Legislature identified moose as a species deserving intensive management actions to restore populations should numbers fall below predetermined population and harvest objectives (AS 16.05.255(e)). Three of the four monitoring networks of the National Park Service (NPS) in Alaska have identified moose as a 'vital sign' for regular monitoring because of the species' role as an indicator of long-term habitat changes and its crucial importance to many subsistence communities as a primary food source (Burch and Lawler 2012): the Central Alaska Network (CAKN), the Southwest Alaska Network (SWAN), and the Arctic Network (ARCN). In 1997, U.S. Fish and Wildlife Refuges (NWRs) in Alaska were specifically tasked by Congress to provide continued opportunity for subsistence hunting, with moose listed as an important subsistence species for 8 of the largest NWRs (West 2009). Additionally, all but 2 of the 16 NWRs in Alaska either have moose specifically listed in the legislating mandates that created them (ANILCA 1980) or identified moose as indicators for their monitoring programs (McCrea Cobb, Ecologist, USFWS, personal communication).

Effective monitoring of moose can be challenging in Alaska. Programs tend to focus on compliance with objectives established by the Alaska Board of Game under intensive management law for population levels and harvest, which are listed in the Alaska Administrative Code as abundances (5 AAC 92.108). Methods are largely limited to aerial observation due to Alaska's vast habitats and lack of road access. Monitoring is often conducted collaboratively among multiple agencies to defray costs and measure populations occurring over multiple land ownership jurisdictions. This provides the opportunity for distributing the data management, process, and analysis workflows across all parties monitoring moose, but it also adds the challenges of interagency communication and agreement on monitoring goals, including selection of parameters for estimation and associated precision.

Anecdotal conversations, moose management reports and recent research publications had indicated that many biologists in Alaska find it increasingly difficult to monitor moose (e.g., Barten 2014, Battle and Stantorf 2018, Wald and Neilson 2014, and personal communication to Joel Reynolds: Courtney Carty, Chief, Division of Natural Resources, Bristol Bay Native Association; Susan Alexander, Manager, Alaska Peninsula and Becharof National Wildlife Refuges, U.S. Fish and Wildlife Service [USFWS]; Troy Hamon, Chief, Natural Resources, Katmai National Park and Preserve, National Park Service [NPS]). In response, a collaborative working group was formed in 2013 between researchers from the Alaska Department of Fish and Game (ADF&G), the USFWS, and the Western Alaska Landscape Conservation Cooperative (LCC) to identify barriers and opportunities for improvement of moose monitoring across Alaska. This working group surveyed field biologists for a direct, holistic evaluation of their monitoring programs. The approach allowed biologists to consider their entire program, including recent and unpublished data, and report in more detail any attempted surveys that were mentioned only briefly, if at all, in reports. The approach also allowed the assessment to consider all moose monitoring programs across this large area (Alaska) using standardized questions, facilitating summarization and evaluation across methods, habitats, and agencies.

In evaluating responses received by the group for this report, we (the authors of this report) sought to assess 1) characteristics of current monitoring programs relative to goals, population dynamics and ecoregions, 2) limitations with current monitoring techniques, and 3) relative importance of limitations with respect to goals, geography or region, commonality, and impact on programs. We aimed to inform research designed to improve and expand options for monitoring. This report is intended to provide context for a sustained interagency conversation among managers, researchers, and administrators seeking to adapt techniques to changing conditions and better achieve their management goals for this species.

Study Area

The group gathered information about moose monitoring programs across Alaska. The study area was divided into 6 ecoregions based on a combination of ADF&G Game Management Units (GMUs), similarities in habitat, and common weather patterns. For example, Interior Alaska was divided into two ecoregions, east and west of Tanana (Eastern Interior and Western Interior), to reflect coastal versus continental influences on weather (Fig. 1).

Methods

To determine the range of issues and probable responses from the target population of field biologists (Vaske 2008), the working group conducted a series of focused interviews with 8 sets of experienced moose biologists from different ecoregions of Alaska (Fig.1, Appendix A). Most discussions included two participants, typically a pair of state and federal biologists with a history of collaboration, though number of participants and composition of the groups varied. For purposes of analysis, conversations were recorded and transcribed. Written informed consent was obtained from participants before the focus interviews. Interview questions were distributed

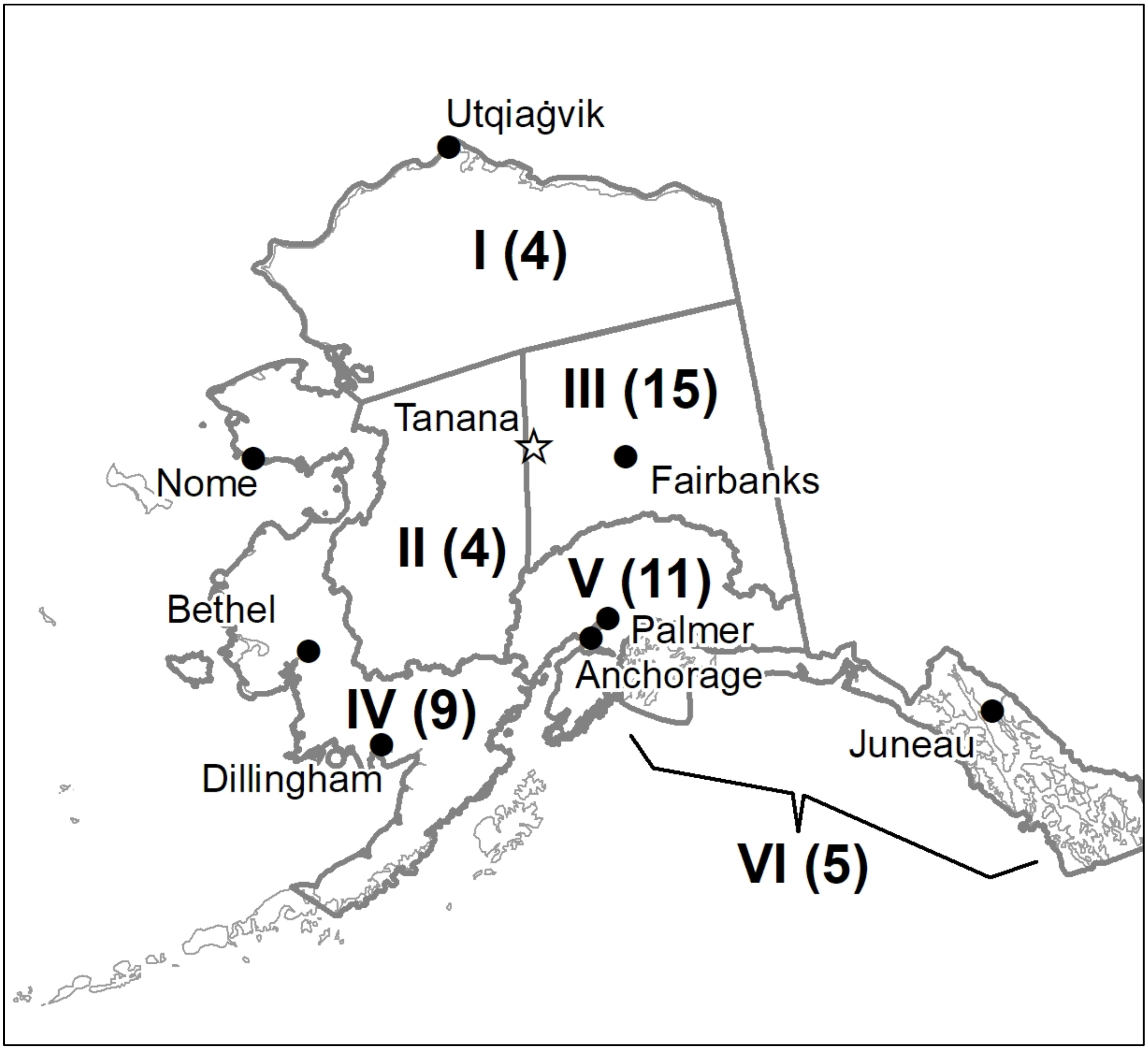

Figure 1. Ecoregions of Alaska that were used to group moose populations in an online questionnaire to field biologists about their moose monitoring programs. Black lines delineate ecoregions: (I) Arctic and Arctic Slope, (II) Western Interior predominantly west of Tanana, (III) Eastern Interior predominantly east of Tanana, (IV) Coastal Subarctic, (V) Kenai/Southcentral, and (VI) Southeast and temperate coast. Ecoregion boundaries were drawn by the authors to align with wildlife management boundaries, areas of common habitat, and areas with similar patterns of winter weather. Major cities (black circles) are provided for reference. The village of Tanana (white star) was used as the east/west boundary for ecoregions II and III. The number of respondents/moose populations represented in this study are given in parentheses within each ecoregion.

to the participants in advance (Appendix A) and interviews took the form of either an in-person or over-the-phone, elicitation-style survey (Manfredo 1992).

The working group used the results from focused discussions to cluster responses and design a structured online questionnaire to be distributed to all field biologists who actively monitor moose in Alaska. Early drafts of the questionnaire were distributed to experts within the Human Dimensions Branch of the USFWS (Fort Collins, CO) and to other human dimensions experts for external expert review and pretesting (Salant and Dillman 1994, Krosnick 1999). Additional rounds of revision and expert feedback ensured proper questionnaire length, tone, and scope. For a final pretest, we administered the questionnaire to a small pool of potential respondents. The final questionnaire consisted of 38 questions and was designed to collect information on respondent demographics, monitoring program goals and approaches, program performance, and direction for future research (Appendix B). We implemented the survey using the Survey Monkey (Portland, OR) platform. Individuals who responded that they did not monitor some category (e.g., did not monitor composition, or monitored only a single area) were automatically advanced to the next relevant section.

The relatively small number of individuals who monitor moose precluded random sampling; the working group sent questionnaires to all biologists who conducted moose monitoring in Alaska within the last few years. Private-sector, university, and nonprofit groups that were likely to have monitored moose were also included to the best of our ability. Only responses from staff directly responsible for monitoring programs or collecting information were used. Respondents who monitored more than one population were asked to provide responses for both their most important populations and for a population considered a lower priority. This broadened collection of information to include programs that receive less funding, but perhaps represent a more prevalent monitoring design. Some questions were designed for respondents to interpret relative to their own programs and associated goals, making it possible to generalize success over a wide range of strategies, levels of detail, and agency mandates. For example, questions regarding precision were phrased in terms of specific predetermined magnitudes of variance for estimates because, rather than statistical performance, the working group was interested in their perspective on whether precision was adequate to achieve program goals. Unique identifiers (IDs) were assigned to potential respondents to facilitate anonymity; participation was optional, with electronic consent solicited at the opening page of the survey. Questionnaires were distributed electronically via email on 1 February 2017 after advance notice was given to supervisory staff. After 2 weeks, those who did not respond were sent follow-up emails, and where possible additional emails or in-person reminders were sent (up to three attempts). The survey was closed on 15 July 2017.

Results

The System and its People

From 85 invitations to participate in the questionnaire, we received 64 complete and 5 partial responses. Roughly half of the respondents in our study worked for ADF&G (47%), with other significant percentages working for NPS (20%) and USFWS (11%, Fig. 2). Response rates varied from 50% to 87% across agencies and were generally higher from agencies that received >10 invitations (Fig. 2). Most respondents (81% of 65 responses) monitored more than one moose population. Fifty-two of 69 respondents (75%) were field biologists involved in monitoring moose, 81% of these were involved in more than one program.

Forty-eight field biologists fully responded to the survey, and the results in this report reflect this sample size unless otherwise noted. Most (77%) of these respondents had > 6 years of experience monitoring moose (Fig. 3) and cooperatively monitored moose with other agencies or organizations (81%). Every ecoregion in Alaska was represented in survey results, with the geographic distribution of responses weighted most heavily toward moose populations in the Eastern Interior (31%) and Kenai/Southcentral (23%) ecoregions of Alaska (Fig. 1). Where this appeared to affect results, we illustrated questionnaire responses geographically to highlight differences among respondents.

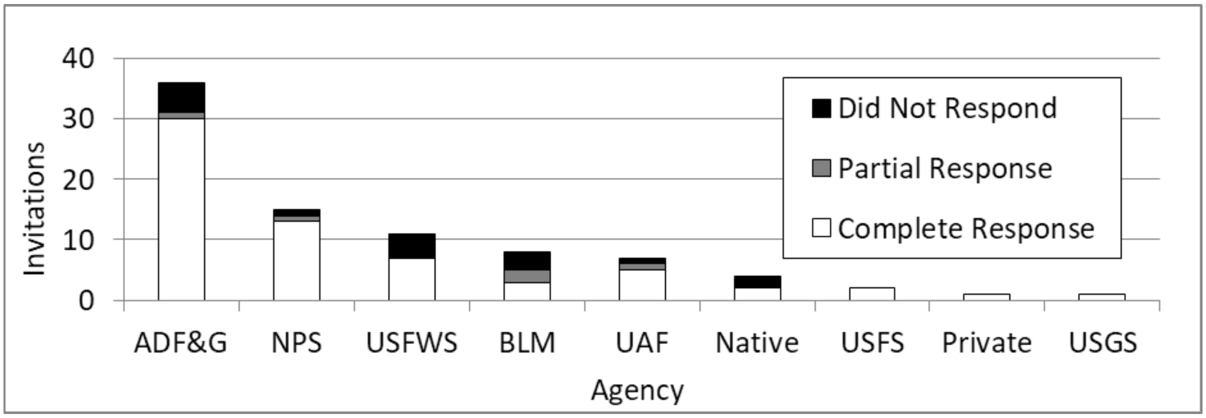

Figure 2. Response by agency affiliation of 85 biologists that were invited to complete an online questionnaire about their moose monitoring program in Alaska. ADF&G = Alaska Department of Fish and Game; NPS = National Park Service; USFWS = U.S. Fish and Wildlife Service; BLM = Bureau of Land Management; UAF = University of Alaska Fairbanks; FS = U.S. Forest Service; Private = Non-Agency Professionals; USGS = U.S. Geological Survey.

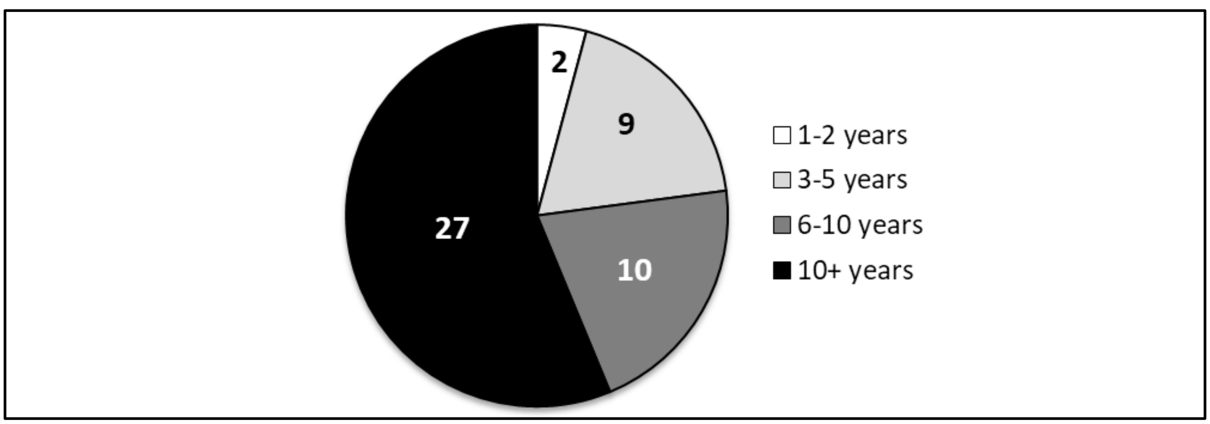

Figure 3. Years of field experience among 48 field biologists who completed an online questionnaire about their moose monitoring program in Alaska. Numeric labels are the number of responses.

Programs and Approaches

Goals for monitoring programs varied substantially among individual respondents (Fig. 4), but several patterns were evident. The first priority for monitoring was most commonly “to inform harvest regulations” (57% of respondents), or “to maintain specific goals for population abundance and trend” (26% of respondents). All other goals were ranked as first priority by only 2–7% of respondents. The most common second priority was “to maintain credibility as an expert” (26%), with a slightly lower percentage of respondents choosing either “to understand the effects of past management actions or assess current management strategy” or “to maintain specific goals for population abundance and trend” (24% each, Fig. 4) as their second priority. When considering less tangible reasons for monitoring, most respondents moderately or strongly agreed that “conducting field work to monitor moose is necessary for public credibility” (67%), “spending time in the field is critical to job satisfaction” (68%) and “conducting field work to monitor moose provides an opportunity to become acquainted with the area in a way that is not possible through other job duties” (71%; Fig. 5). Opinions about the use of moose surveys to non-numerically assess other species were more varied, with “neither agree nor disagree” being the most common response (33%). Most respondents (67%) either moderately or strongly disagreed that “monitoring should only be conducted when quantification is needed to address management concerns” (Fig. 5).

The moose monitoring parameters estimated by respondents fell into 2 broad groupings. Nearly all respondents reported that they estimated abundance, composition, population trend, and harvest (85–94%, n = 48; Fig. 6), and considered each important to their monitoring program. In contrast, relatively few respondents estimated survival, nutritional condition, or habitat use (20%–28%; Fig. 6), and perspectives on the importance of these parameters varied substantially. All of the reasons we listed for monitoring composition were considered important by respondents (i.e., mean importance rating on a scale of 1 to 5 was ≥ 3; n = 46). Of highest importance was information on adult sex ratio ($\bar{x}$ = 4.6) and calf recruitment ($\bar{x}$ = 4.2), followed in importance by bull age structure ($\bar{x}$ = 3.7), overall population age structure ($\bar{x}$ = 3.5) and survival ($\bar{x}$ = 3.2). Among the 43 respondents that monitored ≥ 1 moose population, their ‘least important’ population was monitored primarily through estimates of abundance (30% of respondents), harvest (23%), indices or trend counts (i.e., moose seen/hr: 23%), and composition (12%). Less-used parameters included survival (2%), nutritional condition (2%), habitat use (5%), and public response (2%).

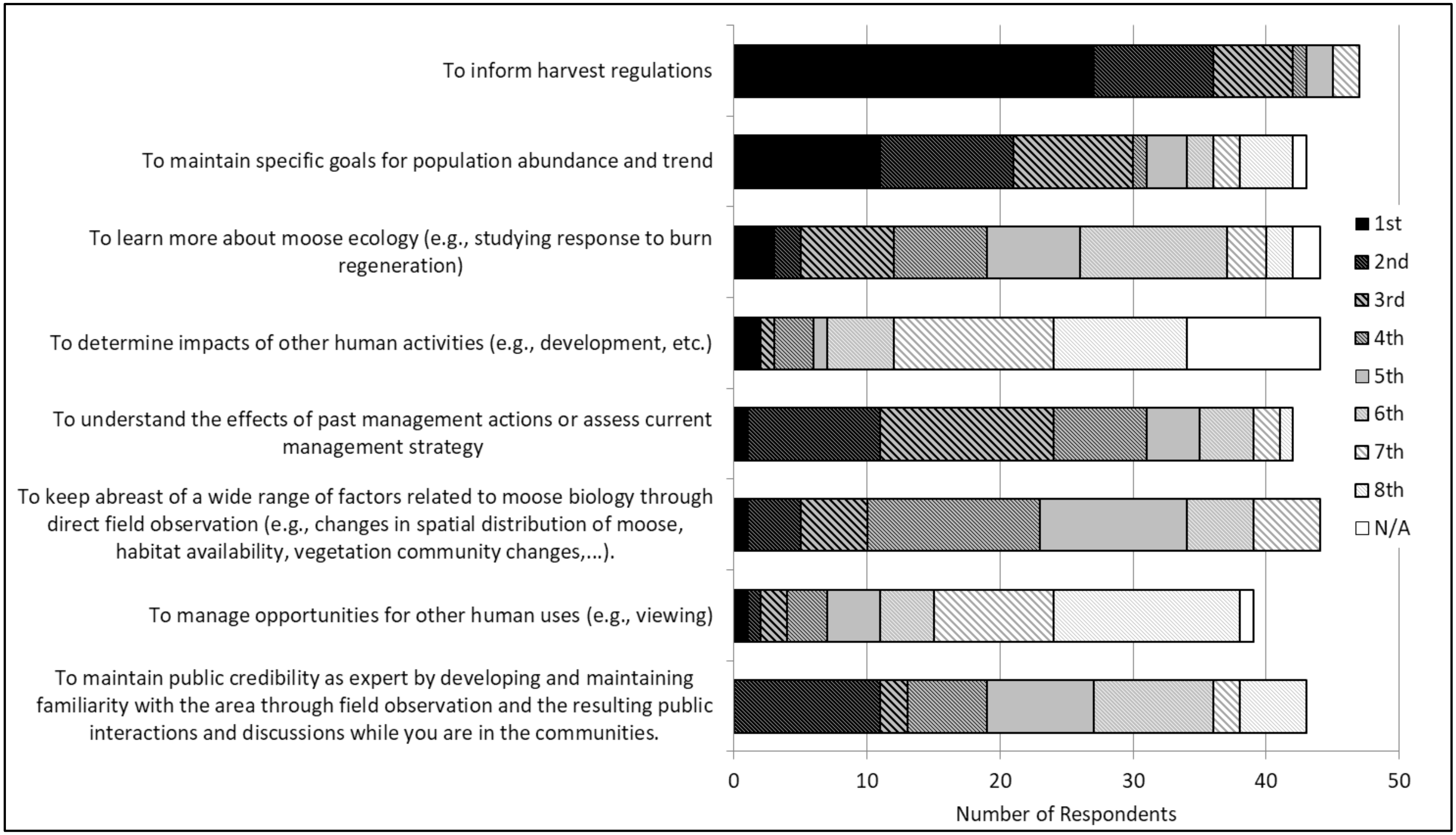

Figure 4. Ranked priority of 8 goals for moose monitoring programs in Alaska provided by field biologists responding to an online questionnaire about their moose monitoring programs. The questionnaire constrained biologists to a different priority level, or an answer of "not applicable" (N/A), for each goal. Goals were predetermined in the questionnaire based on earlier information provided by focus groups. Bars are labeled with number of respondents because not all respondents ranked all monitoring goals.

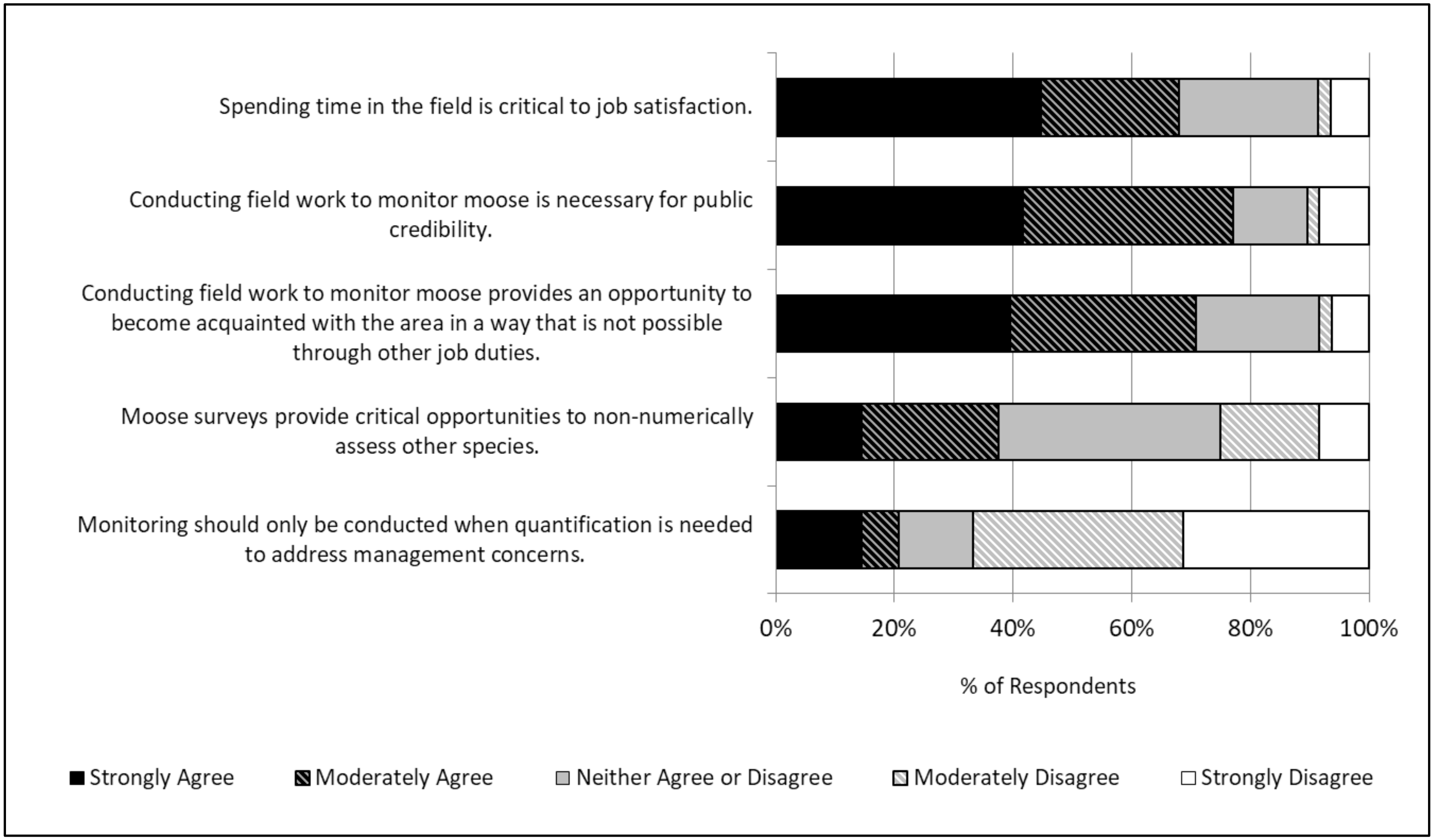

Figure 5. Evaluation of 5 different reasons for monitoring moose provided by field biologists (*n* = 48) responding to an online questionnaire about their moose monitoring program in Alaska. Biologists were asked to report their level of agreement (1 – strongly disagree through 5 – strongly agree) with 5 reasons for moose monitoring. Reasons were defined by the questionnaire and were determined using information from initial focus groups.

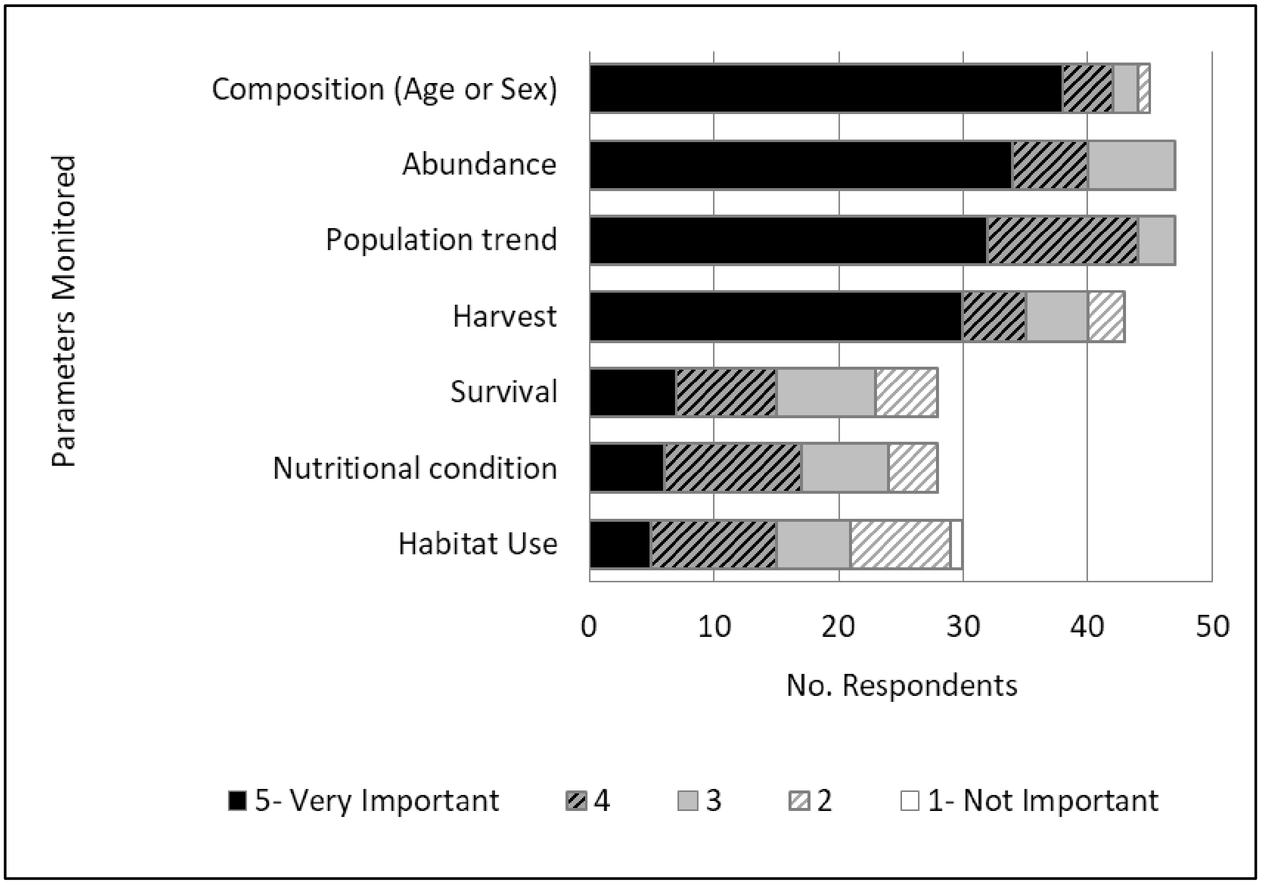

Figure 6. Relative importance of 7 different common population parameters to moose monitoring programs in Alaska. Information was provided by field biologists (*n* = 48) responding to an online questionnaire about their moose monitoring programs. Biologists were asked to rate the importance of parameters that they currently monitor.

Several techniques were used to estimate abundance and composition, the top population parameters measured by respondents. Among 46 respondents estimating abundance, the Geo-Spatial Population Estimator (GSPE) and trend counts were used most frequently (80% and 63% of respondents, respectively) and considered very important to monitoring programs (Table 1). Gasaway estimates, census counts, population dynamics models and integrative population dynamics models were considered important methods and were used by less than half of the respondents (Table 1). Distance sampling and capture-mark-recapture methods were used by the fewest respondents and considered relatively unimportant to monitoring programs (Table 1). One third (33%) of respondents consistently corrected for undetected moose (i.e., employed a sightability correction factor) when estimating abundance, while most (52%) sometimes corrected estimates and 11% never corrected estimates. Two biologists reported that their abundance estimation technique automatically corrected for undetected moose. When asked what relative precision they typically achieved, most respondents reported that their precision was no worse than ±20% of the estimate or lower (73%), and only 4 respondents (9%) achieved a precision that was no worse than ±10% of the estimate (Table 2).

Table 1. Relative importance and use of various techniques to estimate population abundance of moose among 46 field biologists that monitor moose in Alaska. Biologists were responding to an online questionnaire about their moose monitoring programs in Alaska. Respondents were asked whether or not they used specific techniques and evaluated them on a scale of 1 (not an important method) to 5 (a very important method) in their abundance monitoring program.

Technique for estimating abundance	Mean importance rating	Percent (%) of respondents using approach
GeoSpatial Population Estimate (GSPE)	4.8	80%
Trend counts	4.0	63%
Gasaway estimate	3.5	37%
Census counts	3.3	47%
Population dynamics models that combine multiple years of abundance estimates	3.1	43%
Integrative population dynamics models that combine multiple types of information - abundance, survival, etc.	3.1	41%
Capture-Mark-Resight or Capture-Mark-Recapture	2.8	30%
Distance sampling	2.1	26%

Table 2. Reported precision typical of estimates for the top two parameters used to monitor moose populations in Alaska. Respondents were field biologists (*n* = 46) responding to an online questionnaire about their moose monitoring programs.

	Abundance		Composition	
Typical precision of estimate	*n*	%	*n*	%
Less than or equal to ±10% of the estimate	4	9%	4	9%
Less than or equal to ±15% of the estimate	11	25%	8	18%
Less than or equal to ±20% of the estimate	17	39%	13	29%
Less than or equal to ±25% of the estimate	5	11%	2	4%
Greater than ±25% of the estimate	2	5%	5	11%
My technique does not include an estimate of precision	5	11%	13	29%

Biologists preferred early winter for abundance estimation (70%, 31 of 44 respondents). The most common techniques for estimating composition were fall/early winter count areas (74%), the GSPE (59%) and hunter specimens (28%, Table 3). Other techniques for composition estimation were used by fewer than 10% of respondents. Reported relative precision of composition estimates was somewhat similar to precision of abundance estimates, except more respondents reported that their method for estimating composition did not provide an estimate of precision (29%; Table 2). Techniques for estimating moose habitat were employed by 64% (*n* = 48) of respondents, with about a third of these efforts focused on available biomass (35%) or fire succession/seral stages (33%; Table 4).

Table 3. Relative use of various techniques for monitoring among 46 field biologists that use population composition to monitor moose in Alaska. Biologists were responding to an online questionnaire about their moose monitoring programs in Alaska.

Techniques for estimating composition	Percent (%) of respondents using approach
Fall/early winter count areas	74%
GeoSpatial Population Estimate (GSPE)	59%
Hunter specimens	28%
Harvest card information	15%
Mark-resight or Mark-recapture estimate	9%
Gasaway estimate	7%
Cementum ages for all harvested and road kill moose	4%

Table 4. Relative use of 6 different approaches for monitoring moose habitat among 48 field biologists responding to an online questionnaire about their moose monitoring programs in Alaska.

Techniques for estimating moose habitat	Percent (%) of respondents using approach
Available biomass	35%
Fire succession/seral stages	33%
Changes in biomass	21%
Changes in the architecture of browse plants	25%
Nutritional characteristics of browse plants	19%
Changes in carrying capacity of the landscape	17%
I don't monitor habitat	33%

Program Performance

Perceived performance of monitoring programs differed among respondents. More than half of the field biologists responding to the questionnaire (61%, $n = 48$) moderately or strongly agreed that their abundance and composition estimates were adequate for meeting program goals. However, 25% of respondents thought that current estimates were inadequate (Fig. 7). Some dissatisfaction with monitoring programs may have stemmed from a disparity between typical and desired precision when estimating abundance. Among 38 biologists who answered questions regarding both typical and desired precision for abundance estimation, 50% typically met or exceeded the precision goals they desired to effectively inform management decisions. For the other half of respondents, precision of abundance estimates underachieved program goals by 5% (i.e., an additional ±5% of the estimate, $n = 12$), 10% ($n = 5$), or 15% ($n = 2$). Also, some biologists may have been dissatisfied with their monitoring program because they had to change their survey season at least once in the last 10 years to complete surveys (23%), adding seasonal complexity to the interpretation of survey results over time. Finally, dissatisfaction with monitoring programs may have been related to the high survey failure rates in some portions of the state. In the last 10 years, respondents failed to complete 42% of scheduled surveys to estimate abundance ($n = 295$ surveys, 42 respondents). These failure rates were highest in the Kenai/Southcentral (57%), Eastern Interior (43%) and Coastal Subarctic (41%) ecoregions (Fig. 8). Similarly, biologists failed to complete 39% of scheduled surveys to estimate composition ($n = 339$ surveys, 45 respondents). Spatial patterns of composition survey failure were similar to abundance (Fig. 8). In contrast, low rates of survey failure were reported for both composition and abundance in the Western Interior (20%) and Arctic and Arctic Slope (15%) ecoregions of Alaska (Fig. 8).

A few common challenges were responsible for most failed surveys. Lack of adequate snow cover was reported as the most important barrier to completing surveys for estimation of abundance (Fig. 9) and composition (Fig. 10). The influence of inadequate snow cover on success of abundance and composition surveys was felt across all ecoregions, with the exception of abundance estimation in Arctic Slope (Fig. 11). Poor flying weather was the second most important reason given for failing to accomplish scheduled surveys to measure both abundance (Fig. 9) and composition (Fig. 10). However, the importance of this barrier was bimodal (i.e., more extreme agreement and disagreement than middle ground) among respondents, especially relative to abundance surveys (Fig. 9). These differences in opinion regarding the influence of poor flying weather are likely tied to geography: biologists monitoring in coastal areas of Alaska considered it a moderately important or very important reason for survey failure, whereas biologists from the Interior ecoregions considered it unimportant (Fig. 11). For composition estimation, biologists also considered antler drop and daylight to be important factors interfering with their ability to complete surveys (Fig. 10). All other factors listed in the questionnaire were, on average, considered neutral to unimportant reasons for failing to conduct abundance and composition surveys (Fig. 9). Among the 10 respondents that had changed their survey season, all of them listed lack of adequate snow cover as a factor. The most common barriers to adding parameters to existing monitoring programs were the increased workload and the additional cost (Fig. 12).

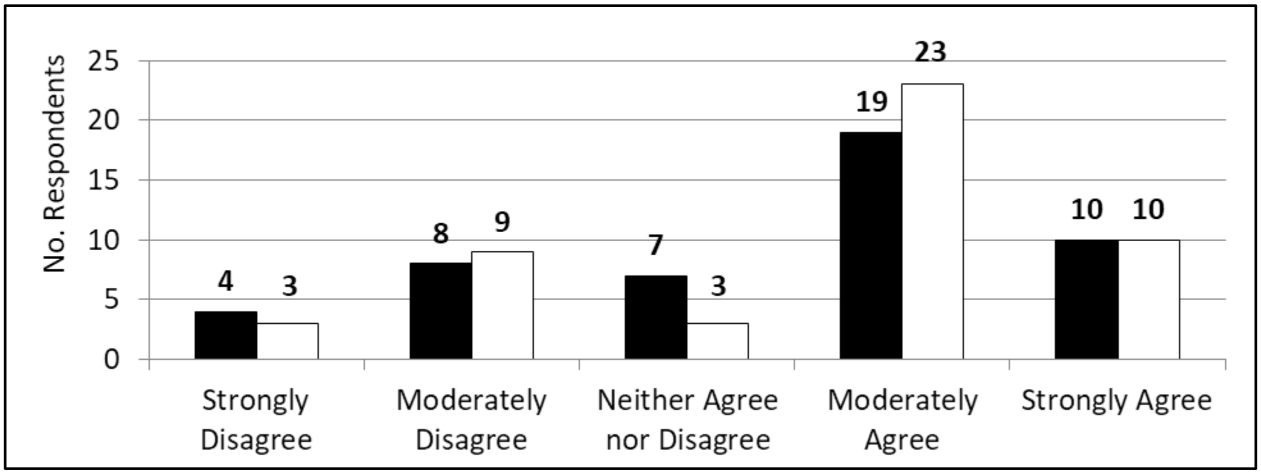

Figure 7. Evaluation of abundance and composition monitoring programs for moose in Alaska relative to program goals. Field biologists (*n* = 48) were asked how well they agreed (1 – strongly disagree through 5 – strongly agree) with this statement: "My abundance (black) [or composition (white)] monitoring program is adequate to address my goals." Bars are labeled with the number of respondents in each category.

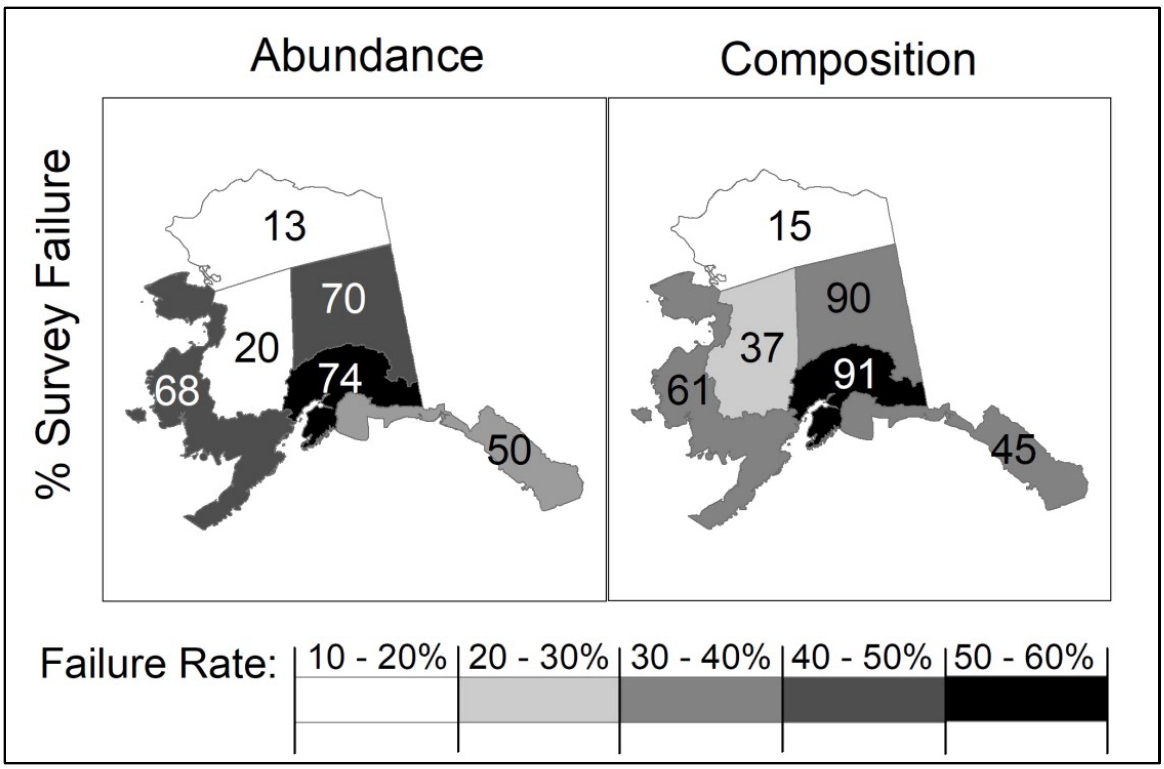

Figure 8. Geographic diversity in the failure of planned surveys estimating the abundance and composition of moose populations in Alaska. Categories represent the mean response among field biologists within each ecoregion who completed an online questionnaire about their moose monitoring programs in Alaska. Ecoregions are labeled with the number of planned surveys.

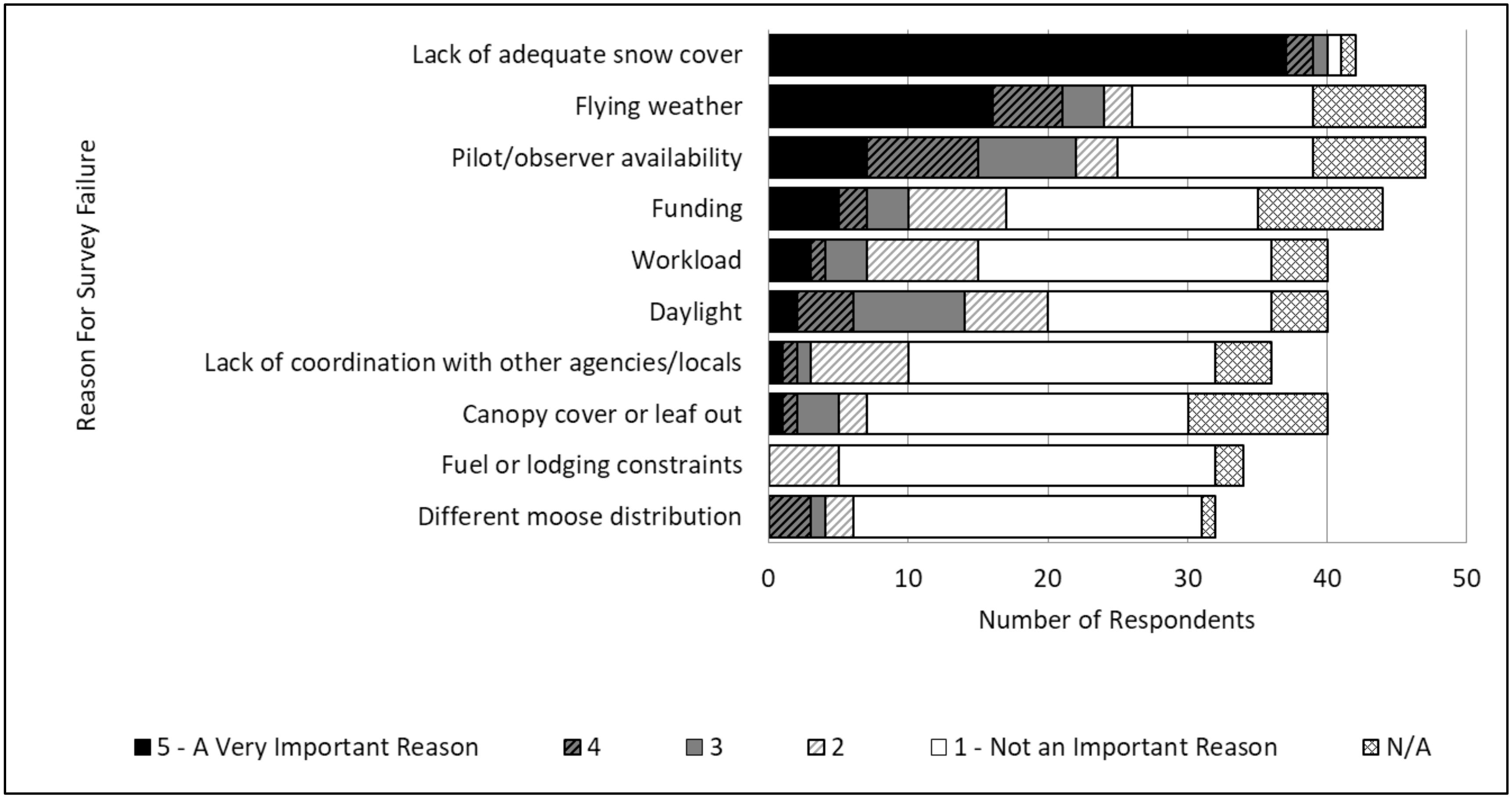

Figure 9. Reasons for failing to conduct surveys to estimate the abundance of moose populations in Alaska as evaluated by 48 moose field biologists responding to an online questionnaire about their moose monitoring programs.

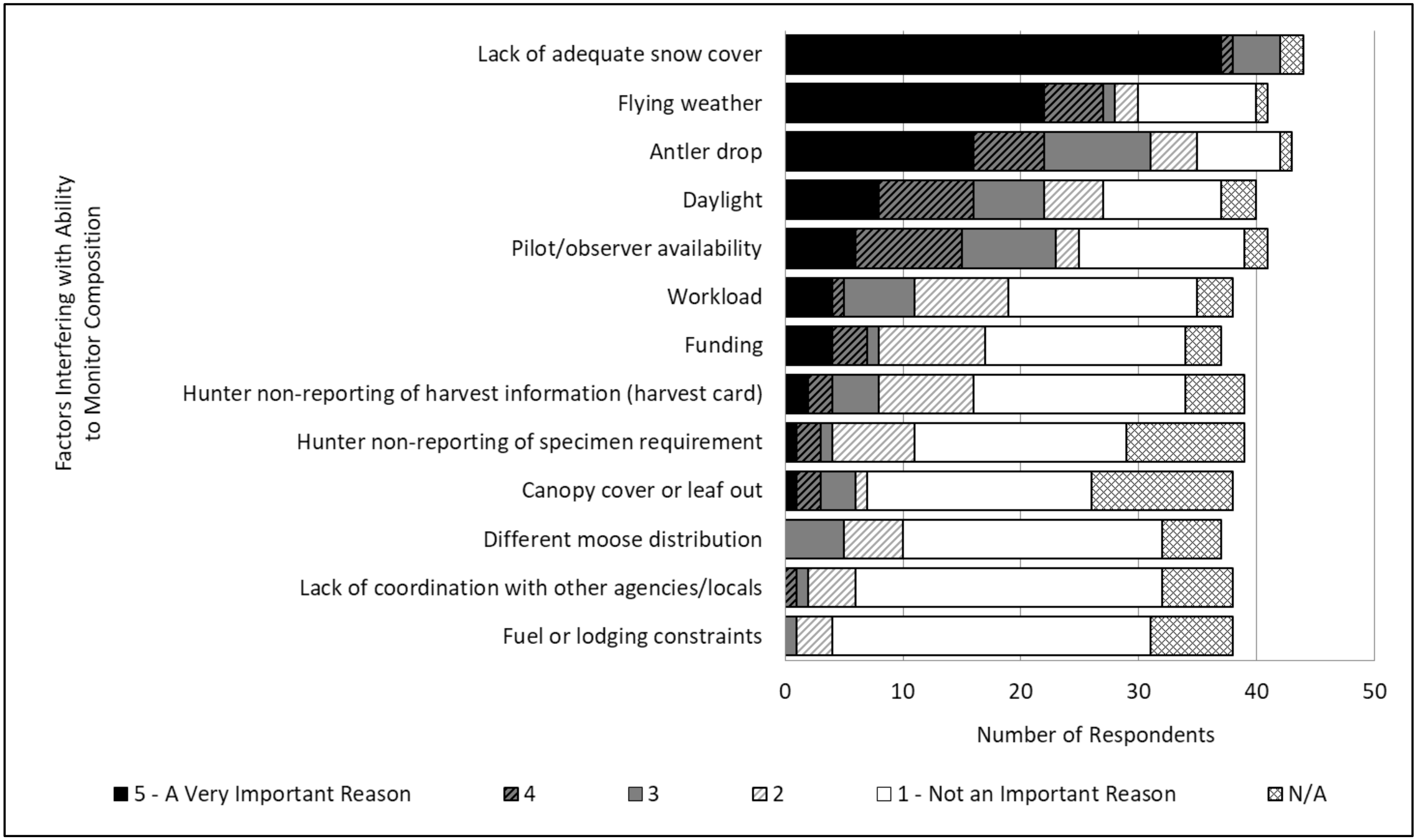

Figure 10. Factors interfering with the ability to monitor the composition of moose populations in Alaska as evaluated by 48 moose field biologists responding to an online questionnaire about their moose monitoring programs.

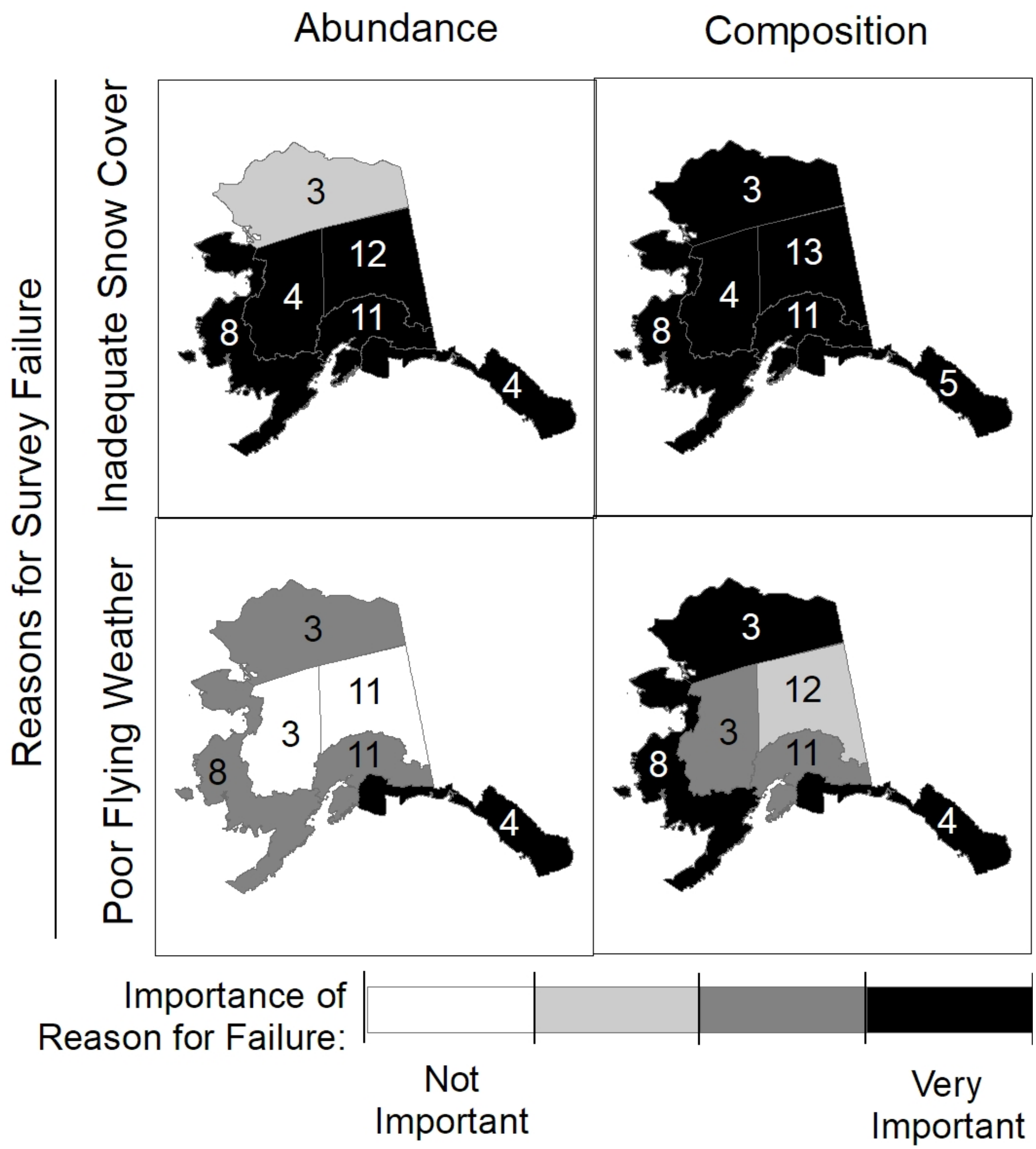

Figure 11. Geographic diversity in the importance of inadequate snow cover and poor flying weather causing the failure of surveys planned to estimate the abundance and composition of moose populations in Alaska. Categories represent the mean response among field biologists within each ecoregion who completed an online questionnaire about their moose monitoring programs in Alaska. Inadequate snow cover and poor flying weather were the top 2 reasons for failure of both abundance and composition surveys. Ecoregions are labeled with the number of biologists who evaluated the specific reasons.

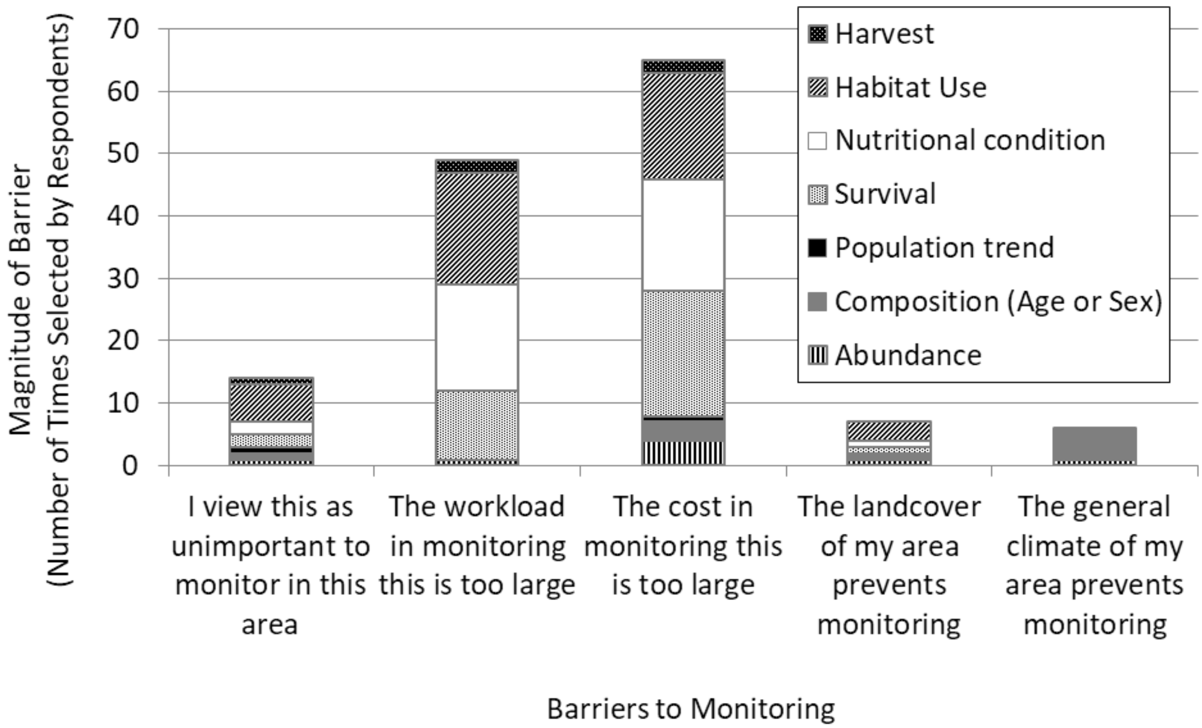

Figure 12. Relative magnitude of 5 common barriers to monitoring moose populations in Alaska. Potential parameters to monitor were evaluated separately and summarized by barrier among 48 field biologists who responded to an online questionnaire about their moose monitoring programs.

SURVEY OF FUTURE RESEARCH NEEDS

Field biologists (n = 48) also evaluated several statements regarding the development of new techniques for monitoring population parameters. When asked to rate a long list of characteristics that could be included in a new survey method (Table 5), biologists strongly agreed that new methods should not rely on complete snow cover, should improve estimate accuracy, improve estimate precision, provide continuity with old methods, be useable where poor flying weather is frequent, be feasible in areas with dense vegetative cover, come with a manual and technical assistance, be similar in cost to current methods, and be more flexible in the targeted time of year. Biologists were not inclined to employ a new method that would require more staff, more staff time, or more funding. On average, a lukewarm response was given to a new survey method that would require analysis by a biometrician, ground observations, biological specimens collected by hunters, or use helicopters (Table 5). Biologists generally agreed that they would use a new monitoring technique that significantly reduced their time in the field if it could be conducted in areas where conditions currently hamper existing methods, if it provided significantly higher precision and a similar cost to current methods, or if it provided a similar precision with a significantly lower cost than current methods (Table 6).

Table 5. Mean agreement on survey characteristics that would make it worthwhile for respondents to switch to a new, hypothetical new survey method. Information based on the responses of 48 field biologists that completed an online questionnaire about their moose monitoring programs in Alaska. Respondents were asked to rate their level of agreement with each statement on a scale of 1="strongly disagree" to 5="strongly agree." Characteristics that received a mean value ≤ 3 (*) were considered disagreeable.

"I would be willing to switch to a new method if..."	Mean
... the new method does not rely on complete snow cover	4.5
... the new method is more accurate than current method	4.5
... the new method provides a higher level of precision	4.4
... the new method provided continuity .. with previous estimates	4.4
... the new method [can be used] where inclement flying weather is frequent	4.3
... the new method could be conducted in areas with dense vegetative cover	4.2
... the new method came with a user manual or technical assistance	4.2
... the new method is similar in cost to current methods	4.1
... the new method is more flexible in the time of year	4.0
... analysis for the new method was available through WinfoNet or online portal	3.9
... the new method uses aerial observation	3.9
... data were archived online	3.8
... the new method requires a similar amount of staff time	3.8
... the new method occurs at the same time of year as current method	3.7
... the new method requires a similar number of staff/charter participants	3.7
... the new method provides a similar level of precision	3.6
... the new method is similar in accuracy to the current method	3.6
... the new method occurs throughout the year	3.4
... the new method uses radiocollared moose	3.3
... the new method requires analysis by a biometrician*	3.0
... the new method uses observations from the ground (e.g., pellet counts)*	2.9
... the new method requires hunters to turn in biological samples*	2.9
... the new method uses helicopters for aerial observation*	2.9
... the new method requires more staff/charter participants*	2.5
... the new method requires double the amount of staff time*	2.4
... the new method is no more than double the cost of current methods*	2.4

Table 6. Evaluation of the importance of field work among 48 field biologists in Alaska relative to hypothetical benefits of a new survey method. Biologists were asked to rate their agreement with 5 statements on a scale of 1 – Strongly disagree to 5 – strongly agree. A mean rating of ≤ 3 indicates moderate to strong disagreement. Biologists were responding to an online questionnaire evaluating their moose monitoring programs.

I would be willing to use a moose technique that significantly reduced my time in the field...	Mean response¥
If it could be conducted in areas where conditions currently hamper current methods	4.4
If it provided similar precision for a significantly lower cost than current methods	4.0
If it provided significantly higher precision and a similar cost to current methods	4.3
If it was less logistically demanding for similar precision and cost as current methods.	3.8
I'm unwilling to reduce my time in the field.	2.4

Discussion and Conclusions

The high risk of failure among long-term monitoring efforts can be ameliorated and avoided by intermittent assessment of all phases of program design (e.g., problem framing, program design, program implementation and associated workflow processes, and 'learning to learn'; Reynolds et al. 2016). The current effort was a first step toward such an evaluation across all moose monitoring programs in Alaska. As such, the focus was primarily on program effectiveness in regularly producing the desired information with estimates meeting the stated goals for precision.

Regular Production of Information for Management Decision Making

Among respondents, the top priorities (i.e., 'program goals') for monitoring moose were to inform harvest-related management decisions and maintain specific population goals (Fig. 4). However, many biologists in Alaska are not regularly producing the information needed to meet those goals. Although respondents mostly agreed that abundance and composition monitoring programs were "adequate to meet their goals (60–68%)," agreement was not universal (Fig. 7), and was not well supported by answers to subsequent questions. Moose monitoring programs were not obtaining information on schedule: in the last decade, only about 60% of scheduled aerial surveys were successfully completed across the state. Delays in acquiring population information hinder the ability of respondents to inform regulatory decisions and management action (Boyce et al. 2012, Barten 2018) especially in populations within the Kenai/Southcentral ecoregion where survey success dropped below 50% (Fig. 8). Additionally, in the last 10 years, several respondents shifted away from their preferred early winter season, when male moose can be distinguished from females, preventing the collection of composition information such as bull:cow and calf:cow ratios but at least securing a population estimate of abundance (e.g., Barten 2018). The inability to distinguish the proportion of males when estimating abundance has implications for harvest decisions: moose hunting seasons in Alaska largely target the males in populations. Likewise, the inability to collect indices such as calf:cow and yearling:cow ratio data hinders detection of management issues affecting population trend such as increasing nutritional stress or the effect of a severe weather event (Ballard et al. 1991). Ultimately, lack of survey data can result in misinterpretation of population dynamics, ill-timed management action (Gasaway et al. 1983, White 2011), and a breach of public trust between agencies and Alaska hunters that can be difficult to repair (Young et al. 2006).

Respondents overwhelmingly identified the same dominant challenges to conducting surveys: lack of adequate snow cover and poor flying weather (Figs. 9 and 10). Indeed, these same factors were common reasons for shifting the timing of surveys to late winter. The geographic pattern of survey failure (Fig. 8) and associated factors (Fig. 11) suggests common impacts of maritime influences on average temperatures, snow deposition and weather patterns. Ironically, the same weather patterns that are creating poor survey conditions in coastal areas of Alaska may also be creating shrub habitat favorable to moose population growth (Tape et al. 2006); high rates of population change have been reported among populations near Bethel and Dillingham, Alaska (Fig. 1 Barten 2014, page 19-1; Wald and Nielson 2014, Barten 2018). Although population increase is generally considered a positive trend for the management of moose, careful monitoring is still needed as populations approach—and may overshoot—carrying capacity (Caughley 1976, McCullough 1997).

Because success rates for aerial surveys appear closely tied with weather conditions, it is likely that survey success will further erode as regional trends in warming and precipitation continue (Intergovernmental Panel on Climate Change [IPCC] 2007, Bieniek et al. 2014, Taylor et al. 2017). Extreme winter temperatures are expected to continue warming much faster than other climate extremes (e.g., summer maximum temperatures; Lader et al. 2017); with greatly increased precipitation throughout Alaska, this is projected to make “freezing temperatures and frozen precipitation … increasingly less frequent by late century” (Lader et al. 2017). In the last 60 years Alaska has warmed at over twice the rate of the contiguous United States (Chapin et al. 2014), with greater warming in winter and spring than summer or fall, and with large regional changes in winter and spring precipitation rates (Bieniek et al. 2014, Table 7). These trends are altering the timing, duration and consistency of snow cover, a major requirement for conducting most aerial moose survey techniques (Gasaway et al. 1985, 1986; Kellie and Delong 2006). Recent work projects a decline in the monthly ‘snow-day fraction’ (i.e., the fraction of wet days in a month which receive snow; McAfee et al. 2014) across all climate regions of Alaska, all emissions scenarios, and all future time periods investigated (2040–2069, 2070–2099) relative to observations from 1970–1999 (Littell et al. 2018). The largest declines in snowfall are expected for the early (autumn) and late (spring) snow season: the seasons when aerial moose surveys are typically conducted in Alaska. This projected shrinking of the snow season will be greatest for the areas that already experience the highest rates of survey failure: the coastal regions of western, southwestern, southcentral, and southeast Alaska (Figs. 8 and 11; Littell et al. 2018).

Ultimately, the conservation of wildlife is jeopardized when management decisions must be made without current biological information. Failure to collect data may be the most severe impediment to monitoring a population, especially when it becomes chronic (e.g., GMU 17, Barten 2018). Also, the need to inform decision-making can apply pressure to survey standards when adequate survey conditions become rare. Where methods fail to include some measure of data quality, the tendency to erode survey standards to meet information needs can bias the measurement of long-term trends. Alas, because warming conditions are also affecting late winter conditions, simply shifting survey timing does not promise to be an effective long-term solution to the underlying problem of meeting survey protocols. A more productive solution appears to require consideration of basic monitoring approaches and/or measurement methods that are robust to current and projected climate conditions and their impacts on survey success.

ACHIEVING INFORMATION GOALS

Even where respondents reported that moose monitoring surveys had been completed, there remained a large mismatch between the desired and achieved levels of survey precision relative to monitoring goals. Among programs that acquired information, a reported 50% did not typically achieve the precision deemed necessary to make decisions. There may be room to improve monitoring survey precision through modifications in survey design (e.g., stratification), sampling intensity, or improvements in measurement methods; all of these topics are beyond the scope of this evaluation.

This undertaking did not include an evaluation of goal specificity, associated information quality (Reynolds 2012), and achievability. Required survey precision differs widely depending on the goal. For example, precision needed for making decisions increases as the program goal changes from: 1) determining whether a population is at a relatively low, medium or high density, to 2) deciding whether to take action when an estimate has crossed a threshold, to 3) assessing a change in direction of population trend. However, all program goals, regardless of their complexity, should to be clearly specified and quantified with regard to survey results such as mean and precision. Without this preparation, biologists cannot fully evaluate program success relative to statistical power, sampling effort and related triggers for management action. At a minimum, one could evaluate the tradeoffs in survey frequency and intensity for achieving a threshold magnitude of detectable trend (e.g., Seaton 2014).

Given the typical level of precision reported for key population parameters (Table 2), many monitoring programs may be unable to detect even moderate changes (i.e., 4% change/yr, Seaton 2014) in population size– especially in time for effective management action. Time to detection for various magnitudes of population change were investigated using simulations based on empirical data from 3 survey areas in Interior Alaska that were selected to represent relatively high, moderate, and low moose densities (Seaton 2014). Annual surveys at current resource levels provided 80% certainty of detecting moderate trends (4% per year) at $\alpha = 0.05$ within 7–10 years in high density areas, 10–13 years in moderate density areas, and ~15 years in low density areas. More dramatic trends were detected more quickly. For example, an 8% change in moose abundance per year may be detectable in 5–7 years in high density areas, 6–8 years in moderate densities and 9–10 years in low densities. However, these times are best-case; in practice, action on detected trends also includes considerable time for agencies to draft action plans, receive plan approval, and fully implement changes.

Precision of current estimates would be improved, presumably, by increasing utilization of existing information from previous surveys and other data streams in integrated population models (e.g., Newman et al. 2014, Taylor and Udevitz 2015). However, GSPE and trend counts, the top two techniques currently used for estimating abundance and composition (Tables 1 and 3), do not now make use of prior survey information except through coarse binary categorization of moose density (i.e., "broad brush stratification," Kellie and Delong 2006). Yet there is large potential for informing future estimates: a recent survey of existing GSPE moose surveys reported more than 450 GSPE archived surveys conducted across Alaska, representing more than 24,000 sampled units from 1997 through 2018 (Seaton 2014, Appendix C). Similarly, consideration should be given to other (hierarchical) analytical approaches that offer the potential for borrowing information across populations or regions, especially in the development of sightability corrections (e.g., Schmidt and Rattenbury 2013).

Satisfaction with Monitoring Programs

The high satisfaction of respondents with their monitoring programs (Fig. 7) seems inconsistent with reported difficulties in key areas such as survey failure rates (Fig. 8) and inadequate precision (i.e., 50% underachieved precision goals by $\geq$ 5% of the mean). Some of this disparity may be explained by highly-valued, but intangible benefits to conducting aerial surveys. During the initial focal group discussions, it became apparent that there were both tangible and intangible deliverables associated with monitoring activities, so the working group attempted to capture this in the questionnaire. Specifically, respondents placed a high level of importance on the usefulness of monitoring programs to maintaining credibility with the public, maintaining familiarity with an area, and contributing to job satisfaction (Fig. 5). Monitoring moose populations to maintain public credibility was also a common secondary program goal for monitoring among our sample of biologists (26%, Fig. 4). Credibility is rarely discussed formally but can play an important role in the acceptance of population data and related management decisions as well as regulatory compliance by citizens (Freddy et al. 2004). It is important to recognize and discuss the value of maintaining public credibility when field biologists are collecting data and communicating related management actions (Young et al. 2006, Brinkman 2018).

Human Surveys: Caveats and Bias

Some caveats must be made in our interpretation of the response to the questionnaire. First, due to the small number of individuals involved, it was important to solicit responses from as close to the entire population of biologists as possible. While we believe we have been thorough in identifying potential respondents, some individuals might have been missed. In a similar vein, the authors of this report engage in monitoring moose but did not respond to the survey to avoid any potential bias.

Second, participation in this survey was voluntary, and a portion of potential respondents elected not to respond. As we did not ascertain why certain respondents did not respond or learn more about their perspectives, it would be speculation on our part whether these individuals were representative of the larger pool of potential respondents, or if they were marked by some overarching characteristic such as above average satisfaction or dissatisfaction with their moose monitoring program.

Finally, the unit of analysis in our case was the individual biologist; in some cases, two or more respondents manage the same population with information from the same surveys (intended or completed). Similarly, hindsight bias and other known reporting biases may have directly or indirectly influenced individual responses. It was infeasible to perform an in-depth analysis that included every monitoring program in Alaska, but we believe that the use of the individual biologists as respondents provided a good compromise between receiving location- and program-specific information and ease of data collection. We similarly avoided all but the most basic descriptive statistics to avoid over-representing these data.

We believe that this is the first concerted effort to survey biologists about factors that help and hinder their ability to engage in biological monitoring in Alaska. This broad evaluation of our current monitoring programs from the perspective of individual biologists has revealed key issues that might not be apparent from evaluation of agency reports, including the relatively low per-survey success rate, the mismatch between the desired level of precision and what biologists were typically able to achieve, and the high relative importance of intangible deliverables. The results from respondent feedback highlight several important issues that commonly impact efforts to monitor moose populations in Alaska.

Management Implications

Developing monitoring methods that are effective and feasible in current (and projected future) conditions requires first identifying the main limitations, in application, of methods currently in use. While many factors influence monitoring success, a few are essential and must be included in evaluating monitoring programs. First, there are factors impacting the ability of biologists to acquire information. In this study, respondents reported that surveys were cancelled largely because snow and weather conditions did not meet requirements in survey protocols (Fig. 9 and 10). Second are factors that can bias information if not accounted for in the analysis and confound trend assessment. We suggest that current monitoring programs may be impacted by marginal survey conditions, undetected moose, or suboptimal survey timing. Third are factors impacting the precision of survey estimates and the power to detect differences or trends in estimates (over space or time). Currently, many field biologists in Alaska are failing to obtain the precision needed to achieve program goals. All 3 factors impact the usability of the resulting information for resource management decision-making.

Given the importance of moose to people in Alaska, the ability to effectively manage this portion of the wildlife public trust (Smith 2011) may rely on more timely and pertinent information. Most moose monitoring programs within Alaska depend heavily on the use of aerial surveys and visual detection of moose on the ground. Although snow depth can affect the distribution of moose (Nordegren et al. 2003, Hundertmark 2007, Månsson 2009), its chief effect on moose monitoring is the inability of observers to reliably visually detect moose (i.e., moose ‘sightability’) where snow cover is discontinuous or absent (Gasaway et al. 1985, 1986). The problem of low sightability is a familiar one: in 2006, the National Conference of The Wildlife Society in Anchorage, Alaska included an all-day workshop to discuss current issues of low sightability during moose surveys using the GSPE (Ver Hoef 2008, Kellie and Delong 2006). However, attempts thus far to mitigate, or develop alternatives to, population estimation under poor sightability conditions have been isolated, unfruitful, or narrowly applied (White 2007, Christ 2011, Seaton 2014, Wald and Nielson 2014, Frye 2016). Further, few attempts have been made in Alaska to investigate performance of methods that detect moose by means other than human observers (e.g., radiometric thermal imaging systems, Millette et al. 2011). Downscaled climate projections under even midrange emission scenarios demonstrate that this problem is expected to worsen,[1] magnifying the need for moose monitoring methods that do not rely on a constant, high detection rate for accuracy. Indeed, the problem of monitoring moose in areas with poor snow conditions is so challenging and pervasive that solutions may require a concentrated, cooperative effort among agencies, including practical feedback from field biologists (e.g., Table 5).

As stated earlier, current levels of precision may not be adequate to detect population trends in a timely manner. Where trend detection ability is unacceptably low, researchers may want to explore hybridizing abundance monitoring programs with more dynamic, coarser sources information capable of providing more immediate notice of impending population change. Some success has been reported for initial trend detection using indices such as nutritional condition (Boertje et al. 2007, 2009), population composition (Harris et al. 2008), recruitment-mortality modeling (Serrouya et al. 2016), harvest reporting (Boyce et al. 2012), citizen science programs (Boyce and Corrigan 2017), and monitoring habitat use (Acevedo et al. 2008). A critical aspect of multi-source monitoring programs is to include decision criteria and explicit, quantified detail regarding how results from each data stream will be used to inform management actions (e.g., Young 2017: Appendix K).

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[1] See the online tools and climate projections available at Scenarios Network for Alaska and Arctic Planning (SNAP), International Arctic Research Center, University of Alaska Fairbanks, https://www.snap.uaf.edu/.

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Appendices

Appendix A. Questions used in a series of focal group interviews among field biologists from 8 ecoregions of Alaska. Questions were distributed to participants prior to the interview. Written consent to record interviews obtained prior to interview. Results of these interviews were used to design an online questionnaire regarding moose monitoring programs in Alaska.

Preamble:

We are investigating the challenges and limitations that biologists face when monitoring moose populations. We're interested in all the information that you use in your capacity as a moose biologist, as well as the information you would like to have, but don't or can't get. This information could take lots of forms, from results from trend count areas, GSPEs, vegetation surveys, and twinning surveys, to harvest data like number harvested and time to harvest, to public feedback at ACs and RACs and anecdotal observations. We ask that you consider all information that feeds into your monitoring program, or that you wish you could have in your monitoring program, when answering these questions.

We also ask that you consider all challenges to collecting that information. Challenges can take the form of uncontrollable natural limitations such as habitat or weather conditions, to logistical limitations such as field facilities or pilot availability, to limitations in our ability to adequately quantify information such as harvest data or sources of mortality. We are also interested in the burdens and barriers to managing the data you already collect.

This knowledge you share with us will help us identify broad categories of topics that represent either useful tools for you, or topics that present challenges that should receive attention to help resolve. We will use this information to develop a survey for a broader section of biologists to find out how widely these problems occur and where they are occurring.

In order to do that, we've sent you a list of questions that we're going to go over now. If you don't understand a question, or want clarification, or feel we're missing out on something that we should be asking that's relevant, please speak up at any time.

Finally, keep in mind this is not a quiz, but a conversation. If something that someone else says makes you think of something to say, chime in.

Interview Questions:

1) Can you give us a brief description of your experience with moose in your region and the types of decisions you are responsible for regarding moose management in your position?
2) Why are you monitoring moose?
3) Are there the non-quantifiable benefits to surveys? If so, please name some.
4) Describe your <u>most</u> intensive monitoring program. Include tools you use and the size of the area.
    a. Which decisions do the monitoring results inform, and how?
    b. How do you make decisions when you don't have adequate data?
5) Describe your <u>least</u> intensive monitoring program. Include tools you use and the size of the area.
    a. Which decisions do the monitoring results inform, and how?
    b. How do you make decisions when you don't have adequate data?
6) What uncontrollable, natural factors affect you accomplishing your goals for monitoring moose?
7) What are the human factors outside your control that affect you accomplishing your goals for monitoring moose in your area?
8) Are there analytical hurdles hindering your use of current monitoring methods?
9) What data do you need to make management decisions that you don't currently collect?
10) What new monitoring approaches have you tried or considered?

Appendix B. Questionnaire content emailed to all known moose field biologists in Alaska on 01 February, 2017 using the Survey Monkey (Portland, OR) platform.

Images of the pages of the questionnaire are placed in order in this appendix. Those viewing this report online or electronically who have access to a program to open a PDF may click on the image of the first page of the questionnaire below to open the full file:

Moose Monitoring Questionnaire

Introduction

This survey is designed for field biologists in Alaska and Northern Canada who monitor moose. Your knowledge and expertise are invaluable and will help better inform moose monitoring efforts. The survey should take 15 minutes or less to complete.

This project is a product of a working group collaboration between the Alaska Department of Fish and Game, the US Fish and Wildlife Service, and the Western Alaska Landscape Conservation Cooperative. The survey aims to address the following objectives:
1) Characterize use of current monitoring tools relative to moose monitoring goals, population dynamics and ecoregions.
2) Identify limitations with current tools for monitoring moose.
3) Characterize the occurrence and importance of these limitations relative to their geography, commonality, agency interest and impact on monitoring programs.
4) Inform prioritization for interagency research toward development or improvement of monitoring tools.

Results from individual participants, such as your name and other personal information, will remain anonymous. Participation on any question is voluntary. We will publish the summarized results from this survey in a short report that will be distributed to all wildlife agencies in Alaska and will also be made available on the web. We will provide a draft copy of the reports resulting from this to our respective agencies before we publish it.

1. Are you involved as a field biologist in at least one moose monitoring program in Alaska or Canada?

◯ Yes

◯ No

1

Monitoring Multiple Areas

2. Do you monitor >1 moose population or area?

- ◯ Yes
- ◯ No

Moose Monitoring Questionnaire

Monitoring for Lowest Importance Area

3. If you monitor more than one moose population or area, what is your **primary** monitoring tool in your LEAST important population or area?

- Abundance
- Composition
- Index or trend counts
- Survival
- Nutritional condition
- Habitat Use
- Harvest
- Other (please specify)

3

Moose Monitoring Questionnaire

Guidance on following questions

If you monitor only one population or area, please answer the following of questions regarding your monitoring approach for that population.
If you monitor more than one population or area, please answer the following questions regarding the MOST important population/area that you monitor.

4

Moose Monitoring Questionnaire

Monitoring Program

4. Rank the following common monitoring goals for this area. (Where 1 is the primary goal, etc. Use N/A for goals that aren't applicable to the area)

	1	2	3	4	5	6	7	8	N/A
To inform harvest regulations	◯	◯	◯	◯	◯	◯	◯	◯	◯
To maintain specific goals for population abundance and trend	◯	◯	◯	◯	◯	◯	◯	◯	◯
To understand the effects of past management actions or assess current management strategy	◯	◯	◯	◯	◯	◯	◯	◯	◯
To manage opportunities for other human uses (e.g., viewing)	◯	◯	◯	◯	◯	◯	◯	◯	◯
To learn more about moose ecology (e.g., studying response to burn regeneration)	◯	◯	◯	◯	◯	◯	◯	◯	◯
To determine impacts of other human activities (e.g., development, etc.)	◯	◯	◯	◯	◯	◯	◯	◯	◯
To keep abreast of a wide range of factors related to moose biology through direct field observation (e.g., changes in spatial distribution of moose, habitat availability, vegetation community changes,...).	◯	◯	◯	◯	◯	◯	◯	◯	◯
To maintain public credibility as expert by developing and maintaining familiarity with the area through field observation and the resulting public interactions and discussions while you are in the communities.	◯	◯	◯	◯	◯	◯	◯	◯	◯

Other (please specify)

5

5. What habitat characteristics do you monitor in your area? Check all that apply.

- [ ] I don't monitor habitat.
- [ ] Available biomass
- [ ] Changes in biomass
- [ ] Fire succession/seral stages
- [ ] Changes in the architecture of browse plants
- [ ] Nutritional characteristics of browse plants
- [ ] Changes in carrying capacity of the landscape
- [ ] Other (please specify)

6. Please rate the relative importance of the following population metrics that you currently monitor in your monitoring program. Rate each on a scale of 1="not important" to 5="very important", with N/A="not currently monitored". Multiple parameters may be 'very important,' etc.

	1 - Not Important	2	3	4	5 - Very Important	N/A - Not Currently Monitored
Abundance	○	○	○	○	○	○
Composition (Age or Sex)	○	○	○	○	○	○
Population trend	○	○	○	○	○	○
Survival	○	○	○	○	○	○
Nutritional condition	○	○	○	○	○	○
Habitat Use	○	○	○	○	○	○
Harvest	○	○	○	○	○	○

6

7. Which of the following metrics would you like to monitor, but do not currently monitor in your program for this area? Please rate their relative importance. Rate each on a scale of 1='not an important addition' to 5='very important addition', with N/A ='I currently monitor this'. Multiple parameters may be 'very important', etc.

	1 - Not An Important Addition	2	3	4	5 - A Very Important Addition	N/A - I Currently Monitor This
Abundance						
Composition						
Population trend						
Survival						
Nutritional condition						
Habitat Use						
Harvest						

8. For each metrics you do not currently monitor in your area, which of the following statements apply? You may check multiple boxes.

	I currently monitor this	I view this as unimportant to monitor in this area	The workload in monitoring this is too large	The cost in monitoring this is too large	The landcover of my area prevents monitoring this	The general climate of my area prevents monitoring this
Abundance						
Composition (Age or Sex)						
Population trend						
Survival						
Nutritional condition						
Habitat Use						
Harvest						

Other (please specify)

7

Moose Monitoring Questionnaire

Monitoring Abundance

9. Do you estimate moose abundance in this area?

- ◯ Yes
- ◯ No

10. How well do you agree with this statement: "My abundance monitoring program is adequate to address my goals."

- ◯ Strongly disagree
- ◯ Moderately disagree
- ◯ Neither agree nor disagree
- ◯ Moderately agree
- ◯ Strongly agree

8

Moose Monitoring Questionnaire

Monitoring Abundance

11. Rate the importance of the following methods in your abundance monitoring program. Rate each on a scale of 1='not important' to 5='very important', with N/A ='not used'. Multiple methods may be 'very important', etc.

	1 - Not an Important Method	2	3	4	5 - A Very Important Method	N/A - I Do Not Use This Method
GSPE Survey	◯	◯	◯	◯	◯	◯
Gasaway Survey	◯	◯	◯	◯	◯	◯
Trend Counts	◯	◯	◯	◯	◯	◯
Census Counts	◯	◯	◯	◯	◯	◯
Distance Sampling	◯	◯	◯	◯	◯	◯
Capture-Mark-Resight or Capture-Mark-Recapture	◯	◯	◯	◯	◯	◯
Population dynamics models that combine multiple years of abundance estimates	◯	◯	◯	◯	◯	◯
Integrative population dynamics models that combine multiple types of information - abundance, survival, etc.	◯	◯	◯	◯	◯	◯

Other (please specify)

12. Do you correct for sightability error when analyzing aerial survey data?

◯ Never

◯ Sometimes

◯ Always

◯ I do not use aerial surveys to estimate abundance

◯ My aerial survey method automatically corrects for sightability error

9

13. What is your typical confidence interval for an estimate of abundance in this area?

- Less than or equal to ±10% of the estimate
- Less than or equal to ±15% of the estimate
- Less than or equal to ±20% of the estimate
- Less than or equal to ±25% of the estimate
- Greater than ±25% of the estimate
- My method for estimating abundance does not include an estimate of precision

14. What level of precision (confidence interval) would achieve your monitoring goals?

- Less than or equal to ±10% of the estimate
- Less than or equal to ±15% of the estimate
- Less than or equal to ±20% of the estimate
- Less than or equal to ±25% of the estimate
- Greater than ±25% of the estimate
- I don't know what level of precision would meet my goals

15. In the last 10 years, how many years have you planned to estimate abundance in your area? Your best estimate is fine.

16. In the last 10 years, how many years have you failed to accomplish a scheduled abundance estimate? Your best estimate is fine.

10

17. If you failed to accomplish at least one planned estimate, please rate the importance of the following reasons. Rate each on a scale of 1='not important' to 5='very important', with N/A ='not applicable'. Multiple reasons may be 'very important', etc.

	1 - Not an Important Reason	2	3	4	5 - A Very Important Reason	N/A - Not Applicable
Flying weather	◯	◯	◯	◯	◯	◯
Pilot/observer availability	◯	◯	◯	◯	◯	◯
Canopy cover or leaf out	◯	◯	◯	◯	◯	◯
Daylight	◯	◯	◯	◯	◯	◯
Funding	◯	◯	◯	◯	◯	◯
Workload	◯	◯	◯	◯	◯	◯
Different moose distribution	◯	◯	◯	◯	◯	◯
Lack of coordination with other agencies/locals	◯	◯	◯	◯	◯	◯
Fuel or lodging constraints	◯	◯	◯	◯	◯	◯
Lack of adequate snow cover	◯	◯	◯	◯	◯	◯

Other (please specify)

18. What season do you prefer for estimating abundance?

- ◯ Early Winter (Oct - Dec)
- ◯ Late Winter (Jan - Apr)
- ◯ Spring-Summer (May - Sept)
- ◯ Other (please specify)

19. During what season do you typically estimate abundance?

- ◯ Early Winter (Oct - Dec)
- ◯ Late Winter (Jan - Apr)
- ◯ Spring-Summer (May - Sept)
- ◯ Other (please specify)

11

20. In the last 10 years, have you changed the season of your abundance surveys? The change could have been either temporary or permanent.

- ◯ Yes
- ◯ No

21. If you have changed the season of your abundance survey in the last 10 years, why did you change seasons?

- ☐ Flying weather
- ☐ Pilot/observer availability
- ☐ Canopy cover or leaf out
- ☐ Daylight
- ☐ Funding
- ☐ Workload
- ☐ Different moose distribution
- ☐ Better coordination with other agencies/locals
- ☐ Fuel or lodging constraints
- ☐ Lack of adequate snow cover
- ☐ N/A - I have not changed season of my abundance survey in the last 10 years.

Other (please specify)

12

Moose Monitoring Questionnaire

Composition

22. Do you monitor age or sex composition in this area?

- ◯ Yes
- ◯ No

23. To what extent do you agree or disagree with this statement: "My monitoring program for composition is adequate to address my goals"

- ◯ Strongly disagree
- ◯ Moderately disagree
- ◯ Neither agree nor disagree
- ◯ Moderately agree
- ◯ Strongly agree

13

Composition

24. Rate the following reasons to monitor composition. Rate each on a scale of 1='not important' to 5='very important'.

	1 - Not an Important Reason	2	3	4	5 - A Very Important Reason
Monitor trends in bull population age structure	◯	◯	◯	◯	◯
Monitor trends in overall population age structure	◯	◯	◯	◯	◯
Monitor survival	◯	◯	◯	◯	◯
Monitor calf recruitment	◯	◯	◯	◯	◯
Monitor population adult sex ratio	◯	◯	◯	◯	◯

Other (please specify)

25. What best describes your use of composition data in making decisions?

◯ Composition data is my primary source of information for making decisions.

◯ I generally use other sources of information, but occasionally rely on composition data when I can't collect other sources of information.

◯ I rarely or never rely primarily on composition data for making decisions.

◯ Other (please specify)

26. What tools do you use to monitor age or sex composition? (Check all that apply)

- [ ] Fall/Early winter count areas
- [ ] GSPE estimate
- [ ] Gasaway estimate
- [ ] Mark-resight or Mark-recapture estimate
- [ ] Harvest card information
- [ ] Hunter specimens
- [ ] Other (please specify)

27. What is your typical confidence interval for an estimate of composition in this area?

- ◯ Less than or equal to ±10% of the estimate
- ◯ Less than or equal to ±15% of the estimate
- ◯ Less than or equal to ±20% of the estimate
- ◯ Less than or equal to ±25% of the estimate
- ◯ Greater than or equal to ±25% of the estimate
- ◯ My method for estimating composition does not include an estimate of precision

28. In the last 10 years, how many years have you planned to measure composition your area? Your best estimate is fine.

29. In the last 10 years, how many years have you failed to accomplish a scheduled composition survey? Your best estimate is fine.

30. What factors interfere with your ability to monitor composition? Rate each on a scale of 1='not important' to 5='very important'. Multiple reasons may be 'very important', etc.

	1 - Not an Important Reason	2	3	4	5 - A Very Important Reason	N/A - Not Applicable
Flying weather	◯	◯	◯	◯	◯	◯
Pilot/observer availability	◯	◯	◯	◯	◯	◯
Canopy cover or leaf out	◯	◯	◯	◯	◯	◯
Daylight	◯	◯	◯	◯	◯	◯
Funding	◯	◯	◯	◯	◯	◯
Workload	◯	◯	◯	◯	◯	◯
Different moose distribution	◯	◯	◯	◯	◯	◯
Lack of coordination with other agencies/locals	◯	◯	◯	◯	◯	◯
Fuel or lodging constraints	◯	◯	◯	◯	◯	◯
Lack of adequate snow cover	◯	◯	◯	◯	◯	◯
Antler drop	◯	◯	◯	◯	◯	◯
Hunter non-reporting of harvest information (harvest card)	◯	◯	◯	◯	◯	◯
Hunter non-reporting of specimen requirement	◯	◯	◯	◯	◯	◯

Other (please specify)

16

Moose Monitoring Questionnaire

Developing Goals for Future Monitoring

31. Think about monitoring moose in your area, how much do you agree or disagree with the following statements? Rate each on a scale of 1='strongly disagree' to 5='strongly agree'.

	1 - Strongly Disagree	2	3 - Neither Agree nor Disagree	4	5 - Strongly Agree
Monitoring should only be conducted when quantification is needed to address management concerns.					
Conducting field work to monitor moose is necessary for public credibility.					
Conducting field work to monitor moose provides an opportunity to become acquainted with the area in a way that is not possible through other job duties.					
Moose surveys provide critical opportunities to non-numerically assess other species.					
Spending time in the field is critical to job satisfaction.					

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32. Thinking about monitoring moose in your area, how much do you agree or disagree with the following statements: "I would be willing to use a moose monitoring technique that significantly reduced my time in the field..." Rate each on a scale of 1='strongly disagree' to 5='strongly agree'.

	1 - Strongly Disagree	2	3 - Neither Agree nor Disagree	4	5 - Strongly Agree
If it could be conducted in areas where conditions currently hamper current methods	◯	◯	◯	◯	◯
If it provided similar precision for a significantly lower cost than current methods	◯	◯	◯	◯	◯
If it provided significantly higher precision and a similar cost to current methods	◯	◯	◯	◯	◯
If it was less logistically demanding for similar precision and cost as current methods.	◯	◯	◯	◯	◯
I'm unwilling to reduce my time in the field.	◯	◯	◯	◯	◯

33. Rate the following characteristics of a hypothetical new survey method that would make it worthwhile to switch to that new method. Rate each on a scale of 1='strongly disagree' to 5='strongly agree'.

"I would be willing to to switch to a new method if..."

	1 - Strongly Disagree	2	3 - Neither Agree nor Disagree	4	5 - Strongly Agree
... the new method provided continuity with, or comparable with previous estimates	◯	◯	◯	◯	◯
... analysis for the new method was available through WinfoNet or other online portal	◯	◯	◯	◯	◯
.... data were archived online	◯	◯	◯	◯	◯
... the new method came with a user manual or technical assistance	◯	◯	◯	◯	◯
... the new method could be conducted in areas with dense vegetative cover	◯	◯	◯	◯	◯

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	1 - Strongly Disagree	2	3 - Neither Agree nor Disagree	4	5 - Strongly Agree
... the new method is flexible enough to use in areas where inclement flying weather is frequent	○	○	○	○	○
... the new method does not rely on complete snow cover	○	○	○	○	○
... the new method is similar in cost to current methods	○	○	○	○	○
... the new method is no more than double the cost of current methods	○	○	○	○	○
... the new method requires a similar amount of staff time	○	○	○	○	○
... the new method requires double the amount of staff time	○	○	○	○	○
... the new method requires analysis by a biometrician	○	○	○	○	○
... the new method occurs throughout the year	○	○	○	○	○
... the new method occurs at the same time of year as current method	○	○	○	○	○
... the new method is more flexible in the time of year	○	○	○	○	○
... the new method requires a similar number of staff/charter participants	○	○	○	○	○
... the new method requires more staff/charter participants	○	○	○	○	○
... the new method provides a similar level of precision	○	○	○	○	○
... the new method provides a higher level of precision	○	○	○	○	○

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	1 - Strongly Disagree	2	3 - Neither Agree nor Disagree	4	5 - Strongly Agree
... the new method is similar in accuracy to the current method	◯	◯	◯	◯	◯
... the new method is more accurate than current method	◯	◯	◯	◯	◯
... the new method uses aerial observation	◯	◯	◯	◯	◯
... the new method uses observations from the ground (e.g., pellet counts)	◯	◯	◯	◯	◯
... the new method uses helicopters for aerial observation	◯	◯	◯	◯	◯
... the new method uses radiocollared moose	◯	◯	◯	◯	◯
... the new method requires hunters to turn in biological samples	◯	◯	◯	◯	◯

Other (please specify)

Moose Monitoring Questionnaire

Demographics

We'd like to ask a few questions about yourself, to help put your responses about moose monitoring and moose monitoring tools into a broader context. As a reminder, results from individual participants, such as your personal information, will remain confidential.

34. Who is your primary employer?

- ◯ Independent/ Private Organization
- ◯ Alaska Department of Fish and Game
- ◯ Bureau of Land Management
- ◯ Canadian Governmental Agency
- ◯ National Park Service
- ◯ Alaska Native Regional Association, Tribal or First Nations organization
- ◯ University or other academic institution
- ◯ US Forest Service
- ◯ US Fish and Wildlife Service
- ◯ US Geological Survey
- ◯ Other (please specify)

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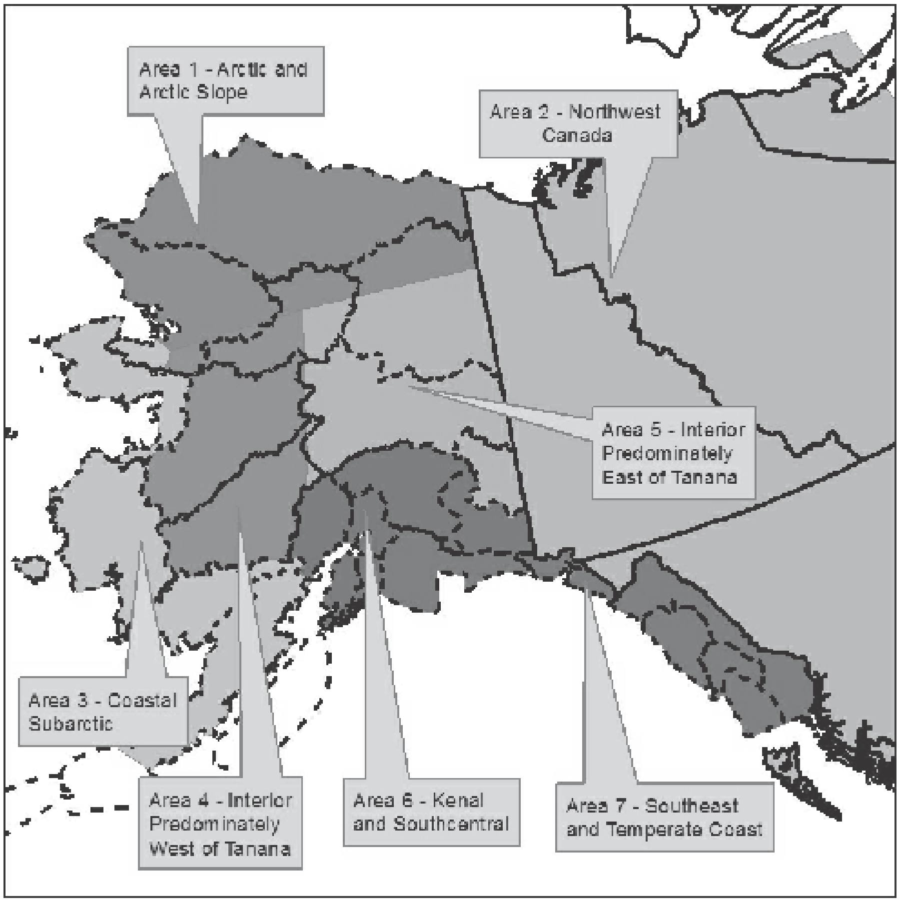

35. Where do you primarily monitor moose?

- ◯ Area 1 - Arctic and Arctic Slope
- ◯ Area 2 - Northwest Canada
- ◯ Area 3 - Coastal subarctic
- ◯ Area 4 - Interior Predominately West of Tanana
- ◯ Area 5 - Interior Predominately East of Tanana
- ◯ Area 6 - Kenai / Southcentral
- ◯ Area 7 - Southeast and Temperate Coast

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36. How long have you been working on moose?

- ◯ 1-2 years
- ◯ 3-5 years
- ◯ 6-10 years
- ◯ 10+ years

37. Do you cooperatively monitor moose in your area(s)? If so, with which organizations?

- ☐ I do not co-monitor moose with other organizations
- ☐ Independent/ Private Organization
- ☐ Alaska Department of Fish and Game
- ☐ Bureau of Land Management
- ☐ Canadian Governmental Agency
- ☐ National Park Service
- ☐ Tribe, First Nation, or associated organization
- ☐ US Forest Service
- ☐ US Fish and Wildlife Service
- ☐ US Geological Survey

Other (please specify)

23

Moose Monitoring Questionnaire

Additional Feedback

38. Written feedback: please provide any additional input you wish to provide on the development or improvement of moose monitoring tools or analysis and reporting processes.

24

Moose Monitoring Questionnaire

Thank you!

Thank you very much for taking the time to participate in this survey. Your contribution is very important to helping improve our understanding moose monitoring in Alaska and Northwest Canada.

We will publish the summarized results from this survey in a short report that will be distributed to all wildlife agencies in Alaska and will also be made available on on the web upon completion of this study. A draft copy of reports resulting from this will be provided to our respective agencies before we publish it.

39. Do you wish to be notified when the report is released?

- ◯ Yes
- ◯ No

40. If you wish to be notified when the report is released, what email address would you like us to use?

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Appendix C. Final Report from the Alaska Moose Monitoring Workshop on 24 – 25 April, 2018 in Anchorage, Alaska.

Images of the pages of the report are placed in order in this appendix. Those viewing this report online or electronically who have access to a program to open a PDF may click on the image of the first page of the report below to open the full file:

Final Report

Alaska Moose Monitoring Workshop

Anchorage, Alaska

April 24 & 25, 2018

Prepared by: Chris Smith
Wildlife Management Institute
May 24, 2018

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.

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

The Workshop

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.

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;
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- Update the GSPE User Manual with lessons learned and improvements.

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With respect to the need for alternative to address the impacts of changing climate on managers' ability to apply GSPE (e.g. lack of adequate snowcover, lack of adequate flying weather, difficulty gathering composition data due to timing of antler drop) Group 2 identified a range of needs and actions (see Appendix 12). Time constraints limited the group's ability to discuss the full range of needs and actions, but the three needs identified by simple majority vote and explored in depth were:

- Developing a "Decision Framework" tool to help biologists evaluate the pros and cons of various monitoring techniques, depending on their 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 to supplement visual observations (e.g. thermal imaging, LiDAR). **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, engaging hunters/communities in gathering data, browse surveys and other indirect measures of condition, etc. **Scott Brainerd** agreed to take the lead on follow-through on this topic.

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