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Distribution and Abundance of Moose in Glacier Bay National Park

Natural Resource Report NPS/GLBA/NRR—2016/1122

ON THIS PAGE
Moose congregate on the Gustavus Forelands during breeding season.
Photograph courtesy of E. Syrene.

ON THE COVER
Young moose eating fireweed in Glacier Bay National Park.
Photograph courtesy of D. Morda/National Park Service

Distribution and Abundance of Moose in Glacier Bay National Park and Preserve

Natural Resource Report NPS/GLBA/NRR—2016/1122

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Executive Summary

Photo 1. Young bull moose examining a bear rub tree captured by remote camera in Glacier Bay National Park. Photo courtesy of T. Lewis/National Park Service.

Moose (*Alces americana*) represent an important wildlife resource providing wildlife viewing opportunities within Glacier Bay National park and Preserve and sport hunting opportunities in portions of the preserve and lands surrounding the park. This project was a collaborative effort between state and federal agencies to: 1) quantify the winter (December - March) distribution, minimum number, and group composition of moose on lands adjacent to Glacier Bay proper, Icy Strait, and the southern outer coast; 2) compare current moose distribution and abundance to historical data within Adams Inlet; and 3) provide baseline data and sampling recommendations for developing long-term monitoring protocols and future research priorities.

Moose aerial surveys were conducted for approximately 15 hours during 3 days from December 8, 2012 – March 16, 2013. A total of 466 moose were observed (percent calves = 11.6). The distribution of moose in the survey area was not uniform with abundance of moose highest in the Gustavus (272) and Adams Inlet (112) areas. In the remainder of the survey area moose appeared to occur at relatively low densities. Within Adams Inlet, comparisons with historical data indicate 43 – 68 moose per hour (mean of 53 ± 13) have been observed in the Adams Inlet survey area from 1984 - 2012. Whereas the number of moose within Adams inlet appears to have remined stable over time, the distribution of moose may have changed over time, likely relating to changes in post-glacial plant succession which has likely influenced the foraging habitat of moose. We recommend that the park develop a long-term monitoring program for moose.

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Introduction

Glacier Bay National Park and Preserve (GLBA) lies within one of the largest protected wilderness areas in the world. Terrestrial wildlife within GLBA is managed by the National Park Service (NPS) in accordance with the Organic Act of 1916. Wildlife on the adjacent private and state land is under the management authority (or jurisdiction) of Alaska Department of Fish and Game (ADF&G). Wildlife within Glacier Bay National Preserve and National Forest land is managed by both state and federal agencies.

Moose (*Alces americana*) represent an important wildlife resource within GLBA. Moose provide visitors with wildlife viewing opportunities within GLBA, and provide sport hunting opportunities in portions of the preserve and lands surrounding the park. Individuals of these highly mobile species may seasonally migrate across NPS, United States Forest Service (USFS), and state boundaries and jurisdictions. Such trans-boundary migrations have been documented for moose in the Gustavus forelands (White et al. 2014) and are strongly suspected for moose in the preserve as well as in the Chilkat Mountain areas on the east side of the park. Migrations between harvested and protected areas necessitate interagency collaboration in order to foster effective regional management strategies (Hansen and Defries 2007).

Ungulates can play key roles in the function of ecosystems. Specifically, northern ungulates affect ecosystems directly and indirectly via bottom-up and top-down pathways. Species such as moose can alter plant community productivity and biodiversity directly through selective herbivory (Pastor et al. 1988). Resulting changes in plant community composition and productivity can then alter soil nutrient cycling processes and also abundance and composition of lower-order vertebrate (Berger et al. 2001) and invertebrate (Suominen et al. 1999) species assemblages.

In Glacier Bay, plant community dynamics have been strongly influenced by glacial processes (Chapin et al. 1994). A key justification for the establishment of Glacier Bay National Park was to allow for the scientific documentation of how glacial processes affect terrestrial ecosystems. Understanding how glaciation induced changes in plant communities have influenced patterns in distribution, composition and abundance of large mammalian herbivores, such as moose, represent an important information need. This is especially relevant since moose are habitat specialists and their distribution is expected to closely track key post-glacial habitats such as early successional shrub habitat types. In addition, northern ungulates also influence carnivore populations that rely on such species as a key food resource (Fuller et al. 2003). While patterns of plant succession in GLBA have been well studied, distributions of large mammal species and their relationships to changing habitats have so far been minimally documented.

Ungulates are listed as a National Park Service Southeast Alaska Inventory and Monitoring vital sign for Glacier Bay National Park and Preserve, signifying a need and interest in long-term monitoring of these populations. Justifications for the selection of ungulates, including moose, as a park vital sign include their ability to transform vegetation and landscapes, their charismatic character, and their harvest on adjoining lands (Sheinberg 2007). Until recently, there was little known about the distribution and abundance of ungulates in the park. Existing data on moose was limited to four opportunistic surveys of moose in Adams Inlet (Vequist 1986, Barten 2001) and long-term research and monitoring of the Gustavus moose population on lands adjacent to the park (White et al. 2007, 2014). Consequently, collection of baseline distribution and abundance data is needed in order to evaluate the current status of this species in GLBA and to provide important information needed for the design of potential future long-term monitoring efforts as well as research studies. Efforts to obtain baseline information on moose are timely given recent concerns about how predicted changes in climate will affect ecosystems. Moose populations are sensitive to variation in climate and habitat conditions (Post and Stenseth 1998, Solberg et al. 2002), a particular concern given that the landscape in Glacier Bay is changing quickly as glaciers continue to retreat and climate is predicted to warm. Existing data suggest that moose survival is negatively affected by severe winter weather (Modafferi 1997, Post and Stenseth 1998, Keech et al. 2011). Overall, climate is likely to play a key role in regulating the abundance of moose populations in Glacier Bay. In addition, given the substantial local variation in climate throughout Glacier Bay (Lawson and Finnegan 2009), distribution and abundance of moose may be linked to local climate conditions.

Baseline data on the spatial distribution and abundance of ungulates is important for NPS and ADF&G to manage current and potential future harvest on NPS and surrounding lands. In addition, information on areas of concentrations of animals and/or critical habitat will be important to inform future Resource Stewardship and Wilderness/Backcountry Management Plans. This project represents a collaborative effort between NPS and ADF&G to obtain such information.

Project Objectives

The overarching goal of this this project was to gather baseline data that could be used to assess spatial distribution and abundance of moose in GLBA and surrounding areas. Project objectives were implemented via collaborative agreement (Task Agreement # P12AC10221) between GLBA Resource Management and ADFG Division of Wildlife Conservation. The primary objectives of the project are to: 1) Quantify the winter (December - March) distribution, minimum number, and group composition of moose on lands adjacent to Glacier Bay proper, Icy Strait, and the southern outer coast, 2) Compare current moose distribution and abundance within Adams Inlet to historical data, 3) Provide baseline data and sampling recommendations for developing long-term monitoring protocols and future research priorities.

Methods

Winter Moose Distribution and Abundance

The survey area (~1327 km^2) for moose included non-glaciated low elevation land surrounding Glacier Bay, Icy Strait, and the southern outer coast (Figure 1). Aerial surveys of the northern outer coast including the National Preserve were not logistically feasible due to the distance and cost. Studies using VHF and GPS collars on moose captured on the Gustavus forelands have shown that moose migrate to low elevations during the rut (September-October) and remain for the duration of the winter with low levels of movement (White et al. 2012, 2014). Aerial surveys for moose were conducted using a Piper PA-18 “supercub” fixed-wing aircraft From December 8, 2012 – March 16, 2013. Aerial survey transects were flown systematically (spaced 500-1000 m apart) over valleys, coastline, and other low elevation land from approximately 500 feet elevation at 60-70 mph. A pilot and single experienced observer (N. Barten or K. White) documented the sex and age composition of each group of moose. Bulls were identified by their antlers, cows were identified by the presence of calves, and single moose without antlers were considered unknown sex. Covariate data for each survey were collected and included: sky conditions, wind speed and direction, temperature, overall and fresh snow depth, area covered by snow, and length of survey. Covariate data were also collected for each group of animals including habitat type, animal activity, percent snow cover, proximity to spruce trees, and light conditions. Sightability models have not yet been developed locally for moose, but the covariate data collected will be relevant and applicable once these models are developed (adequate data have been collected on the Gustavus forelands/Beartrack River but has not yet been analyzed; but see Oehlers et al. 2012 for the Yakutat forelands). Survey routes and group locations were georeferenced to enable characterization of distribution patterns.

Results and Discussion

Current distribution and relative abundance of moose

Overall, a total of 466 moose were observed (percent calves = 11.6; Table 1) in fifteen hours of aerial surveys conducted over three days during the winter of 2012/2013 (12/8/12, 12/18/12 and 3/16/12; Figure 1). The final survey was conducted later than planned due to pilot availability and survey/weather conditions. The total area surveyed encompassed the entirety of land surrounding Glacier Bay proper, as well as Gustavus, Excursion Inlet, Dundas/Taylor Bay and Dixon River (Figure 1, Table 1). Overall, a majority of the moose were observed in the Gustavus (272; 2.7 moose/km^2) and Adams Inlet (112; 0.49 moose/km^2) areas. In the remainder of the survey area moose appeared to occur at relatively low densities. Interestingly, a moderate density of moose (26 in 20 km^2 = 1.3 moose/km^2) and relatively high percentage of calves (23.1%) was observed in the Taylor Bay area. We did not observe any moose in the nearby Dixon River watershed. Although moose have been observed in the summer in the Skidmore/Geikie areas (T. Lewis, pers. obs.) no moose were detected during this survey, possibly due to to survey conditions or restricted seasonal use of this area. Adult males begin dropping antlers in November/ December, therefore it was not possible to accurately estimate the proportion of adult males during the surveys after December. As such, sex ratios for only two survey areas were determined in 2012 including Gustavus (12.1 % bulls) and Excursion (12.5% bulls) and data from other areas represent a minimum estimate of the number of bulls in each area (i.e., an unknown proportion had likely dropped antlers prior to surveys). The percentage of calves ranged from a low of 4.5% in Adams Inlet to a high of 23.1% in Taylor Bay.

The observed winter range densities of moose in Glacier Bay varied geographically but are comparable to other areas in southeastern Alaska. For example, during 2006-2012 moose densities in Berners Bay varied between 1.1 – 0.7 moose/km^2 (following severe winters; White et al. 2012). On the Yakutat forelands, Oehlers et al. (2012) reported a winter range moose density of 0.6 moose/km^2. The Gustavus moose population has varied between 5.1 – 2.4 moose/km^2 during 2003 – 2012 (due to antlerless moose harvest; White et al. 2007, 2014). As demonstrated by the Berners Bay moose population case history, moose populations in coastal Alaska can be significantly influenced by severe winter conditions. In this regard, the observed geographic variation in winter moose density and distribution in Glacier Bay is likely linked to snow depth gradients throughout the Glacier Bay area, which can vary dramatically (D. Lawson, pers. comm.). Further, the distribution and abundance of early-successional stage plant community biomass is likely another determinant of moose density and distribution. The availability of forage biomass in such habitats is positively correlated to moose nutritional condition and reproductive performance (White et al., in prep) and, at a large-scale, would be expected to influence patterns of occurrence and density. Thus, in Glacier Bay we expect patterns of moose density and distribution to reflect availability of early successional stage habitats (as reflected by the chronosequence; sensu Chapin et al. 1994) but be constrained by snow depth. Predation of moose (particularly neonates) by large carnivores (wolves, brown bears and black bears) may also exert effects on moose population productivity and density in Glacier Bay. Yet, our knowledge of moose-large carnivore interactions in Glacier Bay National Park is limited. From a single survey we cannot determine if the absence of moose in suitable habitat indicates that moose have not yet colonized all available habitat in the park, or if environmental variables such as heavy snow and predation have led to low population levels that were not detected.

Sighting probability

Sighting probabilities of moose observed during aerial surveys vary relative to weather, terrain, group characteristics and other factors (Anderson and Lindzey 1996, Drummer and Aho 1998, Quayle et al. 2001). Consequently, the data reported in Table 1 represent the minimum number of moose in the survey area. As a frame of reference, mark-resight surveys conducted in the Gustavus area using marked (with radio collars) moose from 2003-2013 indicate that survey-level sighting probabilities average 0.60 ± 0.05, but can vary considerably between surveys (White, unpublished data). In the future, data collected during the 2012-2013 Glacier Bay moose survey will be analyzed to account for survey- and group-level sighting probabilities via sightability models currently being developed (sensu White and Pendleton 2012). Such efforts will enable estimation of the actual number of moose in the area of Glacier Bay surveyed. These results will be summarized in a separate report and will represent an ADFG-DWC furnished in–kind product beyond the scope of the existing cooperative agreement.

Table 1. Moose population composition and minimum abundance data collected during aerial surveys in Glacier Bay National Park during December 8, 2012-March 16, 2013. These are uncorrected data and do not account for differences in moose sighting probabilities that occurs between groups and surveys. As a result, the number of moose recorded represent the minimum number of animals in each survey area. Note that Adams Inlet moose sightings are further described in Table 2. Bulls were identified by their antlers, cows were identified by lack on antlers and the presence of calves. Bulls drop their antlers in Nov/Dec, so after mid-December all single moose without antlers were considered unknown sex.

Area	**Date**	**Bulls**	**Cows**	**Calves**	**Unk Sex**	**Total**	**% Males**	**% Calves**
Excursion	12/8/2012	1	6	1	0	8	12.5	12.5
Gustavus	12/8/2012	33	199	40	1	272	12.1	14.7
Beartrack River	3/16/2013	0	0	0	4	4	-	0.0
Adams Inlet	12/18/2012	25	5	5	77	112	-	4.5
Wolf Pt Ck	12/18/2012	0	0	0	1	1	-	0.0
Wachusett	12/18/2012	3	1	1	2	7	-	14.3
Morse	12/18/2012	1	0	0	11	12	-	0.0
Tidal Inlet	12/18/2012	2	0	0	0	2	-	0.0
Russell Island	12/18/2012	0	1	1	5	7	-	14.3
Skidmore	12/18/2012	0	0	0	0	0	-	-
Geikie	12/18/2012	0	0	0	0	0	-	-
Dundas River	3/16/2013	0	0	0	15	15	-	0.0
Taylot Bay	3/16/2013	0	5	6	15	26	-	23.1
Dixon River	3/16/2013	0	0	0	0	0	-	-
Total		65	217	54	131	466	-	11.6

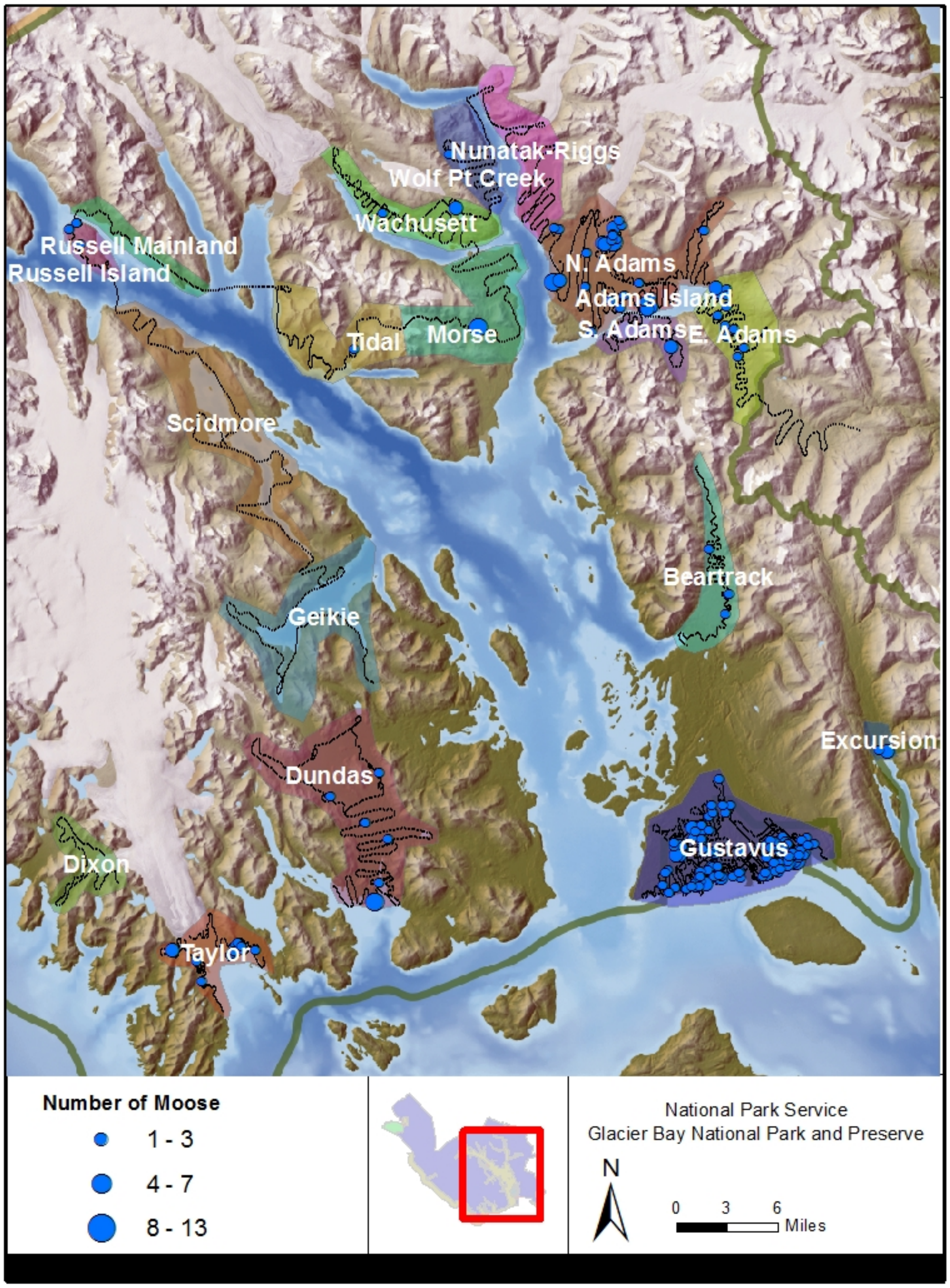

Figure 1. Spatial distribution of moose observed during aerial surveys in Glacier Bay National Park during December 8, 2012-March 16, 2013. The dark lines illustrate the route surveyed. Note that the Adams Inlet survey area is divided into four sub-areas (N. Adams, Adams Island, S. Adams and E. Adams) on this map and further decribed in Table 2.

Comparison of recent survey (2012) with historic data (1984 - 2010) from Adams Inlet

Prior to surveys conducted in 2012, aerial surveys were also previously conducted in Adams Inlet from 1984 - 2010 (Table 2). Adams Inlet was glaciated until 1929 and the first moose was sighted in Adams Inlet in 1967 (Vequist 1986). It is believed that the low elevation pass, Endicott Gap, connecting east Adams Inlet with the Endicott River has been an important movement corridor for moose colonizing Glacier Bay and Gustavus (Streveler and Smith 1987). The Adams Inlet survey area, subdivided into 4 sub-areas in historic survey data (Figure 1), is comprised of several long glacial outflow valleys with abundant maturing willow, alder and cottonwood shrub habitats, some of which is subjected to ongoing disturbance by changing stream flows. Moose surveys from 1984 – 2012 show high variability between the number of moose counted, but much less variability after standardizing the number of moose seen by the survey time (i.e., moose observed per hour; Table 2). Given that surveys were conducted with different aircrafts for varying amounts of time, moose/hour is likely the best metric to compare. With the exception of an extreme low count of 11 moose per hour in 2001, 43 – 68 moose per hour have been observed in the Adams Inlet survey area with a mean of 53 ± 13. Distribution of moose however, may have changed over time. Fewer moose were sighted on Adams Island in 2010 and 2012 compared to 1984 – 1986 whereas more moose were sighted in N. and S. Adams in 2012 compared to surveys in the 1980's. A potential factor influencing the distribution of moose in Adams Inlet from 1984 to 2012 likely relates to changes in post-glacial plant succession which has influenced the foraging habitat of moose and subsequently the winter distribution of moose. For example, the vegetation on Adams Island has changed over the past 30 years from open to closed shrubs, likely minimizing the accessibility and hence reducing the utilization by moose. Yet, it is also possible that habitat changes has resulted in lower aerial survey sighting probabilities in the rapidly maturing early successional habitats in the Adams Island area, and moose densities have remained unchanged. Unfortunately, it is not possible to quantitatively evaluate this hypothesis given the absence of radio-marked animals in the area during the time series.

Table 2. Minimum numbers of moose observed during aerial surveys in the non-glaciated lowlands surrounding Adams Inlet, Glacier Bay 1984 - 2012. Survey aircrafts and methodology varied between years. Dashes indicate no spatially explicit information for these years

Year	Date	Adams Island	N. Adams	E. Adams	S. Adams	Total Moose	Survey Minutes	moose/ hr	Source
1984	winter	8	36	2	1	47	64	44	Vequist 1986
1985	winter	39	31	25	0	95	84	68	Vequist 1986
1986	winter	32	25	4	0	67	70	57	Vequist 1986
1994	2/14/1993	-	-	-	-	97	78	75	Robus 1993
2000	2/22/2001	-	-	-	-	113	100	68	Barten 2001
2001	3/19/2002	-	-	-	-	18	94	11	Barten 2002
2010	12/3/2010	0	27	3	0	30	30	60	Barten 2010
2012	12/18/2012	12	72	23	5	112	156	43	Barten 2012
							mean	**53**	**± 6.7 SE**

Recommendation for Future Work

Develop a long-term monitoring sampling design

A key justification for the establishment of Glacier Bay National Park was to allow for the scientific documentation of how glacial processes affect terrestrial ecosystems. Moose are habitat specialists that tend to be linked to the distribution of post-glacial lowland habitats. As such, these species offer unique insights into how glacial processes (and by extension climate change) influence vertebrate communities. Knowledge of how populations of moose change over time is crucial for understanding the broader dynamics of terrestrial ecosystems in Glacier Bay National Park. Such species exert both top-down and bottom-up effects on terrestrial ecosystems in ways that can be profound and far reaching. For example, in Isle Royale National Park moose have played a major role in the structure and function of plant communities and nutrient cycling processes (McInnes et al. 1992). As such, we recommend that routine monitoring of moose populations in Glacier Bay National Park should be prioritized and implemented in the future.

The intent of the current effort was to provide baseline data that could be used to design and develop a rigorous monitoring program for this species in Glacier Bay National Park. As such, we recommend the implementation of a formal follow-up effort to design a long-term monitoring protocol that includes explicit consideration of appropriate spatial and temporal sampling design and power analyses to detect changes in population size and distribution. Ideally, such an effort would involve collaboration with other National Parks in Alaska and elsewhere to ensure that data collected are spatially comparable.

We suggest a monitoring program that would involve annual or biannual monitoring of moose in a subset (or trend site areas) of the total area surveyed in this current project. At less frequent intervals (e.g. 5-10 years) a complete survey could be conducted. Areas surveyed on an annual or biannual basis would enable a higher degree of temporal resolution for population trend determination. Such areas would need to be strategically selected in order to ensure they are meaningful “barometers” for the overall population. We suggest closing areas such as Adams Inlet due to its history or aerial surveys as well as The Glacier Bay National Preserve where sport and subsitance moose hunting are allowed. The National Preserve is expensive to reach, so partnering with the United States Forest Service who monitor moose populations on adjoining lands may be beneficial. Census level data collected at a lower frequency could be oriented towards assessing changes in distribution and “ground truthing” overall population trend inferences derived from annual surveys. Importantly, such a sampling design needs to be cost-effective in order to be sustainable over the long-term. Fortunately, the fieldwork associated with monitoring moose via aerial surveys is relatively inexpensive. For example, the flight time for the entire census of Glacier Bay proper for moose in 2012 cost less than $5,000. This sum, however, does not including salaries to cover the time surveying, data management and analysis, and report writing.

Overall, there is an important opportunity for Glacier Bay National Park to gain long-term, foundational knowledge about moose populations and by extension post-glacial plant community dynamics, climate change and other dimensions of terrestrial ecosystem dynamics. In time, population monitoring data collected for these species could represent an invaluable resource and highlight the unique contributions National Parks have made in furthering our understanding of terrestrial ecology and conservation. National Parks have an exemplary record in this regard and previous NPS long-term monitoring programs involving caribou in Denali National Park and Preserve, wolves and moose in Isle Royale National Park, elk and wolves in Yellowstone National Park are just a few examples of the key role that National Parks can play in advancing our scientific knowledge of vertebrate population dynamics and conservation capacity. Extending the tradition of long-term monitoring of terrestrial vertebrates in National Parks to include one of the most visible and iconic species of northern ecosystems in the context of a rapidly changing, glacially dominated environment represents an important opportunity for scientific advancement and conservation that is consistent with the mission of the National Park Service and guiding legislation for Glacier Bay National Park.

We recommend that the distribution and abundance of moose be monitored by conducting aerial surveys, as described above. Distributions of moose will undoubtedly change over time and documenting these changes, along with changes in landcover, is crucial to understanding and managing thisspecies. Similarly, abundance of moose is likely to change over time. Once ongoing work to develop sightability models is completed it will be possible to monitor population trends over time. Such information can be combined with existing demographic data (White et al. 2007, 2014, and unpublished data)to manage current and potential future harvest on NPS and surrounding lands, determine areas of concentrations of animals and/or critical habitat important to protect, and assess the impacts of climate change on ungulate species in Glacier Bay National Park and Preserve.

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