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Natural Resource Stewardship and Science

Moose (*Alces alces*) population survey in Yukon-Charley Rivers National Preserve, November 2019

Natural Resource Report NPS/YUCH/NRR—2020/2127

ON THE COVER
Bull moose bedded down in Yukon-Charley Rivers National Preserve, November 2019.
Photograph by: Matt Cameron

Moose (*Alces alces*) population survey in Yukon-Charley Rivers National Preserve, November 2019

Natural Resource Report NPS/YUCH/NRR—2020/2127

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Executive Summary

- Overall survey dates: November 10–23, 2019 (10 days of survey, 4 weather days)
  - Stratification dates: November 11–17, 2019 (5 days of survey, 3 weather days)
  - Survey dates: November 18–23, 2019 (5 days of survey, 1 weather day)
- Total survey area: 3,096 mi^2 (8,018 km^2), 555 survey units
- Area surveyed: 670 mi^2 (1,735 km^2), 120 survey units
- Total moose observed: 249 (142 cows, 37 calves [1 set of twins], 70 bulls [3 spike-fork bulls])
- Average search effort: 5.7 minutes/mi^2 (2.2 minutes/km^2)
- Population estimate: 873 moose (90% CI: 730–1,016; +/−16%)
- Estimated density: 0.28 moose/mi^2 (0.11 moose/km^2)
- Estimated age/sex ratios: 26 calves:100 cows, 2 yearlings bulls:100 cows, 49 bulls:100 cows

Acknowledgments

This survey was funded by U.S. National Park Service, Central Alaska Network Vital Signs Monitoring Program, and Yukon-Charley Rivers National Preserve, Alaska. Many safe flight hours and aircraft support were provided during the survey by pilots Andy Greenblatt, Brett Nigus, Jesse Cummings, and Zack Knaebel. Jordan Pruszenski, Maxwell Newton, Hilary Hilmer, Dylan Schertz, and Matt Cameron served as observers in aircraft, and we thank all observers for their help and dedication to the survey. We thank Kyle Joly, Mat Sorum, Jeff Wells, and Graham Frye for providing invaluable input on earlier versions of this report. We are especially grateful to Mat Sorum, Kyle Joly, and Jeff Wells for their help, advice, and coordination in the planning and implementation of this survey.

Introduction

Moose (*Alces alces*) are an integral component of the boreal ecosystem in Yukon-Charley Rivers National Preserve. Moose are considered good indicators of long-term habitat change within the Preserve ecosystem because they require large quantities of resources from their habitat year-round, and populations have the potential to respond to long-term changes in resource conditions. In addition, moose are an important subsistence and sport hunting resource, and are named specifically in the founding legislation for the Preserve (ANILCA, 1980). The Central Alaska Network (CAKN) of the National Park Service (NPS) designated monitoring fauna distribution and abundance as one of the top 3 Vital Signs for the Network. Moose were identified as one such species to monitor as they are a common herbivore present in all 3 park units and indicate the health of lower elevational ecosystems (relative to the elevations within the Network). The CAKN is monitoring animal species across an elevational gradient as part of an effort to track long-term changes in ecosystems across all 3 Alaskan park units. Moose surveys are scheduled for each park unit every 3 years.

The NPS and CAKN conducted an aerial moose survey in partnership during November 10–23, 2019, in and around Yukon-Charley Rivers National Preserve (YUCH), Alaska (Figure 1). Moose surveys have been conducted within YUCH for over 30 years, with 8 surveys being conducted within the current survey area over the last 22 years.

The objectives of the 2019 moose survey were to: 1) estimate numbers of total moose in a 3,096 mi^2 survey area of the preserve, 2) estimate sex and age ratios, and 3) improve the precision of the population estimate by conducting an aerial stratification prior to the survey.

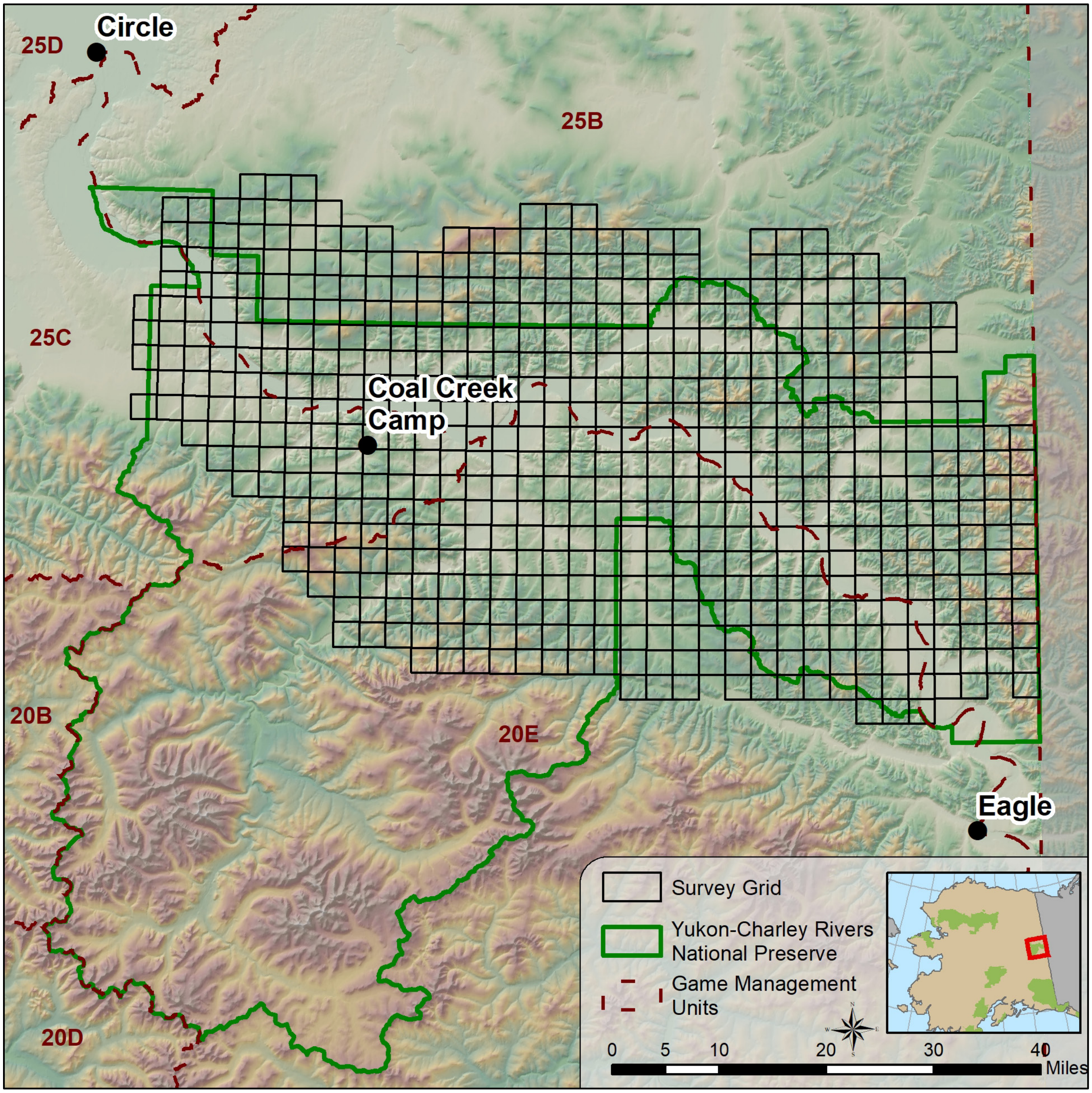

Figure 1. Location of moose survey units within and around Yukon-Charley Rivers National Preserve (YUCH), Alaska. State of Alaska Game Management Unit (GMU) boundaries are indicated in maroon.

Study Area

The moose survey was conducted along a 30–40 mile- (48–64 km) wide corridor of the Yukon River drainage within and around YUCH, between Eagle and Circle, Alaska (Figure 1). The topography of the area consists mainly of rolling hills and river bluffs (Figure 2). Isolated rugged terrain occurs on several eroded mountains, with peaks generally under 6000 feet (1800 meters). Vegetation is dominated by black spruce (*Picea mariana*), and several species of deciduous hardwoods including aspen (*Populus tremuloides*) and birch (*Betula papyrifera*). Ponds, sloughs and large areas of tussock tundra are common in the flats along the Yukon River and lower parts of large tributaries such as the Charley and Kandik rivers. Wildfire burns of varying sizes and ages are present throughout the study area including the more recent large fires from the summers of 1999 and 2004 along the Yukon, Nation and Kandik rivers.

Figure 2. Typical topography and vegetation of the survey area. Foothills of the confluence of the Charley River and Yukon River, photo by Matt Cameron.

Methods

Moose population surveys were conducted using the GeoSpatial Population Estimator (GSPE) method (Ver Hoef 2008), a modification of a technique initially developed by Gasaway et al. (1986). The GSPE method is widely used in Alaska, which allows comparison between survey areas. The publications, "GeoSpatial Survey Operations Manual" (Kellie and DeLong 2006) and "GeoSpatial Population Estimator Software User's Guide" (DeLong 2006) provide guidelines for sample unit design and selection, navigation, and data analysis.

We initially planned to conduct this survey in November of 2018 to maintain the scheduled 3-year interval between surveys. However, temperatures were warmer than normal and adequate snowfall for reliable survey conditions did not accumulate until late in the month (Sousanes and Hill, 2018). Daylight hours are greatly diminished this late in the fall season and surveying at this remote site becomes increasingly difficult and inefficient with such shortened days, so we rescheduled the survey for 2019.

In November 2019, we performed the first aerial stratification of the entire study area prior to conducting the survey, as recommended by Sorum and Joly (2016). We followed the protocol described in Kellie and DeLong (2006) and flew centerline transects through all the survey units at speeds ranging from 100–140 knots and at an altitude of 800–1500 ft above ground level. We flew in a Cessna 185 and then a Found Bush Hawk, placing 3 observers with the pilot. For each unit we recorded the number of moose detected, presence of moose tracks, and predominant habitat. If any moose were detected, a unit was classified as a high stratum. If no moose were detected, presence of tracks and predominant habitat were used to determine strata, with deciduous shrub habitat (such as burned areas, high elevation shrub lines, and riparian corridors) characterizing high stratum (Schwartz and Franzmann, 1989, MacCracken et al. 1997). Since the first half of the stratification effort occurred when snow and light conditions were poor for easily detecting tracks, we relied primarily on habitat classifications. For units which were of questionable stratum and were surveyed previously, we used information from the last 3 surveys to help inform stratum classification (Kellie and DeLong 2006). Because the Yukon River corridor represented a large area of high-quality habitat but virtually no moose were detected within it during the stratification, we flew the river corridor on the last stratification day when tracking conditions were excellent and re-classified units as low strata unless a moose was detected in or near the unit.

Sample units to survey were randomly selected from each density strata following Kellie and DeLong (2006). Approximately 10 – 20% of the units were withheld from the random selection and subjectively used to fill in-between blocks of units because the GSPE has a spatial component whose results are improved if there are no large gaps (> 50 km) among surveyed units. Because observations are more variable in the high stratum than the low stratum, we allocated greater sample effort to the high-density units to reduce overall variance (Kellie and DeLong 2006). We selected 120 units to survey out of the 555 total units, with a goal to sample approximately 40% and 12% of the high and low stratum units, respectively.

For the survey, four tandem seat fixed-winged aircraft (Piper PA-18 and Top Cub CC-18) were used to survey ~ 5.6 mi^2 units that were delineated by 2 minutes of latitude by 5 minutes of longitude. Aircrafts used Global Positioning System (GPS) to navigate to and within assigned units and search intensity varied with habitat. The survey protocol required high search intensity in forested habitats (8–10 minutes per square mile) and lower intensity in open habitats or areas with significant water. Survey patterns varied according to terrain. Within lowland area, survey aircrafts generally flew transects about 300 to 800 feet AGL at 70 knots. Within mountainous terrain, survey aircrafts followed the contour of the mountains.

An observer was paired with each pilot, and the observer's job was to record data on an iPad using the NPS application, "Park Observer," (developed by the Alaska Regional GIS Team). The iPads were loaded with base maps, the survey grid, and the remaining units to be surveyed each day. Using the Park Observer "Fall Moose Comp" (v1.0) protocol, the observer recorded the track log as well as moose group location and composition which were detected during the survey. Numbers of moose in each group were recorded and the sex and age classification of each moose was determined. Moose were classified as: cow, calf, yearling bull (spike or forked antlers), medium bull (antler spread > spike/fork, but < 50 inches [127 cm]), and large bull (antler spread ≥ 50 inches [127 cm]). Total moose, moose density and sex/age ratios were calculated using the GeoSpatial Population Estimator software (DeLong 2006, Kellie and Delong 2006).

Results

Weather and Snow Conditions

The majority of the weather conditions for flying the stratification and survey were fair to excellent. At the beginning of the stratification, Coal Creek weather station recorded 11” of snow depth with 3.5” falling in a storm 4 days prior (MesoWest 2020). Snow cover in the study area was complete except for the Yukon River corridor, which mostly had vegetation showing due to high winds along the river. Tracking conditions were difficult in the first half of the stratification but improved throughout as snow accumulated. These multiple snow events during the stratification resulted in a snow depth at Coal Creek of approximately 15” at the beginning of the survey portion (MesoWest 2020). Snow cover was complete throughout the study area with fresh snow at the onset of the survey, and snow conditions and sightability were good to excellent throughout the survey. Temperatures ranged from −16°F to 34°F at the Coal Creek weather station during the project (MesoWest 2020). The Yukon River was partially frozen-over during the survey, with the ice edge initially beginning approximately halfway across the study area and building upstream throughout the stratification and survey.

Stratification and Survey Details

The combined stratification and survey was conducted between 10–23 November. The stratification was completed in 5 days of flying between 10–17 November, in which all units of the study area were stratified. Of the 555 total units, 202 (36%) were classified as high strata and 353 (64%) as low strata (Figure 3).

We conducted the survey between 19–23 November, completing 120 of 555 survey units which covered 22% of the survey area (Figure 3, Table 1). Eighty (39%) of the high-density units and 40 (11%) of the low-density units were surveyed (Table 1). A total of 64.0 hours (3,839 minutes) of flight time was spent searching for moose for an average of 32.0 minutes per survey unit. Search intensity averaged 5.7 minutes per mi^2 (2.2 minutes/km^2, Table 2). All selected units were completed during the survey.

Aviation and project costs for the 2019 Yukon-Charley Rivers NP fall moose survey are found in Appendix A. Complete survey results for the entire 2019 survey are archived in, and can be retrieved from, the ADFG WINFONET database under the survey name “YUKON-CHARLEY, Fall, 2019” (http://winfonet.alaska.gov/; accessed 20 December 2019) as well as the NPS repository IRMA (“Moose (Alces alces) population survey in Yukon-Charley Rivers National Preserve, November 2019”; Code: 2272089).

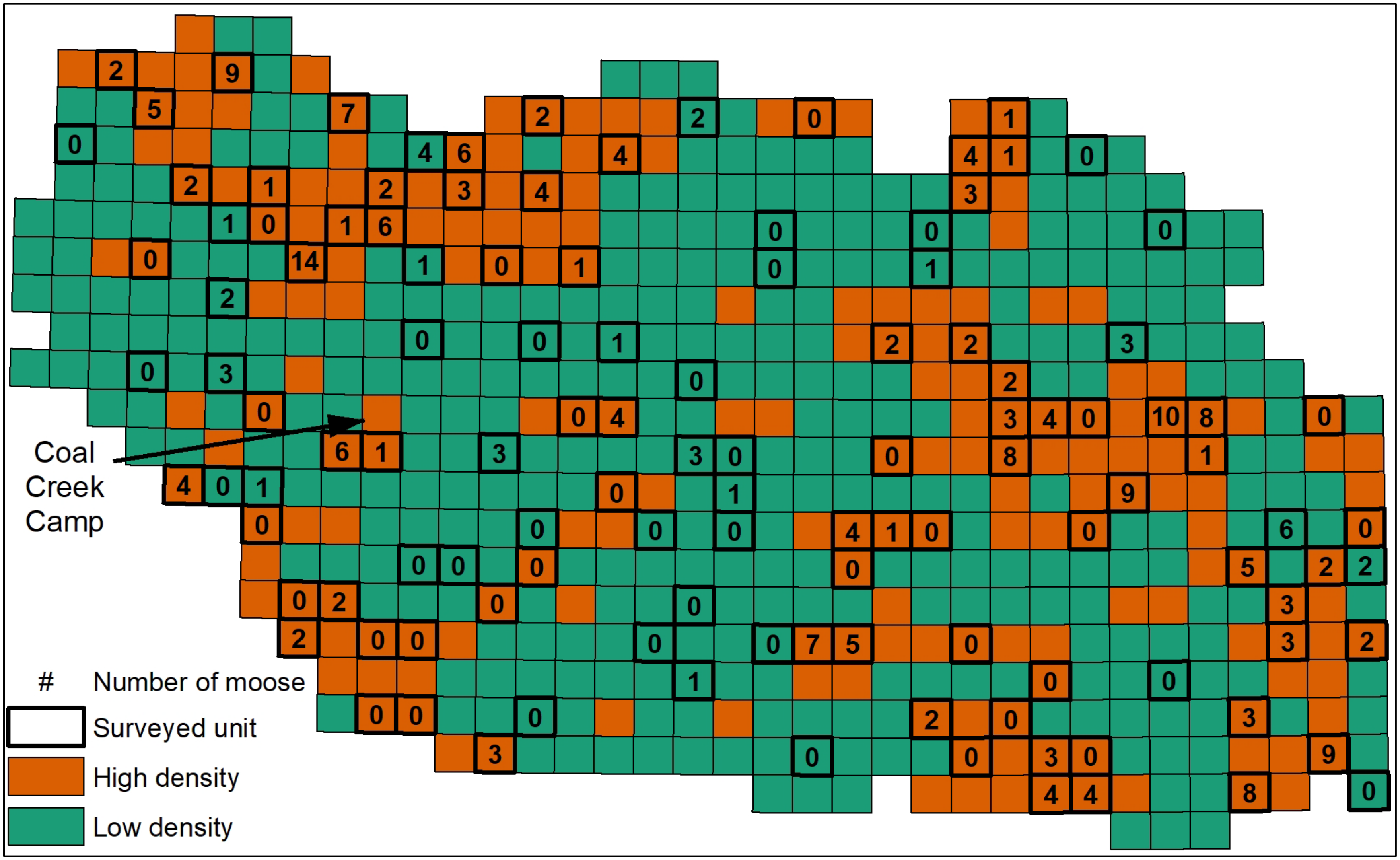

Figure 3. Stratification (indicated by color of survey unit) and numbers of moose counted in each unit in Yukon-Charley Rivers National Preserve, November 2019.

Table 1. Summary of stratification and sampled units from moose population surveys in Yukon-Charley Rivers National Preserve, 1987 to 2019. Areas are presented as square miles and number of units (for stratified random and GSPE surveys) are in parentheses.

Survey Year	Survey Area	Sample Area	% Sampled	Stratification			Survey		
				High	Med	Low	High	Med	Low
1987[a]	3556	240	6.7	–	–	–	–	–	–
1994[a]	2790	1844	66.1	–	–	–	–	–	–
1997	2758 (201)	1358 (98)	49.2	303 (22)	788 (57)	1667 (122)	238 (21)	537 (38)	537 (39)
1999	2745 (200)	1389 (100)	50.6	333 (24)	622 (45)	1790 (131)	333 (24)	576 (42)	480 (34)
2003	3157 (566)	591 (106)	18.7	1049 (188)	–	2108 (378)	340 (61)	–	251 (45)
2006	3096 (555)	841 (151)	27.2	899 (161)	–	2197 (394)	540 (97)	–	301 (54)
2009	3096 (555)	618 (111)	20.0	899 (161)	–	2197 (394)	329 (59)	–	289 (52)
2012	3096 (555)	664 (119)	21.4	899 (161)	–	2197 (394)	362 (65)	–	301 (54)
2015	3096 (555)	714 (128)	23.0	949 (170)	–	2147 (385)	458 (82)	–	256 (46)
2019	3096 (555)	670 (120)	21.6	1127 (202)	–	1969 (353)	447 (80)	–	223 (40)

[a] Not directly comparable with later surveys.

Population Estimate

The GSPE population estimate for observable moose in YUCH was 873 moose (90% confidence interval [CI] = 730–1,016 [16% relative precision]) which yielded a density of 0.28 moose/mi^2 (0.11 moose/km^2; Table 2, Figure 4).

Table 2. Summary of survey statistics and density estimates for moose population surveys in Yukon-Charley Rivers National Preserve, 1987 to 2019.

Year	Method	Survey Area mi^2 (# units)	Sampled Area mi^2 (# units)	Search Intensity (min/mi^2)	Population Estimate	Relative Precision	Density (moose/mi^2)	Sightability Correction Factor
1987[a]	Gasaway	3556	240	4.4	1116	–	0.31	–
1994[a]	Gasaway	2790 (245)	1844 (162)	1.0	551	0.23	0.20	1.34
1997	Stratified Random	2758 (201)	1358 (98)	3.9	602	0.20	0.22	1.22
1999	Stratified Random	2745 (200)	1389 (100)	4.0	830	0.19	0.30	1.18
2003	GSPE	3157 (566)	591 (106)	6.6	696	0.24	0.22	–
2006	GSPE	3096 (555)	841 (151)	5.4	605	0.19	0.20	–
2009	GSPE	3096 (555)	618 (111)	6.7	1109	0.19	0.36	–
2012	GSPE	3096 (555)	664 (119)	6.0	780	0.21	0.25	–
2015	GSPE	3096 (555)	714 (128)	5.0	1138	0.18	0.37	–
2019	GSPE	3096 (555)	670 (120)	5.7	873	0.16	0.28	–

[a] Not directly comparable with later surveys.

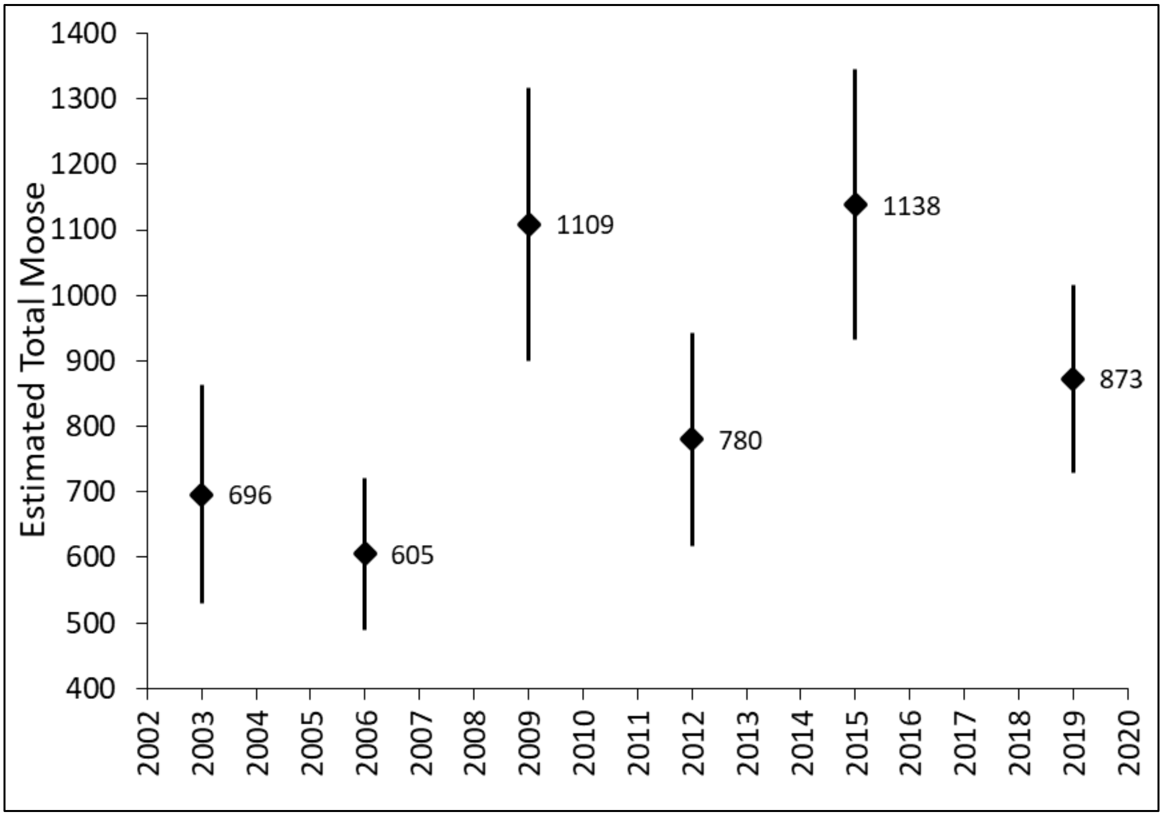

Figure 4. Estimated observable fall moose total (with 90% confidence intervals) for Yukon-Charley Rivers National Preserve from GSPE surveys from 2003–2019, Alaska.

Sex and Age Composition

The sex and age composition of the 249 observed moose were as follows: 142 cows, 70 bulls, and 37 calves (Table 3). Composition of the observed bulls included 3 yearling bulls (spiked or forked antlers), 32 medium bulls, and 35 large bulls (Table 3). No single-antlered bulls were observed, suggesting that antler shedding was not an issue for the survey. The estimated sex and age ratios of the population were 28 calves:100 cows (90% CI = 19-36), 2 yearling bulls (spike/fork):100 cows (90% CI = 0-3), and 49 bulls:100 cows (90% CI = 34-65; Table 3). One set of twins was observed in the survey (Table 4).

Table 3. Summary of observed moose during the surveys in Yukon-Charley Rivers National Preserve, 1987 to 2019. Sex and age ratios were calculated in WinfoNet for GSPE surveys and 90% confidence intervals for these are reported in parentheses.

Survey Year	Area (mi^2)	Total Bulls	Total Cows	Total Calves	Total Moose	Bulls/ 100 Cows	YrlBulls/ 100 Cows	Calves/ 100 Cows	% Bulls	% Cows	% Calves
1987[a]	3556	88	73	7	169	121	14	10	52	43	4
1994[a]	2790	147	176	37	364	84	7	21	40	48	10
1997	1358	136	197	51	384	60	8	28	35	51	13
1999	1389	169	266	77	513	51	5	36	33	52	15
2003	591	55	87	17	159	60 (38–82)	6 (2–11)	25 (13–37)	35	55	11
2006	841	63	89	28	180	73 (53–94)	7 (2–11)	33 (21–46)	35	49	16
2009	618	102	164	42	308	60 (40–79)	13 (8–18)	27 (17–37)	33	53	14
2012	664	80	118	25	223	68 (46–89)	11 (5–17)	24 (15–33)	36	53	11
2015	718	105	165	44	314	72 (50–94)	4 (2–6)	25 (17–32)	33	53	14
2019	670	70	142	37	249	49 (34–65)	2 (0–3)	28 (19–36)	28	57	15

[a] Not directly comparable with later surveys

Table 4. Number of sets of twins seen during moose surveys in Yukon-Charley Rivers National Preserve, 1987 to 2019.

Survey Year	Sets of twins seen
1987	0
1994	1
1997	3
1999	6
2003	1
2006	5
2009	4
2012	0
2015	4
2019	1
Average	3

Discussion

Moose in Yukon-Charley National Preserve (Alaska GMU 20E, 25B, 25C, and 25D) continue to occur at low densities. The fall count of 873 observable moose resulted in a moose density of 0.28 moose /mi^2, or 0.11 moose/km^2. Continued conservative management of harvest is recommended. This report continues the documentation of the Yukon-Charley moose population existing at low densities for over 30 years (Sorum and Joly 2016).

The population estimate of observable moose during the 2019 survey represents a 23% decrease from the previous point estimate of 2015, however, this difference is not statistically significant as the 90% confidence intervals overlap. As such, we interpret these new results as normal fluctuations of a population that is relatively stable at the decadal scale. We observed the greatest proportion of cows ever in this survey, while calf metrics are within previously observed ranges. Notably, we observed the lowest ever percentage of bulls and yearling bulls in this survey (49:100 and 2:100, respectively) and may indicate increased harvest pressure in the Preserve. We interpret these results cautiously, however, since the bulls:100 cows 90% confidence interval overlaps all previous GSPE ratio estimates and the yearling bulls ratio was distinct from only 2 other prior years. Additionally, yearling bull classification can exhibit greater variability between observers and antler development rates may be influenced by range conditions, potentially biasing this metric low (Young and Boertje 2018). For comparison, the 2015 estimate for 25D to the north was 35 bulls:100 cows (Caikoski, 2018) and the Tok Central area of 20E, which has the most similar moose density to YUCH of the GMU, has fluctuated between 54:100 and 67:100 between 2010–2012 (Wells, 2018).

The management goal of the Preserve is for natural and healthy populations (ANILCA 1980), and we interpret these decreased metrics of bulls in the Preserve as cautionary indicators to be monitored further. Low yearling bull recruitment into the population for extended periods could further skew the composition of the population away from natural levels and be an indicator of potential future population decline. Yet without understanding annual harvest within the Preserve, we lack the ability to identify causes of such trends and make sound management decisions. We recommend continued monitoring of these metrics and incorporating measures of harvest within the Preserve in future reports. While the long-term trend (since 1997) of the moose population is likely positive, a rigorous analysis of the population trajectory was outside the scope of this project. With the accumulation of now 8 comparable surveys, we look forward to such an analysis of moose population trends and associated factors.

We made two major changes to the survey this year that we felt improved the overall survey. The first was to conduct the first aerial stratification of the entire study area, and we credit this with resulting in the most precise population estimate of any survey to date (Appendix B). While this addition increased the financial cost and duration of the survey, we believe it will be applicable for future surveys because we based the stratification classification primarily on habitat, which generally changes slowly over time. We recommend further refinement of the stratification classification in future surveys by adjusting strata classes with survey data from the previous decade for those units which have been surveyed (as described in Kellie and DeLong 2006), by re-flying a subset of units prior to the survey, or by incorporating information on moose habitat use gained from concurrent studies in the Preserve. The second change we implemented was to collect data entirely on iPads using the application Park Observer. While we had initial concerns with battery life in the cold conditions and with potential user error, we had no major issues with using the iPads during the survey and external battery packs were adequate to power the iPads all day. Data analysis was greatly expedited since the data was already stored as spatial data and backing up data in the field was easy. An added benefit was that by updating survey maps every day with the remaining units to be surveyed, observers could help pilots plan the most efficient route and we had no units which were surveyed twice. We recommend the continued use of iPads for moose survey data collection.

We see one future improvement that can be made to this survey. Sightability trials were completed for this population in 1997 and 1999 and we recommend re-estimating them when feasible. We did not include sightability corrected population estimates in this report because we felt that the correction factors were outdated and we lacked the detailed information to incorporate the variability of sightability into the population estimate. With the planned deployment of GPS collars on moose in YUCH between this and the next survey, the conditions will be ideal to measure sightability. Additionally, we expect that insights from moose space use at the time of the survey will help inform and refine the stratification classification.

This moose survey was notable for both being delayed by a year due to weather (originally scheduled to occur in 2018) as well as being the longest survey on record for the Preserve. Rescheduling the 2018 survey was due to the later-than-normal arrival of snow conditions and the lack of a clear weather window to initiate the survey. While the long duration of the 2019 survey was principally due to the addition of an aerial stratification, the high degree of weather variability experienced during the survey was notable. Even in late November, we experienced a warming event with rain-on-snow at Coal Creek. Our survey was characterized by working around inclement weather, and in hindsight we never had an obviously clear weather window in which to conduct the survey. While we expect that the next moose survey in Yukon-Charley can be conducted in the fall, given the strong trend of increasingly warm climate conditions in the Arctic (Box et al 2019), we are concerned for the long-term feasibility of continuing these surveys as-is at this time of year. Delaying the survey is constrained by increasingly short days in December, which limit daily flight time to inefficient schedules in this remote location as well as adequate light conditions for surveying. As climate warming continues, managers may need to consider alternative survey methods, such as estimating sightability each year to account for different conditions, emerging technologies such as thermal detectors (McCafferty 2007), or switching to spring population surveys for the Preserve, such as those performed in more western and northern regions (e.g., Sorum et al. 2015).

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Appendix A. Survey Logistics

Table A-1. Aviation usage and cost during the 2019 spring moose survey. Survey and stratification hours include ferry flights.

Planes	Pilots	Description	Hours	Total
C-185, Found	Andy Greenblatt, Brett Nigus	Shuttle	11.47	$4,234
C-185, Found	Andy Greenblatt, Brett Nigus	Stratification	22.4	$8,014
PA-18, Top Cub	Jesse Cummings, Andy Greenblatt, Zack Knaebel, Brett Nigus	Survey	112.3	$31,494
			Total	**$43,742**

Table A-2. Overall project cost during 2019 spring moose survey .

Category	Description	Quantity	Cost/Unit	Total
Food	–	–	–	$2,340
Fuel	CCC/Eagle 100LL	1,310 gal	$6.15	$7,472
–	Ferry 100LL	380 gal	–	$2,064
Housing	NPS housing	–	–	$645
Aviation	Detailed in Table A	–	–	$43,742
			Total Project Cost	**$56,848**

Appendix B. Comparing 2 Stratifications

We were interested in the effect that the new aerial stratification had on the population estimate for Yukon-Charley Rivers Preserve in comparison to the previous desktop stratification. To better understand how both stratifications were performing, we assigned surveyed units in the 2015 and the 2019 surveys with both stratification classifications and compared moose counts in the high and low stratums Tables B-1 and B-2). The goal of the stratification is to partition the variability in the study area (Kellie and DeLong 2006) and since the low strata comprise a greater proportion of the area being estimated, reducing the variability in the low strata has a greater effect on reducing the overall estimate variability. For the 2015 survey, the aerial stratification resulted in a greater spread of average moose counts between the low and high strata (less moose in the low and more in the high strata) as well as reducing the standard deviation of the low strata (Table B-1). This change was primarily due to having more 0 moose counts in the low strata and fewer 0 moose counts in the high strata with the aerial stratification (Figure B-1).

Table B-1. Summaries of count data from GSPE units by stratum for the 2015 YUCH moose survey, for both the desktop stratification used in the survey and the aerial stratification from 2019.

Method	Stratification	Average # of moose	Standard Deviation	# of Units
Desktop Stratification	High	3.0	3.7	82
	Low	1.5	2.5	46
Aerial Stratification	High	3.9	3.9	59
	Low	1.2	2.2	69

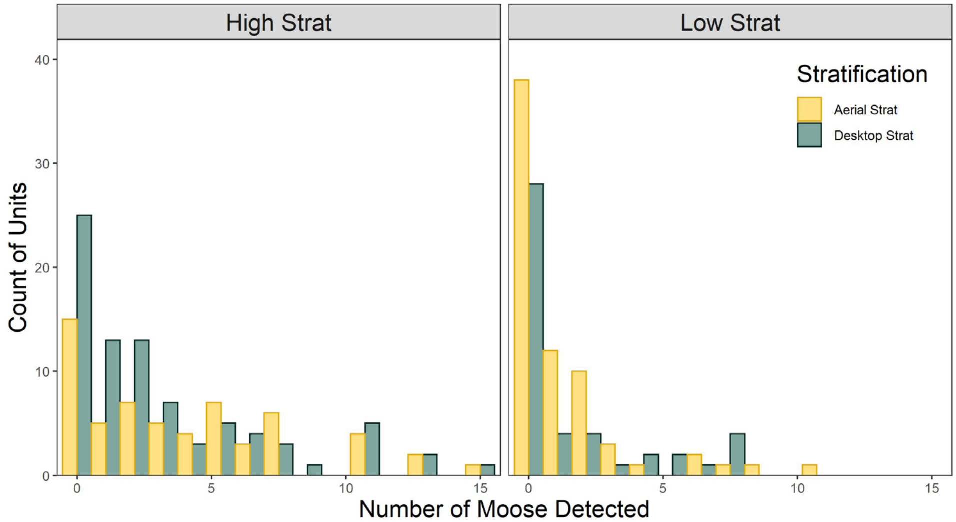

Figure B-1. Counts of moose in GSPE units from the 2015 YUCH survey by strata, separated by both stratification methods. Green indicates the desktop stratification used in the 2015 survey and yellow indicates the aerial stratification flown in 2019.

For the 2019 survey data, the pattern was similar. The aerial stratification resulted in a lower average number of moose in the low strata and a higher average in the high strata compared to the previous desktop stratification (Table B-2). The aerial stratification also resulted in a reduced standard deviation for the low strata, which was likely due to having fewer high counts of moose in the low strata as compared to the desktop stratification (Figure B-2). Interestingly, the aerial stratification included more 0 counts in the high strata than in the desktop stratification, and less 0 counts in the low strata (Figure B-2).

Table B-2. Summaries of count data from GSPE units by stratum for the 2019 YUCH moose survey, for both the desktop stratification used in the survey and the aerial stratification from 2019..

Method	Stratification	Average # of moose	Standard Deviation	# of Units
Desktop Stratification	High	2.5	2.8	53
	Low	1.7	2.6	67
Aerial Stratification	High	2.7	3.0	80
	Low	0.9	1.4	40

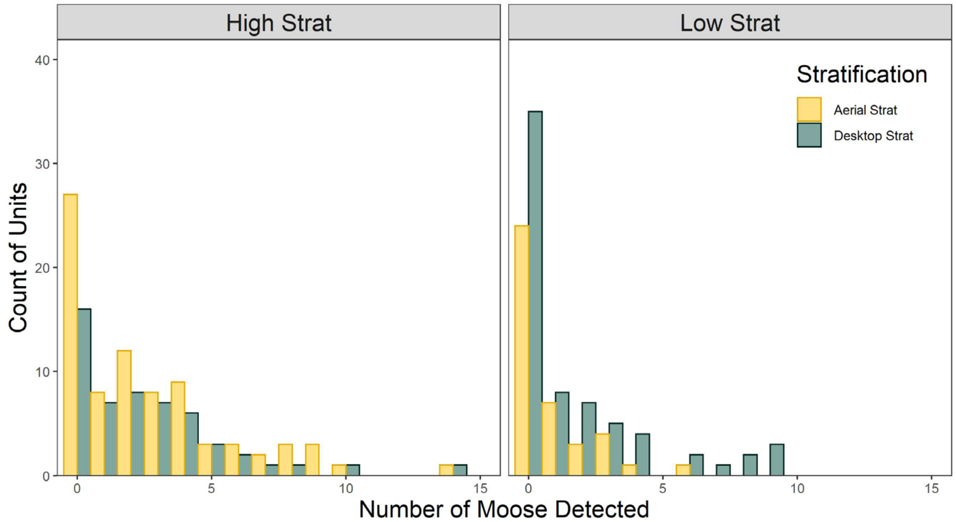

Figure B-2. Counts of moose in GSPE units from the 2019 YUCH survey by strata, separated by both stratification methods. Green indicates the desktop stratification used in the 2015 survey and yellow indicates the aerial stratification flown in 2019.

We do not compare estimates for the study population between the 2 stratification classifications for 2015 and 2019 because the reassignment to different stratification classes invalidates the sample unit selection process as outlined in Kellie and DeLong (2006) and results in undesirable allocations of sample units to the 2 stratums (more low units than high units; Tables B-1 and B-2). But, by examining the effect of stratification classifications on moose counts for these 2 years of surveying, we gained confidence that the new stratification is achieving a better estimate by more effectively partitioning the low-density units into the low stratum. Observed variability was indeed lower for the low strata in both years using the aerial stratification and owing to the greater number of low strata units than high, we expect this to have resulted in the lower overall variability in the 2019 estimate. A potential improvement we see for future surveys would be to reduce the number of units with 0 counts in the high strata, which could help to reduce the observed variability in that category.

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