CARIBOU MONITORING IN THE COLVILLE SOUTH SURVEY AREA, NORTHERN ALASKA, 2018

Alexander K. Prichard
Joseph H. Welch
Brian E. Lawhead

Prepared for
ConocoPhillips Alaska, Inc.
Anchorage, Alaska

Prepared by
ABR, Inc.—Environmental Research & Services
Fairbanks, Alaska

CARIBOU SURVEYS IN THE COLVILLE SOUTH SURVEY AREA, NORTHERN ALASKA, 2018

FINAL REPORT

Prepared for:

ConocoPhillips Alaska, Inc.

P.O. Box 100360

Anchorage, AK 99510

Prepared by:

Alexander K. Prichard

Joseph H. Welch

Brian E. Lawhead

ABR, Inc.—Environmental Research & Services

P.O. Box 80410

Fairbanks, AK 99708

December 2018

EXECUTIVE SUMMARY

- This study investigated the distribution, abundance, and movements of Central Arctic Herd (CAH) and Teshekpuk Herd (TH) caribou in 2018 in the Colville South survey area south of Nuiqsut, Alaska and east of the Colville River; this is an undeveloped area of interest for potential oil development.
- Five aerial surveys were conducted by fixed-wing airplane in spring (May), calving (early June), oestrid fly season (late July), late summer (late August), and fall (late September).
- Telemetry data from the CAH and TH were used to assess movements by individual collared caribou in the vicinity of the survey area.
- The spring of 2018 was colder than average and snow melt was later than average with patchy snow persisting into mid-June. July temperatures were warmer than average and mosquito and oestrid fly harassment was predicted to be high during July. August temperatures were cooler than average and September temperatures were close to average.
- No caribou were observed during the surveys in May and July. We estimated that 26 caribou were in the survey area in June, 26 caribou were in the survey area in August, and 46 caribou were in the survey area in September.
- Based on available telemetry data, the Colville South survey area is not heavily used by either herd. The highest use occurs during oestrid fly season, late summer, and fall migration for the CAH; during spring migration and fall migration for TH females; and during calving season, late summer, and fall for TH males.
- Two moose were seen in or near the survey area, one on 31 July and one on 29 August. The survey area is near the northern extent of moose range in north-central Alaska.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc. (CPAI, and administered by Robyn McGhee, Environmental Studies Coordinator for CPAI, for whose support we are grateful. Assistance with field logistics was provided by Justin Blank, Zac Hobbs, and Krista Kenny. Beth Lenart and Lincoln Parrett of the Alaska Department of Fish and Game, Division of Wildlife Conservation, generously shared unpublished information. Jesse Cummings of Golden Eagle Outfitters, and Bob Gill and Tracy Kraun of 70 North, provided safe and efficient piloting of survey aircraft under flying conditions that often were less than optimal. Skilled assistance in the field was provided by ABR employees Katie Hayden, Robert McNown, Tim Obritschkewitsch, Julie Parrett, and Pam Seiser as well as Tim Vosburgh from BLM. Support during data collection, analysis, and report production was provided by ABR employees Tony LaCortiglia, Will Lentz, Pam Odom, Chris Swingley, and Dorte Dissing. The draft report was improved through reviews by Adrian Gall of ABR as well as Robyn McGhee and Lisa Pekich of CPAI, and Justin Blank of Fairweather Science.

INTRODUCTION

Two herds of barren-ground caribou (*Rangifer tarandus granti*), the Teshekpuk Herd (TH) and the Central Arctic Herd (CAH), inhabit the central Alaskan Arctic. Their summer ranges overlap at the Colville River Delta with the TH generally remaining west of the Colville River and the CAH generally remaining east of the Colville River (Murphy and Lawhead 2000, Person et al. 2007, Lenart 2015, Parrett 2015a). The CAH summer range includes the Kuparuk Oilfield (Figure 1). The TH has had limited exposure to infrastructure, although recent oilfield development has occurred west of the Colville River and additional construction within the TH range is planned.

The CAH typically calves in two broad areas of the coastal plain between the Colville and Canning rivers, uses coastal areas for insect relief, and winters in the central Brooks Range, primarily in the southern foothills in recent years (Arthur and Del Vecchio 2009; Lenart 2015, Nicholson et al. 2016). The herd size of the CAH has varied widely over the past 4 decades. It grew rapidly from ~5,000 animals in the mid-1970s to 23,444 caribou in July 1992 before declining 23% to 18,100 caribou in July 1995. The herd then increased to a peak of 68,442 animals in 2010 (Lenart 2015). The herd subsequently declined to an estimated 50,753 animals by July 2013 (Lenart 2015) and 22,630 animals by July 2016 (Lenart 2017). The magnitude of the recent decline may have been affected by emigration of some CAH animals to the Porcupine Herd and the TH, with which the CAH often intermixes on winter range (Lenart 2017). The most recent estimate of CAH herd size was 28,000 individuals in 2017 (Lenart 2018).

The TH typically calves near Teshekpuk Lake, ~75 km (47 mi) west of Alpine, and uses coastal habitats and areas around Teshekpuk Lake for relief from insect harassment during summer.

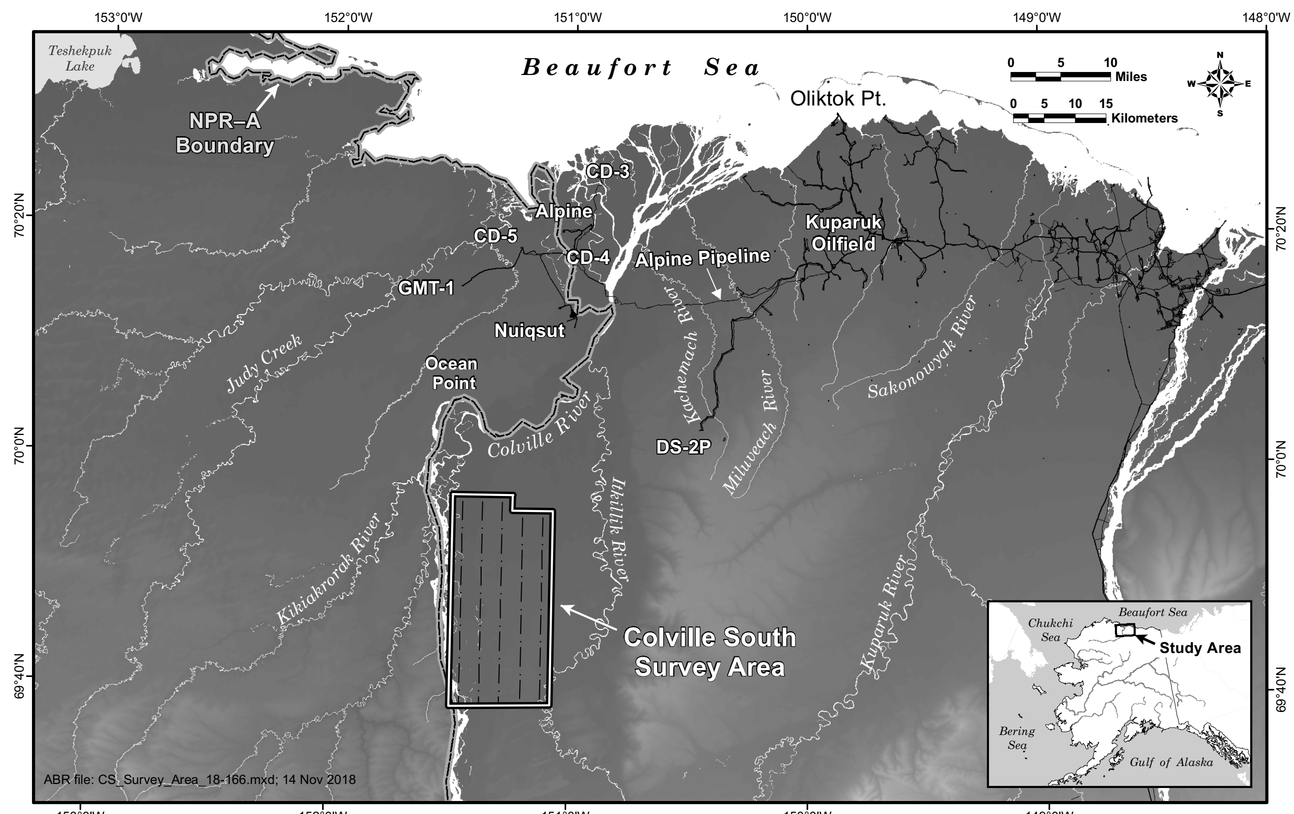


Figure 1. Survey areas and transect lines for systematic aerial surveys of caribou in the Colville South survey area, northern Alaska, in 2018.

Most TH animals winter on the Arctic Coastal Plain (Person et al. 2007), however, in some years, large portions of the herd have wintered in the central Brooks Range or with the Western Arctic Herd (WAH) on and near the Seward Peninsula. An unusual excursion of TH animals to northeastern Alaska occurred in the winter of 2003–2004 (Carroll 2007, Parrett 2009, Lawhead et al. 2010). Similar to the CAH, the TH increased substantially in size from the mid-1970s to an estimated peak population size of 68,902 animals in July 2008 (Parrett 2015a). The herd subsequently declined at least 19% to an estimated 55,704 animals by July 2011 and then dropped at least 30% further to an estimated 39,172 animals by July 2013 (Parrett 2015a). The herd then increased in size to 41,542 animals in July 2015 and 56,255 animals in July 2017 (Klimstra 2018). A new, higher-resolution camera was used for the photo censuses in 2017, and the improvement in photograph quality may have been partially responsible for higher caribou counts in both herds in that year (Lenart 2018).

The study reported here was conducted to establish baseline use of the Colville South area by caribou. Understanding how use of the area varies seasonally by herd will be important for assessing potential impacts if development occurs in the area. Although the primary focus for this study was caribou, observations of other large mammals in the area were recorded as well.

The 2018 study had three objectives:

- Use aerial surveys to document the distribution and abundance of caribou in the Colville South survey area during different seasons;
- use existing radio telemetry data to characterize the caribou use of the Colville South area seasonally and by herd; and
- record the distribution and abundance of other large mammals encountered incidentally during wildlife surveys in the Colville South area.

STUDY AREA

The Kuparuk oilfield and surrounding area (known as the Greater Kuparuk Area, or GKA) is located on the outer coastal plain in the western portion of the summer range of the CAH. Since 1978, shortly before development of the Kuparuk oilfield, considerable interest has focused on the use of the oilfield and surrounding area by the CAH.

The Colville South study area is southwest of the Kuparuk oilfield, and south of the Alpine oilfield (Figure 1). The area is between the Colville River to the west and the Itkillik River to the east, approximately 50 km (31 mi) from the Beaufort Sea coast, and 30 km (19 mi) south of the community of Nuiqsut. The physiography, vegetation, and climate of the central Arctic Coastal Plain were described by Walker et al. (1980).The landscape in the Kuparuk–Colville region slopes gently downward from upland, moist tussock tundra in the upper reaches of the Sakonowyak, Ugnuravik, Kalubik, Miluveach, and Kachemach river drainages to moist and wet tundra near the sea coast. The terrain is characterized by permafrost-related features, such as oriented thaw-lakes, drained-lake basins, beaded streams, and pingos. The Colville South study area is largely composed of sedge-shrub tundra and wet sedge land cover types and is near the northern extent of tall shrubs in the central Alaskan Arctic (Figure 2).

METHODS

WEATHER AND INSECT CONDITIONS

Spring weather influences the location of calving (Carroll et al. 2005; Griffith et al. 2002) and the availability of highly nutritious early-emerging forage (Kuropat 1984, Johnstone et al. 2002, Johnson et al. 2018). Summer weather conditions can be used to predict the occurrence of harassment by mosquitoes (*Aedes* spp.) and oestrid flies (warble fly *Hypoderma tarandi* and nose bot fly *Cephenemyia trompe*) (White et al. 1975, Fancy 1983, Dau 1986, Russell et al. 1993, Mörschel 1999). To estimate spring and summer weather conditions in the area during 2018, we used meteorological data from National Weather Service reporting stations at Kuparuk and Nuiqsut. Thawing degree-day sums (TDD; total degrees Celsius above zero) were calculated using average daily temperatures at the Kuparuk airstrip. The estimated probability of mosquito activity was

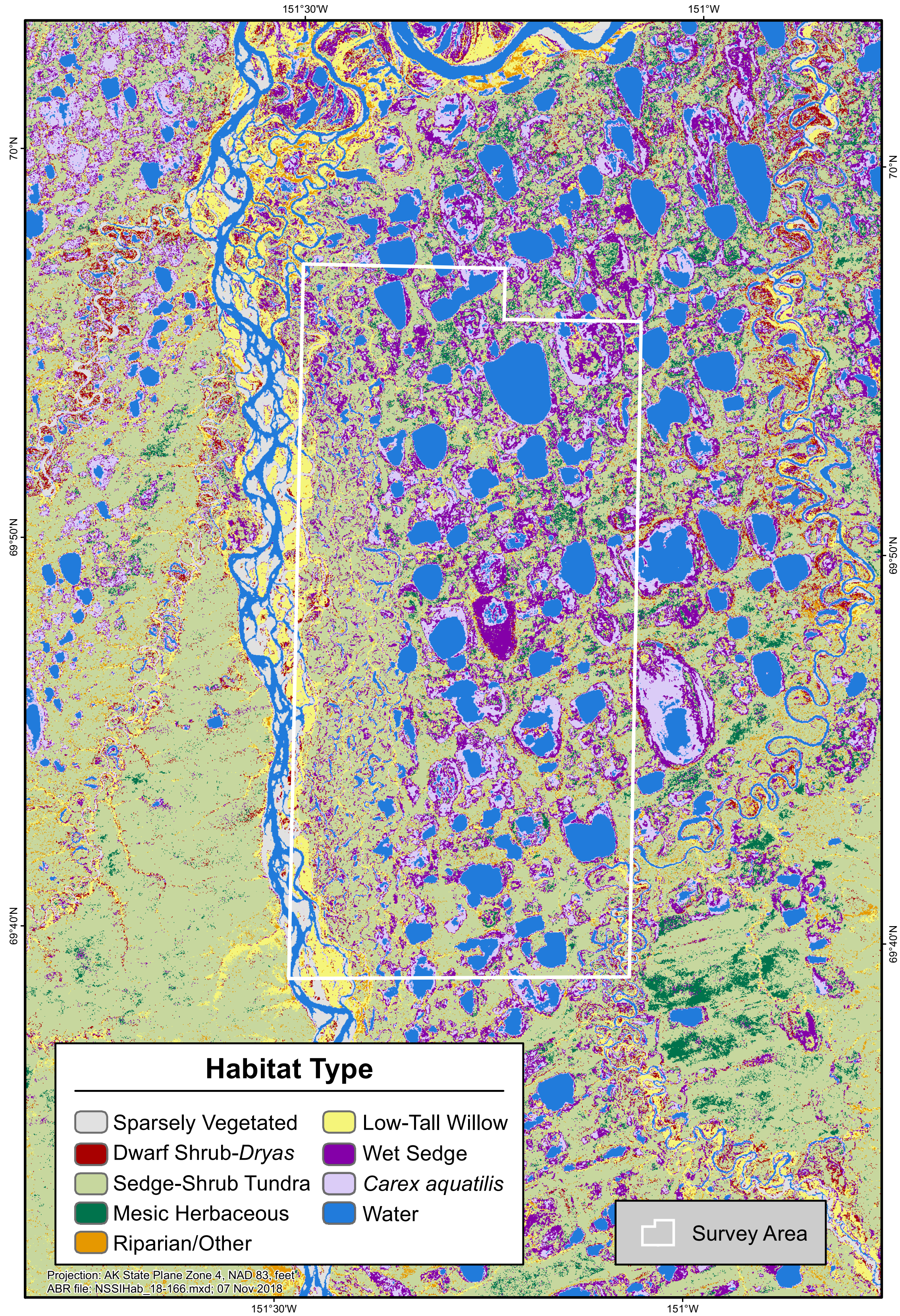


Figure 2. Habitat types in the vicinity of the Colville South survey area.

estimated based on hourly temperatures and wind speeds from Nuiqsut, using an equation developed by Russell et al. (1993). The estimated probability of oestrid-fly activity was calculated from average hourly wind speeds and temperatures recorded at Nuiqsut, using equations developed by Mörschel (1999).

AERIAL SURVEYS

Five aerial surveys of the Colville South area were conducted by ABR in 2018: a spring survey on 21 May; a calving survey on 8 June; an oestrid fly season survey on 31 July; a late summer survey on 29 August; and a fall survey on 24 September. These time periods were chosen to coincide with the different seasons when caribou were more likely to be present in the area based on previously collected telemetry data for the CAH and TH.

Caribou were counted and mapped by two observers, looking on opposite sides of a Cessna 206 survey airplane. In each survey area, the pilot navigated along north–south-oriented transect lines using route coordinates loaded into a GPS receiver. The pilot maintained the aircraft speed at ~150 km/h and the altitude at ~150 m (500 ft) above ground level (agl). Transect lines were spaced systematically at intervals of 3.2 km (2 mi), following section lines (Figure 1).

Observers counted caribou within an 800-m-wide strip on each side of the flight line, for a sampling intensity of 50% (1.6 km of each 3.2 km). The strip width was estimated visually by comparison with background maps loaded into the observers' GPS receivers. For each caribou group observed within the strip, the airplane location was recorded using a GPS receiver, the number of adults and calves were recorded, and the group was assigned to a distance category (one of four 200-m-wide zones) east or west of the airplane. Caribou groups were then assigned to the midpoint of the distance zone (100, 300, 500, 700 m) in which they were seen. All surveys were conducted in accordance with a scientific research permit issued by the Alaska Department of Fish and Game.

Population estimates for total caribou were extrapolated from their respective counts and standard errors were calculated using formulas modified from Gasaway et al. (1986). Because surveys covered 50% of the study area, the "observable population" (i.e., the estimated number of caribou in the entire survey area) was estimated by doubling the number of caribou observed. In this report, we provide an 80% confidence interval (CI) for estimates; for example, an observable population estimate of 70 ± 30 caribou means that the 80% CI ranges from 40 to 100 caribou.

The percentage of ground surface covered by snow was documented in photographs and was estimated visually in the survey area as an index to survey conditions. The patchy background of snow and bare ground resulting from spring snow melt is the most important factor affecting sightability—defined as "the probability that an animal within the observer's field of search will be seen by that observer" (Caughley 1974: 923)—during the calving season (Lawhead and Cameron 1988). Caribou are more difficult to detect in patchy snow cover than in continuous snow cover or in absence of snow. One way to adjust counts made during poor viewing conditions is to estimate sightability using a double-survey technique and then to calculate a sightability correction factor (SCF) for post-survey adjustment of counts (Gasaway et al. 1986). In 1993, an SCF (1.88) for large caribou was calculated for conditions of patchy (20–70%) snow cover during calving surveys, using nearly simultaneous coverage by fixed-wing airplane and helicopter survey platforms (Lawhead et al. 1994). The timing of snow melt was very late in 2018 requiring the use of the SCF for the calving surveys.

TELEMETRY DATA

We analyzed telemetry data from 636 collar deployments on 490 caribou (Table 1). Telemetry data collected between 1990– October 2018 for the TH and 2001– October 2018 for the CAH was used for analysis. This included 185 satellite collar deployments on 165 TH animals, 260 GPS collar deployments on 188 TH animals, 24 satellite collar deployments on 24 CAH animals, and 167 GPS deployments on 113 CAH animals. A total of 79% of TH deployments and 97% of CAH deployments were on female caribou. Telemetry data were provided through a data sharing agreement with

Table 1. Number of TH and CAH radio-collar deployments and total number of collared animals that provided movement data for the Colville South caribou study.

Herd [a] / Collar Type	Years	Female		Male		Total Deployments
		Deployments	Individuals	Deployments	Individuals	
Teshekpuk Herd						
Satellite collars	1990–2018	98	87	87	78	185
GPS collars	2004–2018	254	182	6	6	260
Central Arctic Herd						
Satellite collars	2001–2004	10	10	2	2	12
Satellite collars	2012–2015	6	6	6	6	12
GPS collars	2003–2018	167	113	0	0	167

[a] Herd affiliation at time of capture.

ADFG, BLM, and North Slope Borough and additional GPS collars were funded by CPAI and deployed by ADFG.

We used fixed-kernel density estimation (KDE) to quantify the spatial distribution of CAH and TH caribou by season. Because most collared CAH caribou were females, we only conducted separate analyses by sex for the TH. Caribou in northern Alaska are sexually segregated during some seasons, especially calving, so our results during these time periods may underrepresent male CAH caribou.

To conduct KDE, we calculated the average latitude and longitude of each caribou for every two day period of the year (all years combined). We used the *ks* package for *R* (Duong 2017) and the plug-in method to calculate the bandwidth of the smoothing parameter create KDE utilization distributions of relative caribou density for each herd for each two day period. We then averaged the resulting utilization distributions together for each combination of herd, sex (TH only), and season to get the final seasonal kernels. This method allowed us to capture caribou movements during a season without biasing the results towards individual animals with many locations.

Monthly use of the Colville South survey area was evaluated based on KDE results. We calculated the proportion of each monthly utilization distribution from kernel density estimation within the survey areas for TH females, TH males, and CAH males and females combined, after first removing the portion of each seasonal utilization distribution contour that overlapped the ocean. To estimate the number of caribou expected in the Colville South survey area based on the KDE results, we multiplied the proportion of the utilization distribution in the survey area times the estimated herd size (56,000 for the TH and 28,000 for the CAH) assuming 75% of the TH was female (Parrett 2015a).

To visualize caribou movements based on GPS collars, we used dynamic Brownian Bridge Movement Models (dBBMM) models to create maps of caribou movements based on the locations of GPS-collared individuals (Kranstauber et al. 2012). Because very few GPS collars were deployed on males (Table 1), we only ran dBBMM models for female caribou. These dBBMM models, a modification of earlier Brownian bridge models (Horne et al. 2007), use an animal's speed of movement and trajectory calculated from intermittent GPS locations to create a probability map describing relative use of the area traversed. We computed the 95% isopleth of movements for each individual caribou outfitted with a GPS collar moving through the area and then overlaid the isopleth layers for each season and herd to calculate the proportion of collared caribou using each 100-m pixel. This visualization displayed the seasonal use of the area by caribou as a function of both caribou distribution and movements. The dBBMM models were computed using the *move* package in *R* (Kranstauber et al. 2017).

OTHER MAMMALS

The locations and numbers of large mammals other than caribou were recorded and mapped during aerial transect surveys.

RESULTS

WEATHER AND INSECT CONDITIONS

Spring 2018 was colder than average and snow melted later than usual (Figure 3). Snow depth at the Kuparuk airstrip remained above average until 8 June and was above the 95% confidence interval of annual snow depths in late May (Figure 3). Temperatures at the Deadhorse airport were almost entirely below average from mid-May through the end of June (Figure 3).

During the summer insect season (mid/late June to mid-August), variability in weather conditions typically results in fluctuating insect activity levels and corresponding changes in caribou distribution. Caribou move rapidly toward the coast in response to mosquito harassment and then move inland when mosquito activity abates, in response to cooler temperatures or higher wind speeds (Murphy and Lawhead 2000, Yokel et al. 2009). July was largely warmer than average with multiple days near the upper 95% confidence interval of daily average temperatures and many days with a high probability of mosquito and oestrid fly activity (Figures 3–4; Appendix A). August temperatures were largely cooler than average and September temperatures were close to average (Figure 3; Appendix A).

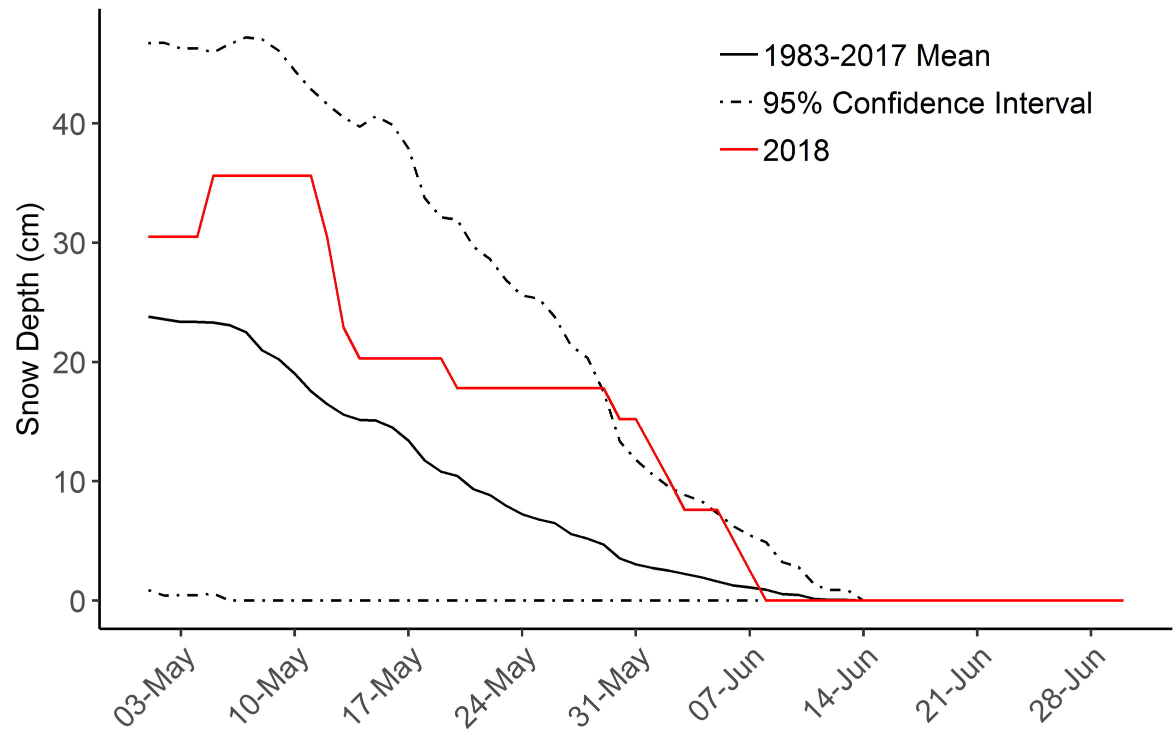
AERIAL SURVEYS

Five complete surveys were conducted in 2018. No caribou were observed during two of those surveys; 21 May and 31 July. During the calving survey on 8 June, we counted a total of 6 adult and 1 calf caribou. Doubling our 50% sample and applying the SCF produced estimates of 22.6 ± 13.6 large caribou and 3.8 ± 3.5 calves, for a total estimate of 26.3 ± 15.2 animals (Figure 5, Table 2). The estimated mean density of all caribou during the calving survey was 0.027 ± 0.014 caribou/km² (Table 2). During the late summer survey on 29 August we counted a total of 13 adult caribou. Doubling our 50% sample produced an estimate of 26 ± 15 total caribou (Figure 5, Table 2). The estimated mean caribou density during the late summer survey was 0.049 ± 0.028 caribou/km² (Table 2). During the fall survey on 24 September we counted a total of 23 adult caribou. Doubling our 50% sample produced an estimate of 46 ± 20 total caribou (Figure 5, Table 2). The estimated mean density of all caribou during the fall survey was 0.087 ± 0.038 caribou/km² (Table 2). Caribou were widely spread across the study area with no obvious areas of higher density (Figure 5).

TELEMETRY DATA

KERNEL DENSITY ESTIMATION

The KDE estimates for the CAH indicate that CAH caribou are located primarily near the Brooks Range and south of the survey area during winter (Figure 6). The survey area is on the periphery of the herd's typical range during much of the summer but is in the medium density portion of the herd range during late summer and close to medium density portions of the range during fall migration. The KDEs for the TH indicate higher use of the study area by the TH than the CAH during some seasons (Figures 6–8). The survey area is in the high density portion of the TH females herd's range during winter and in medium density portions of the herd's range during spring migration and fall migration (Figure 7). A higher proportion of TH males than TH females winter in the Brooks Range and the survey area is in the high density area for TH males during calving and fall migration and in the medium density area during spring migration, postcalving, and late summer (Figure 8).



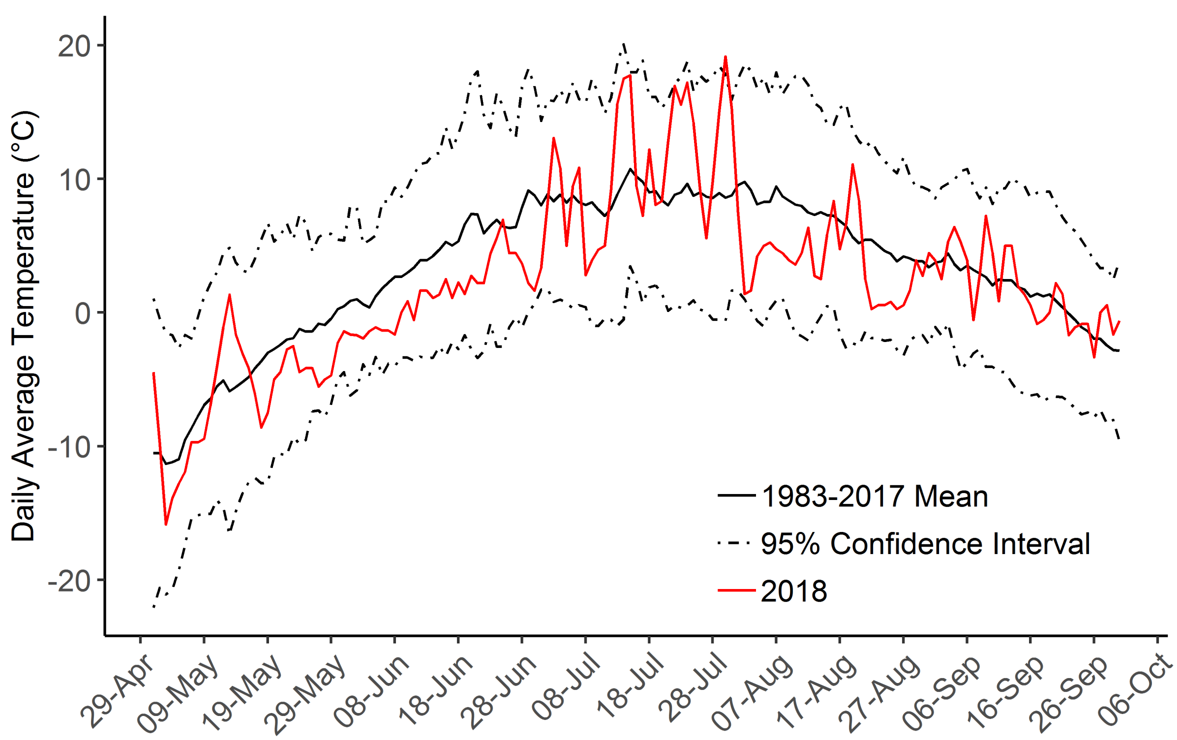


Figure 3. Snow depth at the Kuparuk airstrip during May–June 2018, compared with the long-term mean and 95% confidence interval and daily average air temperature at Kuparuk during May–September 2018 compared with the long-term mean and 95% confidence interval.

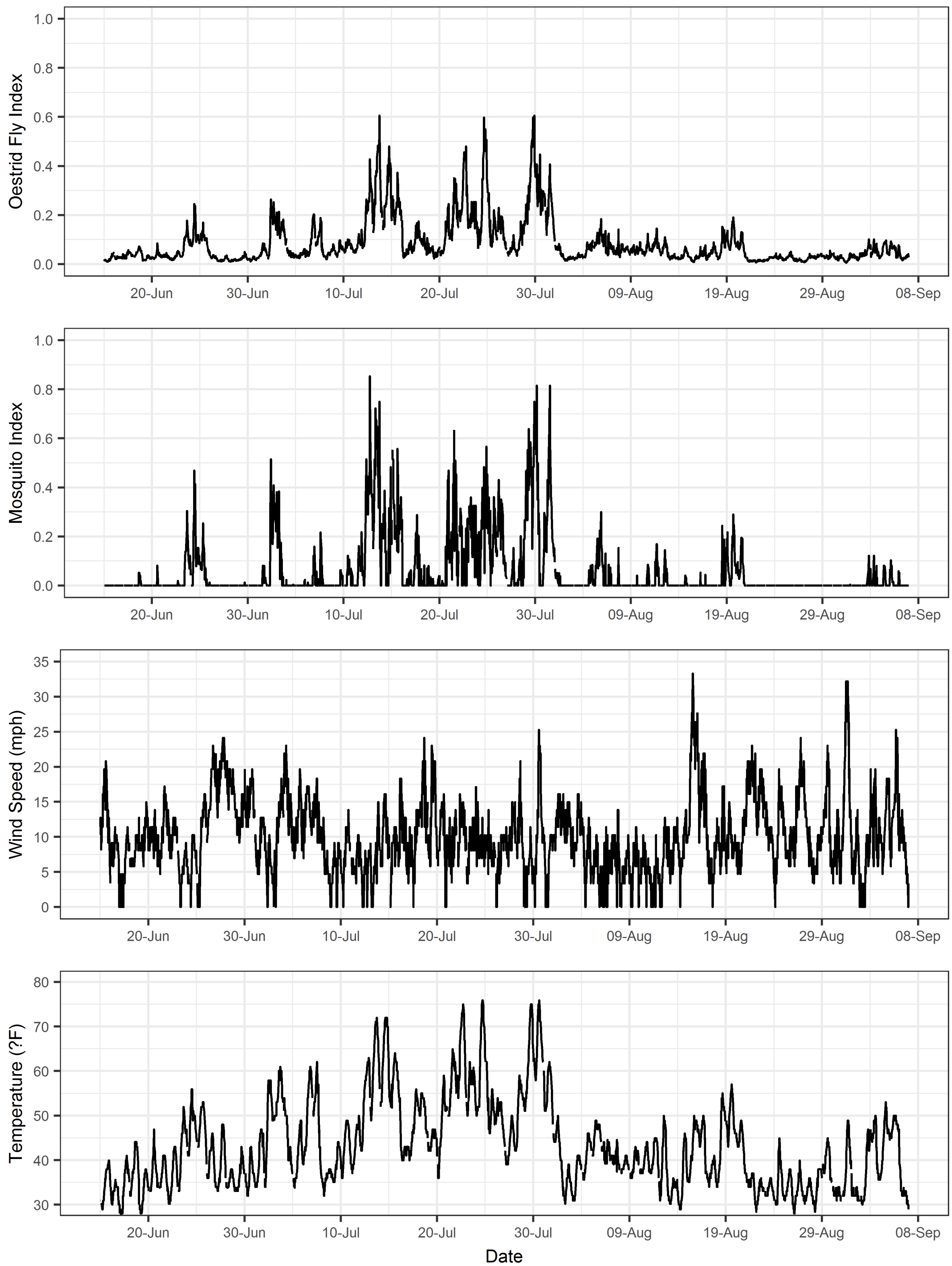


Figure 4. Hourly air temperature, wind speed, mosquito probability, and oestrid fly probability at Nuiqsut during 15 June–7 September 2018.

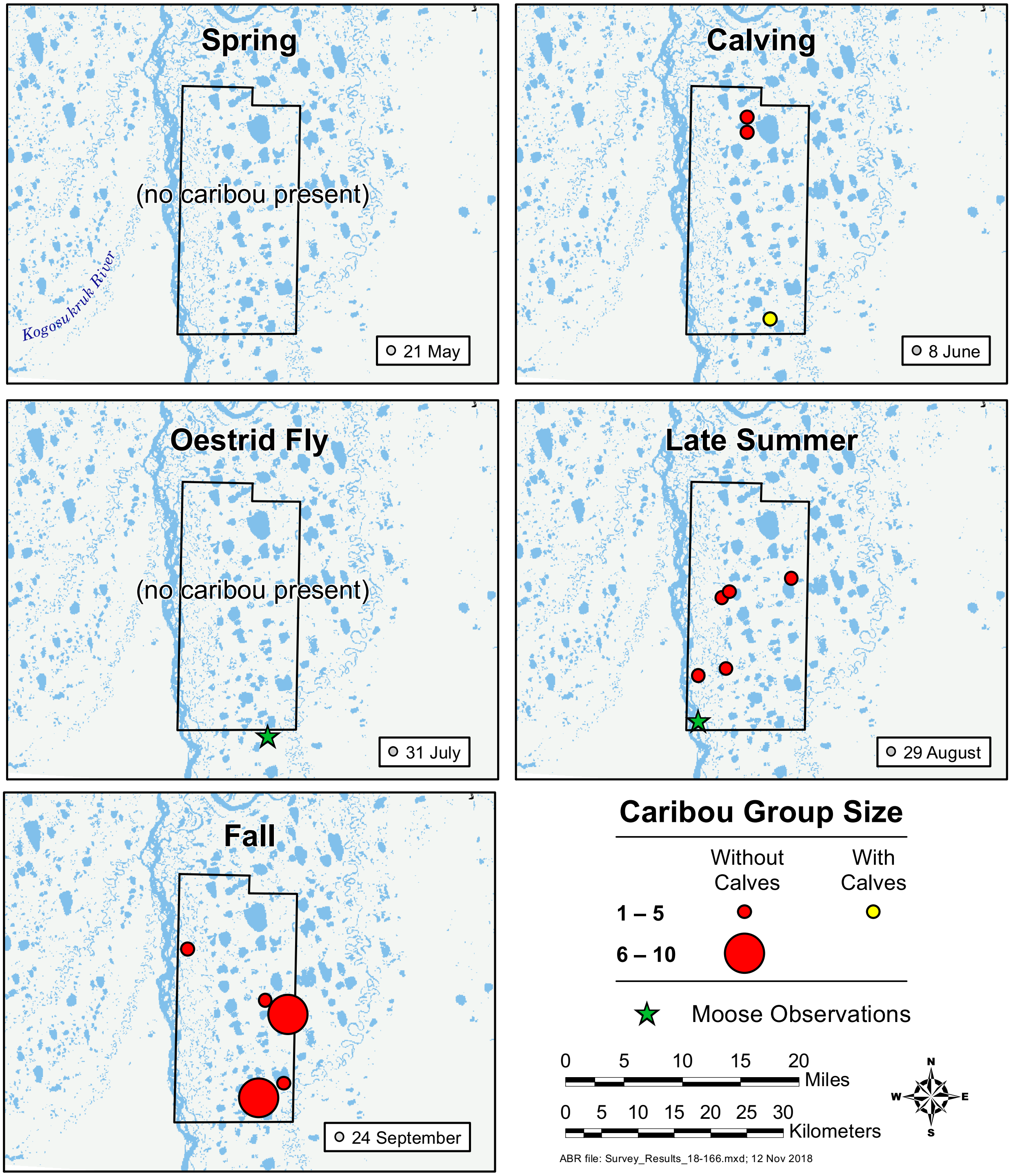


Figure 5. Distribution and number of caribou in the Colville South survey area May–September 2018.

Table 2. Number and density of caribou in the Colville South survey area ± 80% confidence interval, May–September 2018.

Date	Area Surveyed [a] (km²)	Adults Counted	Calves Counted	Total Counted	Estimated Total	Density (caribou/km²)	Number of Groups
May 21	264	0	0	0	0	0	0
June 8[b]	264	6	1	7	26 ± 15	0.027 ± 0.014	3
July 31	264	0	0	0	0	0	0
Aug. 29	264	13	0	13	26 ± 15	0.049 ± 0.028	5
Sept. 24	264	23	0	23	46 ± 20	0.087 ± 0.038	5

[a] 50% coverage of survey area; total area was 527 km².
[b] Applied sightability correction factor of 1.88 (Lawhead et al. 1994).

The predicted number of caribou in the survey area based on the proportion of utilization distribution surface from the KDE within the survey area ranged from 200 to over 500 animals, with the highest numbers occurring during October and the lowest numbers occurring in July. The predicted numbers were substantially higher than what we observed during aerial surveys (Figure 9; Table 2).

DYNAMIC BROWNIAN BRIDGE MOVEMENT MODELS

The dBBMM models show movements of female collared caribou during different seasons. Unlike KDE, they do not attempt to account for uncollared caribou. With high sample sizes, however, they may approximate the herd distribution. Similar to KDE results, few collared CAH caribou were in the Kuparuk area during winter (Figure 10). The few collared caribou in the area were likely animals that remained in the area during early winter before migrating south later in the year. Few collared animals were in the area during spring migration, calving, postcalving, or the mosquito season. Some CAH caribou moved through the survey area during oestrid fly season, late summer, and fall migration (Figure 10). The dBBMM results for the TH indicate that some collared TH females moved through the Colville South area during winter, spring migration and calving, but TH females were largely absent from the area during postcalving, mosquito harassment, oestrid fly seasons, and late summer (Figure 11). Some collared TH females did move through the area again during fall migration.

OTHER MAMMALS

One bull moose (*Alces alces*) was observed on 31 July just outside of the survey area to the south. One moose of unknown sex was observed on 29 August in the southwestern corner of the survey area along the Colville River (Figure 5).

DISCUSSION

Densities of caribou were low in the Colville South survey area during five aerial surveys conducted during 2018. Six adults and a single calf were observed during the calving survey, although sightability was poor due to patchy snow cover. In years of late snow melt, calving tends to occur farther inland (Lawhead and Prichard 2001, 2002; Carroll et al. 2005). Snowmelt occurred very late in 2018, and the CAH calved farther south than usual and well outside the survey area (E. Lenart ADFG, pers. comm., unpublished data).

The CAH calving distribution in the area northeast of the survey area has been surveyed during most years 1993–2017 (Prichard et al. 2018b), and low calving densities in the Colville South survey area are consistent with distribution patterns described in these previous surveys. The densities of calving caribou generally declined near the Itkillik River and the highest density calving in the region occurred on the higher elevation areas near the upper Miluveach, Kachemach, and Sakonowyak Rivers (Prichard et al. 2018b). This western edge of the calving distribution is seen clearly in the dBBMM results for the CAH (Figure 10).

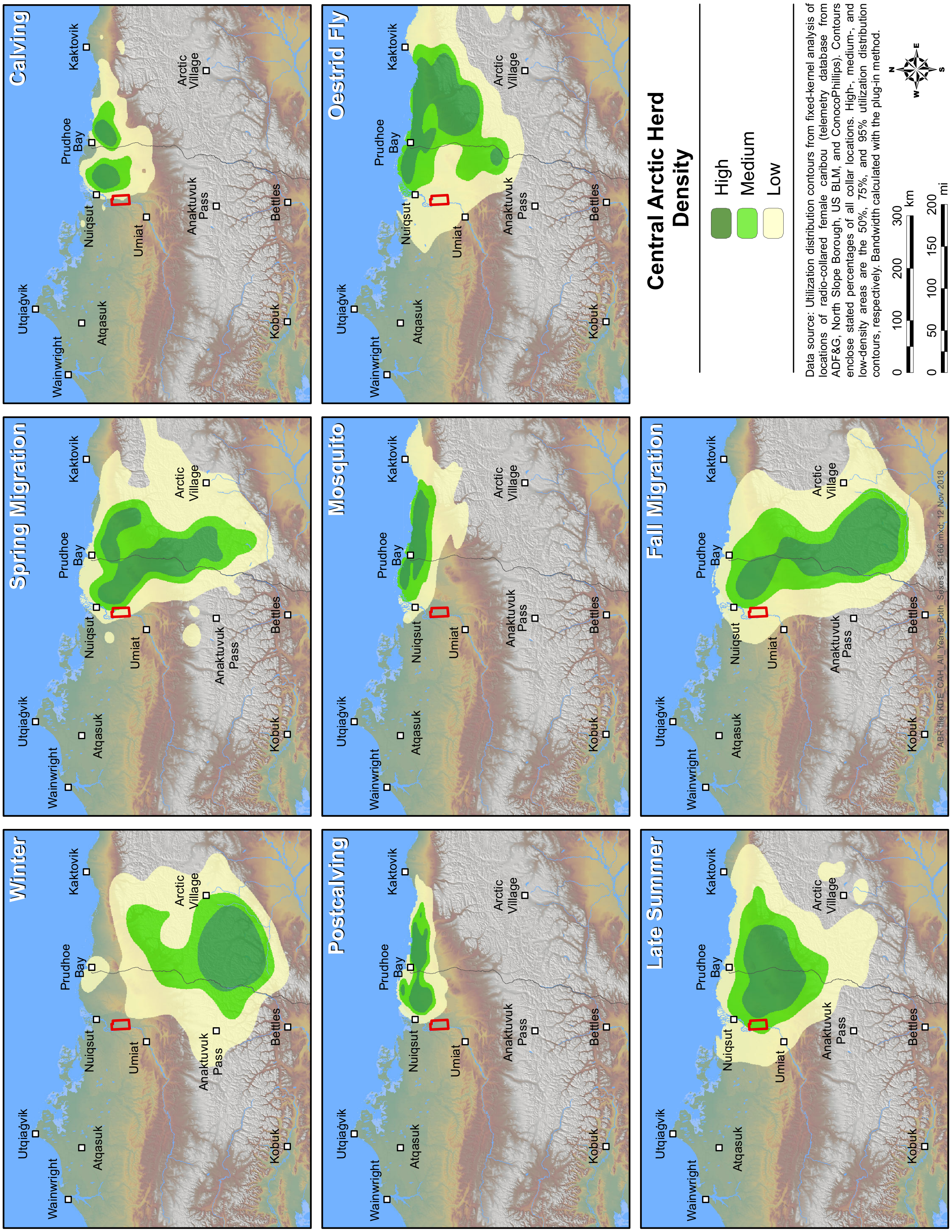


Figure 6. Kernel Density Estimates of seasonal distribution of female caribou from the Central Arctic Herd.

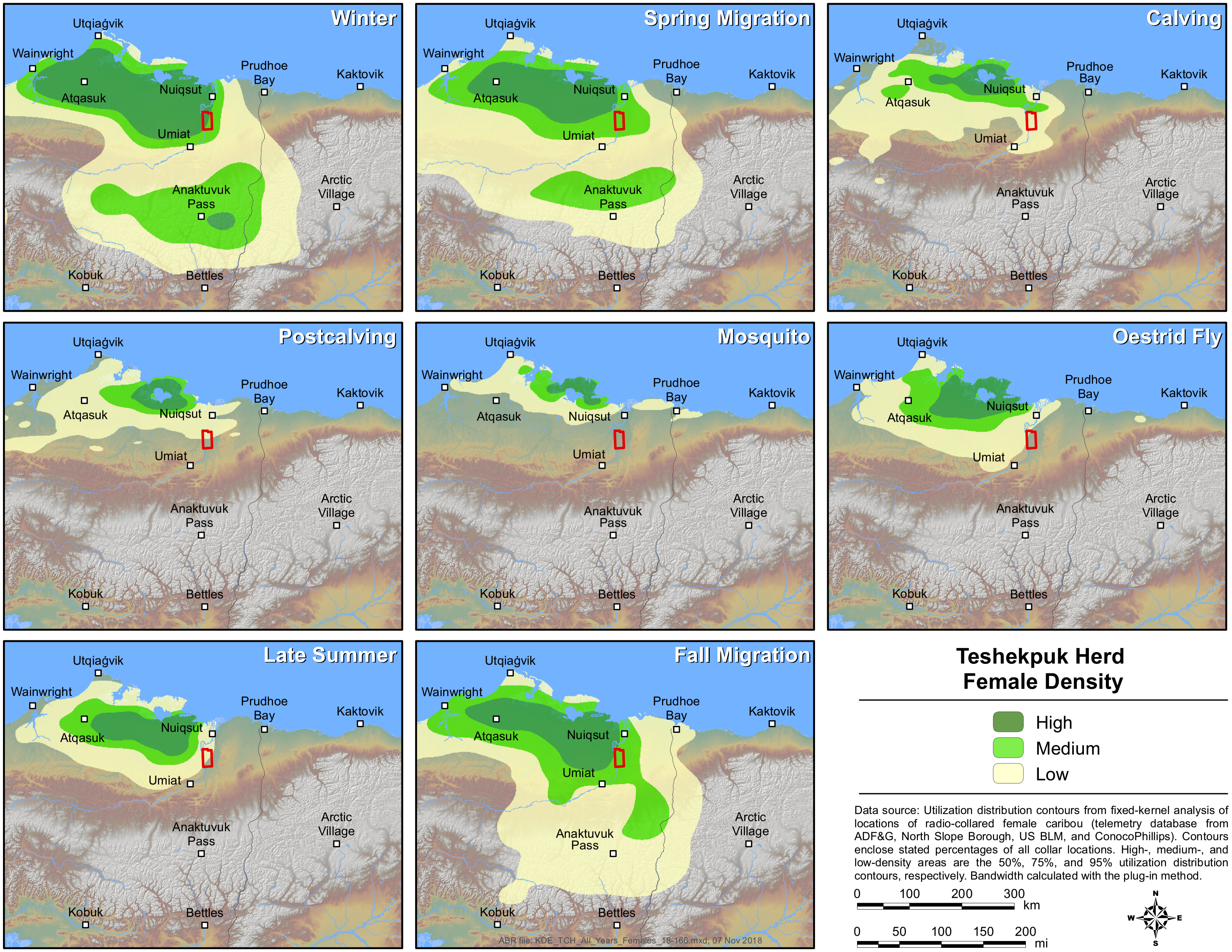


Figure 7. Kernel Density Estimates of seasonal distribution of female caribou from the Teshekpuk Herd.

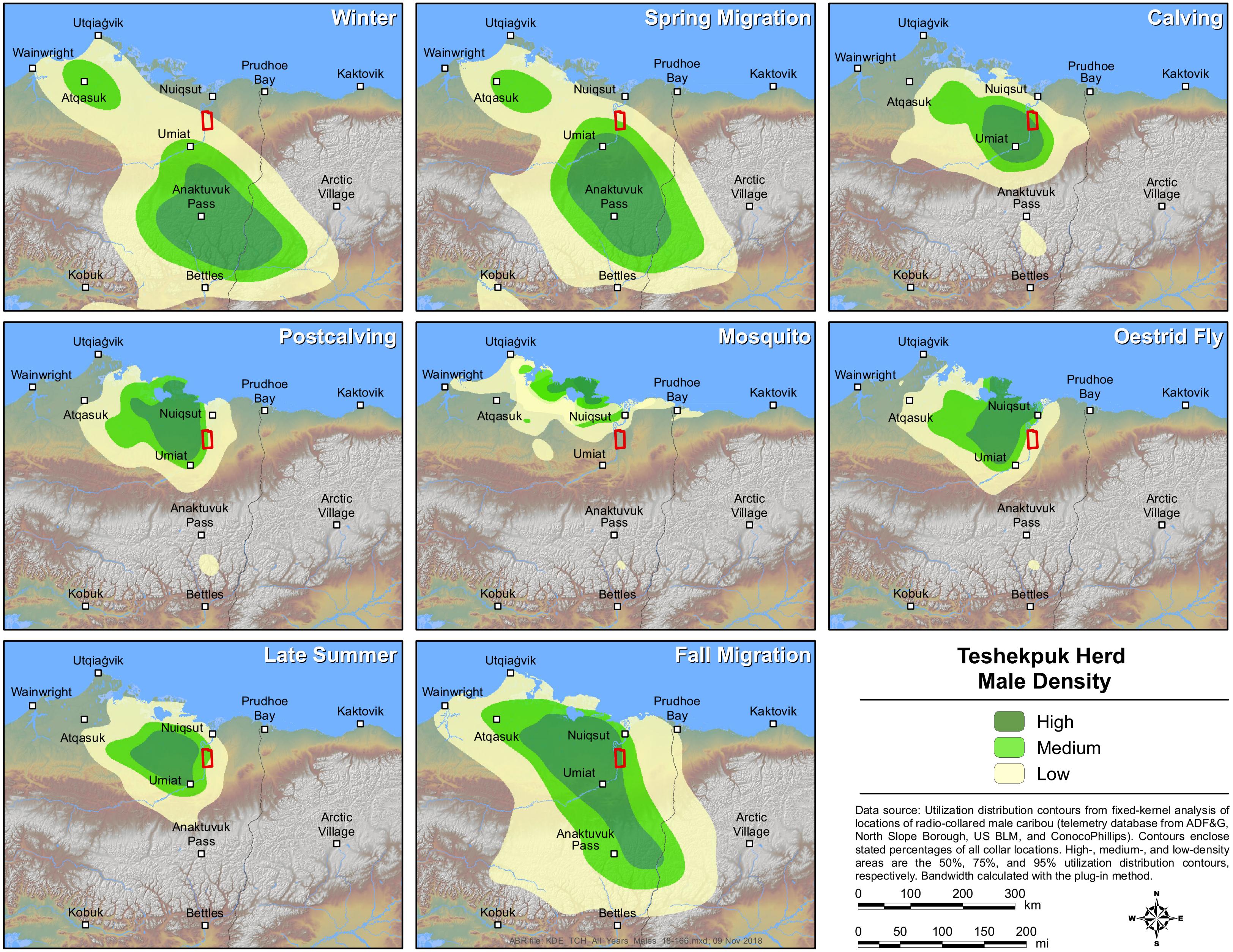


Figure 8. Kernel Density Estimates of seasonal distribution of male caribou from the Teshekpuk Herd.

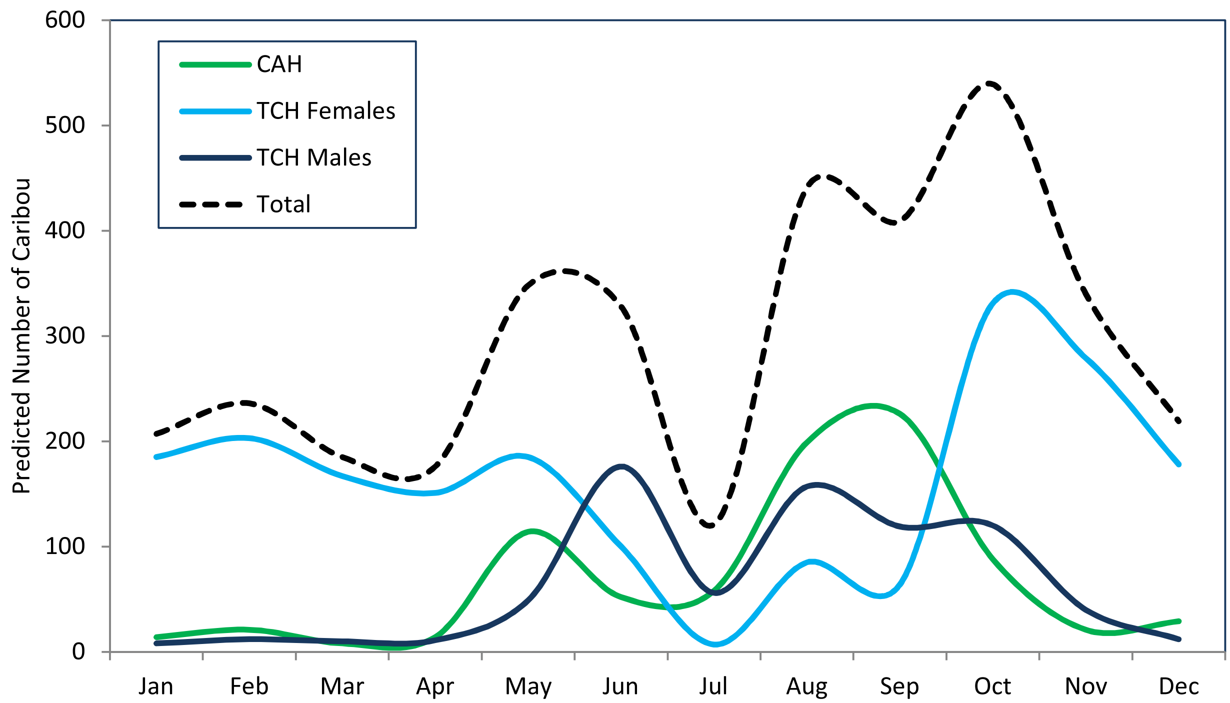


Figure 9. Predicted number of caribou in the Colville South survey area by month based on Kernel Density Estimation.

Following calving, the CAH generally move north prior to the emergence of mosquitoes which typically occurs in late June. Once mosquito harassment begins, CAH caribou move to the coast where mosquito harassment is typically less severe due to higher winds and lower temperatures. Caribou then drift inland when cooler temperatures or high winds cause harassment to abate (Murphy and Lawhead 2000, Parrett 2007, Yokel et al. 2009, Wilson et al. 2012). In mid-July, oestrid flies are the primary driver of caribou behavior and CAH caribou disperse into smaller groups and move inland, often using ridges, gravel bars, roads, and pads as areas for oestrid fly relief (Pollard et al. 1996, Murphy and Lawhead 2000). The CAH migrates south to winter in the Brooks Range, usually east of the Dalton Highway (Arthur and Del Vecchio 2009, Nicholson et al. 2016).

The Colville South survey area was largely outside of the typical distribution of the CAH during winter through mosquito season. Some CAH caribou used the area from oestrid fly season through fall migration as the CAH disperse widely across the central Coastal Plain and several notable incursions of the CAH to the west side of the Colville River have been recorded sporadically over the years (Prichard et al. 2018a).

The TH differs from most arctic caribou herds in that most animals remain on the Arctic Coastal Plain during winter, although a portion of the herd, including most males, winter in the Brooks Range predominantly west of the Dalton Highway (Person et al. 2007, Parrett 2015a, Prichard et al. 2018a). The highest density of TH calving occurs near Teshekpuk Lake and the area north of the lake is used for the predominant mosquito-relief area (Person et al. 2007, Yokel et al. 2009, Wilson et al. 2012, Prichard et al. 2018a). Similar to the CAH, the TH disperses into smaller groups and spreads inland from the oestrid fly season to fall migration. Most TH animals remain west of the Colville River during the summer. Hence, the major use of the Colville South area by the TH occurs during migratory movements by the portion of the herd that winters in the central Brooks Range.

Our predicted numbers of caribou in the survey area based on monthly KDE analyses were much higher than what we observed during aerial

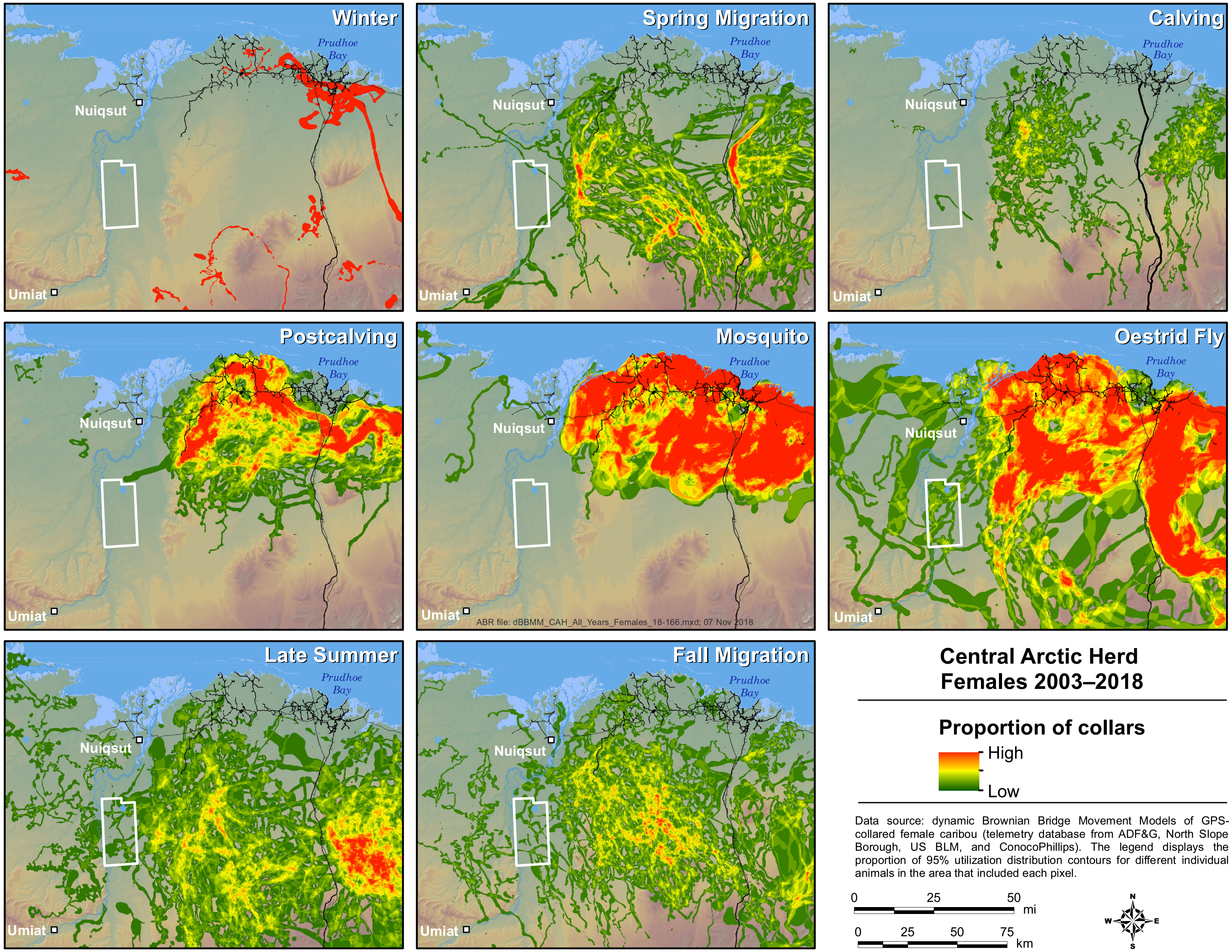


Figure 10. Seasonal movements of female caribou of the Central Arctic Herd based on dynamic Brownian Bridge Movement Models.

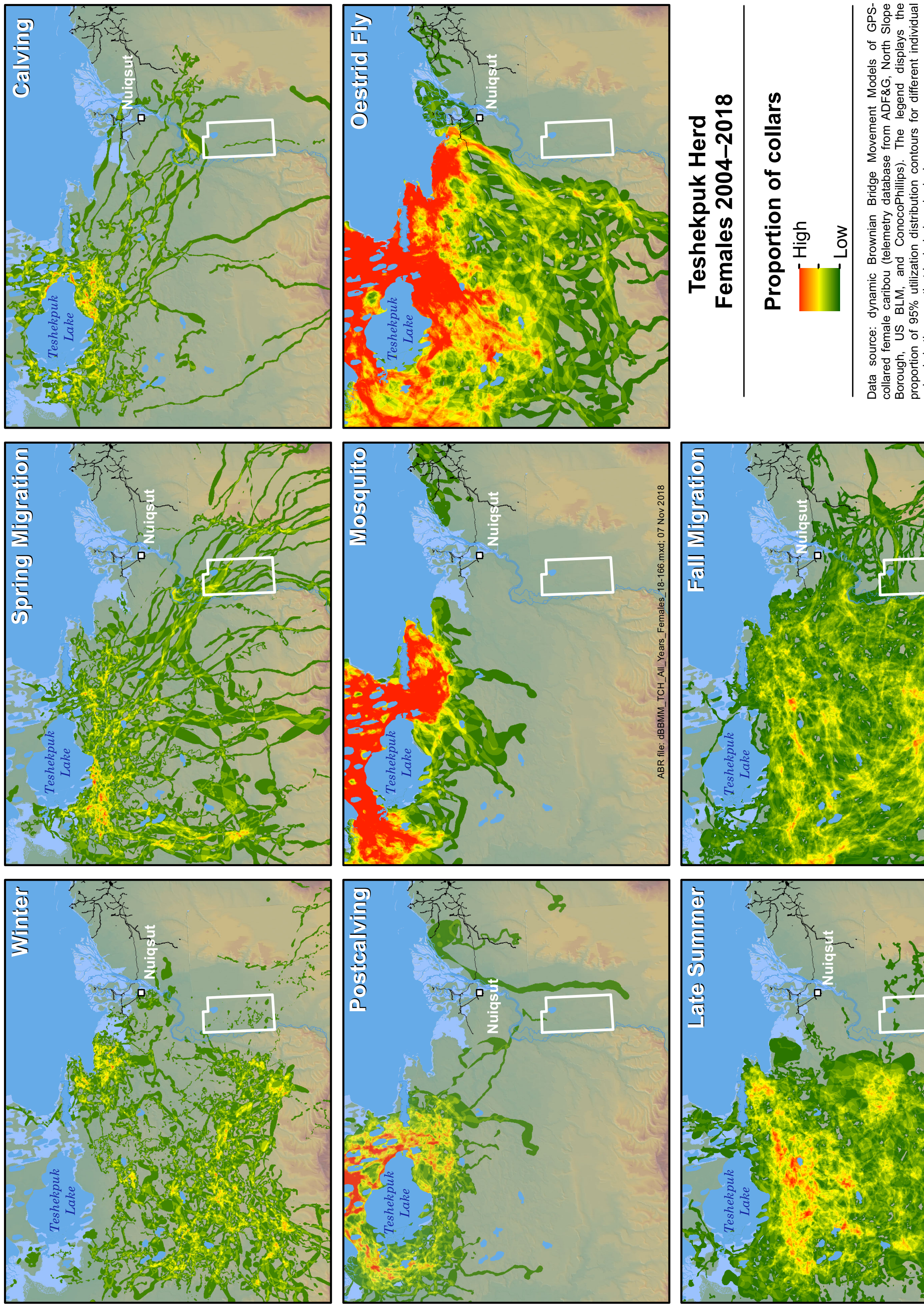


Figure 11. Seasonal movements of female caribou of the Teshekpuk Herd based on dynamic Brownian Bridge Movement Models.

surveys. This is likely a result of overestimates of the number of TH animals in the area based on KDE analyses. KDE creates a smoothed surface from caribou locations; however, it does not take into account abrupt changes in distribution that could occur near prominent landscape features such as rivers. If the TH generally remains on the west side of the Colville River, the KDE may overestimate densities along the east side of the river. Similarly, the CAH appears to use the higher elevation areas east of the survey area preferentially. KDE smoothing near this edge of the range may have overestimated CAH numbers in the Colville South area. Another factor that could have contributed to the disparity between estimated and observed densities is that the distribution of caribou in 2018 may have differed from the typical distribution for the CAH and TH over all years. Spring was very late in 2018 resulting in an unusual spring distribution of caribou.

OTHER MAMMALS

Two moose were observed near the survey area on aerial surveys conducted in July and August, 2018. Both the Colville and Itkillik Rivers are used for moose hunting by residents of Nuiqsut (SRB&A 2010). Moose on the North Slope are primarily found in riparian areas with tall shrubs, especially tall willows (*Salix* spp.). Our aerial survey transects were offset from the tall willow habitat along the Colville River in order to minimize disturbance of subsistence hunters. This made it more difficult to observe moose in the area, however, the fact that we observed two moose during five surveys suggests that this area is regularly used by moose.

The survey area is on the northern extent of tall willow and moose range although moose have occasionally been observed farther north during ABR surveys (Lawhead et al. 2014). Climate warming has resulted in a northward range expansion for both tall shrubs, and associated species like moose and snowshoe hares (*Lepus americanus;* Tape et al. 2016). Tape et al. (2016) estimated that the height of tall shrubs along the Colville River increased 63% from 1901 to 2009.

Other large mammals occur at low densities across the Coastal Plain and are likely to use the area regularly. These species include brown bears (*Ursus arctos*), wolves (*Canis lupus*), wolverines (*Gulo gulo),* red fox (*Vulpes vulpes*), and arctic fox (*Alopex lagopus*). A small group of muskox (*Ovibos moschatus*) has typically been located east of Nuiqsut in recent years (Prichard et al. 2018b) and may occasionally use the Colville South area.

CONCLUSIONS

Analysis of existing telemetry data indicates that the Colville South survey area is between the ranges of the TH and CAH and gets little use by either herd as reflected by the low density of caribou observed in the area during aerial surveys in most seasons. The area is expected to have low densities of caribou during calving and caribou are least likely to be in the area during postcalving and the mosquito seasons. The area is used during spring and fall migration by the portion of the TH that migrates to the central Brooks Range. The area is on the northern extent of moose range in north-central Alaska and the presence of tall willow and moose numbers may continue to increase in the future due to climate warming.

LITERATURE CITED

Arthur, S. M., and P. A. Del Vecchio. 2009. Effects of oil field development on calf production and survival in the Central Arctic Herd. Final research technical report, Federal Aid in Wildlife Restoration Project 3.46. Alaska Department of Fish and Game, Juneau. 36 pp.

Carroll, G. 2007. Teshekpuk Herd. Pages 262–283 *in* P. Harper, editor. Caribou management report of survey and inventory activities, 1 July 2004–30 June 2006. Alaska Department of Fish and Game, Juneau.

Carroll, G. M., L. S. Parrett, C. George, and D. A. Yokel. 2005. Calving distribution of the Teshekpuk caribou herd, 1994–2003. Rangifer Special Issue 16: 27–35.

Caughley, G. C. 1974. Bias in aerial survey. Journal of Wildlife Management 38: 921–933.

Dau, J. R. 1986. Distribution and behavior of barren-ground caribou in relation to weather and parasitic insects. M.S. thesis, University of Alaska, Fairbanks. 149 pp.

Duong, T. 2017. ks: Kernel Smoothing. R package version 1.10.7. Available online: https://CRAN.R-project.org/package=ks (accessed 16 February 2018).

Fancy, S. G. 1983. Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok River floodplain, Alaska. Arctic 36: 193–197.

Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska, No. 22, Fairbanks. 108 pp.

Horne, J. S., E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology 88: 2354–2363.

Johnstone, J., D. E. Russell, and D. B. Griffith. 2002. Variations in plant forage quality in the range of the Porcupine caribou herd. Rangifer 22: 83–91.

Klimstra, R. 2018. Summary of Teshekpuk caribou herd photocensus conducted July 14, 2017. State of Alaska memorandum, Department of Fish and Game, Division of Wildlife Conservation (Northwest), Fairbanks. 6 pp.

Kranstauber, B., R. Kays, S. D. LaPoint, M Wikelski, and K. Safi. 2012. A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous animal movement. Journal of Animal Ecology 81: 738–746.

Kranstauber, B., M. Smolla, and A. K. Scharf. 2017. Move: visualizing and analyzing animal track data. R package version 3.0.1. Available online: https://CRAN.R-project.org/package=move.L awhead, B. E., and R. D. Cameron. 1988. Caribou distribution on the calving grounds of the Central Arctic Herd, 1987. Report for ARCO Alaska, Inc., and the Kuparuk River Unit, Anchorage, by Alaska Biological Research, Inc., and Alaska Department of Fish and Game, Fairbanks. 59 pp.

Kuropat, P. J. 1984. Foraging behavior of caribou on a calving ground in northwestern Alaska. M.S. thesis, University of Alaska, Fairbanks. 95 pp.

Lawhead, B. E., and A. K. Prichard. 2001. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 2000. Report for Phillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 39 pp.

Lawhead, B. E., and A. K. Prichard. 2002. Surveys of caribou and muskoxen in the Kuparuk–Colville region, Alaska, 2001. Report for Phillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 37 pp.

Lawhead, B. E., C. B. Johnson, and L. C. Byrne. 1994. Caribou surveys in the Kuparuk oilfield during the 1993 calving and insect seasons. Report for ARCO Alaska, Inc., and the Kuparuk River Unit, Anchorage, by Alaska Biological Research, Inc., Fairbanks. 38 pp.

Lawhead, B. E., A. K. Prichard, and M. J. Macander. 2010. Caribou monitoring study for the Alpine Satellite Development Program, 2009. Fifth annual report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 101 pp.

Lawhead, B. E., A. K. Prichard, and J. H. Welch. 2014. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2013. Report for ConocoPhillips Alaska, Inc., and the Greater Kuparuk Area, Anchorage, by ABR, Inc., Fairbanks. 37 pp.

Lenart, E. A. 2015. Units 26B and 26C — Caribou. Chapter 18, Pages 18-1 through 18-38 *in* P. Harper and L. A. McCarthy, editors. Caribou management report of survey and inventory activities, 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau.

Lenart, E. A. 2017. 2016 Central Arctic caribou photocensus results. State of Alaska memorandum to D. I. Parker McNeill, Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks. 5 pp.

Lenart, E. A. 2018. 2017 Central Arctic caribou digital camera system photocensus results. Memorandum dated February 9, 2018. Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks.

Mörschel, F. M. 1999. Use of climatic data to model the presence of oestrid flies in caribou herds. Journal of Wildlife Management 63: 588–593.

Murphy, S. M., and B. E. Lawhead. 2000. Caribou. Chapter 4, pages 59–84 *in* J. Truett and S. R. Johnson, editors. The Natural History of an Arctic Oil Field: Development and the Biota. Academic Press, San Diego, CA.

NSSI. 2013. North Slope Science Initiative land-cover mapping summary report. Report for NSSI by Ducks Unlimited, Inc., Rancho Cordova, CA. 51 pp. + maps.

Nicholson, K. L., S. M. Arthur, J. S. Horne, E. O. Garton, and P. A. Del Vecchio. 2016. Modeling caribou movements: seasonal ranges and migration routes of the Central Arctic Herd. PLoS ONE 11(4): e0150333. doi:10.1371/journal.pone.0150333.

Parrett, L. S. 2007. Summer ecology of the Teshekpuk caribou herd. M.S. thesis, University of Alaska, Fairbanks. 149 pp.

Parrett, L. S. 2009. Unit 26A, Teshekpuk caribou herd. Pages 271–298 in P. Harper, editor. Caribou management report of survey and inventory activities, 1 July 2006–30 June 2008. Federal Aid in Wildlife Restoration Project 3.0, Alaska Department of Fish and Game, Juneau.

Parrett, L. S. 2015a. Unit 26A, Teshekpuk caribou herd. Chapter 17, pages 17-1 through 17-28 *in* P. Harper and L. A. McCarthy, editors. Caribou management report of survey and inventory activities, 1 July 2012–30 June 2014. Alaska Department of Fish and Game, Species Management Report ADF&G/DWC/SMR-2015-4, Juneau.

Parrett, L. S. 2015b. Summary of Teshekpuk Caribou Herd photocensus conducted July 6, 2015. Memorandum to Peter L. Bente, Region V Management Coordinator. Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks. 6 pp.

Person, B. T., A. K. Prichard, G. M. Carroll, D. A. Yokel, R. S. Suydam, and J. C. George. 2007. Distribution and movements of the Teshekpuk Caribou Herd, 1990–2005: prior to oil and gas development. Arctic 60: 238–250.

Pollard, R. H., W. B. Ballard, M. A. Cronin, and L. E. Noel. 1996. Parasitic insect abundance and microclimate of gravel pads and tundra within the Prudhoe Bay oil field, Alaska, in relation to use by caribou, Rangifer tarandus granti. Canadian Field-Naturalist 110: 649–658.

Prichard, A. K., J. H. Welch, M. J. Macander, and B. E. Lawhead. 2018a. Caribou monitoring study for the Alpine Satellite Development Program, 2017. Thirteenth annual report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 63 pp + Appendices.

Prichard, A. K., J. H. Welch, and B. E. Lawhead. 2018b. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2017. Report for ConocoPhillips Alaska, Inc., and the Greater Kuparuk Area, Anchorage, by ABR, Inc., Fairbanks. 52 pp.

Russell, D. E., A. M. Martell, and W. A. C. Nixon. 1993. Range ecology of the Porcupine caribou herd in Canada. Rangifer, Special Issue No. 8. 167 pp.

Stephen R. Braund and Associates (SRB&A). 2010. Subsistence mapping of Nuiqsut, Kaktovik and, Barrow. Report for US Department of the Interior, Minerals Management Service. MMS OCS study number 2009-003. 349 pp + appendices

Tape K.D., D.D. Gustine, R.W. Ruess, L.G. Adams, J.A. Clark. 2016. Range expansion of moose in arctic Alaska linked to warming and increased shrub habitat. PLoS ONE 11(4): e0152636. doi:10.1371/journal.pone.0152636

Walker, D. A., K. R. Everett, P. J. Webber, and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay region, Alaska. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory Report 80-14, Hanover, New Hampshire.

White, R. G., B. R. Thomson, T. Skogland, S. J. Person, D. E. Russell, D. F. Holleman, and J. R. Luick. 1975. Ecology of caribou at Prudhoe Bay, Alaska. Pages 151–201 *in* J. Brown, editor. Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska. Biological Papers of the University of Alaska, Special Report No. 2.

Wilson, H. E., D. D. Gustine, T. S. Golden, L. G. Adams, L. S. Parrett, E. A. Lenart, and P. S. Barboza. 2018. NDVI exhibits mixed success in predicting spatiotemporalvariation in caribou summer forage quality and quantity. Ecosphere 9: 1:19. DOI: 10.1002/ecs2.2461.

Wilson, R. R., A. K. Prichard, L. S. Parrett, B. T. Person, G. M. Carroll, M. A. Smith, C. L. Rea, and D. A. Yokel. 2012. Summer resource selection and identification of important habitat prior to industrial development for the Teshekpuk caribou herd in northern Alaska. PLoS One 7(11): e48697.doi:10.1371/journal.pone.0048697.

Yokel, D. A., A. K. Prichard, G. Carroll, L. Parrett, B. Person, and C. Rea. 2009. Teshekpuk Caribou Herd movement through narrow corridors around Teshekpuk Lake, Alaska. Alaska Park Science 8(2): 64–67.

Appendix A. Sum of thawing degree-days (ºC above freezing) at the Kuparuk airstrip during five periods of the insect season, mid-June through August 1983–2018.

Year	June 16–30	July 1–15	July 16–31	August 1–15	August 16–31	Total
1983 [a]	66.2	74.8	103.9	100.1	50.7	395.7
1984	75.3	122.8	146.4	99.6	59.8	503.9
1985	92.9	84.8	99.5	100.0	70.8	447.8
1986	100.9	112.3	124.7	109.6	54.4	501.8
1987	61.3	112.2	127.9	93.1	109.3	503.7
1988	78.0	108.5	143.0	137.7	52.3	519.3
1989	109.5	214.7	168.1	215.8	133.9	842.0
1990	132.2	145.0	150.0	82.5	72.8	582.5
1991	127.6	73.3	115.0	70.7	54.5	441.1
1992	85.2	113.9	166.1	104.2	96.2	565.5
1993	94.4	175.9	149.8	96.1	78.0	594.2
1994	51.6	149.7	175.8	222.2	92.4	691.6
1995	87.5	162.9	106.9	83.4	83.6	524.1
1996	121.1	138.9	168.1	95.8	34.7	558.6
1997	109.7	101.7	177.8	194.2	97.8	681.1
1998	135.0	158.9	184.4	174.4	123.1	775.8
1999	67.8	173.3	81.1	177.6	69.8	569.5
2000	169.8	113.4	127.2	118.6	53.6	582.5
2001	72.2	79.8	183.9	131.7	32.5	500.0
2002	70.2	92.3	134.5	106.2	90.7	493.8
2003	77.4	140.0	144.7	91.9	54.9	508.8
2004	185.7	148.0	151.5	153.4	123.2	761.7
2005	78.3	67.5	79.5	176.8	44.5	446.5
2006	153.2	82.3	186.2	109.6	36.9	568.1
2007	81.8	115.2	138.9	134.4	103.5	573.7
2008	138.9	172.3	132.5	86.0	73.9	603.5
2009	44.5	142.7	126.5	133.7	95.0	542.3
2010	51.1	126.7	168.8	149.2	115.2	610.9
2011 [b]	103.0	122.4	171.6	142.8	83.7	623.3
2012 [b]	137.3	140.2	194.1	142.9	166.3	780.7
2013	131.7	112.8	185.5	185.4	52.9	668.3
2014	82.0	127.2	102.3	67.9	112.0	491.2
2015	197.2	117.9	95.7	108.8	51.4	571.0
2016	131.2	174.7	130.8	98.1	132.7	667.4
2017	121.3	173.4	174.5	150.5	74.7	694.3
2018	47.7	137.0	195.9	63.6	57.4	501.6
Mean	101.9	128.0	144.8	125.2	80.2	580.2

[a] Some missing values estimated by interpolation.
[b] Estimated by averaging data from Nuiqsut and Deadhorse while Kuparuk airstrip was closed for paving (Lawhead et al. 2013).