CARIBOU USE OF THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2020

Alexander K. Prichard
Joseph H. Welch

Prepared for
ConocoPhillips Alaska, Inc.
Greater Kuparuk Area
Anchorage, Alaska

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

CARIBOU USE OF THE GREATER KUPARUK AREA, NORTHERN ALASKA, 2020

Prepared for:

ConocoPhillips Alaska, Inc.
Greater Kuparuk Area
P.O. Box 100360
Anchorage, AK 99510

Prepared by:

Alexander K. Prichard
Joseph H. Welch

ABR, Inc.—Environmental Research & Services
P.O. Box 80410
Fairbanks, AK 99708

June 2021

EXECUTIVE SUMMARY

- This study investigated the distribution and movements of Central Arctic Herd (CAH) caribou in 2019–2020 between the Colville and Kuparuk rivers in northern Alaska.
- Telemetry data from 1 November 2019 to 31 October 2020 were used to examine movements by individual collared caribou in the vicinity of the Kuparuk oilfields and Alpine pipelines between the Colville River and Kuparuk CPF-2.
- Temperatures during the spring of 2020 were near average and snow melted slightly earlier than average. July temperatures were cooler than average and mosquito and oestrid fly harassment was predicted to be very low during that month. August and September temperatures were near average.
- The mean proportion of GPS-collared CAH caribou crossing the Alpine pipelines by season during 2003–2020 ranged from 0.004 during winter to 0.245 during the mosquito season. Eight different collared CAH caribou crossed the Alpine pipelines 48 times between 1 December 2019 and 30 November 2020. One TCH caribou crossed the Alpine pipeline in October 2020.
- Because few ABR biologists were in the area during 2020, few observations of other large mammals were recorded. One sow grizzly bear with 2 cubs was observed on the Colville Delta and 4 observations of groups of muskoxen were recorded along the Colville River. The maximum count of muskoxen in the area was 33 adults and 11 calves recorded on 15 June.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc. (CPAI) and the Greater Kuparuk Area Unit owners, and was administered by Christina Pohl, Environmental Studies Coordinator for CPAI with support from Robyn McGhee of CPAI and Jasmine Woodland from Weston Solutions Inc., for whose support we are grateful. Beth Lenart and Lincoln Parrett of the Alaska Department of Fish and Game, Division of Wildlife Conservation, generously shared unpublished information. Support during data analysis and report production was provided by ABR employees Pam Odom, Chris Swingley, Matt Macander, and Dorte Dissing. The report was improved through review by Adrian Gall of ABR and Christina Pohl and Wendy Mahan of CPAI.

INTRODUCTION

Four herds of barren-ground caribou (*Rangifer tarandus granti*) inhabit Arctic Alaska north of the Brooks Range. The herds differ in their use of calving, insect-relief, and winter ranges (Caikoski 2015, Dau 2015, Lenart 2015a, Parrett 2015a, Prichard et al. 2020b). The Central Arctic Herd (CAH) is the primary herd using the oilfield region on the central Arctic Coastal Plain, whereas the ranges of the neighboring Teshekpuk Caribou Herd (TCH) and Porcupine Caribou Herd (PCH) are located west and east of the oilfields, respectively. The Western Arctic Herd (WAH) is the westernmost herd in northern Alaska. The Kuparuk and Alpine oilfields are on the periphery of the TCH range and TCH caribou regularly move east of the Colville River, especially during fall. The annual range of the PCH and WAH do not currently include the North Slope oilfields.

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 northern foothills in recent years (Arthur and Del Vecchio 2009; Lenart 2015a, Nicholson et al. 2016). Calving occurs both between the Colville and Kuparuk Rivers in the area of the Kuparuk and Milne Point oilfields and east of the Sagavanirktok River in an area with limited oil development (Murphy and Lawhead 2000, Arthur and Del Vecchio 2009).

The CAH was first identified as a separate herd in the 1970s. From the early 1970s to 2002, the CAH grew at an overall rate of 7% per year (Lenart 2015a). The herd grew rapidly from ~5,000 animals in the mid-1970s to the early 1990s, reaching a count of 23,444 caribou in July 1992 before declining 23% to 18,100 caribou in July 1995. By July 1997, the herd size had increased and was estimated at 18,824 animals. The herd continued increasing, reaching 66,666 caribou in July 2008 (Lenart 2015a), representing a mean annual increase of 13% since 2002. A photocensus in July 2010 produced an estimate of 68,442 caribou, demonstrating that herd growth had slowed (Lenart 2015a). The herd subsequently declined to an estimated 50,753 caribou by July 2013 (Lenart 2015a) and 22,630 caribou by July 2016 (Lenart 2017), but increased to 30,069 caribou by July 2019 (Lenart 2019). The magnitude of the decline from 2013 to 2016 may have been affected by emigration of some CAH animals to the PCH and TCH, with which the CAH often intermixes on winter range (Prichard et al. 2020b).

The TCH typically calves near Teshekpuk Lake, ~130 km (80 mi) west of Kuparuk, uses coastal habitats and areas around Teshekpuk Lake for relief from insect harassment during summer (Yokel et al. 2009), and winters on the Arctic Coastal Plain (Person et al. 2007). However, approximately 30% of the herd, including a disproportionate number of males, winter in the central Brooks Range or with the Western Arctic Herd (WAH) on and near the Seward Peninsula. An unusual excursion occurred in the winter of 2003–2004 when a large proportion of the herd wintered in northeast Alaska following an October icing event (Carroll 2007, Parrett 2009, Bieniek et al. 2018).

Similar to the CAH, the TCH has also varied in abundance over the past 40 years. The TCH 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 (Parrett 2015b, 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 for the TCH and CAH in that year (Lenart 2019).

The Kuparuk oilfield and surrounding area (known as the Greater Kuparuk Area, or GKA) is located on the outer coastal plain (Figure 1) in the western portion of the summer range of the CAH. Beginning in 1978, shortly before development of the Kuparuk oilfield, considerable interest has focused on the use of the oilfield and surrounding area (particularly the Milne Point Unit) by the CAH during calving. The Kuparuk–Milne Point area is one of two locations (the other being the area between the Sagavanirktok and Canning rivers, east of the Prudhoe Bay oilfield) that consistently host concentrated use during the

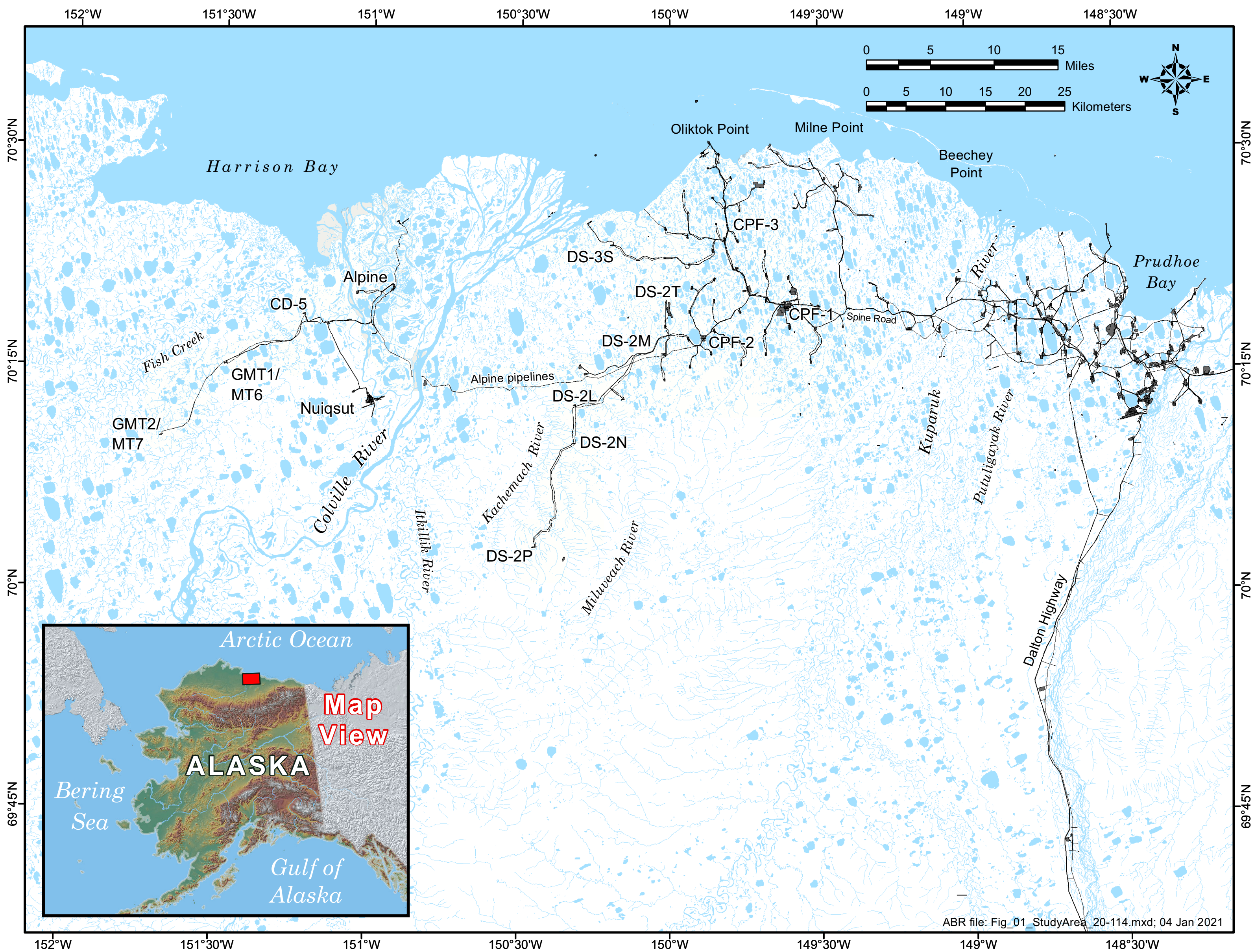


Figure 1. The Greater Kuparuk Area, North Slope, Alaska, 2020.

calving season since the late 1970s (Whitten and Cameron 1985, Lawhead and Cameron 1988). Studies by ADFG reported local avoidance of oilfield facilities and human activities by cows with young calves in the Kuparuk–Milne area during the calving season (Dau and Cameron 1986, Cameron et al. 1992). From 1978 through 1992, ADFG conducted aerial transect surveys of caribou distribution annually during the latter portion of the calving season (usually 10–15 June). After 1992, however, that annual effort was cut back due to budget constraints and ADFG conducted only two more transect surveys, in June 1997 and June 2000. Funded by CPAI and its heritage companies, ABR conducted similar transect surveys of the calving grounds of the western segment of the CAH from 1995–2017 and also conducted calving surveys in the region in 1983, 1984, 1987, and 1993.

The data described in this report complement the data from radio-telemetry studies by ADFG and other entities, including CPAI. Since 1992, ADFG survey efforts have focused primarily on tracking radio-collared female caribou, following a known-age sample of 60–80 cows annually (Arthur and Del Vecchio 2009, Lenart 2015a). A small sample of 10-month-old CAH females is outfitted annually with conventional VHF radio collars by ADFG (Lenart 2015a) and some animals are recaptured and recollared 4–6 years later. Satellite (Platform Terminal Transmitter, or PTT) collars have been deployed on a small numbers of bulls in recent years (Lenart 2015a). Additional PTT satellite collars and satellite-linked Global Positioning System (GPS) collars have been deployed since 2001 on female CAH caribou by ADFG biologists for several cooperative studies involving the North Slope Borough (NSB) Department of Wildlife Management, the federal Bureau of Land Management (BLM), and CPAI, to study the distribution and movements of the CAH throughout the year (Arthur and Del Vecchio 2009, Lawhead et al. 2015a, Nicholson et al. 2016, Prichard et al. 2020a, 2020b).

The study reported here was conducted under contract to CPAI to monitor the distribution and abundance of caribou in and near the Kuparuk oilfield in 2020. In addition, beginning in 2016 (Prichard et al. 2017), this study incorporates information on caribou movements near the Alpine pipelines that previously was addressed in a separate report (Lawhead et al. 2015b and references therein). The State of Alaska's Right-of-Way Lease/Grant Stipulation 2.6.1 states that the pipeline systems carrying liquids between the Alpine Development Project and the Kuparuk Oilfield "…shall be maintained to avoid significant alteration of caribou and other ungulate movement patterns. The Commissioner may require additional measures to mitigate impacts to ungulate movements." This report addresses that stipulation by summarizing data on caribou distribution and movements from radio telemetry data from the period November 2019–October 2020 in the area traversed by the Alpine pipeline corridor, which comprises three adjacent pipelines sharing the same support structure between the Alpine Central Processing Facility (CPF) on the central Colville River delta and Kuparuk CPF-2.

Although the focus of this study was caribou, ongoing research in the area for other projects provided an opportunity to record data on the distribution and abundance of other large mammals as well, most notably muskox (*Ovibos moschatus*) and brown bear (hereafter, grizzly bear; *Ursus arctos*).

The 2020 study had 3 objectives:

- Document the distribution and abundance of caribou in the region between the Kuparuk and Colville rivers during different life-history seasons;
- Summarize data on caribou distribution and movements from radio telemetry in the area crossed by the Alpine pipeline corridor; and
- Record the distribution and abundance of other large mammals encountered incidentally during research conducted in the Kuparuk–Colville region.

STUDY AREA

The study area extended east from the Colville River delta to the Kuparuk River and north from 70º N to the Beaufort Sea coast (Figure 1). This area encompassed the entire Kuparuk oilfield, the Alpine pipeline corridor between the Kuparuk oilfield and Colville River delta, the Milne Point oilfield, and the westernmost portion of the Prudhoe Bay oilfield (west of the Kuparuk River).

Constructed in the winter of 1998–1999, the Alpine pipeline corridor extends 55 km (34 mi) from the processing facilities at the Alpine CD-1 pad to those at Kuparuk CPF-2.

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 study area terrain is characterized by permafrost-related features, such as oriented thaw-lakes, drained-lake basins, beaded streams, and pingos. The physiography, vegetation, and climate of the central Arctic Coastal Plain were described by Walker et al. (1980).

METHODS

WEATHER AND INSECT CONDITIONS

Spring weather influences the location of calving (Carroll et al. 2005, Noel et al. 2004, Dau 2015) 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 2020, 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 probability of mosquito activity was estimated based on hourly temperatures and wind speeds from Nuiqsut using an equation developed by Russell et al. (1993). The probability of oestrid-fly activity was estimated from average hourly wind speeds and temperatures recorded at Nuiqsut using equations developed by Mörschel (1999).

TELEMETRY DATA ANALYSIS

Eight seasons were used for analysis of telemetry, based on mean movement rates and observed timing of caribou life-history events (adapted from Russell et al. 1993 and Person et al. 2007): winter (1 December–30 April); spring migration (1–29 May); calving (30 May–15 June); postcalving (16–24 June); mosquito harassment (25 June–15 July); oestrid fly harassment (16 July–7 August, a period that also includes some mosquito harassment); late summer (8 August–15 September); and fall migration, a period that includes the breeding season, or rut (16 September–30 November).

We analyzed telemetry data from 709 collar deployments on 540 caribou (Table 1). Telemetry data used for this analysis were collected between 1990 and October 2020 for the TCH and 2001–October 2020 for the CAH. This included 186 satellite (PTT) collar deployments on 166 TCH animals, 317 GPS collar deployments on 223 TCH animals, 24 satellite collar deployments on 24 CAH animals, and 182 GPS deployments on 127 CAH animals. A total of 79% of TCH deployments and 96% of CAH deployments were on female caribou. Telemetry data were provided through a data sharing agreement with ADFG, Bureau of Land Management, and the 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 TCH caribou by season. Because most collared CAH caribou were females, we only conducted separate analyses by sex for the TCH. Caribou in northern Alaska are sexually segregated during some seasons, especially calving, so our results during these time periods may not represent the distribution of male CAH caribou during those seasons.

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 to 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 (TCH 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.

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

Herd [a] / Collar Type	Years	Female Deployments	Female Individuals	Male Deployments	Male Individuals	Total Deployments
Teshekpuk Herd						
Satellite collars	1990–2020	97	86	89	80	186
GPS collars	2004–2020	299	208	18	15	317
Central Arctic Herd						
Satellite collars	2001–2004	10	10	2	2	12
Satellite collars	2012–2020	6	6	6	6	12
GPS collars	2003–2020	182	127	0	0	182

[a] Herd affiliation at time of capture.

During the period from 1 November 2019 through 31 October 2020, telemetry data were available from 16 GPS-collared female CAH caribou, 99 GPS-collared female TCH caribou, 12 GPS-collared male TCH caribou, and 7 PTT satellite-collared TCH caribou (6 males and 1 female). In previous years, most CAH caribou were collared in the central Brooks Range during late winter (usually April). Beginning in 2017, CAH animals were collared in late June on the coastal plain, primarily west of the Sagavanirktok River. No collars were deployed on CAH caribou in 2018 or 2020, but in 2019, 10 GPS collars were deployed on CAH females (3 previously uncollared and 7 previously collared animals). In all years, the TCH collars were deployed by ADFG biologists in that herd's summer range, centered on Teshekpuk Lake >50 km west of the GKA study area. In 2019, GPS collars were deployed on 36 TCH females (19 previously uncollared and 17 previously collared) and 9 TCH males (5 previously uncollared and 4 previously collared). All deployments for both herds and years took place during 19–26 June. In late June 2020, 32 GPS-collars were deployed on TCH caribou (29 females and 3 males).

RESULTS AND DISCUSSION

WEATHER AND INSECT CONDITIONS

Spring 2020 had temperatures that were close to average and snow melted slightly earlier than usual at the Kuparuk airport (Figure 2, Appendix A). May temperatures were near the average with a short period of warmer than average temperatures in early May. Snow depth at the Kuparuk airstrip remained below or near average until 20 May and then completely melted by 29 May (Figure 2, Appendix A). Temperatures and the sum of thawing degree days were near average during the calving and postcalving periods in early and mid-June (Figure 2, Appendix A).

The 2020 insect season generally had slightly below average temperatures in late June, well below average temperatures in July, and August and September temperatures near the long-term average (Figure 3, Appendix B). Estimated mosquito and fly activity started out near average in June, was very low in July, and was near average for August (Appendices C, D). This resulted in 4 days with a high probability of mosquitos (mosquito index >50%; 30 July, 11, 13, 23 August) but no days with a high probability oestrid fly activity oestrid fly index >50%; Figure 3). There were 12 days with a mosquito activity index greater than 40% (1 in June, 3 in July, and 8 in

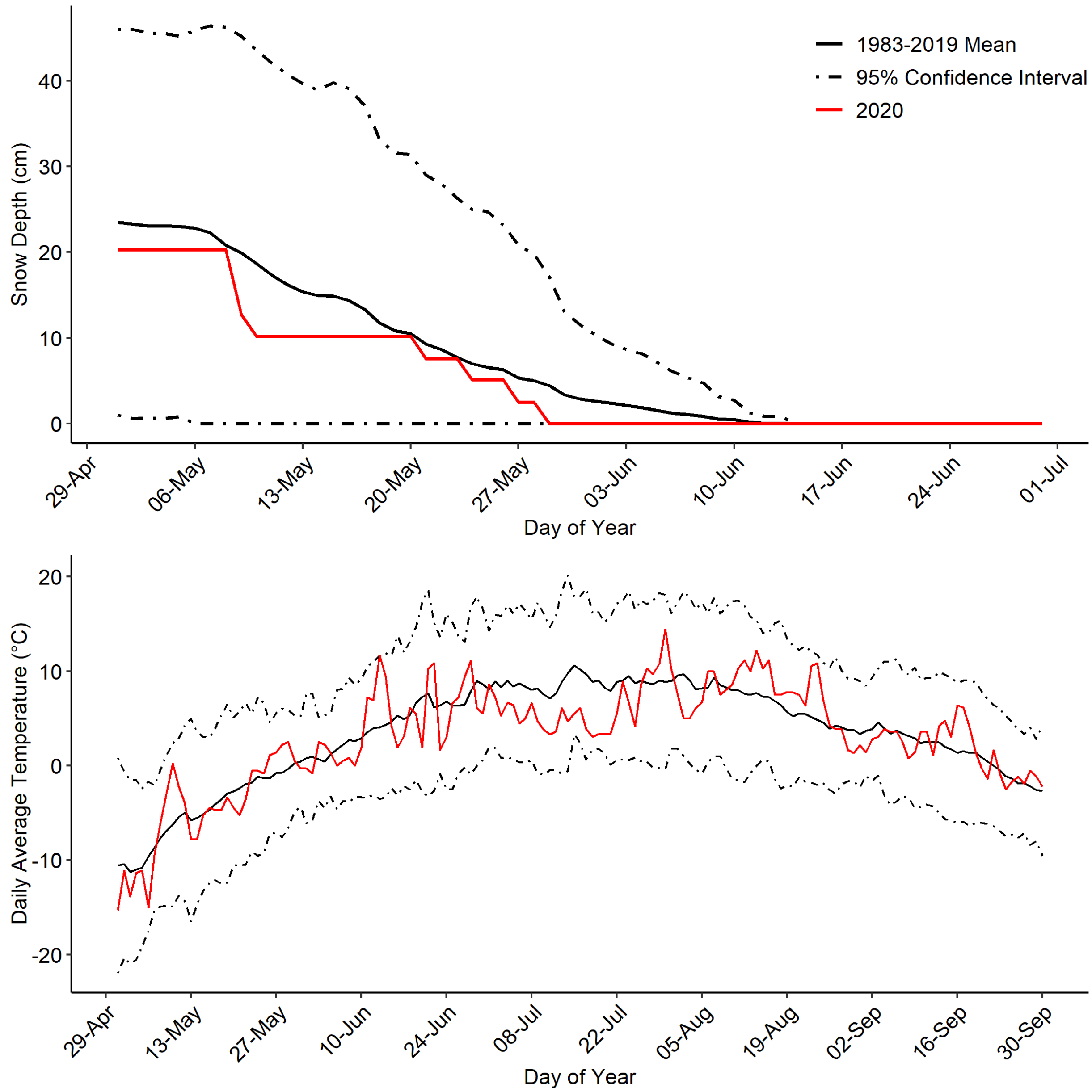


Figure 2. Snow depth during 1 May–30 June 2020 and average daily temperature 1 May–30 September at the Kuparuk airstrip compared to the mean and 95% confidence interval for 1983–2019.

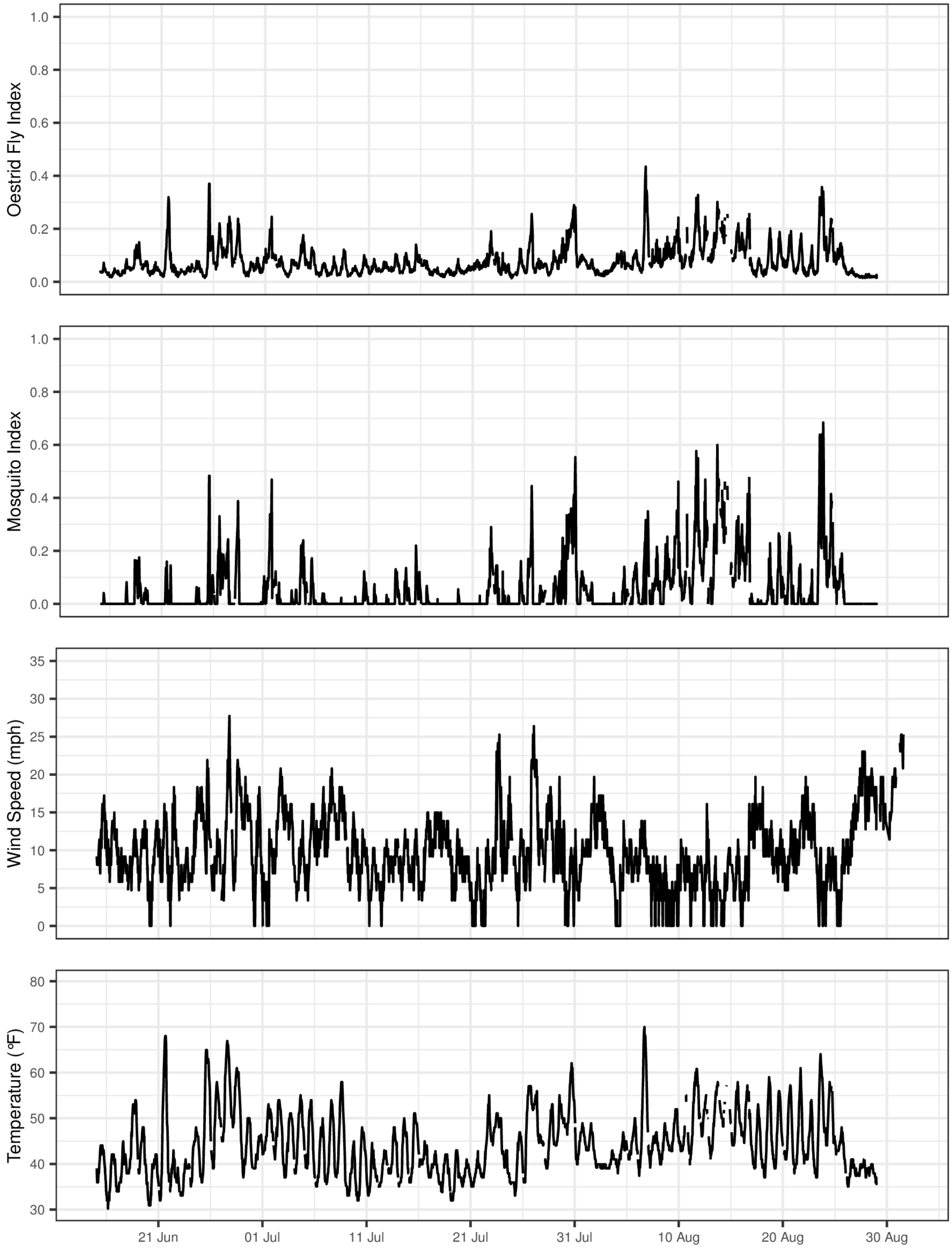


Figure 3. Probability of mosquito and oestrid fly activity (Russell et al. 1993, Mörschel 1999) in summer 2020 based on hourly wind speed and temperature data recorded at the Nuiqsut airstrip.

August) and only one day with an oestrid fly activity index greater than 40% (6 August).

TELEMETRY DATA ANALYSIS

SEASONAL DISTRIBUTION AND ABUNDANCE

KDE Analysis

CAH caribou winter primarily in the Brooks Range or in the foothills just to the north, with few caribou remaining near the oilfields (Appendix E; Arthur and Del Vecchio 2009, Lenart 2015a, Nicholson et al. 2016). CAH caribou move back onto the Coastal Plain and into the southern GKA during spring migration. The CAH then calve in two separate groups, one east of the Sagavanirktok River and one to the west of the river (Arthur and Del Vecchio 2009, Lenart 2015a, Nicholson et al. 2016). The areas of greatest calving activity for the western segment of the herd—in terms of both caribou distribution and density—are located consistently south or southwest of the Kuparuk oilfield, although the region of highest use by parturient caribou shifts somewhat from year to year (Prichard et al. 2018). Few caribou have used the Kuparuk–Milne concentration area (north of the Spine Road and east of the Oliktok Point Road in the Kuparuk Field survey area) for calving in recent years compared to the observations during ADFG surveys in 1979–1987 (Cameron 1994, Prichard et al. 2020a). CAH caribou that calve in the western area exhibit localized avoidance (within 2–5 km) of active roads and pads during and for 2–3 weeks immediately after calving (Dau and Cameron 1986, Cameron et al. 1992, Lawhead et al. 2004, Johnson et al. 2020, Prichard et al. 2020a).

Caribou distributions during the postcalving season are usually similar to the calving season (Appendix E), but caribou move north and show less avoidance of roads (Lawhead et al. 2004, Prichard et al. 2020a). The CAH animals typically move through the oilfields to the Beaufort Sea coast during periods of mosquito harassment which generally begins in late June (White et al. 1975, Dau 1986, Prichard et al. 2020a). Once mosquito harassment subsides, caribou then tend to disperse inland during the oestrid fly season and select areas with oestrid fly relief, such as gravel bars and gravel roads (Pollard et al. 1998, Prichard et al. 2020a). They remain inland for the late summer season and then migrate to their wintering grounds in the fall.

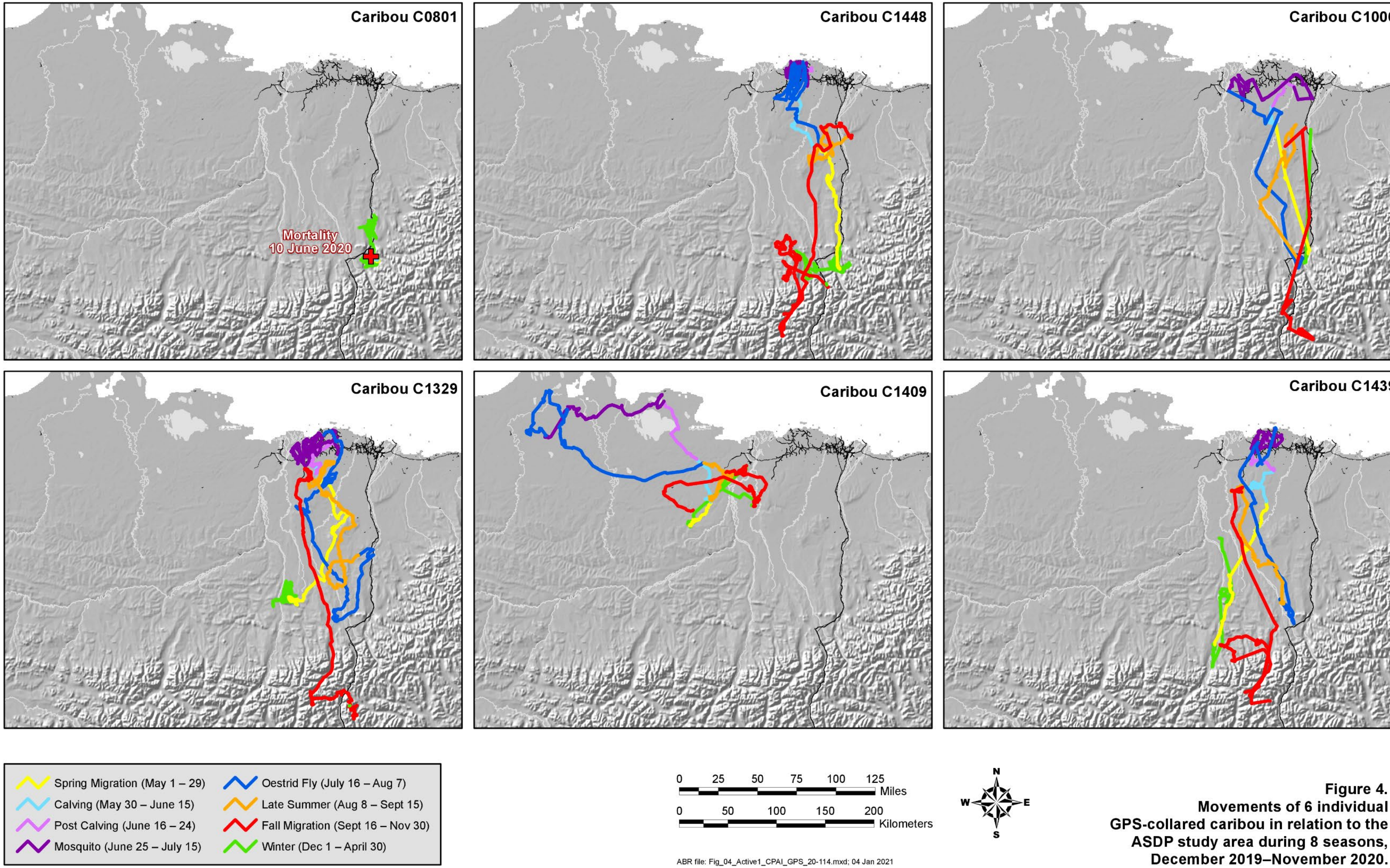
The KDEs for the TCH indicate low to no use of the GKA for both males and females (Appendices F–G). TCH caribou rarely move east of the Colville River, although mixing with the CAH is quite common and can lead to dispersions into the CAH herd (Prichard 2020b). The seasons when TCH caribou are most likely to be in the GKA area are spring and fall migration. In the past 2 years, substantial numbers of TCH caribou have been east of the Colville River during fall.

CPAI Collared Caribou

We mapped the movements of 16 female CAH caribou with active CPAI-funded GPS collars from December 2019 through November 2020 (Figures 4–6). Nine of these caribou were collared around the oilfields in June 2019, and the other 7 were collared prior to 2019.

Most (13) of the collared caribou spent the majority of 2020 within the normal annual range of the CAH (Figures 4–6). Of the other 3, two died in 2020; caribou C0801 died on approximately 10 June 2020 near the Dalton Highway (Figure 4) and caribou C1706 died on approximately 7 May 2020 near the upper Kuparuk River (Figure 5). One caribou (C1409) spent the entire year in typical TCH range for the second year in a row: it wintered along the Colville River south of Nuiqsut during the winter of 2019–2020, migrated towards Teshekpuk Lake during calving, moved north of Teshekpuk Lake during postcalving, continued west during the mosquito season, and then moved back east on the south side of Teshekpuk Lake during the oestrid fly season. It then moved past GMT2/MT7 and Nuiqust during late summer and fall (Figure 5).

Of the 13 collared caribou in the CAH range, 11 spent the calving season on the west side of the Sagavanirktok River and 2 were on the east side during calving. This is consistent with observations that an increasing proportion of CAH caribou are calving on the west side of the Sagavanirktok in recent years. All 13 collared caribou remained on the same side of the Sagavanirktok River during the postcalving and mosquito season, although some individuals crossed the Sagavanirktok River during the oestrid fly season. During late summer,



ABR file: Fig_04_Active1_CPAI_GPS_20-114.mxd; 04 Jan 2021

**Figure 4.
Movements of 6 individual
GPS-collared caribou in relation to the
ASDP study area during 8 seasons,
December 2019–November 2020.**

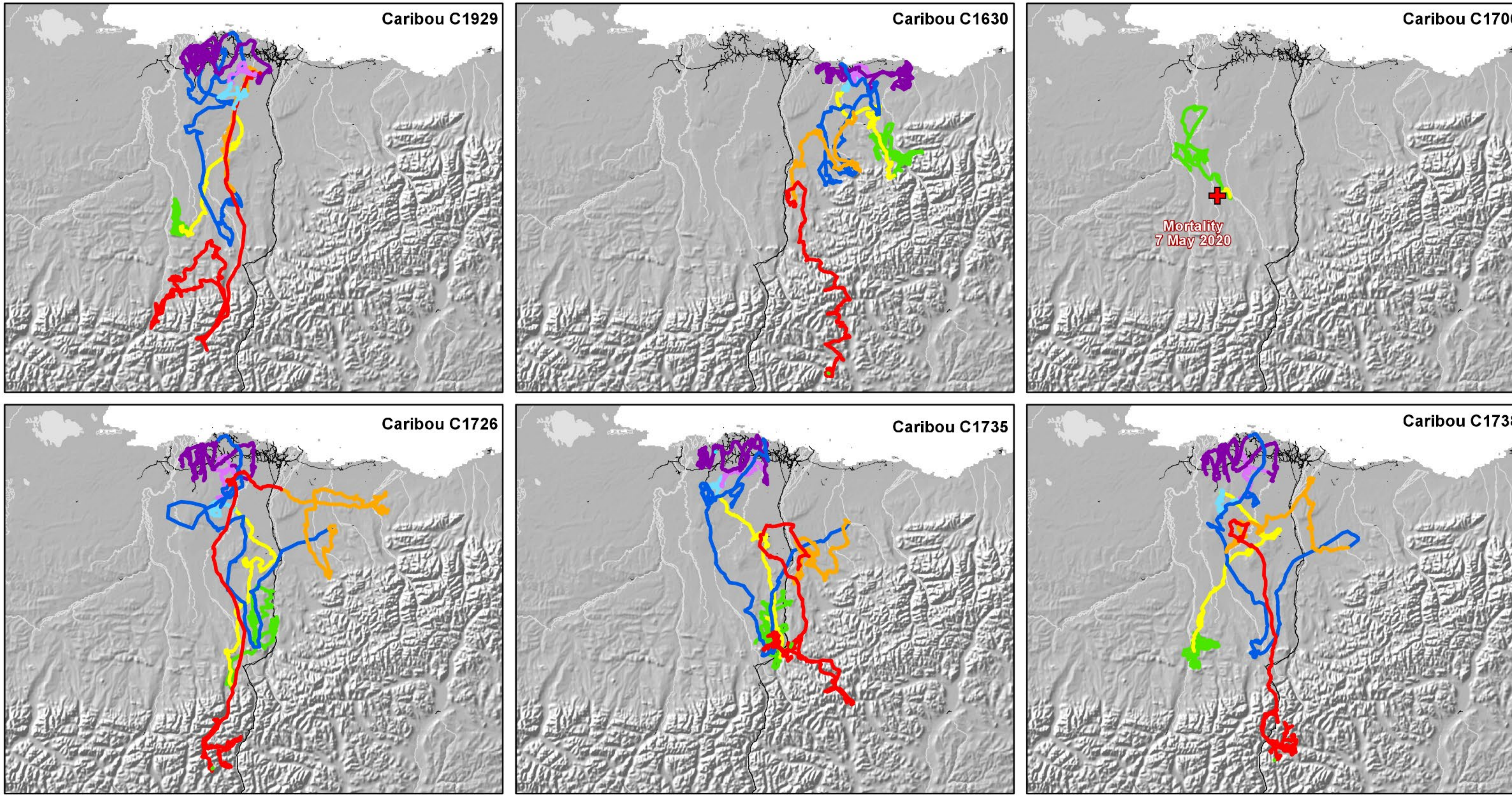


Figure 5.
Movements of 6 individual GPS-collared caribou in relation to the ASDP study area during 8 seasons, December 2019–November 2020.

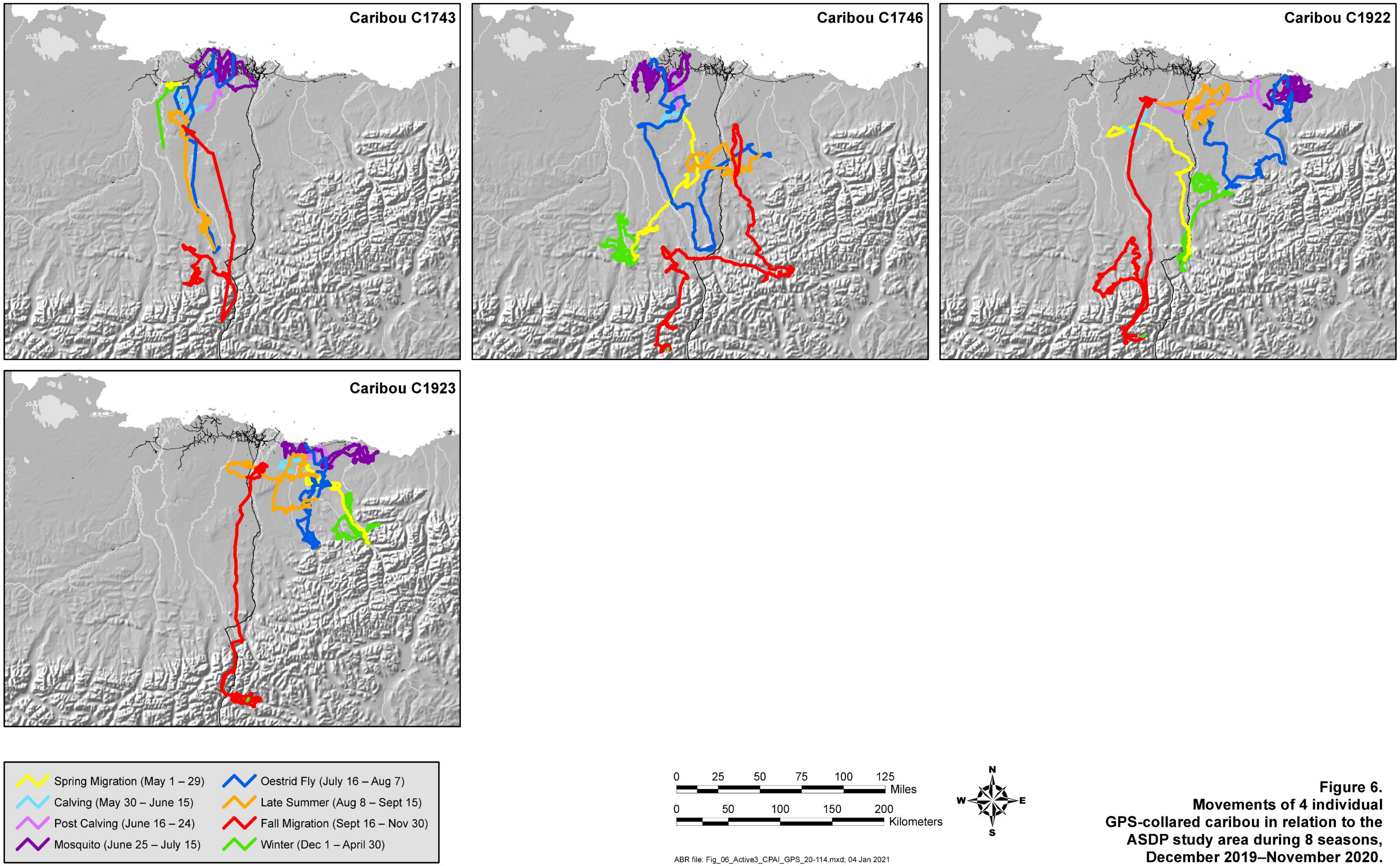


Figure 6.
Movements of 4 individual GPS-collared caribou in relation to the ASDP study area during 8 seasons, December 2019–November 2020.

Page intentionally blank.

6 caribou were primarily west of the Sagavanirktok River, 5 were primarily east, and 2 were in both areas approximately equally (Figures 4–6). All 13 caribou moved in the northern Brooks Range during fall 2020.

Similar to previous years, there were few collared CAH caribou in the GKA study area during winter 2019–2020, but there were numerous TCH caribou south of Nuiqsut (Figure 7). CAH caribou began to arrive in the study area in spring, but most caribou remained south of the oilfields during that season. CAH caribou C1743 was somewhat unusual in that it was south of the Alpine pipelines during both late winter and spring (Figure 8). Numerous CAH caribou were in the study area south of the oilfields during calving with most remaining east of the Meltwater Pad (DS-2P; Figure 9). CAH caribou moved up into the oilfields during the postcalving season (Figure 10). There was heavy use of the Kuparuk oilfields during the mosquito season with rapid movements crossing many roads in the area (Figure 11). Prichard et al. (2020a) found that caribou in this area crossed roads or pads more than twice per day when mosquitoes or flies were active.

There were also numerous caribou moving through the oilfields during the oestrid fly season, although movements were generally farther inland compared to the mosquito season (Figure 12). Multiple collared CAH caribou were located in the GKA study area but south of the oil fields during late summer (Figure 13) and fall (Figure 14). There is some indication that CAH caribou are remaining north longer in recent years, possibly as a result of later onset of sea ice and warmer fall temperatures and later snow cover (Wendler et al. 2014). TCH caribou were largely absent from the area from calving through late summer, but multiple TCH caribou were south of Nuiqsut in fall 2020 (Figure 14). There was little use of the Colville Delta by collared caribou in 2020.

MOVEMENTS OF COLLARED CARIBOU NEAR THE ALPINE PIPELINES

CAH Collars

The movements of GPS-collared caribou near the Alpine pipelines before November 2019 were described in previous reports (Prichard and Welch 2020 and references therein). Eight different collared CAH caribou crossed the Alpine pipelines 48 times between December 2019 and November 2020 (Table 2). A total of 45 (94%) of crossings occurred during the mosquito season and the remaining 3 crossings occurred during the oestrid fly season in late July.

From 2004 to 2013, most collared CAH caribou moved eastward out of the GKA area after the onset of mosquito harassment (Lawhead et al 2015a), but in 2014–2020 many animals from the CAH western segment remained in the GKA area throughout the summer, similar to the pattern of use seen in the 1980s and 1990s. These animals typically make repeated crossings of infrastructure while moving between coastal mosquito-relief habitat and inland foraging areas (Murphy and Lawhead 2000, Prichard et al. 2020b).

Across all years with GPS-collar data for CAH caribou (2003–2020), the proportion of collared caribou crossing the Alpine pipelines was highest during the mosquito season (24.5%) and the oestrid fly season (14.1%; Table 3). The crossing rate was generally the highest during 2016–2019. The crossing rate for the mosquito season was higher during 2020 than during 2016–2019, but the crossing rate in 2020 was based on just 14 collared caribou in that season compared to 43 caribou during 2016–2019.

TCH Collars

The movements of collared TCH caribou near the Alpine pipelines before November 2019 were described in previous reports (Prichard and Welch 2020 and references therein). Similar to 2019, during fall 2020, there was an unusually large number of TCH caribou to the southwest of the Meltwater (DS-2P) pad (Figure 14). From November 2019 through October 2020, only one TCH caribou crossed the Alpine Pipeline. Caribou FY1528 crossed the pipeline in October 2020 (Figure 14). This caribou moved in to the area between Alpine and Nuiqsut on 11 October. It then moved along the south side of the Alpine pipelines until reaching oilfields roads on 17 October, crossed to the north side of the pipelines on 19 October, and remained north of the pipelines for the rest of the month (Figure 14). Although the straight-line tracks between locations crossed the Alpine pipelines 6 times, all the caribou locations prior to October 19 are south of the Alpine

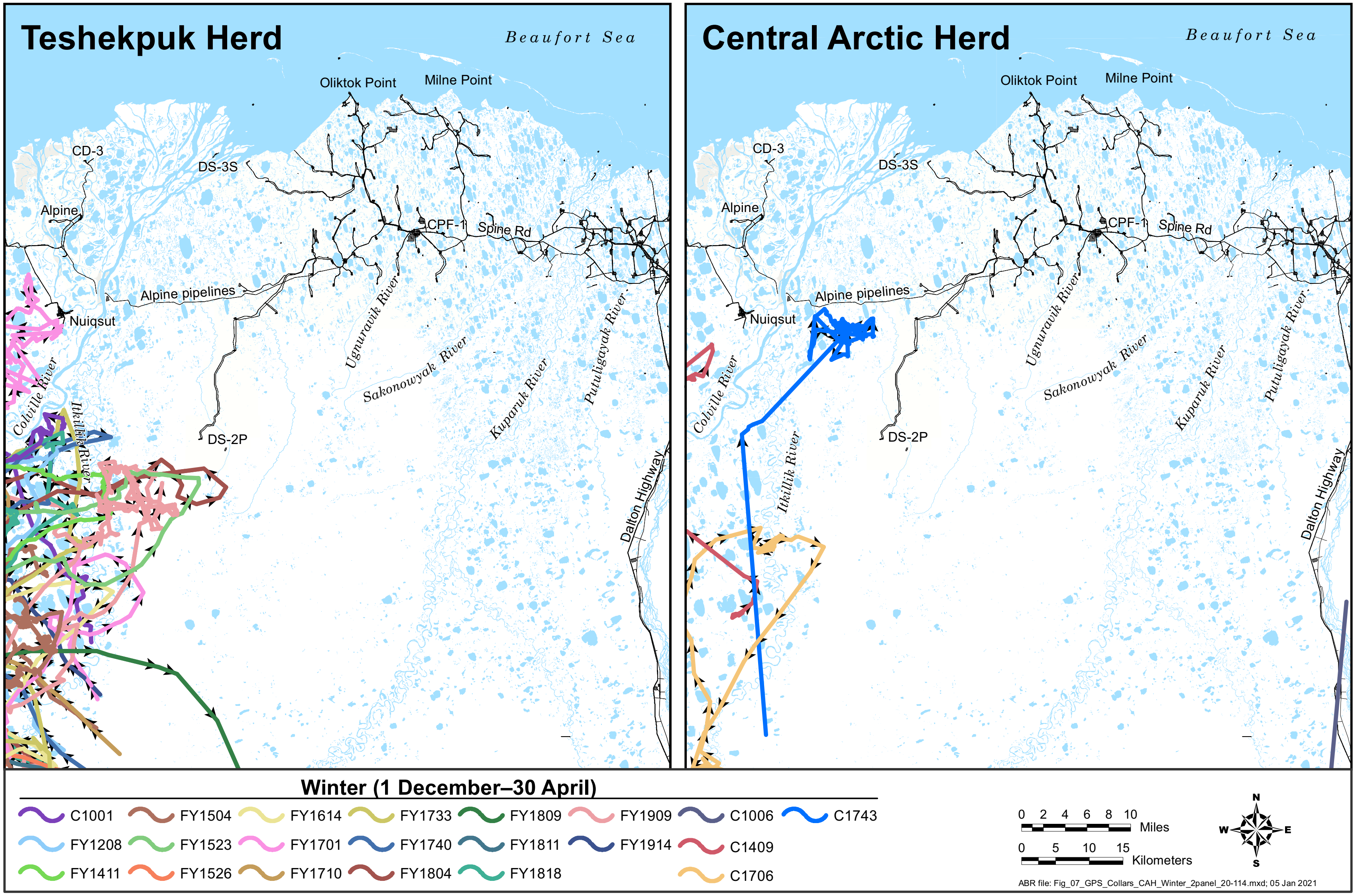


Figure 7. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2019–2020 winter season.

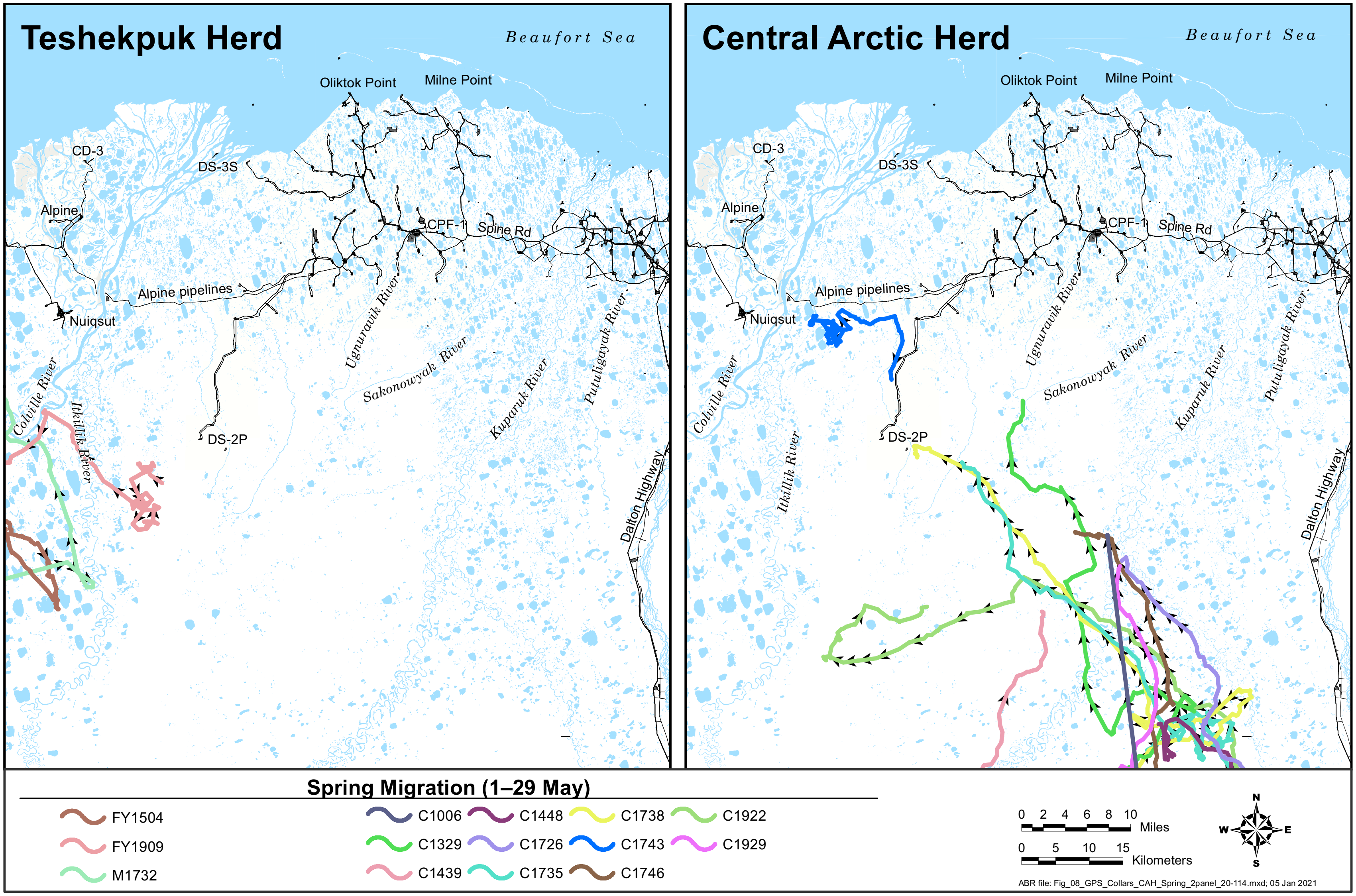


Figure 8. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 spring migration season.

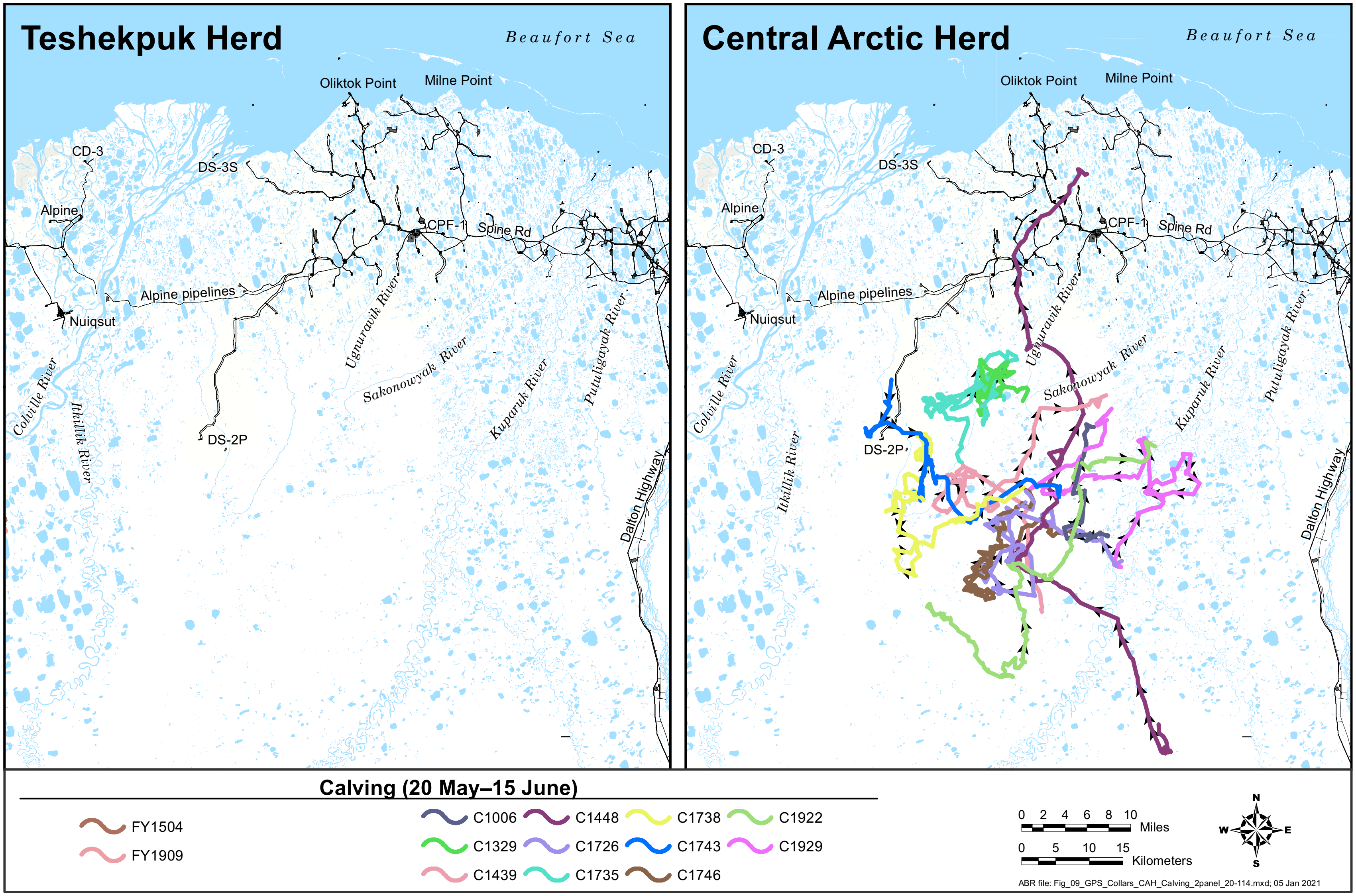


Figure 9. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 calving season.

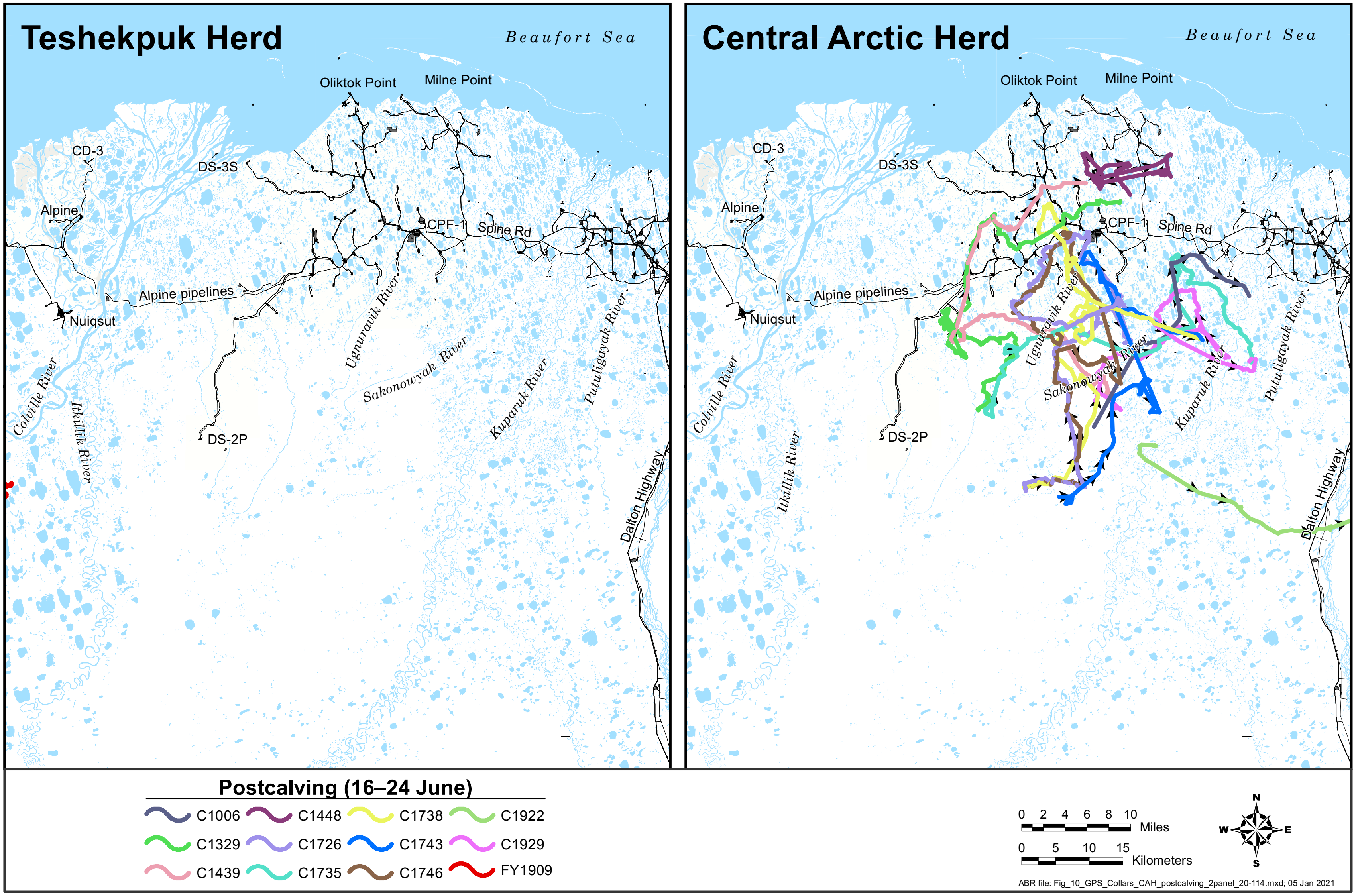


Figure 10. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 postcalving season.

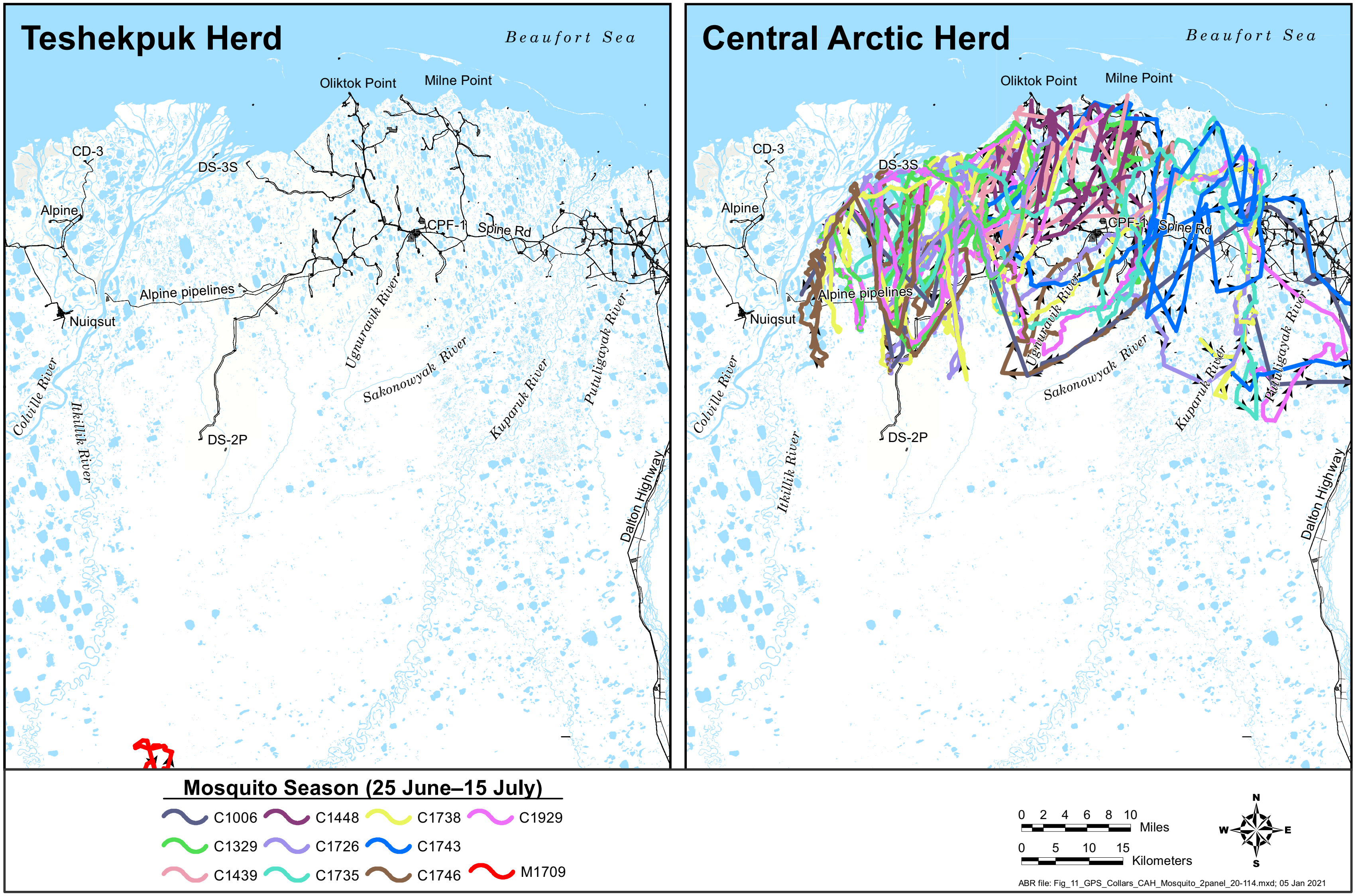


Figure 11. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 mosquito season.

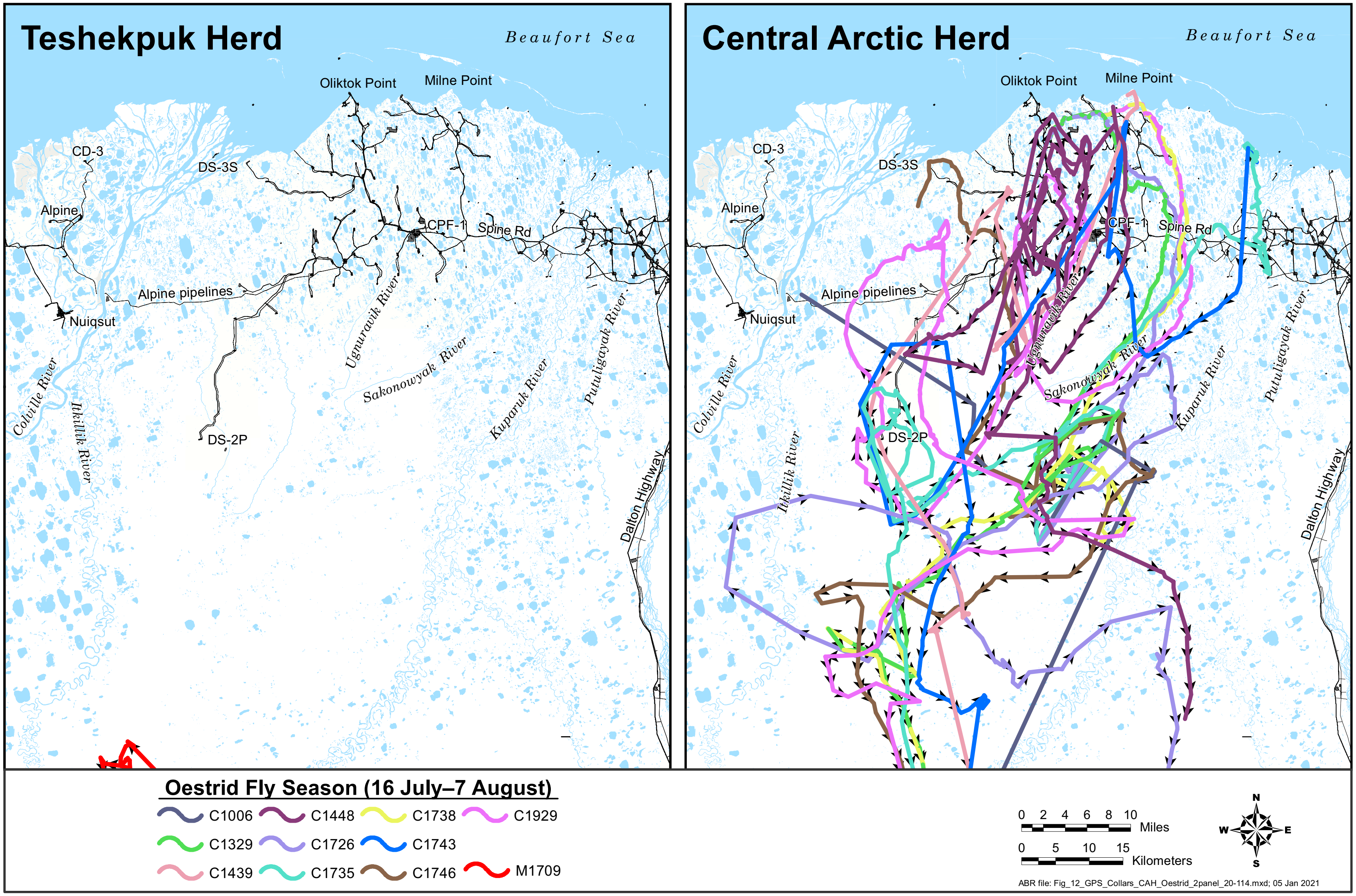


Figure 12. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 oestrid fly season.

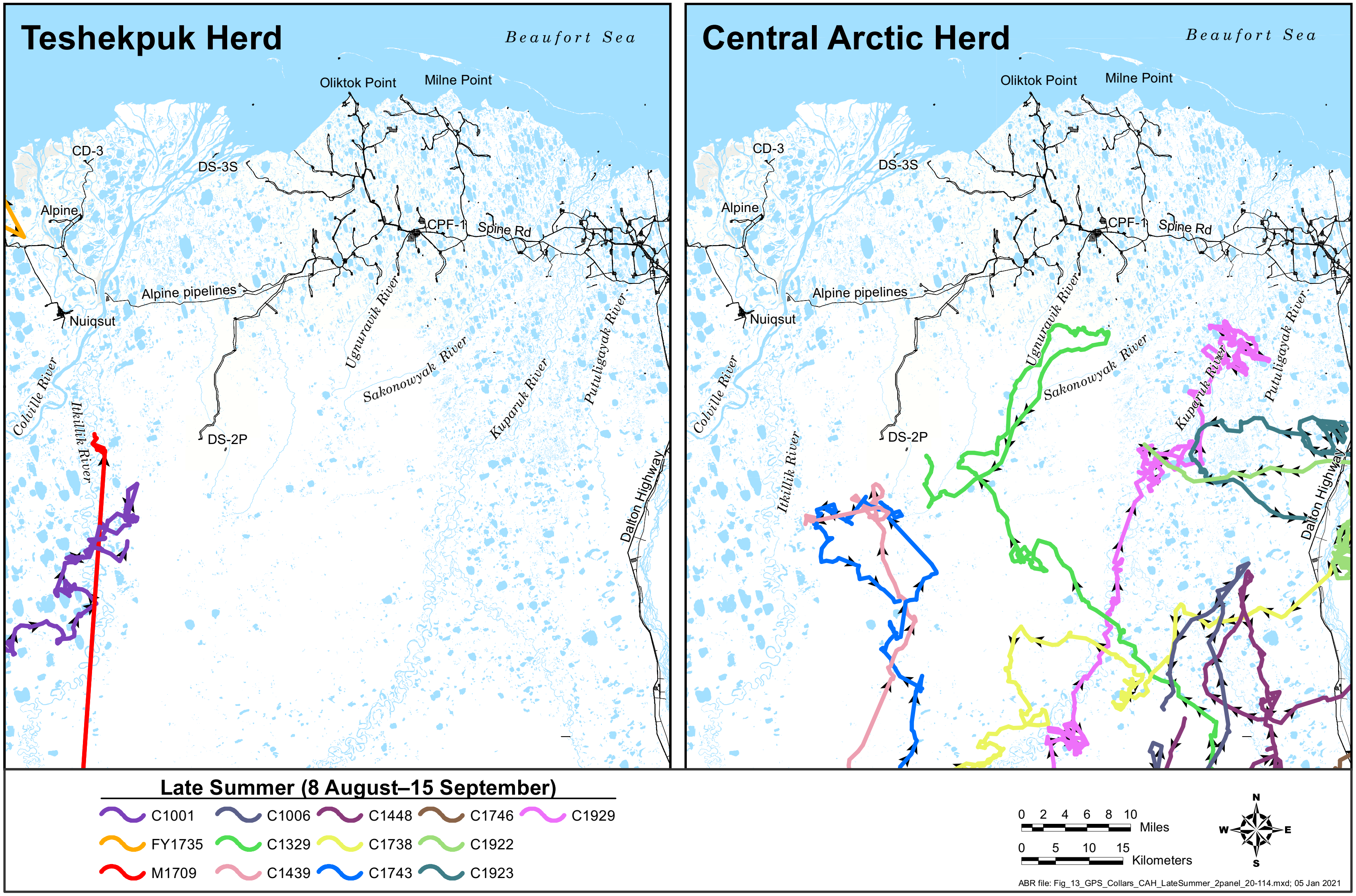


Figure 13. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 late summer season.

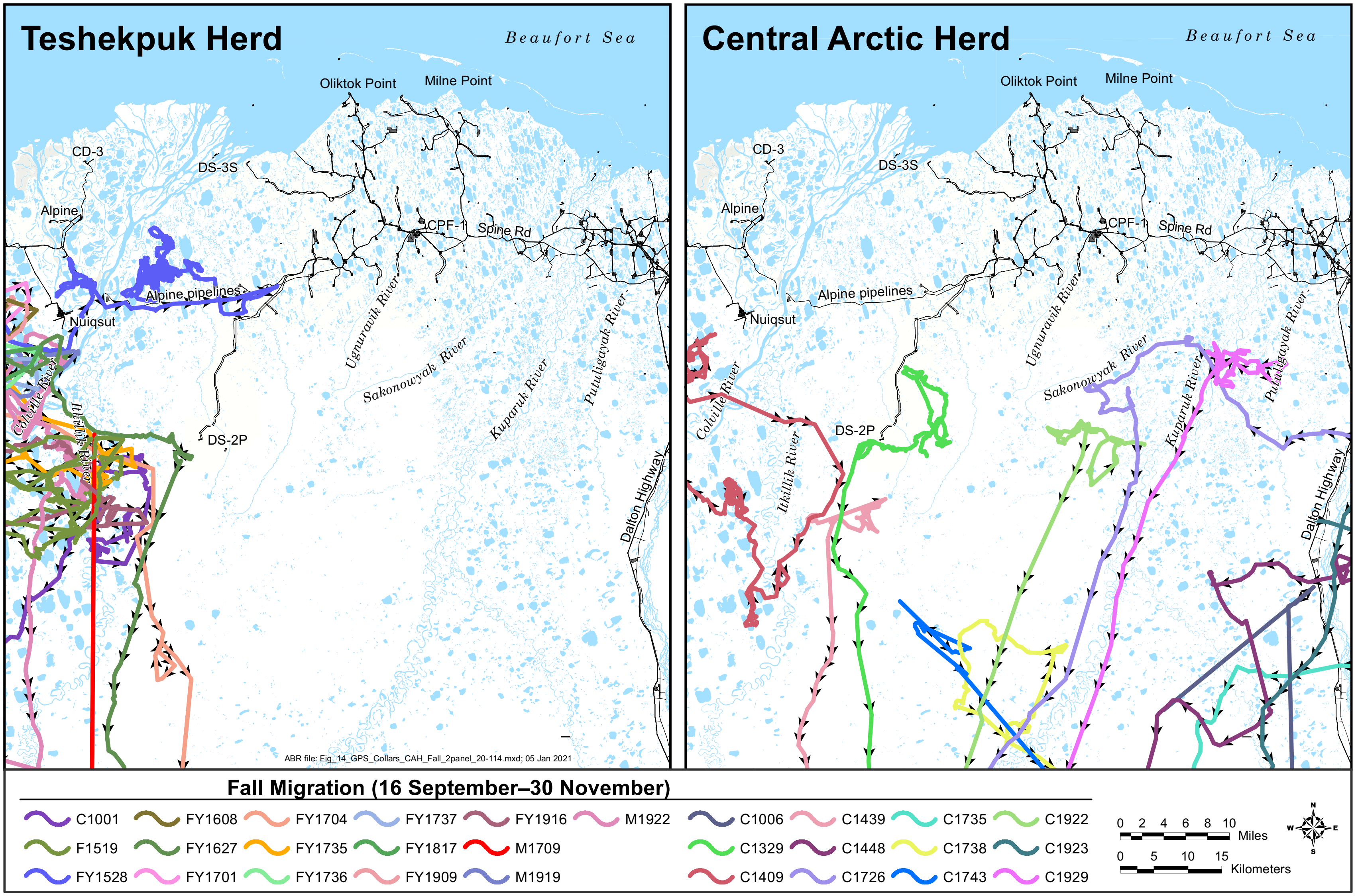


Figure 14. Movements of GPS-collared female caribou of the Teshekpuk and Central Arctic herds in the Greater Kuparuk Area during the 2020 fall migration season.

Table 2. Number of CAH and TCH radio-collared caribou crossing the Alpine pipelines between 1 December 2019 and 30 November 2020 based on straight line distances between locations.

Season	Caribou ID	Herd	Times Crossed	Dates
Mosquito	C1006	CAH	4	6–9 July
	C1329	CAH	6	10–15 July
	C1726	CAH	4	7–11 July
	C1735	CAH	2	10–11 July
	C1738	CAH	8	7–14 July
	C1746	CAH	11	7–16 July
	C1929	CAH	10	8–15 July
Oestrid Fly	C1439	CAH	1	21 July
	C1929	CAH	2	23–25 July
Fall	FY1528	TCH	6	16–19 October
Total	9 [a]		54	

[a] Number of unique individuals.

pipelines, and it is likely that caribou FY1528 crossed the pipeline only once. This suggests that the movements of this caribou were influenced by the Alpine pipelines to a much larger degree than is generally apparent in CAH caribou. This may be attributed to TCH caribou having less exposure to pipelines than CAH caribou. Caribou will also follow linear features when they are generally parallel to their direction of movement (LeResche and Linderman 1975, Bergerud et al. 1984, Lawhead et al. 1993).

OTHER MAMMALS

Because there were few ABR biologists working in the Kuparuk Area during 2020, there were few other mammals observed in the area (Figure 15). Most observations were collected by aerial survey crews while commuting to and from Deadhorse for surveys farther west.

GRIZZLY BEAR

In 2020, we observed one bear group, a sow with a cub of the year, on the Colville River delta, but no bears were observed in the GKA (Figure 15). Again, the lack of observations is primarily due to a lack of surveys in this area. Observations reported by ADFG and CPAI suggest that multiple grizzly bears continue to use the Kuparuk area (C. Pohl, CPAI, pers. comm.)

MUSKOX

A total of 4 observations of groups of muskoxen were recorded along the Colville River (Figure 15). On 9 June, 3 adults and 1 calf were observed south of Nuiqsut. On 15 June, a large group of 33 adults and 11 calves was observed northeast of Nuiqsut. One adult muskox was observed on 19 August, and 2 adults were observed on 6 October. In recent years, two mixed-sex groups of muskoxen generally have been seen during surveys for other species, one along the Colville River and delta and the other between the Kuparuk River delta and Milne Point (Prichard et al. 2018, 2019, Prichard and Welch 2020). Most of the muskoxen along the Kuparuk River moved to the Sagavanirktok River in 2019 and ADFG only observed 4 muskoxen along the Kuparuk River in 2020 (E. Lenart, ADFG, pers. comm.).

The muskox population on the North Slope of Alaska has declined since 1999, evidently due to a combination of predation by grizzly bears, human interactions, disease, and unusual mortality events such as drowning (Reynolds et al. 2002, Shideler et al. 2007, Lenart 2015b). The decline was noted

Table 3. Proportion of female Central Arctic Herd caribou outfitted with GPS collars crossing or within 1 km of the Alpine Pipelines, by season and year.

Season	Year(s)	Collars[a]	Crossed	Within 1 km
Spring Migration	2003–08	132	0.038	0.061
	2009–12	50	0	0
	2013–15	24	0.042	0.042
	2016–2019	38	0.026	0.026
	2020	14	0	0
	Total	258	0.027	0.039
Calving	2003–08	132	0.068	0.076
	2009–12	51	0	0.020
	2013–15	45	0	0
	2016–2019	39	0.026	0.026
	2020	15	0	0
	Total	282	0.035	0.043
Postcalving	2003–08	128	0.063	0.102
	2009–12	35	0.029	0.057
	2013–15	45	0.044	0.044
	2016–2019	37	0	0
	2020	13	0	0.154
	Total	258	0.043	0.074
Mosquito	2003–08	128	0.227	0.242
	2009–12	50	0.100	0.100
	2013–15	43	0.279	0.279
	2016–2019	43	0.349	0.419
	2020	14	0.500	0.500
	Total	278	0.245	0.263
Oestrid Fly	2003–08	125	0.072	0.072
	2009–12	55	0.091	0.109
	2013–15	37	0.243	0.243
	2016–2019	45	0.311	0.400
	2020	14	0.143	0.143
	Total	276	0.141	0.159
Late Summer	2003–08	139	0.007	0.022
	2009–12	55	0	0
	2013–15	33	0	0
	2016–2019	53	0.057	0.057
	2020	14	0	0
	Total	294	0.014	0.020
Fall Migration	2004–08	136	0.022	0.022
	2009–12	51	0	0
	2013–15	35	0.029	0.029
	2016–2019	50	0.100	0.120
	2020	14	0	0
	Total	286	0.031	0.035

Table 3. Continued.

Season	Year(s)	Collars[a]	Crossed	Within 1 km
Winter	2004–08	131	0	0
	2009–12	50	0	0
	2013–15	33	0	0
	2016–2019	49	0.020	0.041
	Total	263	0.004	0.008

[a] Locations within 30 days of collaring were removed and then animals with fewer than 30 locations or active less than half the season were removed from the analysis.

first in the Arctic National Wildlife Refuge but later was documented farther west on the central coastal plain. Population surveys by ADFG in late winter (April) found 216 muskoxen in 2006. Since then, the population on the central North Slope has remained relatively stable at approximately 190–200 animals (Lenart 2015b, Arthur and Del Vecchio 2017). Predation by grizzly bears was the most common cause of death, responsible for an estimated 58% of calf mortalities and 62% of adult mortalities when a cause of death could be determined (Arthur and Del Vecchio 2017).

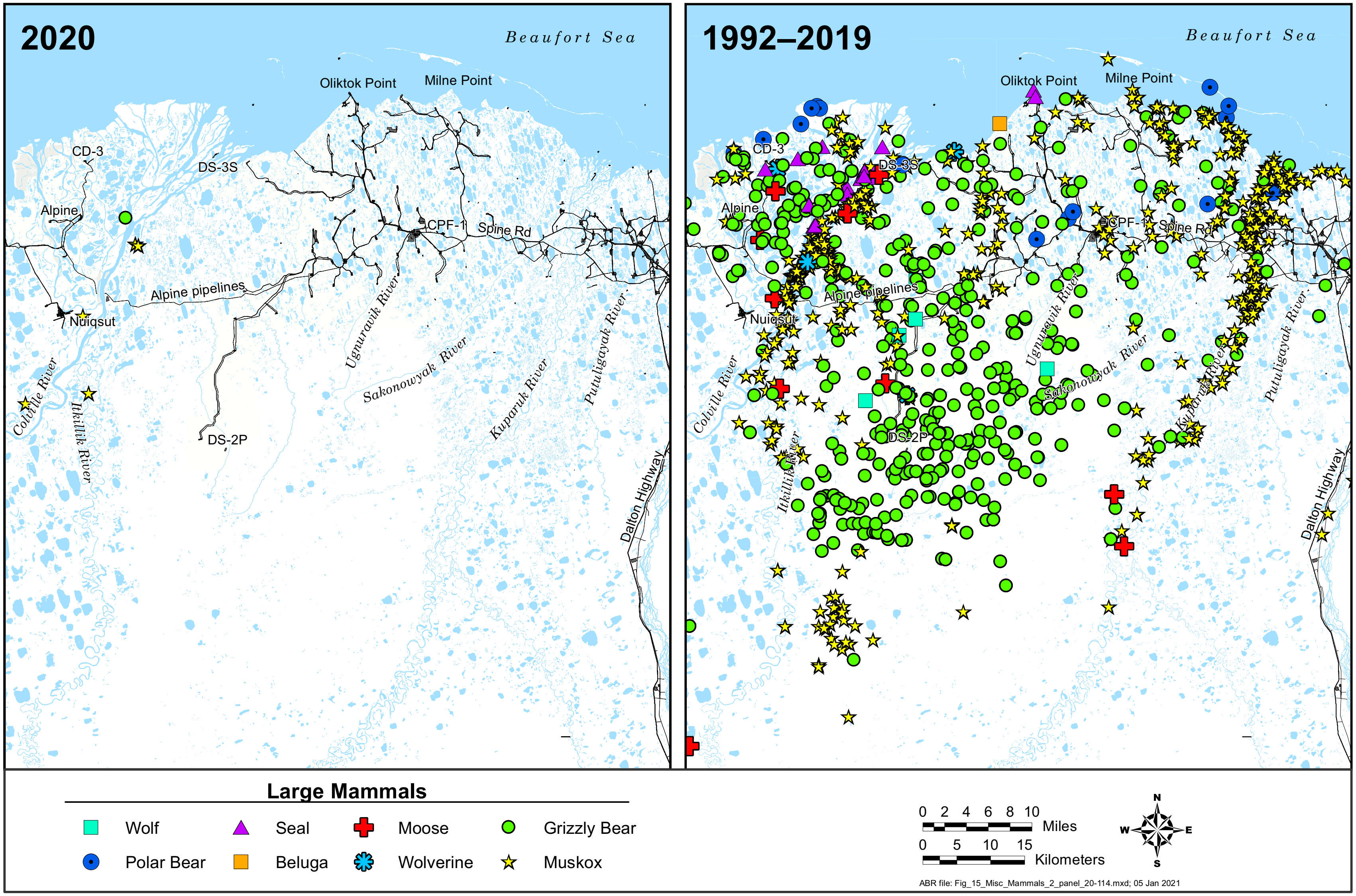


Figure 15. Distribution of other large mammals observed during aerial and ground surveys in the Greater Kuparuk Area, April–October 2020 and for the years 1992–2019 combined.

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, Alaska. 36 p.

Arthur, S. M., and P. A. Del Vecchio. 2017. Effects of grizzly bear predation on muskoxen in northeastern Alaska. Ursus 28: 81–91.

Bergerud, A.T., R. D. Jakimchuk, and D. R. Carruthers. 1984. The buffalo of the north: caribou (*Rangifer tarandus*) and human developments. Arctic 37: 7–22.

Bieniek, P.A., U.S. Bhatt, J.E. Walsh, R. Lader, B. Griffith, J. K. Roach, and R.L. Thoman. 2018. Assessment of Alaska rain-on-snow events using dynamical downscaling. Journal of Applied Meteorology and Climatology 57: 1847–1863.

Caikoski, J. R. 2015. Units 25A, 25B, 25D, and 26C — Caribou. Chapter 15, Pages 15-1 through 15-24 *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, Alaska.

Caikoski, J. R. 2017. 2017 Photocensus of the Porcupine Caribou Herd. State of Alaska Memorandum, Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks, Alaska. 9 p.

Cameron, R. 1994. Distribution and productivity of the Central Arctic caribou herd in relation to petroleum development: case-history studies with a nutritional perspective. Research final report, Federal Aid in Wildlife Restoration Study 3.35. Alaska Department of Fish and Game, Juneau, Alaska. 35 p.

Cameron, R. D., D. J. Reed, J. R. Dau, and W. T. Smith. 1992. Redistribution of calving caribou in response to oil-field development on the Arctic Slope of Alaska. Arctic 45: 338–342.

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, Alaska.

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.

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 p.

Dau, J. R. 2015. Units 21D, 22A, 22B, 22C, 22D, 22E, 23, 24, and 26A — Caribou. Chapter 14, pages 14-1 through 14-89 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, Alaska.

Dau, J. R., and R. D. Cameron. 1986. Effects of a road system on caribou distribution during calving. Rangifer, Special Issue 1: 95–101.

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

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).

Johnson H. E., T. S. Golden, L. G. Adams, D. D. Gustine, and E. A. Lenart. 2020. Caribou Use of Habitat Near Energy Development in Arctic Alaska Journal of Wildlife Management. 84 401–12 Online: https://doi.org/10.1002/jwmg.21809

Johnson, H. E., D. D. Gustine, T. S. Golden, L. G. Adams, L. S. Parrett, E. A. Lenart, P. S. Barboza. 2018. NDVI exhibits mixed success in predicting spatiotemporal variation in caribou summer forage quality and quantity. Ecosphere 9: e02461.

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, Alaska Department of Fish and Game, Division of Wildlife Conservation (Northwest), Fairbanks, Alaska. 6 p.

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

Lawhead, B.E., L.C. Byrne, and C.B. Johnson. 1993. 1990 Endicott Environmental Monitoring Program Final Report: Caribou synthesis, 1987-1990. Prepared for U.S. Army Corps of Engineers, Alaska District, Anchorage, AK by Alaska Biological Research, Fairbanks, AK. Edited by Science Applications International Corporation, Anchorage, AK.

Lawhead, 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, Alaska. 59 p.

Lawhead, B. E., A. K. Prichard, M. J. Macander, and M. Emers. 2004. Caribou mitigation monitoring study for the Meltwater Project, 2003. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 104 p.

Lawhead, B. E., A. K. Prichard, M. J. Macander, and J. H. Welch. 2015a. Caribou monitoring study for the Alpine Satellite Development Program, 2014. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 100 p.

Lawhead, B. E., A. K. Prichard, and J. H. Welch. 2015b. Data report for Alpine pipeline caribou surveys, 2015. Report to ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 21 p.

Lenart, E. A. 2015a. 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, Alaska.

Lenart, E.A. 2015b. Units 26B and 26C — Muskox. Chapter 4, pp. 4-1 through 4-26 *in* P. Harper and L. A. McCarthy, editors. Muskox 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-2015-2, Juneau, Alaska.

Lenart, E. A. 2017. 2016 Central Arctic caribou photocensus results. State of Alaska Memorandum, Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks, Alaska. 5 p.

Lenart, E. A. 2019. 2019 Central Arctic caribou photocensus results. State of Alaska Memorandum. Alaska Department of Fish and Game, Division of Wildlife Conservation. Fairbanks, Alaska. 8 p.

LeResche, R. E., and S. A. Linderman. 1975. Caribou trail systems in northeastern Alaska. Arctic 28: 54–61.

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, California.

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: e0150333. doi:10.1371/journal.pone.0150333.

Noel, L. E., K. R. Parker, and M. A. Cronin. 2004. Caribou distribution near an oilfield road on Alaska's North Slope, 1978-–2001. Wildlife Society Bulletin 32: 757–771.

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. Alaska Department of Fish and Game, Juneau, Alaska.

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, Alaska.

Parrett, L. S. 2015b. Summary of Teshekpuk Caribou Herd photocensus conducted July 6, 2015. State of Alaska Memorandum, Alaska Department of Fish and Game, Division of Wildlife Conservation, Fairbanks, Alaska. 6 p.

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, L. E. Noel, and M. A. Cronin. 1996. Summer distribution of caribou, *Rangifer tarandus granti*, in the area of the Prudhoe Bay oil field, Alaska, 1990–1994. Canadian Field-Naturalist 110: 659–674.

Prichard, A. K., B. E. Lawhead, E. A. Lenart, and J. H. Welch. 2020a. Caribou distribution and movements in a northern Alaska oilfield. Journal of Wildlife Management. 84: 1483–1499.

Prichard, A.K., L.S. Parrett, E.A. Lenart, J. Caikoski, K. Joly, and B.T. Person. 2020b. Interchange and overlap among four adjacent Arctic caribou herds. Journal of Wildlife Management. 84: 1500–1514. https://doi.org/10.1002/jwmg.21934

Prichard, A. K., and J. H. Welch. 2020. Caribou use of the Greater Kuparuk Area, Northern Alaska, 2018–2019. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 43 p.

Prichard, A. K., J. H. Welch, and B. E. Lawhead. 2017. Mammal surveys in the Greater Kuparuk Area, northern Alaska, 2016. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 51 p.

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

Prichard, A. K., J. H. Welch, M. J. Macander, and B. E. Lawhead. 2019. Caribou Monitoring study for the Alpine Satellite Development Program and Greater Moose's Tooth Unit, 2018. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, Alaska. 78 p.

Reynolds, P. E., H. V. Reynolds, and R. A. Shideler. 2002. Predation and multiple kills of muskoxen by grizzly bears. Ursus 13: 79–84.

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 p.

Shideler, R., P. Reynolds, S. Arthur, E. Lenart, and T. Paragi. 2007. Decline of eastern North Slope muskoxen. The Alaskan Wildlifer, August 2007: 5–6.

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.

Wendler, G., B. Moore, and K. Galloway. 2014. Strong temperature increase and shrinking sea ice in Arctic Alaska. The Open Atmospheric Science Journal 8: 7–15.

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. Pp. 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.

Whitten, K. R., and R. D. Cameron. 1985. Distribution of calving caribou in relation to the Prudhoe Bay oil field. Pp. 35–39 *in* A. M. Martell and D. E. Russell, editors. Caribou and human activity: Proceedings of the 1st North American Caribou Workshop. Canadian Wildlife Service Publication, Ottawa, Ontario.

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. Proceedings of Park Science in the Arctic Symposium. Oct 14–16, 2008, Fairbanks, Alaska.

Appendix A. Snow depth (cm) and sum of thawing degree-days (TDD; ºC above freezing) at the Kuparuk airstrip, 1 April–15 June 1983–2020.

	Snow Depth (cm)			Sum of TDD (ºC)		
Year	April 1	May 15	May 31	May 1–15	May 16–31	June 1–15
1983	10	5	0	0	3.6	53.8
1984	18	15	0	0	0	55.6
1985	10	8	0	0	10.2	18.6
1986	33	20	10	0	0	5.0
1987	15	8	3	0	0.6	6.7
1988	10	5	5	0	0	16.6
1989	33	–	10 [a]	0	5.6	20.5
1990	8	3	0	0	16.1	39.7
1991	23	8	3	0	7.8	14.4
1992	13	8	0	0.3	20.3	55.1
1993	13	5	0	0	8.6	33.6
1994	20	18	8	0	4.4	49.3
1995	18	5	0	0	1.1	59.5
1996	23	5	0	8.1	41.7	86.1
1997	28	18	8	0	20.8	36.1
1998	25	8	0	3.6	45.8	74.2
1999	28	15	10	0	1.4	30.3
2000	30	23	13	0	0	36.6
2001	23	30	5	0	0.8	51.8
2002	30	trace	0	4.2	30.2	57.7
2003	28	13	trace	0	10.8	23.6
2004	36	10	5	0	9.0	26.3
2005	23	13	0	0	2.4	14.0
2006	23	5	0	0	23.3	93.4
2007	25	46	5	0	0	46.6
2008	20	18	0	0	32.8	71.7
2009	36	13	0	0	16.8	71.8
2010	41	43	13	0	1.4	53.4
2011	25	18	0	0	28.0	12.4
2012	48	53	2	0	1.7	26.8
2013	33	18	2	0	4.2	79.2
2014	33	0 [b]	0 [b]	11.1	4.2	28.6
2015	38	18	0	1.4	46.4	78.1
2016	25	0	0	15.6	12.4	63.7
2017	36	14	0	0	12.1	5.2
2018	40.6	20.3	15.2	1.4	0	6.6
2019	22.9	12.7	0	1.1	11.9	31.1
2020	25.4	4.0	0	0.3	7.8	48.9
Mean	25.5	14.2	3.1	1.2	11.7	41.6

[a] Value for 1 June.

[b] Kuparuk airstrip station reported no snow after 8 May 2014, whereas other weather stations nearby reported snow until 31 May and patchy snow was present in the GKA survey areas into early June. Therefore, if accurate, the airport information was not representative of the study area.

Appendix B. Sum of thawing degree-days (ºC above freezing) at the Kuparuk airstrip during five periods of the insect season, mid-June through August 1983–2020.

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
2019	108.5	180.3	181.3	118.0	85.6	673.7
2020	90.7	82.3	112.6	128.4	101.1	515.1
Mean	101.8	128.2	144.9	125.1	80.9	581.0

[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).

Appendix C. Average index values of mosquito activity[a] (adapted from Russell et al. 1993) during June–August 1983–2020, based on daily maximum temperatures at the Kuparuk airstrip.

	June			July			August		
Year	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0.28	0.31	0.30	0.28	0.42	0.35	0.43	0.15	0.29
1984	0.26	0.37	0.31	0.60	0.68	0.64	0.46	0.20	0.33
1985	0.08	0.48	0.28	0.42	0.45	0.44	0.52	0.31	0.42
1986	0.01	0.46	0.24	0.62	0.54	0.58	0.53	0.21	0.37
1987	0	0.22	0.11	0.52	0.47	0.49	0.33	0.42	0.38
1988	0.04	0.32	0.18	0.50	0.64	0.57	0.73	0.19	0.46
1989	0.01	0.58	0.29	0.90	0.74	0.82	0.84	0.59	0.72
1990	0.17	0.69	0.43	0.68	0.62	0.65	0.30	0.21	0.25
1991	0.01	0.58	0.30	0.35	0.48	0.42	0.27	0.27	0.27
1992	0.29	0.36	0.33	0.49	0.77	0.63	0.48	0.42	0.45
1993	0.13	0.42	0.28	0.80	0.66	0.73	0.37	0.26	0.32
1994	0.23	0.18	0.21	0.73	0.77	0.75	0.97	0.37	0.67
1995	0.28	0.36	0.32	0.83	0.35	0.59	0.30	0.36	0.33
1996	0.44	0.54	0.49	0.72	0.69	0.70	0.46	0.14	0.30
1997	0.07	0.50	0.28	0.41	0.82	0.62	0.84	0.33	0.58
1998	0.30	0.55	0.43	0.72	0.81	0.76	0.70	0.46	0.58
1999	0.11	0.28	0.19	0.84	0.29	0.56	0.82	0.20	0.51
2000	0.11	0.82	0.47	0.50	0.47	0.49	0.59	0.27	0.43
2001	0.25	0.33	0.29	0.32	0.75	0.54	0.60	0.05	0.32
2002	0.25	0.30	0.28	0.43	0.61	0.52	0.40	0.36	0.38
2003	0.10	0.39	0.24	0.65	0.58	0.62	0.45	0.09	0.27
2004	0.04	0.89	0.47	0.72	0.65	0.68	0.70	0.44	0.57
2005	0.01	0.34	0.18	0.29	0.28	0.28	0.82	0.11	0.46
2006	0.49	0.73	0.61	0.33	0.81	0.57	0.50	0.06	0.28
2007	0.14	0.38	0.26	0.56	0.55	0.56	0.60	0.41	0.51
2008	0.31	0.71	0.51	0.85	0.59	0.72	0.22	0.22	0.22
2009	0.32	0.11	0.22	0.60	0.53	0.56	0.56	0.36	0.46
2010	0.22	0.14	0.18	0.56	0.74	0.65	0.61	0.43	0.52
2011[b]	0.05	0.48	0.27	0.54	0.71	0.63	0.61	0.28	0.44
2012[b]	0.07	0.64	0.35	0.67	0.80	0.73	0.67	0.67	0.67
2013	0.40	0.72	0.56	0.50	0.83	0.66	0.82	0.13	0.48
2014	0.11	0.35	0.23	0.61	0.33	0.47	0.14	0.52	0.33
2015	0.43	0.87	0.65	0.52	0.34	0.43	0.47	0.16	0.31
2016	0.30	0.70	0.50	0.77	0.55	0.66	0.37	0.60	0.49
2017	0.01	0.55	0.28	0.71	0.76	0.72	0.65	0.16	0.45
2018	0	0.14	0.07	0.62	0.79	0.71	0.15	0.19	0.17
2019	0.12	0.49	0.31	0.85	0.81	0.83	0.45	0.19	0.32
2020	0.24	0.42	0.33	0.33	0.40	0.37	0.54	0.37	0.46
Mean	0.18	0.47	0.32	0.59	0.61	0.60	0.53	0.29	0.41

[a] Average Mosquito Index: if daily maximum temperature <6 °C, then index = 0; if daily maximum temperature >18 °C, then index = 1; otherwise, index = 1 – [(18 – daily maximum temperature)/13].

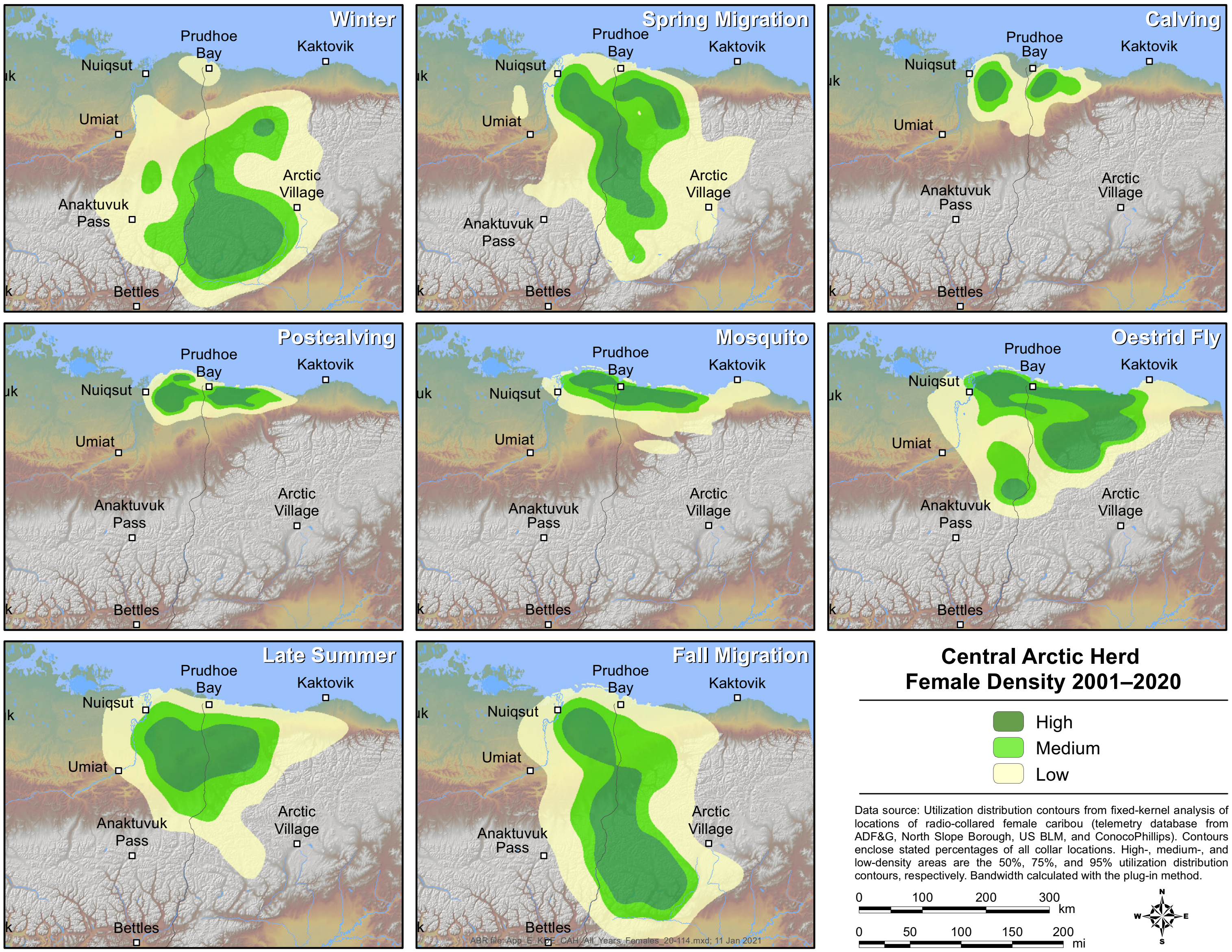
[b] Index values for late June through August were estimated by averaging data from Deadhorse and Nuiqsut while Kuparuk airstrip was closed for paving (Lawhead et al. 2013).

Appendix D. Average index values of oestrid fly activity[a] (adapted from Russell et al. 1993) during June–August 1983–2020, based on daily maximum temperatures at the Kuparuk airstrip.

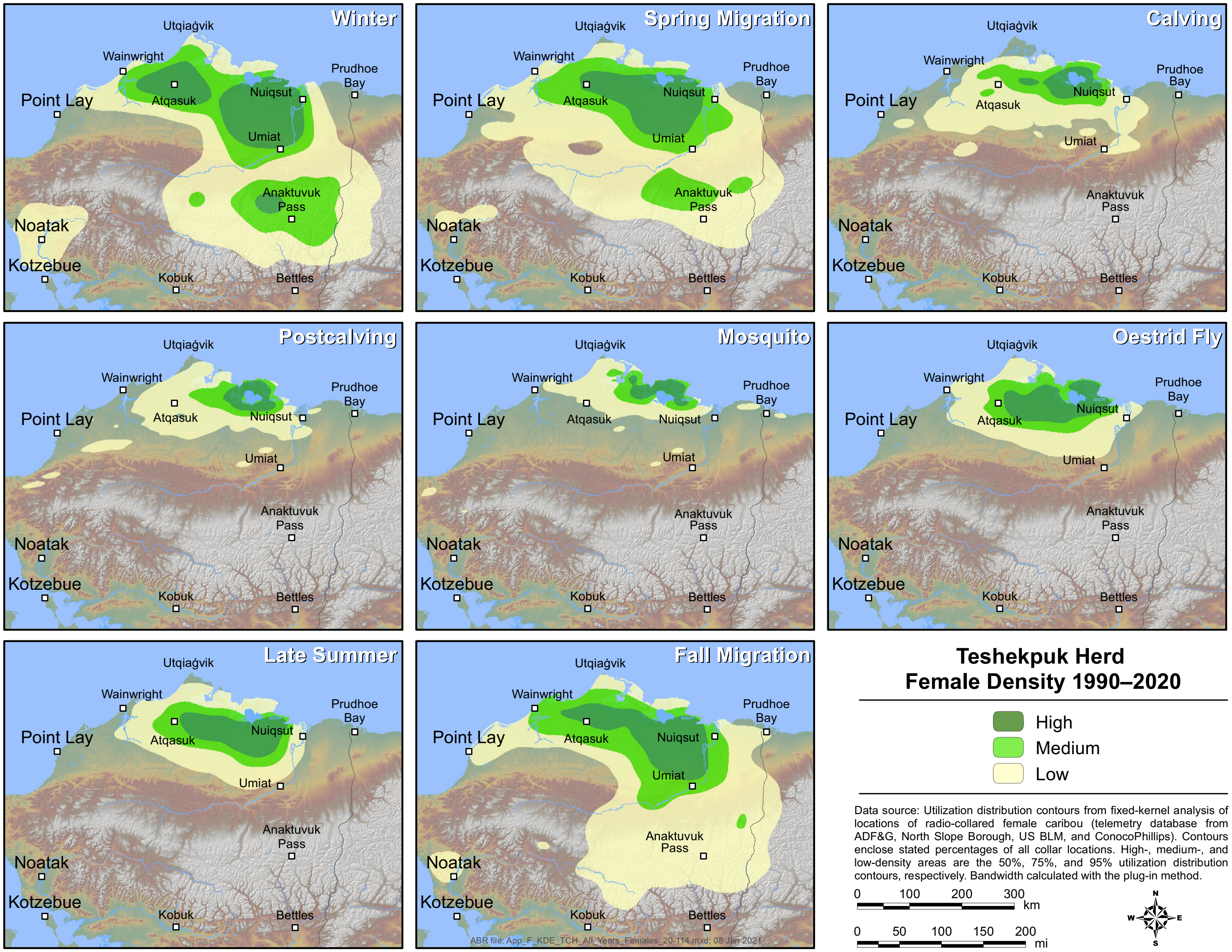
Year	June			July			August		
	Early	Late	Total	Early	Late	Total	Early	Late	Total
1983	0	0.10	0.05	0	0.30	0.16	0.08	0	0.04
1984	0.03	0.13	0.08	0.25	0.50	0.38	0.21	0.03	0.12
1985	0.01	0.16	0.08	0.24	0.23	0.24	0.26	0.15	0.20
1986	0	0.26	0.13	0.40	0.20	0.29	0.23	0.01	0.12
1987	0	<0.01	<0.01	0.22	0.25	0.24	0.01	0.10	0.06
1988	0	0.03	0.01	0.19	0.30	0.25	0.47	0.12	0.29
1989	0	0.32	0.16	0.80	0.59	0.69	0.69	0.40	0.54
1990	0	0.41	0.20	0.60	0.44	0.52	<0.01	0.02	0.01
1991	0	0.41	0.20	0.17	0.25	0.21	0.09	0.09	0.09
1992	0.15	0.09	0.12	0.27	0.55	0.42	0.26	0.18	0.22
1993	0	0.32	0.16	0.61	0.31	0.46	0.19	0.11	0.15
1994	<0.01	0.09	0.04	0.46	0.66	0.56	0.93	0.15	0.52
1995	0.09	0.09	0.09	0.62	0.24	0.42	0.06	0.13	0.09
1996	0.28	0.44	0.36	0.54	0.51	0.53	0.26	0	0.12
1997	0	0.23	0.12	0.31	0.61	0.47	0.64	0.08	0.35
1998	0.06	0.40	0.23	0.40	0.56	0.48	0.39	0.15	0.27
1999	0	0.01	<0.01	0.64	0.14	0.38	0.54	0.03	0.28
2000	0.02	0.68	0.35	0.28	0.27	0.27	0.38	0.15	0.26
2001	0.17	0.05	0.11	0.19	0.55	0.37	0.26	0	0.13
2002	0.10	0.15	0.12	0.13	0.37	0.25	0.25	0.14	0.19
2003	0	0.16	0.08	0.27	0.39	0.33	0.29	0	0.14
2004	0	0.75	0.38	0.50	0.41	0.45	0.59	0.27	0.42
2005	0	0.21	0.10	0.02	0	0.01	0.71	0	0.34
2006	0.34	0.58	0.46	0.11	0.65	0.39	0.16	<0.01	0.08
2007	0	0.17	0.08	0.27	0.18	0.22	0.27	0.01	0.14
2008	0.09	0.42	0.26	0.61	0.38	0.49	0	0	0
2009	0.06	<0.01	0.03	0.26	0.30	0.28	0.39	0.18	0.28
2010	0.05	0	0.03	0.29	0.47	0.38	0.51	0.13	0.31
2011[b]	0.03	0.22	0.13	0.17	0.39	0.29	0.29	0.01	0.15
2012[b]	0.01	0.42	0.22	0.35	0.61	0.48	0.30	0.47	0.39
2013	0.22	0.45	0.34	0.24	0.62	0.44	0.73	0.01	0.36
2014	0	0.21	0.11	0.24	0.14	0.19	0	0.28	0.14
2015	0.25	0.71	0.48	0.38	0.11	0.24	0.14	0.05	0.09
2016	0.18	0.50	0.34	0.51	0.36	0.43	0.20	0.43	0.32
2017	0	0.32	0.16	0.50	0.50	0.50	0.50	0	0.20
2018	0	0	0	0.47	0.58	0.53	0	0	0
2019	0	0.18	0.09	0.68	0.52	0.60	0.11	0	0.06
2020	0.10	0.21	0.16	0.00	0.15	0.08	0.23	0.13	0.18
Mean	0.06	0.26	0.16	0.35	0.38	0.37	0.31	0.11	0.20

[a] Average Fly Index: if daily maximum temperature <13 °C, then index = 0; if daily maximum temperature >18 °C, then index = 1; otherwise, index = 1 – [(18 – daily maximum temperature)/5].

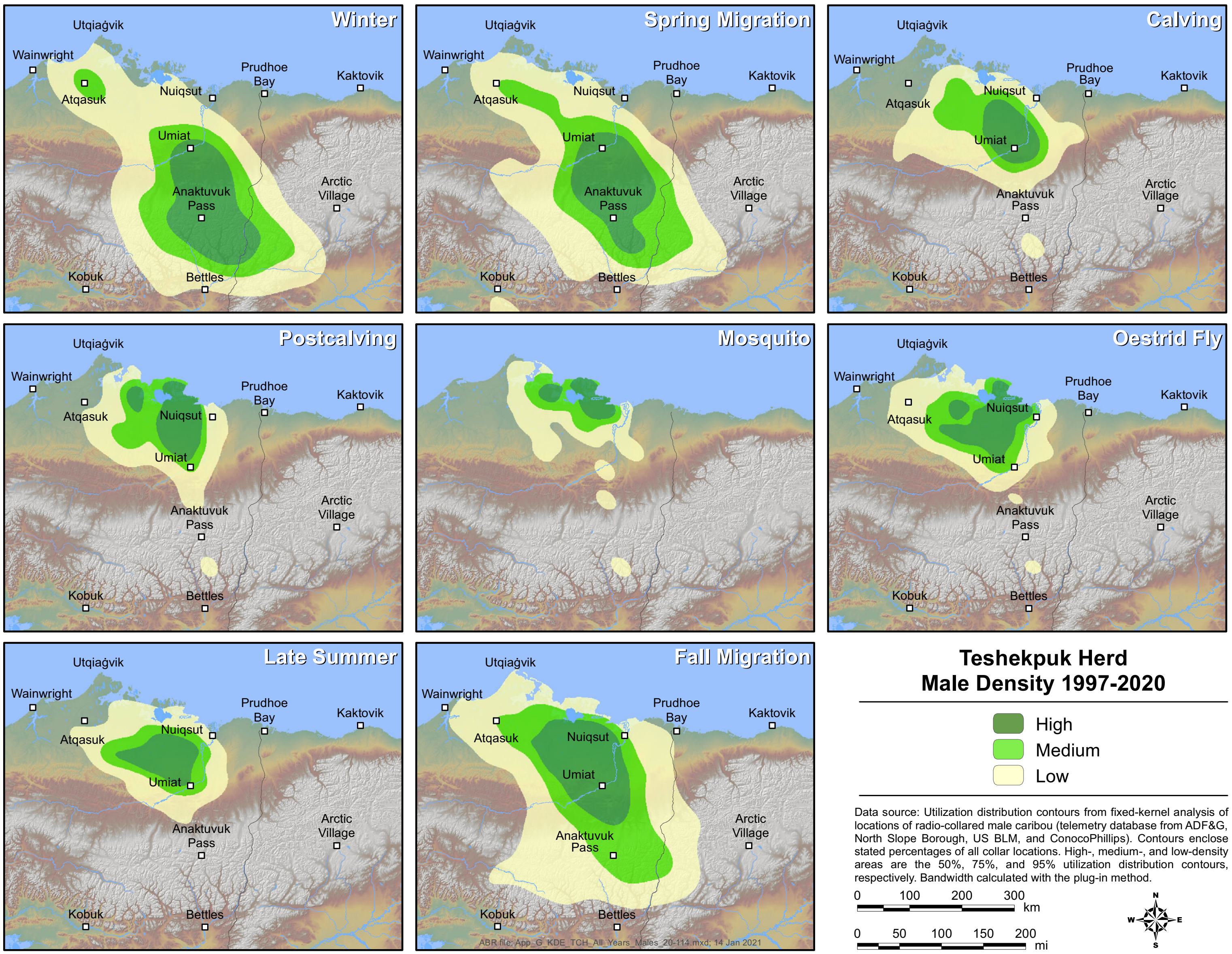
[b] Values for late June through August were estimated by averaging values from Deadhorse and Nuiqsut while Kuparuk airstrip was closed for paving (Lawhead et al. 2013).



Appendix E. Kernel Density Estimates of seasonal distribution of female caribou from the Central Arctic Herd.



Appendix F. Kernel Density Estimates of seasonal distribution of female caribou from the Teshekpuk Caribou Herd.



Appendix G. Kernel Density Estimates of seasonal distribution of male caribou from the Teshekpuk Caribou Herd.