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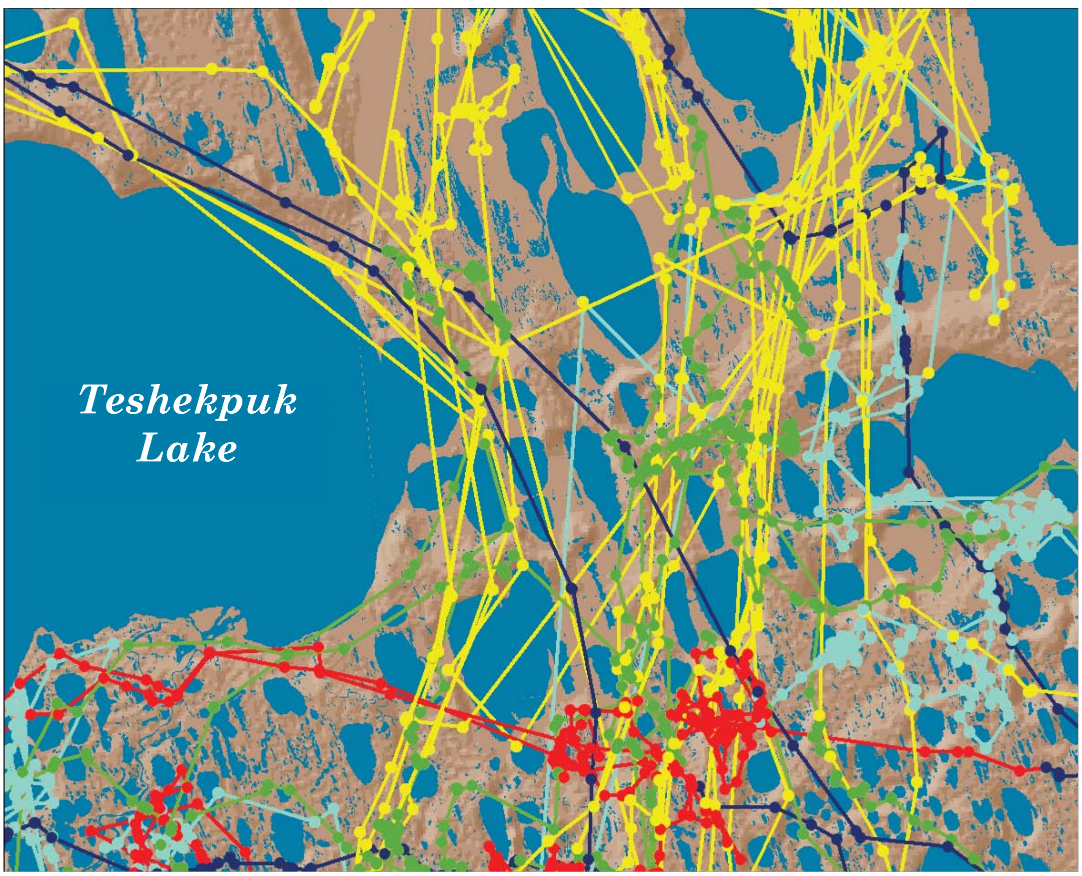
Caribou Use of Narrow Land Corridors around Teshekpuk Lake, Alaska

Dave Yokel, Alex Prichard, Geoff Carroll, Lincoln Parrett, Brian Person, and Caryn Rea



Alaska

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Cover Illustration

Movements of caribou outfitted with GPS collars around Teshekpuk Lake in 2004 and 2005 (see Figure 6, page 10).

Authors

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Abstract

We used 17 years of satellite- and GPS-collar location data to investigate how 2 narrow land areas constricted movement of the Teshekpuk Caribou Herd around Teshekpuk Lake in northern Alaska. In the future, the oil industry may build pipelines in one or both of these constricted zones, identified as the Smith Area (northwest of the lake) and the Kogru Area (east of the lake). To mitigate impacts of pipelines on caribou movements, we need pre-development movement data to understand how caribou use these corridors in the absence of pipelines. Caribou used the areas most extensively during summer, especially in early July, when at least 73% of collared caribou accessed the area north of the lake through one or both narrow corridors. The proportion of collared caribou was consistently higher in the Kogru Area than in the Smith Area. A slightly higher proportion of caribou moved north across the Smith Area than moved south, while a higher proportion moved south across the Kogru Area than moved north. This resulted in a tendency for a clockwise movement around the lake. Weather patterns and caribou behavior during mosquito season may explain this pattern. The proportion of satellite-collared caribou moving across the constricted zones varied widely among years—from 14% to 83% for the Smith Area and from 17% to 77% for the Kogru Area. Caribou movements were slowest in June and most rapid in July, when caribou movements were also more rapid in the constricted zones than on either side of them. Although GPS-collar data provide more extensive and accurate information than satellite-collar data, some of the trends observed from GPS-collar data in this study were relatively weak due to the small sample size. The BLM needs to stay engaged in the collection of those data and require an updated analysis before approving any future pipelines through one or both constricted zones.

Acknowledgements

In addition to the authors, many biologists, pilots, and high school students have helped with annual collaring operations over the 17 years of data collection. Attempting to list all of them here would inevitably result in some omissions. Likewise, many additional people from the authors' agencies or corporations have contributed to project planning and implementation, funding, data administration and analysis, and publications. We express our gratitude to all.

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Introduction

Caribou (*Rangifer tarandus*) of the Teshekpuk Caribou Herd (TCH) calve near Teshekpuk Lake in northern Alaska (Carroll et al. 2005; Parrett 2007; Person et al. 2007). To the north of Teshekpuk Lake is an isthmus approximately 40 mi (60 km) long and 20 mi (30 km) wide between the lake and the Beaufort Sea. On both the eastern and western sides of the lake, narrow corridors of land extend from the lake to the sea coast. These corridors create constricted zones through which caribou must pass to access the area north of Teshekpuk Lake (Figure 1). On the western side of Teshekpuk Lake is a constricted zone about 7 mi (11 km) wide between the lake and Smith Bay (hereafter designated as the Smith Area). On the eastern side of Teshekpuk Lake is a constricted zone about 8 mi (13 km) wide between the lake and the Kogru River (hereafter designated as the Kogru Area). On warm, calm days in late June, July, and early August, mosquito harassment of TCH caribou can be severe. A large proportion of the TCH use the area north of Teshekpuk Lake for mosquito relief during these periods (Prichard and Murphy 2004; Parrett 2007; Person et al. 2007), when the proximity of the Beaufort Sea and Teshekpuk Lake generally keeps temperatures lower and wind speeds higher than in areas farther inland (Parrett 2007). Thus, caribou heavily use the constricted zones on either side of Teshekpuk Lake during midsummer as they travel to and from mosquito-relief habitat north of the lake (Person et al. 2007).

As early as 2018, the Bureau of Land Management (BLM) may hold oil and gas lease sales for the area north of Teshekpuk Lake (USDOI BLM 2008). Any subsequent development would include pipelines transporting products to market through the constricted zones. Pipelines have the potential to impede or deflect caribou movements (Lawhead et al. 2006). If caribou were unable to achieve an optimal spatial and temporal pattern of insect avoidance, the negative impact on caribou energy balance could lower the ability of females to bear calves the following year (Murphy and Lawhead 2000). Baseline data on constricted zone use by caribou will be crucial for mitigating impacts through effective planning for potential oil development and testing the efficacy of mitigations following development.

Methods

Satellite Collars

We analyzed existing telemetry data to better understand caribou distributions and movements in the vicinity of Teshekpuk Lake. Over a 17-year period (1990–2007), we outfitted a total of 102 caribou (81 females, 21 males) with satellite collars (Platform Transmitter Terminals; Service ARGOS 1988) as part of a cooperative program between the BLM, the North Slope Borough (NSB), and the Alaska Department of Fish and Game (Philo et al. 1993; Person et al. 2007). Data from TCH caribou fitted with satellite collars were obtained for the period July 1990–August 2007. Collars on marked caribou transmitted signals for a mean duration of 526 days per collar. A few caribou moved between herds after collaring; 4 female TCH animals joined the Central Arctic herd and 5 TCH animals, 1 male and 4 females, joined the Western Arctic herd (Person et al. 2007). We assumed a caribou to have switched herds if it was in the calving area of another herd during a subsequent calving season. We included only locations from TCH caribou in this analysis.

Polar-orbiting satellites received TCH collar locations from satellite collars and transmitted them through Command and Acquisition Stations to data-processing centers operated by Service Argos (Landover, Maryland), which forwarded them monthly to the North Slope Borough for data archiving. In 1990–1991, we programmed TCH satellite transmitters to transmit 6 h/day for a month after deployment, then 6 h/2 days for 11 months. During 1991–2002, we programmed most collars to transmit 6 h/2 days throughout the year. After 2002, we had most collars programmed to transmit once every 6 days in winter and every other day during summer. Most of the TCH collars deployed in 2000 malfunctioned and transmitted data only sporadically.

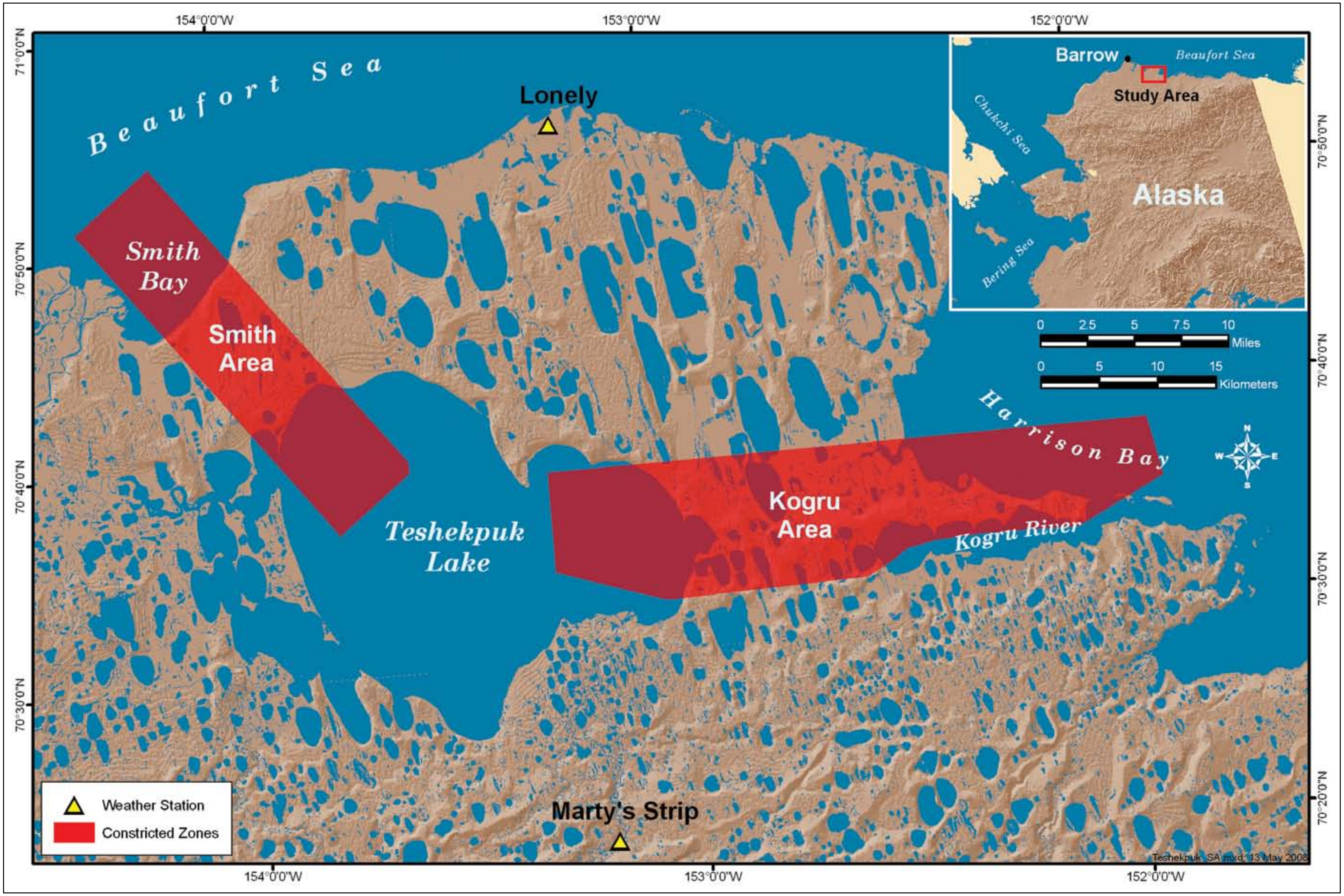

Figure 1. The study area, showing the locations of the 2 constricted zones around Teshekpuk Lake, Alaska, and 2 weather stations recording temperature and wind speed during summer 2004.

Although satellite-telemetry locations are considered accurate to within 0.3–0.6 mi (0.5–1 km) of the true locations (Service Argos 1988), the data also require screening to remove spurious locations. Using the method of Prichard and Murphy (2004), we screened data to remove 1) duplicate locations, 2) locations obtained before collaring or after mortality or collar removal occurred, and 3) locations for which the Argos-designated location-quality score (NQ) had a score of zero or "B", indicating unreliability (Service Argos 1988). NQ scores of "A" tend to be more accurate than scores of zero (Hays et al. 2001; Vincent et al. 2002), so they were retained. We removed locations that obviously were inaccurate because they were far offshore or far from other locations. We applied a distance/rate/angle (DRA) filter to remove locations that appeared to be incorrect based on the distance and rate of travel between subsequent points and the angle formed by 3 consecutive points. Any 3 locations with an intervening angle of <20 degrees where both "legs" had speeds greater than 6 mi/h (10 km/h) were assumed to be inaccurate and were removed, unless the distance of either leg was less than 0.6 mi (1 km) (Prichard and Murphy 2004). If the distance of any leg was <0.6 mi (<1 km), then we did not remove the location because it was close to a previous or subsequent location and, therefore, likely to be accurate.

We selected the location with the highest NQ score during each duty cycle, defined as a period of transmission of location data (typically 6 h/2 days), for further analyses. If multiple records in a duty cycle were tied for the highest NQ score, we chose the location with both the highest NQ score and the lowest value of epsilon (ε; Keating 1994). Epsilon is similar to our DRA filter, because it is calculated using 3 successive locations and is a measure of the distance between locations, the angle formed by the 3 locations, and the similarity of length between the 2 legs (Keating 1994).

Because satellite-collar data have low spatial accuracy and temporal resolution (relative to GPS collars, see below), we did not consider these data adequate for determining specific caribou movement paths used to traverse the constricted zones or movement rates between locations. Such data, however, do provide accurate information on timing of use of the areas as well as movements through these zones. In the case of our dataset, they also provide a large enough sample size to account for variation among years. To determine the proportion of caribou using the constricted zones and the area north of Teshekpuk Lake, we analyzed caribou point locations and determined which caribou movements crossed each constricted zone, as depicted in Figure 1, and recorded the direction of movement (north-to-south or south-to-north). We determined the proportion of collared caribou using the constricted zones during each of 24 half-month time periods (e.g., 1–15 January, 16–31 January, 1–15 February, etc.). Because we captured and collared most caribou in the vicinity of Teshekpuk Lake, we screened out locations within 30 days of capture. In this way, we eliminated potential bias that could have occurred from a preponderance of movement rates for caribou close to the sites where we chose to capture and collar them. We included only those animals that had 6 or more locations within each time period to ensure that we had a good record of an animal's movement for that period (Person et al. 2007).

GPS Collars

In recent years (2004 and 2006) we fitted some TCH caribou with geospatial positioning system (GPS) collars, which provide more frequent locations (a location every 2 or 3 hours throughout the entire year) with increased accuracy.

We fitted 10 female caribou from the TCH with GPS collars in July 2004 (collar model: Telonics [Mesa, AZ] TGW-3680 GEN 3; store-on-board configuration with Argos satellite uplink). We recaptured these animals and removed the collars in July 2005. All 10 caribou survived for the entire period; 7 had calves in 2005, 2 did not, and 1 had a calf that died soon after birth. The GPS collars recorded locations every 3 hours.

We fitted 12 female caribou from the TCH with GPS collars (also Telonics model TGW-3680) during 8–10 July 2006. The sample of collared female caribou comprised 7 adults aged 3 years or more, 3 two-year-olds, and 2 yearlings. These collars were programmed to record locations every 2 hours. Two caribou died in spring 2007 (1 in March and 1 in May), and we retrieved the other 10 collars in late June 2007.

We analyzed the movements of these 22 female caribou to determine how often caribou traveled through the 2 constricted zones on either side of Teshekpuk Lake. As with the satellite data, we screened the GPS data to remove any locations obtained before collaring or after collars were removed or mortality occurred, as well as any locations that obviously were incorrect because they were far offshore or far from previous and subsequent locations. We also used a distance/rate/angle filter, described above, to screen out erroneous locations. The high spatial and temporal resolution of these data provided relatively accurate estimates of the movement paths of caribou using the corridors.

We calculated movement rates by dividing the straight-line distance between consecutive locations by the time difference between locations. To calculate the average movement rate for caribou traveling through a constricted zone, we calculated the average movement rate of all caribou segments while the caribou was in the constricted zone. Because calculations of movement rates are sensitive to the duration of time between locations (i.e., the fix interval), we increased movement rates estimated from locations with a 3-h fix interval by 5.6% to make them approximately comparable to movement rates calculated from locations with a 2-h fix interval. We based this adjustment on an analysis of the change in movement rate estimates with fix interval conducted with this data set (Prichard 2008).

We compared movement rates during July with a 2-factor ANOVA model with year (2004 or 2006) and area (Kogru Area, Smith Area, or North of Teshekpuk Lake) as factors and natural logarithm of movement rate as the dependent variable. Only movement rates 2 or 3 h apart were included in the analysis. We conducted post-hoc comparisons and corrected for multiple comparisons with a Bonferroni joint estimation procedure (Neter et al. 1990). We calculated the proportion of July caribou movements falling into each of 5 movement rate categories (0–83, 84–330, 331–821, 822–3300, >3300 ft/h; 0–25, 26–100, 101–250, 251–1000, >1000 m/h) for all movements in each of 4 areas (Kogru Area, Smith Area, North of Teshekpuk Lake, and all other locations in the study area).

Weather Data

Parrett (2007) collected temperatures and wind speeds for 2 locations near Teshekpuk Lake during summer 2004 (Figure 1). The Marty's Strip weather station was located approximately 9 mi (15 km) south of Teshekpuk Lake (lat 70.358°N, long 153.206°W), and the Lonely weather station was located on the Beaufort Sea coast directly north of Teshekpuk Lake (lat 70.910°N, long 153.215°W). Additional weather information was collected from the NOAA Earth System Research Laboratory at Barrow, Alaska (lat 71.323°N, long 156.611°W).

Results

Satellite Collars

Caribou outfitted with satellite collars frequently used the constricted zones on either side of Teshekpuk Lake during midsummer (Figure 2). Based on satellite-collar locations, the estimated proportion of collared caribou with at least one location per half-month time period in the area north of Teshekpuk Lake peaked at 73% during early July (Figure 3). This proportion dropped sharply during other periods; little use of the area occurred outside the summer months. The proportion of collared caribou in the Kogru Area was consistently higher than the proportion in the Smith Area. A similar pattern was observed for the proportion of satellite-collared caribou traversing constricted zones (Figure 4). An estimated 38% and 50% of satellite-collared caribou crossed the Smith Area and Kogru Area, respectively, during early July. A slightly higher proportion of caribou moved north across the Smith Area than moved south. In contrast, a higher proportion moved south across the Kogru Area than moved north.

The proportion of satellite-collared caribou

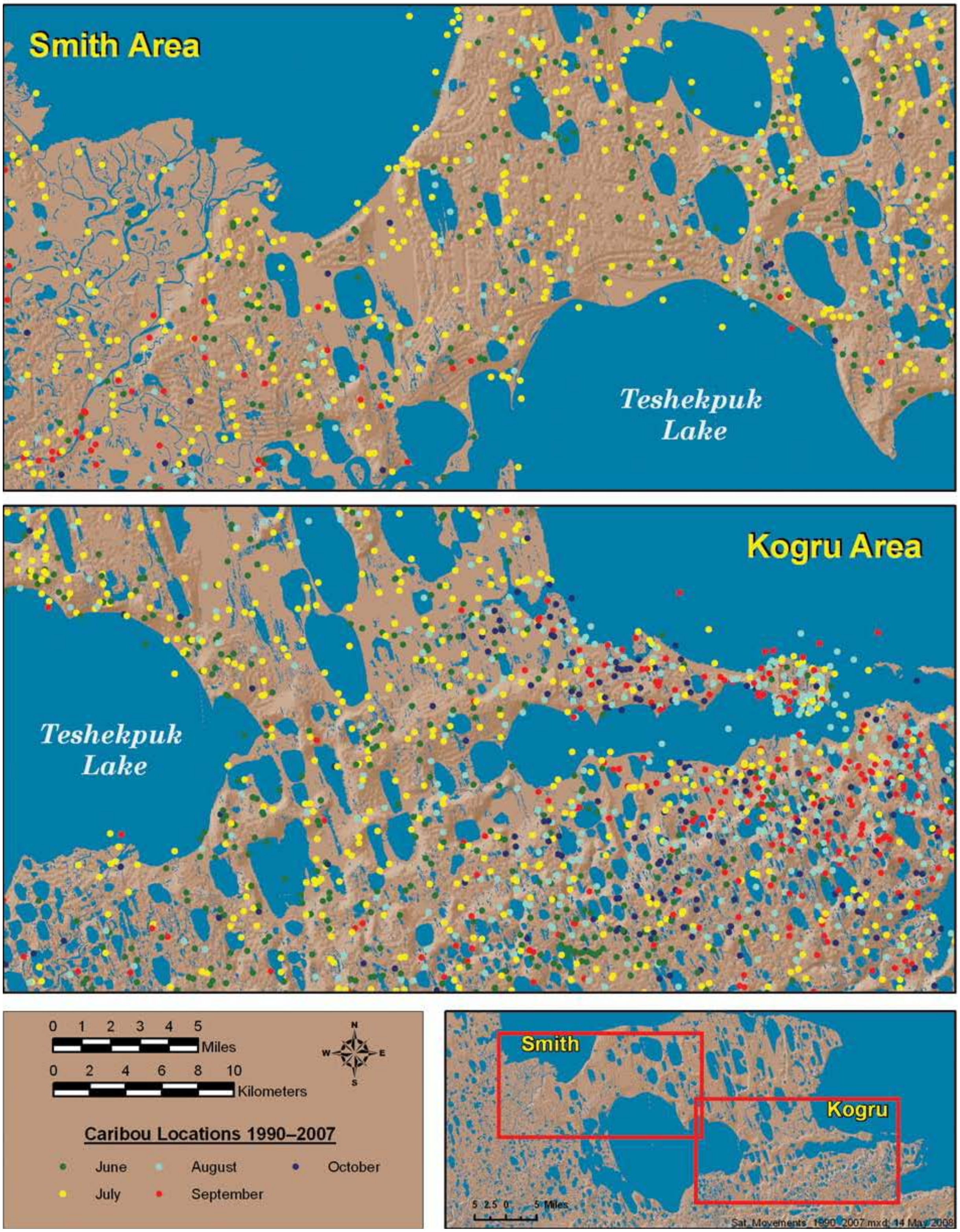

Figure 2. The locations of 102 caribou outfitted with satellite collars around the 2 constricted zones near Teshekpuk Lake, Alaska, 1990–2007.

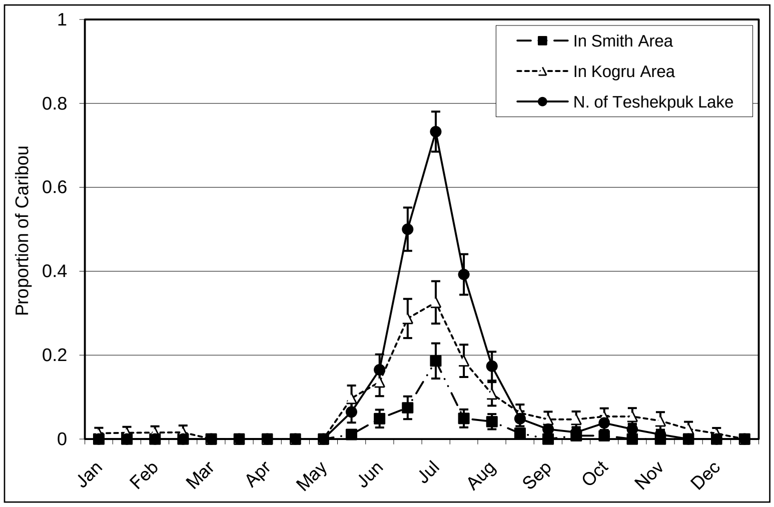

Figure 3. The mean proportion (±1 standard error) of satellite-collared caribou with at least one location in constricted zones or north of Teshekpuk Lake, Alaska, during each of 24 two-week time periods per year, 1990–2007.

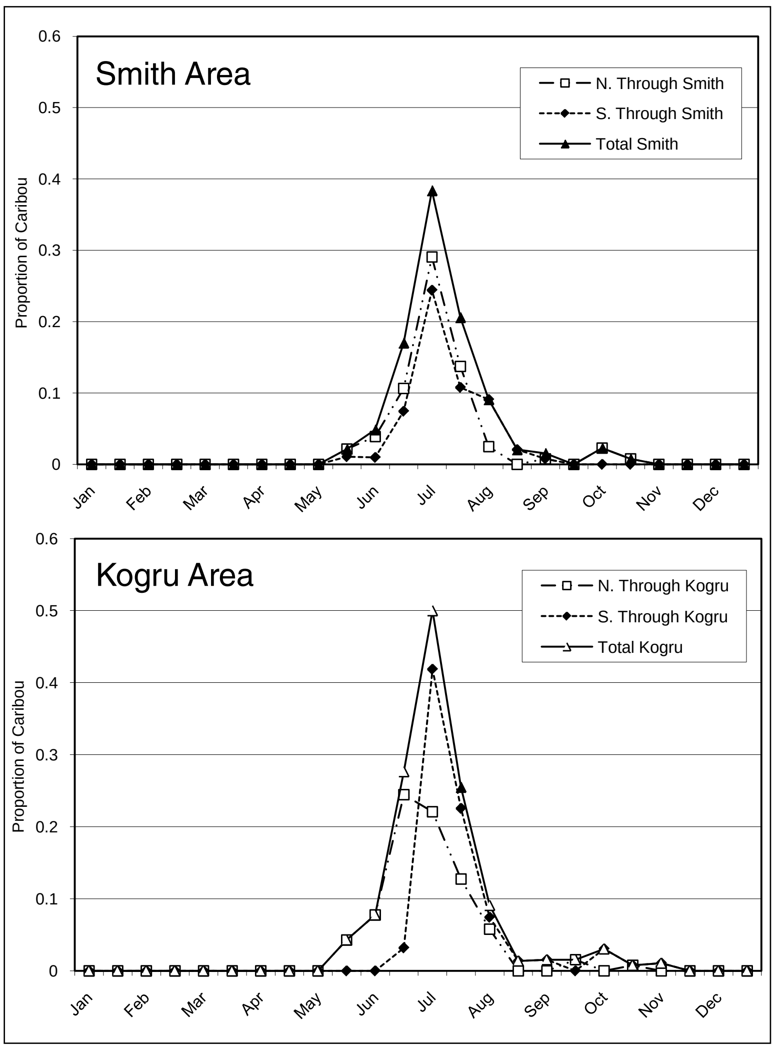

Figure 4. The mean proportion of satellite-collared caribou crossing each constricted zone near Teshekpuk Lake, Alaska, by direction of travel and total, during each of 24 two-week time periods per year, 1990–2007.

moving across the constricted zones varied widely among years (Figure 5). The estimated percentage of caribou crossing the zones ranged from 14% to 83% for the Smith Area and from 17% to 77% for the Kogru Area. The proportion crossing the 2 different constricted zones within a year were not correlated ($R = 0.564$, $P = 0.114$).

These analyses of satellite-collared caribou were limited by the frequency of satellite locations acquisition, generally 1 location every 2 days during the summer, and by missing locations. Some movements across constricted zones may have been missed if they were of limited duration.

GPS Collars

Caribou outfitted with GPS collars frequently used the constricted zones on either side of Teshekpuk Lake during midsummer, especially during 2004 (Tables 1 and 2; Figures 6 and 7). In July 2004, all 10 GPS-collared caribou moved from north of the lake southward through the Kogru Area, some of them multiple times (Table 1). All 10 caribou had been captured north of Teshekpuk Lake in early July. Eight of the caribou made a circular, clockwise movement around Teshekpuk Lake, moving south through the Kogru Area from 6 to 8 July, north through the Smith Area from 20 to 22 July, and then south again through the Kogru Area on 27 July. The remaining 2 collared caribou also moved south through the Kogru area on 27 July.

The apparent reasons for these movement patterns are supported by weather observations in July 2004 (Figure 8). Barrow, which is exposed to both the Chukchi and Beaufort seas, generally has cooler temperatures and higher wind speeds than Lonely, the coastal site north of Teshekpuk Lake. The Lonely site, in turn, is generally cooler than our inland site, Marty's Strip. In 2004, high temperatures were measured in Barrow during the first few days of July. During this period caribou moved to the area north of Teshekpuk Lake where that year's GPS-collaring operations occurred. The weather was cooler from 6 to 8 July, when 8 of 10 GPS-collared caribou moved south through the Kogru Area, and conditions generally remained cooler (albeit with some brief, intra-day spikes) and also windier until 20 July. During that period, the 8 caribou that had moved south through the Kogru Area from 6 to 8 July remained inland and drifted west past the Ikpikpuk River. This cooler period was followed by a sustained period of warm weather with less wind from about 21 to 26 July, with temperatures somewhat cooler (but still high) at Lonely than at Marty's Strip. During this warmer period, caribou again moved north of Teshekpuk Lake, this time through the Smith Area. After temperatures dropped considerably and wind speed increased on 27 July, all

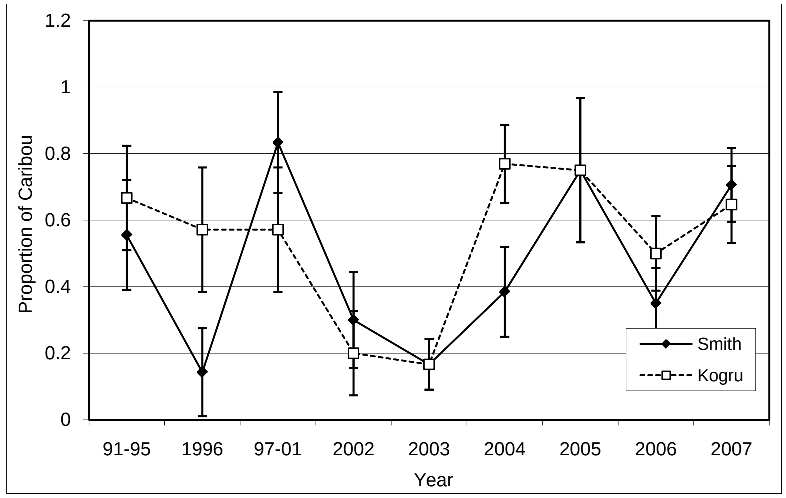

Figure 5. The mean proportion (±1 standard error) of satellite-collared caribou crossing each of the 2 constricted zones near Teshekpuk Lake, Alaska, during July, 1991–2007. Some years were grouped together due to small sample sizes.

Table 1. Number of times (number of individual caribou) GPS-collared caribou entered constricted zones near Teshekpuk Lake, Alaska, by year, month, and movement direction. No caribou entered the constricted zones during November–May of any year. Ten caribou were collared from early July 2004 to early July 2005, 12 caribou were collared from early July 2006 to late June 2007, and 2 collared caribou died in spring 2007.

			Kogru Area				Smith Area			
Year	Month	# Caribou	S to S[a]	S to N[b]	N to N[c]	N to S[d]	S to S	S to N	N to N	N to S
2004	July	10	0	2 (2)	7 (4)	19 (10)	2 (2)	7 (7)	0	0
	August	10	3 (1)	1 (1)	0	1 (1)	0	0	0	0
	September	10	0	0	0	0	0	2 (2)	0	0
	October	10	0	0	0	3 (3)	0	1 (1)	0	0
2005	June	10	3 (3)	1 (1)	0	1 (1)	0	0	0	0
2006	July	12	8 (5)	6 (5)	3 (2)	3 (3)	0	3 (3)	2 (2)	4 (4)
	August	12	0	0	0	2 (2)	0	0	0	0
	September	12	0	0	0	0	0	0	0	0
	October	12	0	0	0	0	0	0	0	0
2007	June	10	0	2 (2)	2 (1)	0	0	0	0	0

[a] South to South = caribou entered constricted zone from the south and exited to the south.
[b] South to North = caribou entered constricted zone from the south and exited to the north.
[c] North to North = caribou entered constricted zone from the north and exited to the north.
[d] North to South = caribou entered constricted zone from the north and exited to the south.

Table 2. Number of GPS-collared caribou entering the constricted zones on either side of Teshekpuk Lake, Alaska, 2004–2007.

	Kogru Area				Smith Area			
Date[a]	**S to S[b]**	**S to N[c]**	**N to N[d]**	**N to S[e]**	**S to S**	**S to N**	**N to N**	**N to S**
06-Jul-04			2	4				
07-Jul-04			2	3				
08-Jul-04			1	1				
18-Jul-04			1					
20-Jul-04					2	4		
21-Jul-04				1		2		
22-Jul-04			1	2		1		
23-Jul-04		2						
27-Jul-04				8				
03-Aug-04		1						
07-Aug-04				1				
17-Aug-04	1							
18-Aug-04	1							
21-Aug-04	1							
30-Sep-04						2		
01-Oct-04						1		
02-Oct-04				2				
11-Oct-04				1				
12-Jun-05		1						
14-Jun-05	1							
18-Jun-05	1			1				
30-Jun-05	1							
10-Jul-06	1							
11-Jul-06	1	1						
12-Jul-06	2							
13-Jul-06	2							
14-Jul-06		1		1				
15-Jul-06		3						
17-Jul-06	1		1	1				1
18-Jul-06		1	1					
20-Jul-06							1	
21-Jul-06								3
22-Jul-06						1		
24-Jul-06						1	1	
26-Jul-06						1		
28-Jul-06	1							
30-Jul-06			1					
31-Jul-06				1				
01-Aug-06				1				
06-Aug-06				1				
10-Jun-07		1						
18-Jun-07		1						
20-Jun-07			1					
22-Jun-07			1					
Total	**14**	**12**	**11**	**29**	**2**	**13**	**2**	**4**

[a] Date caribou left constricted zone.
[b] South to South = caribou entered constricted zone from the south and exited to the north.
[c] South to North = caribou entered constricted zone from the south and exited to the north.
[d] North to North = caribou entered constricted zone from the north and exited to the north.
[e] North to South = caribou entered constricted zone from the north and exited to the south.

10 collared caribou moved south through the Kogru Area.

In 2006, no pattern of clockwise movement around Teshekpuk Lake was apparent among the GPS-collared caribou. Five of 12 caribou traveled north through the Kogru Area, 3 traveled south through the Kogru Area, 3 traveled north through the Smith Area, and 4 traveled south through the Smith Area. Only 2 caribou used the corridors in August and none between September 2006 and May 2007. Only 2 different caribou moved through the corridors in June 2007, although the collars were removed around 25 June 2007. The temporary weather stations at Lonely and Marty's Strip (Figure 8) were not present in 2006, so no local weather observations are available for that summer.

Caribou moved fastest in July and slowest in June (Table 3). They generally moved slower north of Teshekpuk Lake than in either constricted zone. There was a significant 2-way interaction between year and area for July movement rates ($P < 0.001$). In 2004, caribou moved slower north of Teshekpuk Lake than in the Kogru Area ($P < 0.001$) or the Smith Area ($P = 0.005$), but there was no significant difference between the Kogru and Smith areas ($P = 1.00$). In 2006, caribou moved faster in the Smith Area than north of Teshekpuk Lake ($P = 0.008$) or the Kogru Area ($P = 0.014$), but there was no significant difference between the Kogru Area and the area north of Teshekpuk Lake ($P = 1.00$). The combined 2004 and 2006 data for July showed that fewer caribou moved very rapidly (>3,300 ft/h; >1,000 m/h) north of the lake than in the constricted areas and that few caribou moved at the slowest rate category (<83 ft/h; <25 m/h) within the Smith Area (Figure 9).

Caribou traveling through the constricted zones showed no distinct pattern in their movement rates by direction of movement (Table 4). However, caribou appeared to move at slower rates and take a longer period of time to traverse the constricted zones while moving south than while moving north.

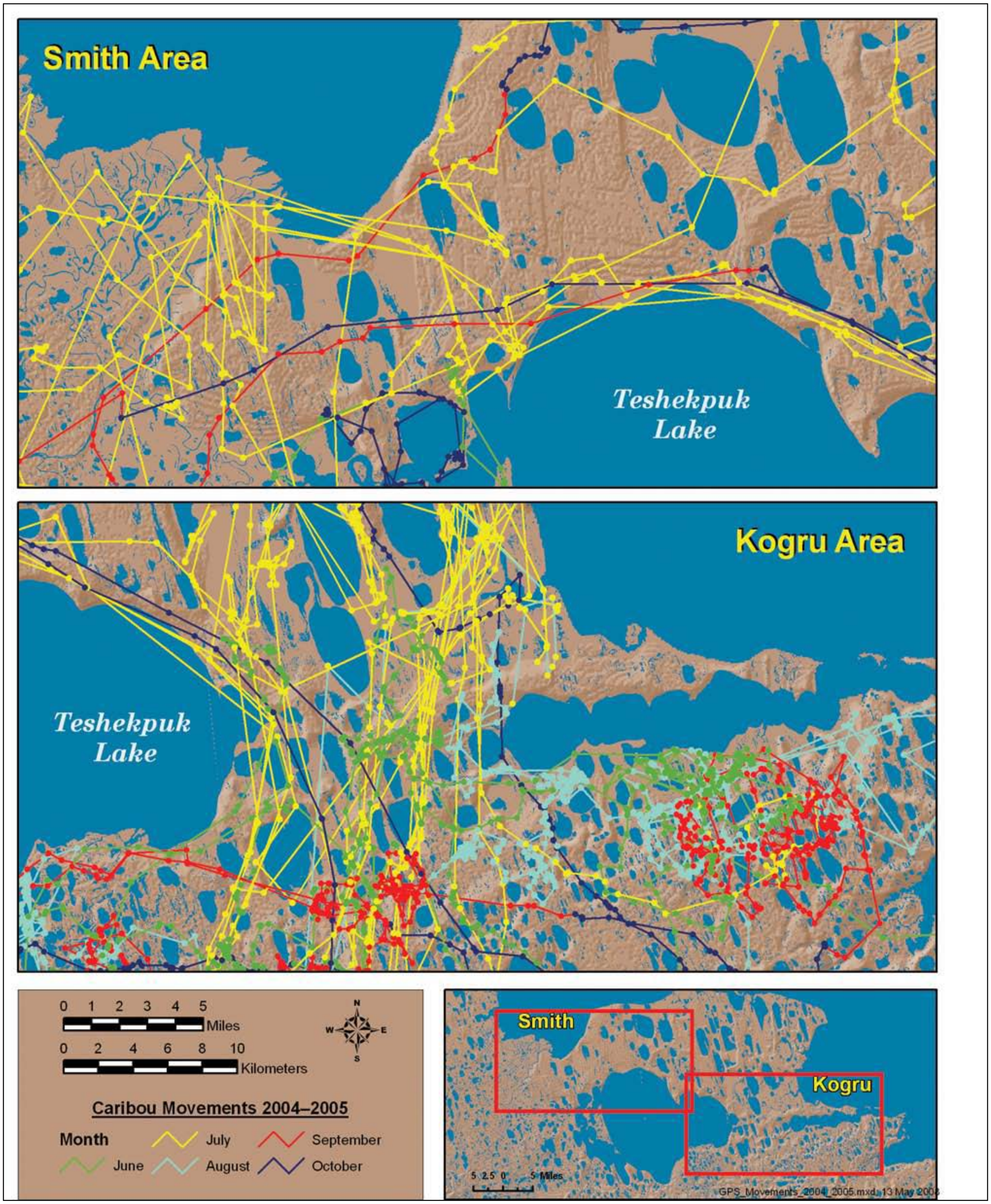

Figure 6. The locations and movements of 10 caribou outfitted with GPS collars (recording locations every 3 hours) around the 2 constricted zones near Teshekpuk Lake, Alaska, July 2004–June 2005.

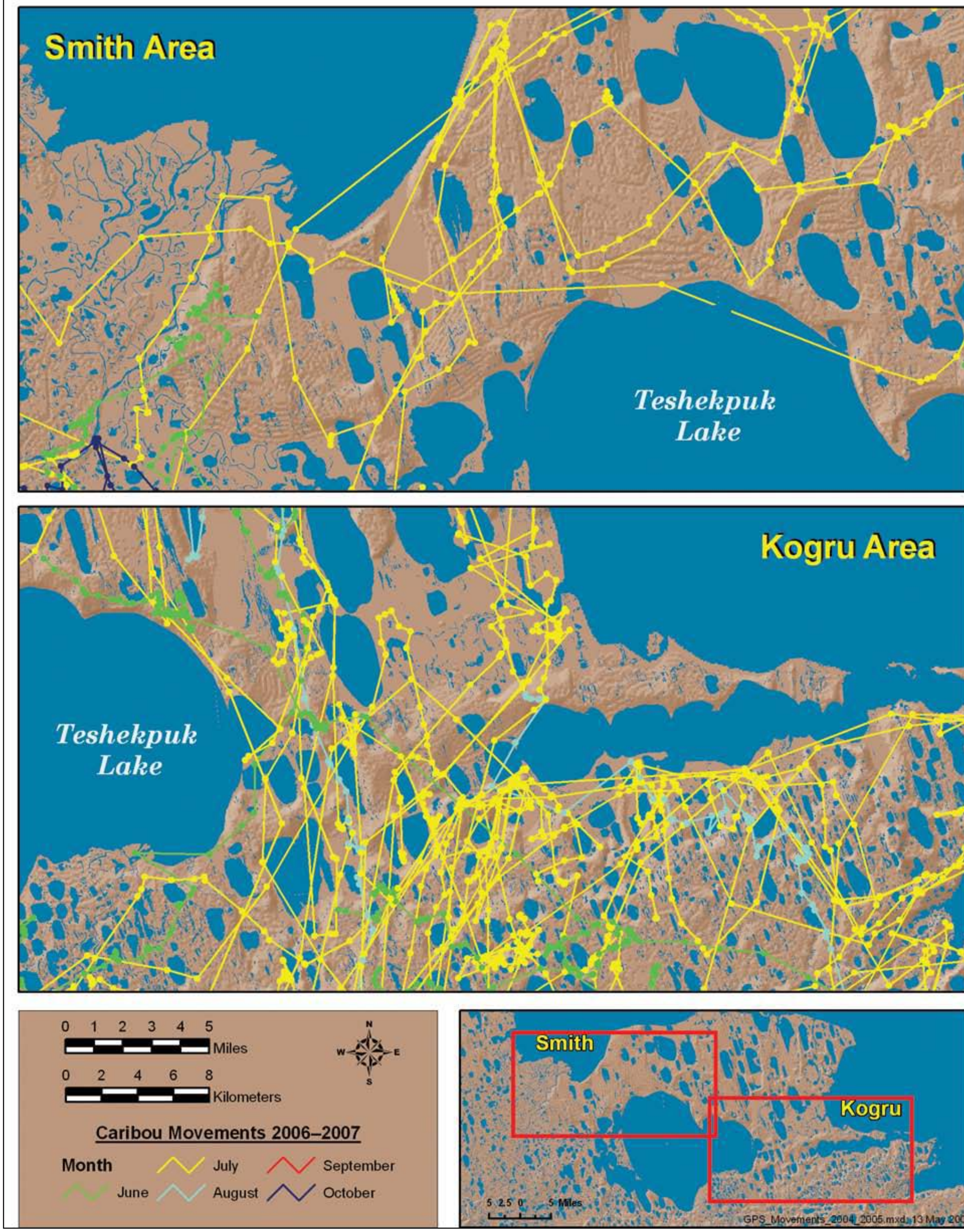

Figure 7. The locations and movements of 12 caribou outfitted with GPS collars (recording locations every 2 hours) around the 2 constricted zones near Teshekpuk Lake, Alaska, July 2006–June 2007.

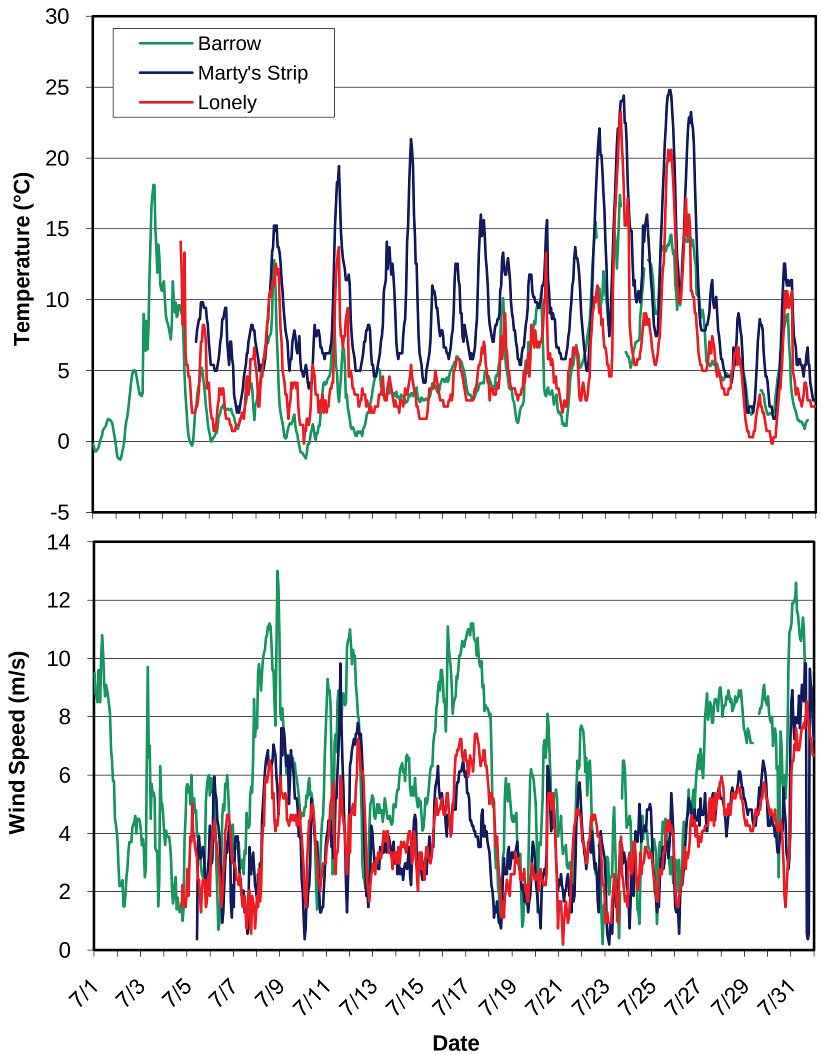

Figure 8. Temperatures (°C) and wind speeds (m/s) at Barrow, Lonely, and Marty's Strip, Alaska, during July 2004.

Table 3. Movement rates (km/h) of GPS-collared caribou north of Teshekpuk Lake and in constricted zones on either side of Teshekpuk Lake, Alaska, 2004–2007 based on distance between locations 2 or 3 h apart. Movement rate based on locations taken 3 h apart were multiplied by 1.056 to adjust for the longer fix interval.

		North of Teshekpuk Lake			Kogru Area			Smith Area		
Year	Month	Average	n	SE	Average	n	SE	Average	n	SE
2004	Jul	0.70	612	0.03	1.45	123	0.13	1.16	57	0.16
	Aug	0.52	25	0.11	0.40	56	0.05	–	–	–
	Sep	0.58	7	0.22	–	–	–	1.83	5	0.24
	Oct	0.47	76	0.06	0.97	26	0.18	2.95	3	0.86
2005	Jun	0.17	3	0.03	0.21	164	0.02	1.14	1	–
2006	Jul	0.88	430	0.05	1.02	169	0.10	1.63	38	0.3
	Aug	0.60	58	0.14	0.75	17	0.17	–	–	–
2007	Jun	0.18	218	0.02	0.43	52	0.11	–	–	–
	All Months Combined	**0.65**	**1429**	**0.02**	**0.77**	**607**	**0.04**	**1.41**	**103**	**0.14**

Table 4. Movement rates (km/h) of GPS-collared caribou that crossed constricted zones near Teshekpuk Lake and duration (h) of crossing.

			Kogru Area						Smith Area					
			S to N[a]			N to S[b]			S to N			N to S		
	Year	Month	Average	n	SE	Average	n	SE	Average	n	SE	Average	n	SE
Rate	2004	Jul	1.60	2	0.09	1.77	19	0.15	1.32	7	0.26	–	–	–
		Aug	0.28	1	–	0.73	1	–	–	–	–	–	–	–
		Sep	–	–	–	–	–	–	1.34	2	0.19	–	–	–
		Oct	–	–	–	1.34	3	0.45	2.65	1	–	–	–	–
	2005	Jun	0.44	1	–	0.17	1	–	–	–	–	–	–	–
	2006	Jul	1.50	6	0.22	1.61	3	0.97	3.19	3	1.28	1.94	4	1.12
		Aug	–	–	–	0.73	2	0.00	–	–	–	–	–	–
	2007	Jun	0.69	2	0.22	–	–	–	–	–	–	–	–	–
		All Months Combined	**1.19**	**12**	**0.18**	**1.55**	**29**	**0.15**	**1.85**	**13**	**0.37**	**1.94**	**4**	**1.12**
Duration	2004	July	27.00	2	0.004	12.00	19	1.45	21.00	7	4.72	–	–	–
		Aug	44.99	1	–	23.99	1	–	–	–	–	–	–	–
		Sep	–	–	–	–	–	–	7.50	2	1.50	–	–	–
		Oct	–	–	–	27.00	3	15.00	9.00	1	–	–	–	–
	2005	Jun	51.00	1	–	159.00	1	–	–	–	–	–	–	–
	2006	Jul	18.00	6	3.69	24.00	3	13.62	6.00	3	2.31	10.99	4	2.65
		Aug	–	–	–	24.00	2	6.00	–	–	–	–	–	–
	2007	Jun	41.00	2	25.00	–	–	–	–	–	–	–	–	–
		All Months Combined	**28.33**	**12**	**5.09**	**21.11**	**29**	**5.44**	**14.54**	**13**	**3.22**	**10.99**	**4**	**2.65**

[a] South to North = caribou entered constricted zone from the south and exited to the north.
[b] North to South = caribou entered constricted zone from the north and exited to the south.

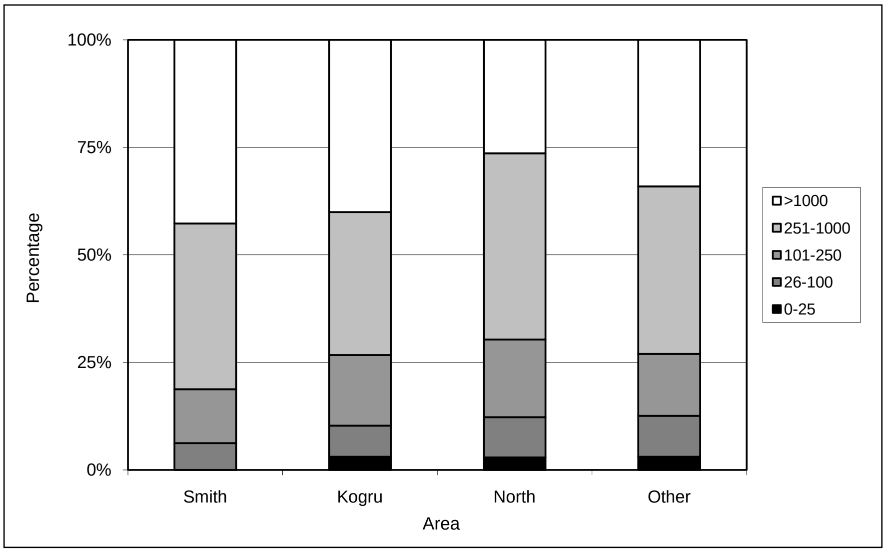

Figure 9. Movement rates of 22 GPS-collared caribou in 4 geographic areas by 5 movement categories (meters/hour) in July 2004 and July 2006. The 4 geographic areas are the Smith Area, Kogru Area, North of Teshekpuk Lake, and the remainder of the study area (Other).

Discussion

During the insect season, which generally occurs from late June through early August, avoidance of insects often takes precedence over optimal foraging in shaping caribou behavior on the coastal plain (White et al. 1975; Roby 1978; Dau 1986; Lawhead 1988). Mosquito activity peaks on warm, relatively calm days. Parrett (2007) suggests that wind speed may be more important than temperature in determining the severity of mosquito harassment. His data indicate that mosquito activity, although proportional to temperature, occurs across the range of July temperatures. Wind speed, however, acts as a threshold variable, with speeds above 9 mi/h (4 m/s) keeping mosquito activity below high levels. During insect harassment the daily energy budget of a lactating female caribou may suffer a negative balance (Fancy 1986), which may in turn reduce the female's probability of bearing a calf the following spring (Cameron et al. 1993; Cameron 1994).

As previously reported (Person et al. 2007), the constricted zones around Teshekpuk Lake are important movement corridors for caribou moving north of Teshekpuk Lake for mosquito relief. Satellite-collar data indicate that these areas may be used throughout the year (Prichard and Murphy 2004), but most movement across the constricted zones occurs in July, the period of greatest mosquito activity. These patterns were generally known from field observations prior to the use of satellite collars (Davis and Valkenburg 1979; Silva et al. 1985), but our data quantify both use and variation among years.

Both TCH and Central Arctic Herd caribou summer on the Arctic Coastal Plain, and when harassed by mosquitoes, move upwind (generally northeastward) to reach mosquito-relief habitats (Murphy and Lawhead 2000). They move back inland to better foraging habitat when mosquito activity decreases (Smith 1996).

Our data from both satellite- and GPS-collared caribou show a tendency of TCH caribou to move in a clockwise pattern around Teshekpuk Lake, although caribou do move both directions through both corridors. Just as temperature and wind speed may explain the timing of caribou movements to the north of the lake versus inland, we hypothesize that wind direction and the lake's position in the middle of the herd's July range may drive this tendency for a clockwise movement. During low mosquito activity, caribou tend to move with the predominantly northeasterly winds as they forage, heading away from mosquito-relief areas. If mosquito activity remains low for long enough, caribou are likely to end up west or southwest of the lake. Then when mosquito activity increases again, caribou head upwind, returning to relief habitat via the quickest route, i.e., through the Smith Area. The headwind helps decrease insect harassment during the return trip to the mosquito-relief area. As this weather/insect regime continues, further caribou movement into the wind is limited by the sea coast northeast of the lake. Then when mosquito activity once again abates, the shortest route inland is south through the Kogru Area.

Our GPS-collar data indicate this clockwise pattern in 2004 but not in 2006. Because caribou movements are influenced by weather patterns that vary among years, additional years of GPS-collar data, in conjunction with local weather observation stations north and south of the lake, are needed to confirm the frequency of the clockwise movements.

Due to their short fix intervals, GPS collars provide the best evidence of specific caribou movement paths and rates of movement both within the constricted zones and elsewhere. Observed variation in movement rates is consistent with use of the area north of Teshekpuk Lake for mosquito relief. Movement rates are fastest during July, when mosquito activity is usually greatest. During July, movements are slower north of the lake, where mosquito activity is lower, than they are in areas that have greater potential for mosquito harassment. Movements tend to be faster when caribou are headed north toward mosquito-relief areas than when headed south under reduced insect stress. Our failure to observe a larger difference in movement rates by direction may be an artifact of our relatively small sample size of GPS-collar locations.

Management Implications

If oil field development were to hinder caribou from reaching mosquito-relief habitat north of Teshekpuk Lake, the consequent energetic stress might result in lower fecundity and ultimately reduced population size (Cameron 1994, 1995). The BLM has already acknowledged the importance of the Teshekpuk Lake area, including the 2 constricted zones, to the TCH (USDOI BLM 2008). Our results not only confirm but quantify both spatial and temporal aspects of that importance. Results from our GPS-collar data suggest that caribou do not consistently favor specific paths to cross the constricted zones, so there may not be a "best" pipeline route through either zone. Similarly, if direction of caribou movement relative to the orientation of oil field infrastructure is an important consideration, our data do not confirm a consistent pattern; a clockwise movement is apparent in one year but not another. Thus there may not be a best orientation.

Alternatively, further studies may yet reveal identifiable trends in paths used by caribou as well as in their directions of movement through the constricted zones. Our GPS-collar results are based on a relatively small sample of 22 caribou over just 2 years. The more extensive satellite-collar dataset displays ample variability among years. Although the higher-resolution GPS-collar data provide better information on which to base management decisions, we will require additional years of data collection to discern real trends within the natural variability. The BLM needs to stay engaged in the collection of that data. In addition, the agency should require an updated analysis including all new location data before approving any future pipelines through one or both constricted zones.

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