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Effects of roads on individual caribou movements during migration

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ABSTRACT

Long distance migrations by large mammals are increasingly imperiled by human development. We studied autumn migratory patterns of caribou (*Rangifer tarandus*) in relation to an industrial road in northwestern Alaska. We built null movement models to determine the expected time to cross the road if caribou movements were not affected by the road. We then identified individuals that took longer to cross than expected (slow crossers) and those that did not differ from that expected from the null model (normal crossers). We identified eight as slow and 20 as normal crossers. Slow crossers took an average of 33.3 ± 17.0 (±SD) days to cross the road compared to 3.1 ± 5.5 days for normal crossers. Slow crossers had an average crossing date of 8 Nov. ± 7.7 days versus 25 Oct. ± 20.6 days for normal crossers. Movement rates of the two classes did not differ before crossing the road, but slow crossers moved >1.5 times as fast as normal crossers after crossing the road. Movement patterns were partially explained by environmental attributes, but were most strongly affected by how far a caribou was from the road and whether it was classified as slow or normal crosser. While avoidance is an important aspect of the effects of roads on populations, our results show the importance of other factors, such as how long individuals are delayed in crossing when assessing the influence of development on wildlife.

1. Introduction

The preservation of long-distance terrestrial migrations has received increased attention as some migratory populations have been lost due to human development (e.g. Berger, 2004, Bolger et al., 2008, Harris et al., 2009). Migration, the cyclical movement between disjunct ranges, is thought to evolve where the behavior enhances fitness by either accessing ranges with higher quality or quantity of forage or reducing exposure to predation and parasites (e.g., Avgar et al., 2014). With some individuals traveling >5000 km annually as they migrate between seasonal ranges, caribou undertake one of the longest recorded migrations of any terrestrial mammal species (Fancy et al., 1989). Caribou are facing increased human development across their range (Festa-Bianchet et al., 2011) that have led to shifts in space use (Cameron et al., 2005), reductions in habitat (Nellemann et al., 2003), and impeded movements (Vistnes et al., 2004). All of these changes have the potential to restrict caribou migrations and may lead to population-level effects (Bolger et al., 2008).

While the complete restriction of migration is likely to have the greatest effect on populations (Bolger et al., 2008, Berger et al., 2006), negative effects to populations are possible even if migration is partially restricted. This is evident in developed areas where animal passage has continued despite a network of roads and buildings (e.g., Lendrum et al., 2013). For example, in the near absence of development, mule deer (*Odocoileus hemionus*) spent 95% of their migration at stop-over sites to take advantage of high quality forage (Sawyer and Kauffman, 2011). When development increased, however, the use of stop-over sites was significantly reduced (Sawyer et al., 2013). Thus, semi-permeable barriers to movement, such as roads, can affect animals even though they are still capable of moving between seasonal ranges.

The influence of roads and other semi-permeable infrastructure on caribou migration is not well documented or understood. The scale and extent to which deflections and avoidance occur remains an unanswered question, particularly for migrating caribou. The majority of the early literature on caribou-infrastructure interactions summarized observations of caribou in the immediate vicinity of a road or pipeline (e.g., Curatolo and Murphy, 1986, Dau and Cameron, 1986, Murphy and Curatolo, 1987, Singer and Beattie, 1986). These studies documented rates of crossing success, distribution, and behavior near infrastructure, but may have included repeat observations of the same individuals, were often unable to account for the entire movement paths of individual animals when they encountered roads, and did not account for individuals that avoided roads at greater distances (Vistnes and Nellemann, 2008). Since the advent of global positioning system (GPS) collars, year-round movement paths of individual animals can be recorded and analyzed at multiple spatial and temporal scales.

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Although studies have documented large-scale patterns of caribou responses to infrastructure (e.g., Johnson et al., 2005, Boulanger et al., 2012), few studies have quantified the behavior of individual caribou as they attempt to cross a road or other infrastructure during migration. The few studies that have been conducted on caribou have shown that migratory movements can be hindered by development with the potential for delayed arrival at seasonal ranges (Dyer et al., 2002, Mahoney and Schaefer, 2002, Vistnes et al., 2004, Panzacchi et al., 2013). For example, a recent study by Panzacchi et al. (2013) found that reindeer migration in Norway was delayed approximately five days as individuals moved parallel to the road looking for an optimal crossing location.

Given the importance of preserving the long distance migrations of caribou (Bolger et al., 2008) and the current rate of development in the north (Festa-Bianchet et al., 2011), it is important to understand how developments influence migratory behavior in individuals and how this might translate into population-level effects. This is especially true in northwestern Alaska where there is currently limited industrial development, but large-scale developments are in various stages of planning with many potentially bisecting caribou migration routes (AECOM, 2012, Wilson et al., 2014). Therefore, we sought to understand how autumn migration patterns of caribou in northwestern Alaska were affected by the presence of an industrial road. Specifically, we quantified how movement patterns of individuals were influenced by the road and what the consequences of these changes were for the duration of migration and final wintering location, while accounting for the influence of environmental variables.

2. Materials and methods

2.1. Study area

The Red Dog Mine is a zinc–lead mine located in northwest Alaska, approximately 100 km north of Kotzebue, Alaska, and 70 km east of the Arctic Ocean (Fig. 1), and is the world's largest producer of zinc concentrate. The mine has been in operation since 1989 and operates year-round, transporting concentrate to the port facility along an approximately 80 km long road (hereafter, 'the road'). The road only connects the mine to the port and is not accessible by any other road in the state. Traffic along the road, primarily large trucks hauling ore, is constant throughout the year, although it is halted when caribou are on or adjacent to the road. The road is approximately 12 m wide and has no lateral barriers to movement (e.g., fences), nor does it have linear features (e.g., power lines) adjacent to it that might deter caribou from crossing (Tyler et al., 2014). Average traffic levels are approximately 49 round trips per day, or just over 4 vehicles per hour, 24 h a day (Tetratech, 2009). Some additional traffic occurs seasonally in the form of all terrain vehicles used for hunting, primarily limited to residents of the nearest community, Kivalina (pop. 374).

Two caribou herds contact the road: the Western Arctic (WAH) and Teshekpuk (TCH) caribou herds. The WAH is currently the largest herd in the state (~235,000; Dau, 2013), whereas the Teshekpuk herd is considerably smaller (~32,000; L. Parrett unpublished data). The primary period each year when individuals from both herds interact with the road is during autumn migration (Appendix A), but individuals from the WAH can also encounter the road in summer as they move to and from coastal areas in search of insect relief habitat, or during winter when they are relatively immobile. Neither herd crosses the road during spring migration, which occurs approximately 100 km east of the road (Dau, 2013, Parrett, 2013).

2.2. Data collection and handling

We captured adult female caribou from both herds (TCH: 2004–2012; WAH 2009 — 2012) and fit individuals with GPS collars. During September of each year, we captured WAH individuals (2009 = 39; 2010 = 15; 2011 = 14; and 2012 = 12) as they swam across the Kobuk River at Onion Portage in autumn (Fig. 1; Dau, 1997). We programmed GPS collars for WAH individuals to receive locations every 8 h. We captured individuals in the TCH each year in June (2004 = 10, 2006 = 12, 2007 = 12, 2008 = 27, 2009 = 21, 2010 = 14, 2011 = 9, 2012 = 17, 2013 = 14) with a net gun fired from a helicopter (Rongstad and McCabe, 1984)

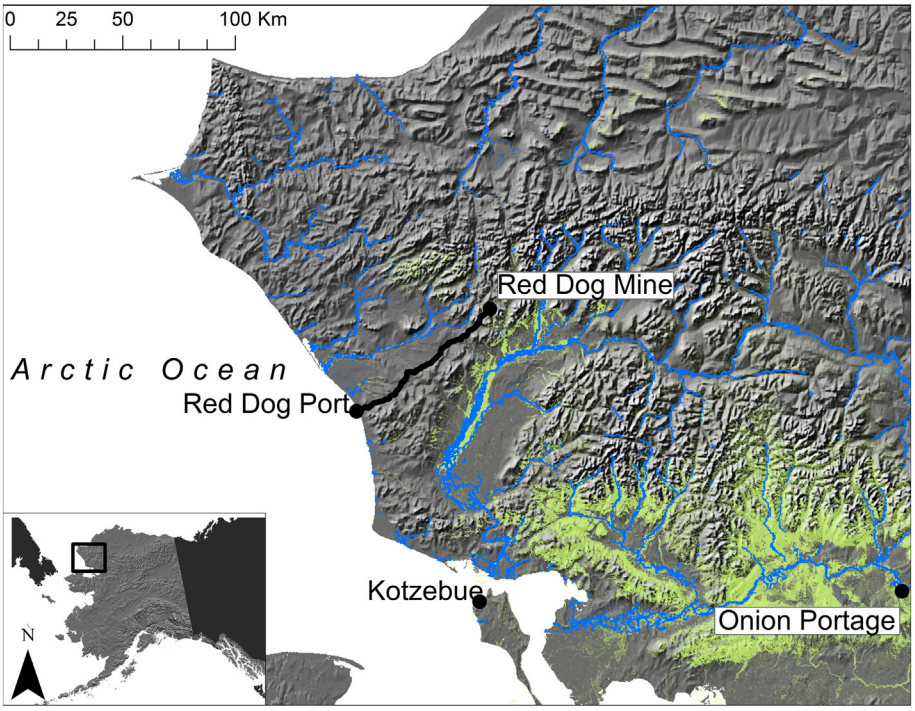

Fig. 1. The Red Dog Mine and its controlled access road in northwestern Alaska (black line); the concentrate storage and port facility is located at the western terminus of the road, whereas the mine is located at the eastern terminus. Major rivers are labeled in blue and areas with dense vegetation are labeled in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)