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Long-term distribution responses of a migratory caribou herd to human disturbance

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ABSTRACT

Caribou and reindeer (*Rangifer* spp.) are known to respond negatively to human activities. Disturbance stimuli can result in short-term behavioural responses or the abandonment of portions of seasonal range. There is relatively little understanding, however, of the ability of caribou to adapt or habituate to long-term human-caused disturbance. We fit species distribution models to 27 years of location data collected for the Porcupine caribou herd (Alaska, USA; Yukon and Northwest Territories, Canada) during winter. We used a novel technique to quantify the avoidance responses and zone of influence associated with human settlements, main roads and minor disturbance features including wells, trails, and seismic lines. We hypothesised that during the early period of monitoring (1985–1998), caribou would demonstrate a greater sensitivity to human disturbance and a larger zone of influence relative to industrial development. Consistent with the assumed level and timing of disturbance, caribou demonstrated the strongest avoidance response to settlements, followed by main roads and minor disturbance features. The data suggested that avoidance, noted as the zone of influence, was less during the more recent time period (1999–2012), but still relatively large when compared to the reported disturbance responses of other populations of *Rangifer*. A precise habituation response was obscured by uncertainty in the data describing human activities and variation in the distribution and population dynamics of the herd for such an extensive time period. These results suggest that the large-scale behavioural responses of wide-ranging mammals to disturbance stimuli are dynamic. The study of such responses requires accurate data describing human activities as well as long-term monitoring and periodic evaluation.

1. Introduction

Caribou and reindeer (*Rangifer tarandus*) are an important component of community dynamics in some northern ecosystems where they act as a keystone species, and they are highly valued by many aboriginal groups. Despite corresponding levels of monitoring and management actions, many populations have shown steep declines in distribution and abundance across much of the circumpolar range (Vors and Boyce, 2009). In response to this unfolding dynamic, and the rapid pace of human expansion across Boreal and Arctic landscapes, wildlife and conservation professionals are attempting to understand the short- and long-term implications of human development for this species (Johnson et al., 2005; Reimers and Colman, 2006; Gunn et al., 2009; Festa-Bianchet et al., 2011; Taillon et al., 2012). Such work is made difficult by populations that can extend across broad seasonal ranges, exhibit migration that exceeds 500 km, and fluctuate according to multi-decadal cyclical periods (Messier et al., 1988; Zalatan et al., 2006).

Human–*Rangifer* interactions are studied using techniques that capture a range of spatiotemporal and biological scales (Vistnes and Nellemann, 2008). At large spatial scales, species distribution models are commonly used to identify important habitat resources and the avoidance of human infrastructure or other disturbance events (Guisan and Thuiller, 2005; Johnson et al., 2006). Following the quantification of a disturbance response, one can identify the zone of influence for specific types of human development (Johnson et al., 2005). An observed impact within that zone might correspond with an avoidance response, where animals shift their distribution away from a development or alter behaviour in the vicinity of that disturbance (Johnson and St.-Laurent, 2011).

Although an intuitive concept, the zone of influence and measures of significance are difficult to quantify (Quinonez-Pinon et al., 2007). Species distribution models have proven utility, but the mechanisms underlying the modelled responses are often indeterminate and the patterns idiosyncratic. Individual animals,

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for example, may choose not to use habitats near a road because a habitat resource has changed in quality or quantity. Alternatively, human presence may be perceived as a threat to survival, once again forcing an individual to move away from such areas (Frid and Dill, 2002). The lack of understanding of mechanisms has led to the observation that populations of the same species vary in their responses to the same disturbance type and magnitude, as illustrated by the different zones of influence recorded for woodland caribou (*R. t. caribou*) populations avoiding roads (Dyer et al., 2001; Vors et al., 2007; Leblond et al., 2011; Polfus et al., 2011; Dussault et al., 2012).

Contributing to the reported variation in the zone of influence among individuals or populations, *Rangifer* may demonstrate a delay or some other temporal response to a disturbance. Dussault et al. (2012), for example, reported that woodland caribou (*R. t. caribou*) occupied recently harvested forest patches, not recognising the implications for calf survival of the early seral habitat that supported a high abundance of predators. In contrast, where human developments do not have extreme fitness consequences, *Rangifer* may habituate to disturbance stimuli (Colman et al., 2001). Habituation represents an evolving behaviour, where an animal demonstrates a decreased response to a human-caused disturbance following some period of exposure. This has been observed for ungulates, but there is little documentation of a habituation response by *Rangifer* at large spatial scales representing the seasonal distribution of populations (Reimers and Colman, 2006; Seip et al., 2007; Stankowich, 2008; Boulanger et al., 2012). The measurement of such responses requires a long time series of data that must be considered relative to natural fluctuations in behaviour and population dynamics (e.g., Zalatan et al., 2006).

The Porcupine caribou herd (*R. t. granti*) ranges across an area of approximately 250,000 km^2 in the United States and Canada. This is one of the most intensively studied migratory populations in North America (Russell et al., 2000). Satellite transmitters have provided broad-scale location data for a subsample of caribou for over 27 years and field studies and community-based monitoring have described the habitat ecology and population dynamics of the herd (Russell et al., 1993; Griffith et al., 2002). Consistent with many Arctic landscapes, there has been relatively little human development across the seasonal ranges of the herd. However, oil and gas exploration through the 1950s to 1970s, all-season roads (Dempster Highway completed 1979), and human settlements were thought to potentially influence the behaviour and distribution of these caribou (Klein, 1971). In response to the construction of the Dempster Highway, a number of studies addressed hypothesised impacts including altered activity budgets (Russell and Martell, 1985), overt reactions (Surrendi and DeBock, 1976; Horejsi, 1981), and the physical characteristics of crossing sites (Miller, 1985). There is a need, however, for a better understanding of the long-term interactions between caribou and these disturbances when considering herd dynamics in the context of future development activities. This includes identifying and mitigating the existing industrial footprint; planning to identify total levels and areas for future resource development; harvest management; and expectations of herd dynamics in the context of climate change (Francis and Hamm, 2011).

In this study, we used a long-term data set of locations and a species distribution model to quantify resource selection and the influence of human disturbances on the distribution of caribou from the Porcupine herd during winter. We used an innovative statistical method (Boulanger et al., 2012) to calculate a zone of influence around human settlements, main roads and minor disturbance features including wells, trails, and seismic lines. Recognising that these location data captured the distribution patterns of Porcupine Caribou for a 27-year interval, we tested for a habituation effect over time. We hypothesised that caribou monitored during the early and most intensive period of industrial development (1985–1998) would demonstrate a greater sensitivity to human disturbance and a greater zone of influence relative to caribou that were monitored more recently (1999–2012).

2. Study area

We studied the distribution dynamics of Porcupine caribou when they occupied the winter range (Fig. 1). Russell et al. (1993) identified three winter periods; because of sample size constraints we identified a more broad winter season (December 1–March 31). During this period the herd is found primarily across the Yukon Territory, Canada, and northeastern Alaska, USA. Habitat across that area varies dramatically as caribou occupy both the arctic tundra close to the Beaufort Sea and non-arctic ecosystems in the southern portion of the range (Walker et al., 2002). A large portion of that area was unglaciated during the last ice age resulting in a diversity of habitats associated with mountainous to low-elevation valley-bottom landscapes (Russell et al., 1993). Snow accumulation is variable, both across the winter range and among years, but averaged 0.45 m (SD = 0.05) from 1978–2011 (Russell et al., 2013).

During winter, caribou are exposed to a number of human disturbances. Likely of greatest severity are human settlements oriented to the east and south of the core winter range (80% isopleth – adaptive kernel method). On an annual basis, caribou are exposed to the Dempster Highway, bisecting the eastern portion of the winter range. As well, a temporary winter road from the Dempster Highway to Old Crow, Yukon, has been established when significant supplies and building materials were required in the village. From the 1950s to the 1970s oil and gas exploration and development occurred in the eastern portion of the winter range resulting in the cutting of seismic lines and the establishment of wells and well pads. Currently there are no active production facilities within the winter range. There are numerous other sources of past and present disturbance including relatively small tracks of winter road and trails, gravel pits, airstrips, traditional camps and cabins (Francis, 2010).

3. Statistical methods and data

3.1. Development of resource selection functions

We used a resource selection function (RSF), a type of species distribution model, to quantify the selection and disturbance responses of monitored Porcupine caribou. An RSF model is generated using a collection of animal locations that are contrasted with a set of locations that represent the availability of habitats or random distances to some feature, such as a road. We applied 27 years of location data collected by satellite collars deployed on 92 female caribou. Typically, collars were scheduled to record 1 location every 7 days, although some duty cycles resulted in locations as frequent as 1 per day.

Caribou were collared during spring migration (late March–April) often near the northern extent of the seasonal winter range, but the location of collaring activities varied among years. We restricted our analyses to the winter season (December 1–March 31; Russell et al., 1993) that followed collar deployment. Thus, animal capture or capture location likely had little direct influence on the behaviour or distribution of caribou that were monitored during the following winter, >9 months following capture and collaring.

For each caribou location, we generated 5 paired random locations that quantified resource availability. Those locations were selected from within a circle that represented the potential