Behavioral Ecology

The official journal of the ISBE International Society for Behavioral Ecology

Behavioral Ecology (2018), 00(00), 1–9. doi:10.1093/beheco/arx182

Original Article

Roads elicit negative movement and habitat-selection responses by wolverines (*Gulo gulo luscus*)

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Received 15 June 2017; revised 19 November 2017; editorial decision 26 November 2017; accepted 6 December 2017.

The fine-scale behavior of wildlife when crossing roads and interacting with traffic is likely to mirror natural responses to predation risk including not responding, pausing, avoiding, or increasing speed during crossing. We generated coarse-scale behavioral predictions based on these expectations that could be assessed with GPS radiotelemetry. We evaluated our predictions using an integrated step-selection analysis of wolverine (*Gulo gulo luscus*) space use in relation to spatially and temporally dynamic vehicle traffic on industrial roads in northern Alberta. We compared support for alternative models of road avoidance, increased speed near roads, and road avoidance and increased speed near roads. We predicted that wolverines would avoid roads and increase their speed near roads and that these behaviors would increase with traffic volume. We found that vehicle traffic was relatively low (0–30 vehicles/12 h) but important for explaining wolverine space use. Top winter and summer models indicated that wolverines avoided and increased speed near roads. Wolverine movement, but not avoidance, increased with traffic volume. We suggest that movement is a fine-scaled response that is more responsive to vehicle traffic than habitat selection. We show that roads, regardless of traffic volume, reduce the quality of wolverine habitats and that higher-traffic roads might be most deleterious. We suggest that wildlife behavior near roads should be viewed as a continuum and that accurate modeling of behavior when near roads requires quantification of both movement and habitat selection. Mitigating the effects of roads on wolverines would require clustering roads, road closures, or access management.

Key words: **boreal forest, *Gulo gulo*, habitat selection, movement, oil extraction, roads, step selection, traffic volume, wolverine.**

INTRODUCTION

The growth of human populations and our demand for natural resources has caused the development of roads in wild areas throughout the world (Hansen et al. 2013). Road networks have expanded and densified for the extraction of oil, gas, mining, and timber resources resulting in forest fragmentation and reduction in core areas (Schnieder 2002; Pickell et al. 2014; Pickell et al. 2016). The change in the characteristics of forested landscapes has had cascading effects on the behavior and abundance of many wildlife species (Rytwinski and Fahrig 2012; Latham and Boutin 2015).

Roads are an interface between humans and wildlife. Roads can have positive effects on wildlife by providing protection from predators (Berger 2007), enhanced movement (Whittington et al. 2011), or foraging opportunities (Scrafford et al. 2017b). Roads also can have negative effects on wildlife (Forman and Alexander 1998; Rytwinski and Fahrig 2012) including vehicle-caused mortality (Da Rosa and Bager 2013; McClintock et al. 2015; Niemi et al. 2017) or displacement (Shannon et al. 2014; Abrahms et al. 2016). As per the risk-disturbance hypothesis, displacement of wildlife by roads is because wildlife perceives roads, and associated human activity, as a predation risk (Frid and Dill 2002). Road avoidance can result in a reduction of suitable habitats for wildlife (Beyer et al. 2016; D'Amico et al. 2016; Kite et al. 2016).

Road effects on wildlife are often discerned without data on traffic volume (e.g. Krebs et al. 2007; Roever et al. 2010; Beyer et al. 2016). However, this approach neglects the varied responses of wildlife to the magnitude of human use of roads. The risk-disturbance hypothesis predicts that wildlife perception of risk increases with human activity. A high frequency of vehicles should therefore be viewed by wildlife as a large-predator group that is a threat to their security (Frid and Dill 2002; Jacobson et al. 2016). For example, grizzly bears (*Ursus arctos*) avoided high-traffic roads by crossing roads at night when traffic volume was low (Northrup et al. 2012). Similarly, squirrels (*Tamiasciurus hudsonicus grahamensis* and *Sciurus aberti*) reduced their movement across roads as traffic volume

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