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Wolf habitat selection is shaped by human activities in a highly managed boreal forest

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ABSTRACT

Throughout the southern part of the boreal forest, timber harvesting has generated a young forest matrix interspersed with mature remnants and fragmented by numerous roads. These changes have modified the abundance and diversity of many animal species and destabilized some trophic networks. Because wolves (*Canis lupus*) are apex predators of the boreal food web, wolf response to cumulative disturbances could have important impacts on the entire ecosystem. Our objective was to assess the impacts of anthropogenic disturbance on wolf habitat selection in a highly disturbed landscape. Between 2005 and 2010, we tracked 22 wolves with GPS collars in nine packs inhabiting the southern fringe of Québec's boreal forest. Using resource selection functions, we assessed the synergistic impacts of anthropogenic disturbances and habitat quality on habitat selection. Wolves selected areas providing food or likely to improve hunting success, but avoided anthropogenic disturbances, especially in regions with high levels of human activity. Interestingly, wolves seemed more tolerant of infrastructure when frequenting high-quality habitats. We demonstrate how anthropogenic disturbances may influence wolf habitat selection. Wildlife managers should take into account predator responses to logging-related disturbances when planning forest management for potential prey species.

1. Introduction

During the last decade, the impact of human activities on large mammalian carnivores has received increased attention (Houle et al., 2010; Laliberte and Ripple, 2004; Woodroffe, 2011). Many wildlife managers and researchers recognize the high variability in the behavioural responses of larges carnivores to anthropogenic disturbances (Hebblewhite and Merrill, 2008; Woodroffe 2000) and their potentially important impacts on community structure (Courbin et al., 2009; Hebblewhite et al., 2005). The ability of large carnivores to persist in human-modified landscapes has been debated (Linnell et al., 2001; Woodroffe, 2000), but anthropogenic disturbances have influenced their current distribution worldwide (Laliberte and Ripple, 2004; Woodroffe, 2000). Anthropogenic disturbances and infrastructure may have both negative and positive impacts on large carnivore distribution. They may favour predators by facilitating their movements (James and Stuart-Smith 2000) and by increasing food availability through anthropogenic food sources, livestock, and the creation of suitable habitats for prey (Chavez and Gese, 2005; Messier and Crête, 1985). On the other hand, they may also be detrimental to large carnivores by modifying behaviours such as movement rate (Kolowski and Holekamp, 2009), dispersal (Riley et al., 2006) and habitat selection (Gibeau et al., 2002; Houle et al., 2010), and ultimately increase mortality rate. This concern about human impacts on large carnivore populations is increasingly relevant due to growing human encroachment within wildlife habitat, an increased footprint insufficiently compensated by conservation-oriented management or protective legislation (Linnell et al., 2001; Mech and Boitani, 2003).

Gray wolves (*Canis lupus*) occupy the upper trophic level in North America. Like other large carnivores, wolves have experienced major declines in response to the expansion of human settlements, but some populations have been reintroduced (Mech and Boitani, 2003). Recently, habitat modifications combined with a growing popular interest for recreational activities have increased the density and diversity of anthropogenic disturbances likely to impact wolves, especially at the southern fringe of their distribution range. Logging is probably one of the most beneficial type of disturbance for wolves, as it creates a forest matrix dominated by early seral stands (Lindenmayer and Franklin, 2003) where prey species such as white-tailed deer (*Odocoileus virginianus*) (Johnson et al., 1995) and moose (*Alces alces*) (Potvin et al., 2005a) thrive. Modern forestry has also generated a complex network of forest roads that wolves may use to facilitate their

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movements and increase their foraging opportunities (James and Stuart-Smith, 2000; Whittington et al., 2011).

Roads, on the other hand, also represent a risk of vehicle collision mortality for many species (Dussault et al., 2006a; Fuller, 1989). In fact, collisions with vehicles are one of the most important cause of wolf mortality in several regions (Italy 52% [Lovari et al., 2007]; Croatia 24% [Huber et al., 2002]; and Minnesota 11% [Fuller, 1989]). By increasing accessibility to previously undisturbed areas, roads favour the establishment of cabins within suitable wolf habitat as well as the occurrence of recreational activities such as trapping and hunting that often lead to higher harvest rates (>40%) (Fuller, 1989; Larivière et al., 2000). In such human-modified landscapes, wolves need to balance selection for food resources with mortality risk associated with human presence, a trade-off that we highlight by investigating wolf responses to various types of anthropogenic disturbances.

Previous studies principally focused on the impacts of roads and/or human density on wolf habitat selection and spatial distribution (Ciucci et al., 2003; Houle et al., 2010; Whittington et al., 2005). In this study, our objective was to investigate wolf responses to human-related habitat modifications, focusing on the impacts of such modifications on habitat selection. We hypothesize that anthropogenic disturbances will influence habitat selection by wolves, and that wolf response will depend on the disturbance density. Because some disturbances might be beneficial to wolves, we believe responses to anthropogenic disturbances and infrastructure to be indicative of a trade-off between the perceived costs and benefits that wolves experience in using them. We expected that wolves will; (1) select areas providing high food availability and/or features that are likely to increase hunting success like anthropogenic food sources, suitable moose habitat (e.g., mixed-deciduous and young regenerating stands) (Dussault et al. 2005), streams, and low-use roads (James and Stuart-Smith, 2000; Houle et al., 2010); (2) exhibit avoidance of high infrastructure density and (3) be more tolerant toward human infrastructure when using suitable habitat types.

2. Study area

The study area covered 12,907 km^2 and was located near the southern limit of the boreal forest (47°41′N; 71°20′W) in the province of Québec (Canada), between the cities of Québec and Saguenay. It encompassed two Québec national parks (Jacques-Cartier and Grands-Jardins) and almost the entire Laurentides Wildlife Reserve. Vegetation in the study area is characterized by coniferous stands, dominated by balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*), interspersed with mixed stands where conifer trees are found together with white birch (*Betula papyrifera*), maples (*Acer* spp.), and trembling aspen (*Populus tremuloides*). Deciduous species were found principally at low altitude and in the northern part of our study area. Elevation ranged from 500 m to 1000 m above mean sea level. Precipitation amounts were high (1500 mm/yr), particularly during winter when snow accumulation could be more than 3 m (Robitaille and Saucier, 1998). Other than wolf, the large mammal community is composed of black bear (*Ursus americanus*), moose, woodland caribou (*Rangifer tarandus caribou*), and a few white-tailed deer. Intensive forest harvesting and establishment of the two provincial national parks have created a heterogeneous mosaic of mature forest stands and regenerating cutblocks. The road network developed by forestry companies increased accessibility of the forested landscape to hunters, trappers, and tourists which promoted wolf harvesting (Larivière et al., 2000) and the establishment of infrastructure such as recreational cabins. In addition, several moose-vehicle collisions were recorded along provincial roads in our study area (Dussault et al., 2006a) and wolves could access four roadkill carcass deposits during our study. These carcass deposits received on average approximately 70 big game carcasses each year, mostly during June and July.

3. Methods

3.1. Capture and telemetry

Between 2005 and 2010, we captured 26 wolves belonging to 9 packs, and fitted them with Global Positioning System (GPS) telemetry collars (model 3300SW from Lotek Engineering Inc., Newmarket, Ontario or model TGW-4580 from Telonics Inc., Mesa, Arizona). We captured animals either by helicopter darting or net-gunning in winter, or foot-hold trapping during summer (Houle et al., 2010) following approval by the Animal Welfare Committees of the Ministère des Ressources naturelles et de la Faune du Québec (MRNF; certificate # CPA-07–00-02) and the Université du Québec à Rimouski (UQAR; certificate # CPA-27–07-53-R2). GPS collars were programmed to acquire location fixes every 4 h year-round. We recaptured wolves every year to download data and replace battery packs. We removed pups and wolves with insufficient locations from our dataset which resulted in a total of 22 wolves belonging to 9 packs (27 wolf-years).

3.2. Annual periods

We defined three periods based on wolf ecology, hunting behaviour, movement pattern, and reproductive stages during which wolf resource selection was likely to change (Mech and Boitani, 2003). We visually determined beginning and ending dates for each period by looking at abrupt variations in net displacement from capture location (Courbin et al., 2009) and daily movement rate, and used the yearly average beginning and ending dates to delimit each period. The denning period began between 23 April and 6 May, and ended between 1 and 23 July, while the rendezvous period started between 2 and 24 July, and ended between 14 September and 15 November. During the denning period, we could easily identify breeding females as they mostly remained close to the den while other members of the pack patrolled the territory and returned only periodically to the den to feed and protect pups. This behaviour was also observed during the rendezvous period, but instead of one site, we noted several location clusters identified as rendezvous points (Mech and Boitani, 2003). During the nomadic period, wolves usually moved together as a pack and did not use rendezvous points.

3.3. Habitat categories

We used 1:20,000 digital ecoforest maps published by the MRNF to classify available habitat polygons into 10 categories based on cover type and stand age (Table 1). These maps were based on the photo-interpretation of 1:15,000 aerial photographs taken in 1998–1999. Using field surveys, Dussault et al. (2001) demonstrated that cover type and age class were the two variables for which the agreement between map information and field measurements was the best, indicating that habitat polygons based on these fields could be suitable to model species-habitat relationships. Minimum mapping unit size was 4 ha for forested polygons and 2 ha for non-forested areas (e.g., water bodies, bogs). We updated maps each year in order to include new cutblocks (no size limit) and natural disturbance polygons (e.g., fires, windthrows, and insect outbreaks). As we aimed to highlight the impacts of human disturbances on wolf habitat selection, we further regrouped all habitat types in one of the following two categories by period: selected or not selected by wolves. To do so, we built resource