ECOLOGICAL MODELLING 212 (2008) 372–381

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/ecolmodel

Modelling potential dispersal corridors for cougars in midwestern North America using least-cost path methods

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ARTICLE INFO

Article history:
Received 30 May 2007
Received in revised form
6 October 2007
Accepted 23 October 2007
Published on line 20 February 2008

Keywords:
Analytical hierarchy process
Cougar
Dispersal
GIS
Habitat modelling
Least-cost path
Midwest
Puma concolor
Wildlife corridors

ABSTRACT

Since 1990, cougar (*Puma concolor*) presence in midwestern North America has been increasing, with >130 confirmed cougar occurrences (i.e., tracks, photos, carcasses) being verified by professional wildlife biologists during this time. Because many of these confirmed cougar occurrences (>30%) have been carcasses of juvenile males, it is likely that cougars are dispersing into the Midwest from established western populations. Although several wildlife biologists have acknowledged the possibility of cougar presence in the region, no research has been conducted regarding potential corridors that may facilitate dispersal. Therefore, our goal was to determine potential dispersal corridors for cougars in a 9-state portion of the Midwest using a habitat suitability model and least-cost path analysis. We modelled 2-km wide dispersal corridors from established western cougar populations to (1) large areas ($\geq$2500 km^2) of highly suitable cougar habitat, and (2) locations of confirmed cougar occurrences ($n = 29$) in North Dakota, Nebraska, and Missouri. The most likely dispersal corridor to large areas of highly suitable cougar habitat originated in western Texas and branched into the Ouachita and Ozark National Forests of Oklahoma, Arkansas, and Missouri. Within this corridor, road density was low (79 m/km^2) and forests comprised 45% of land cover; these results are consistent with empirical studies that indicate dispersing cougars travel in habitat that provides cover while generally avoiding human influence. Corridor lengths from potential source populations to confirmed cougar occurrences ranged from 3 km to 1100 km, stream density (i.e., an index of riparian zones) ranged from 79 m/km^2 to 249 m/km^2, and grassland cover comprised >40% of corridors from occupied cougar habitat to confirmed occurrences. High grassland cover and riparian zones within these corridors may allow for movement between forest patches while dispersing through the highly agricultural Midwest. Our analysis provides the first description of potential dispersal corridors for cougars from established western populations into the Midwest. Primary benefits from this research include providing an understanding of landscape permeability for large carnivores in a largely unsuitable matrix, and presenting conservation agencies with useful information should cougars continue to disperse into the region.

1. Introduction

The possibility that cougars could re-colonize previously extirpated areas in midwestern North America is provocative given the implications of this phenomenon to conservation and management of large carnivore populations and their prey. Although considered extirpated for >100 years, cougars have been reported in the Midwest consistently since

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doi:10.1016/j.ecolmodel.2007.10.036

1990, with >130 confirmed cougar occurrences (i.e., tracks, photographs, or carcasses) reported by the Cougar Network (2006); one-third of these confirmations are of carcasses of juvenile male cougars killed by vehicles or hunters. Since similar re-colonization events have occurred in other carnivore populations, such as wolves (*Canis lupus*) in Wisconsin and Michigan (Mech et al., 1995; Gehring and Potter, 2005), cougar presence in the Midwest a phenomenon that warrants attention and further investigation, although male-biased dispersal in cougars may influence the rate at which re-colonization of the Midwest may occur (Maehr et al., 2003).

Given the paucity of research regarding cougar presence in the Midwest, reasons for increasing confirmations of cougar presence are unknown. However, one theory appears the most valid: since most carcass confirmation occurrences have been of juvenile males, the most plausible explanation is that juveniles are dispersing from established populations in the west (Nielsen et al., 2006). Dispersal is a permanent movement away from a natal home range to a place where an animal reproduces or would have reproduced had it survived and or found a mate (Howard, 1960; Greenwood and Harvey, 1982). In cougar populations, dispersal generally occurs between the ages of 10–33 months (Hemker et al., 1984; Maehr et al., 1991; Lindzey et al., 1994; Logan et al., 1996) and consistent with polygynous mammals, juvenile males are the primary dispersers (Anderson et al., 1992; Sweanor et al., 2000). Cougars are capable of dispersing long distances (Murphy et al., 1999; Logan and Sweanor, 2001; Thompson and Jenks, 2005); long distance dispersal is important in cougar populations, as recruitment often occurs because of immigration of juveniles from adjacent populations (Beier, 1995; Sweanor et al., 2000). Furthermore, dispersal enables cougars to expand their distributional range and can lead to gene flow between populations and re-colonization of unoccupied areas (Beier, 1995; Penrod et al., 2006). Vacant habitats may become re-colonized if they are linked geographically to populations that could provide sources of immigrants (Murphy et al., 1999).

Since the 1960s, cougar populations in the west have increased dramatically, primarily because of management that has protected the species from indiscriminate killing (Nadeau, 2005) and because of increasing ungulate populations throughout cougar range (Berger and Weyhausen, 1991). There also appears to be healthy gene flow between several western populations, indicating that western populations are somewhat interconnected (Anderson et al., 2004). Elevated cougar populations in the west may be pushing juvenile dispersers into the Midwest (Maehr et al., 2002) in search of available habitat to establish home ranges, as relatively few vacancies may exist within western cougar range. Indeed, genetic studies of cougar populations in Wyoming discovered high migration rates across open and unsuitable habitat, as male dispersal has presumably maintained connectivity between populations (Anderson et al., 2004). Effective cougar population size in Wyoming was estimated to be 500 individuals and actual size of these populations well exceeded the minimum at nearly 4500 individuals (Anderson et al., 2004). Another study found that the age structure of cougar populations in Wyoming were primarily sub-adults (Anderson and Lindzey, 2005), which constitute most of dispersers (Anderson et al., 1992; Sweanor et al., 2000).

Populations on the eastern edge of western cougar range exist as potential sources of cougar dispersal into the Midwest. For instance, the Black Hills, South Dakota, contains a cougar population with approximately 150 individuals (Fecske, 2003), and sub-adult dispersal has been frequently documented within the past 5 years (D. Thompson, personal communication, 2006; Cougar Network, 2006). One particular male was recorded traveling 1067 km during dispersal (Thompson and Jenks, 2005) and several others have dispersed >400 km (D. Thompson, personal communication, 2006; Cougar Network, 2006). Also, populations in Texas appear to be expanding eastward, as the eastern-most counties within current Texas range have recently reported the highest cougar presence of any county in the state (Harveson et al., 2003).

Because there is a possibility that cougar range may expand into the Midwest, an investigation of potential paths of dispersal is timely. A useful method of determining dispersal corridors is through the development of least-cost paths (Meegan and Maehr, 2002; Schad et al., 2002; Larkin et al., 2004; Kautz et al., 2006; Penrod et al., 2006). This technique models the relative cost for an animal to move between two areas of suitable habitat (Penrod et al., 2006). Least-cost path (LCP) analysis is based on how the movement path of an animal may be affected by characteristics of the landscape, such as land cover, human density, roads, or slope (Singleton et al., 2002; Penrod et al., 2006). Within a GIS, each cell in a raster dataset is assigned a value for cost of movement. The model creates the most likely travel route by selecting a combination of cells that accrue the least resistance with the shortest distance between two areas of suitable habitat (Larkin et al., 2004). Least-cost paths contain the most suitable habitat and fewest movement barriers (Larkin et al., 2004), and therefore, the best theoretical route for a dispersing animal.

Although a few studies have addressed confirmations of cougar occurrence in the Midwest (Tischendorf, 2003; Nielsen et al., 2006), no research has been conducted regarding potential dispersal from western populations into the region. Our goal was to model LCP for cougars in the Midwest, using a habitat suitability model (LaRue, 2007) as the basis for analysis. We identified corridors through the Midwest where the landscape would facilitate dispersal of cougars to provide an understanding of landscape permeability for large carnivores in a largely unsuitable matrix, and to present conservation agencies with useful information should cougars continue to disperse into the region.

2. Methods

2.1. Study area

The study area covered 3,182,294 km^2 of the midwestern and western United States, including the states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Arkansas, Missouri, Iowa, Minnesota, Wyoming, Colorado, New Mexico, and Texas (Fig. 1). This region was selected because of the increasing numbers of confirmed cougar occurrences in the area (Fig. 1), its proximity to western cougar populations, the likelihood of potential dispersal corridors, and the scarcity of cougar occurrence confirmations east of the Mississippi River