Ecological Modelling 222 (2011) 897–900

Contents lists available at ScienceDirect

Ecological Modelling

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

Short communication

Modelling potential habitat for cougars in midwestern North America

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ARTICLE INFO

Article history:
Received 6 October 2010
Received in revised form
12 November 2010
Accepted 15 November 2010
Available online 9 December 2010

Keywords:
Cougar
GIS
Habitat modelling
Midwestern North America
Puma concolor

ABSTRACT

Cougars (*Puma concolor*) are of considerable interest to wildlife biologists and the general public in midwestern North America, yet no researchers have modelled potential habitat in the region. We created a model of potential cougar habitat in 9 midwestern states using geospatial data, expert-opinion surveys, the analytical hierarchy process, and a GIS. About 8% of the study region contained highly favorable habitat (with favorability scores ≥75%) for cougars; the states of Arkansas (19%) and Missouri (16%) contained the highest proportions of potentially favorable habitat. We identified 6 large (≥2500 km^2 in size), contiguous areas of highly favorable habitat for cougars. Model testing procedures indicated a valid model when compared to an independent set of cougar locations, a null dataset, and similar studies. Our model is useful as a planning tool to proactively address future human–cougar conflicts should cougars re-colonize the Midwest via subadult dispersal.

1. Introduction

Cougars (*Puma concolor*) have historically occupied most of the western hemisphere, ranging from the Atlantic to Pacific oceans and from northern British Columbia to southern Chile (Sunquist and Sunquist, 2002). These top predators were extirpated from eastern and midwestern North America by the early 1900s, however, because of habitat loss and intentional killing due to concerns about human safety, ungulate populations, and livestock depredation (Sunquist and Sunquist, 2002). Distributions were restricted to the rugged topography and remoteness of the west, where cougars remained a bountied animal until the 1960s (Desimone et al., 2005). Cougars were then reclassified and managed as a big game species in most western states (Desimone et al., 2005; Nadeau, 2005; Whittaker, 2005). Increased protection, along with increasing prey densities (e.g., elk), has allowed for a rebound in cougar numbers across the West (Nadeau, 2005). The potential for re-colonization of cougars in the region is of considerable interest to wildlife managers and the public alike (Nielsen et al., 2006; Davenport et al., 2010; Beier, 2010).

Large-scale habitat models have been created for many carnivore species using animal location information, remotely sensed data, multivariate statistics, and a geographic information system (GIS; Carroll et al., 1999; Mace et al., 1999; Nielsen and Woolf, 2002; Treves et al., 2004; McDonald et al., 2008). These models are created by statistically evaluating relationships between species occurrences and landscape characteristics (Store and Kangas, 2001); such analyses typically rely upon empirical data regarding species occurrence. However, empirical data may not be available, especially in the case of rare species. Expert-opinion surveys can be used in lieu of empirical data to obtain information regarding habitat needs (Pearce et al., 2001; Clevenger et al., 2002; Martin et al., 2004; LaRue and Nielsen, 2008). Store and Kangas (2001) describe a technique in which GIS, spatial analysis, and decision analysis techniques are used to develop large-scale habitat models. Expert opinion and multi-criteria analysis, specifically the analytical hierarchy process (AHP; Saaty, 1980), transform expert knowledge regarding wildlife habitat needs into numerical form. Geographic information system applications are then used to produce cartographic maps by combining the expert-assisted data and spatial analysis of landscape information (LaRue and Nielsen, 2008).

Although confirmations of cougar presence (i.e., carcasses, DNA, photographs, and video) in midwestern North America have increased dramatically during the past 20 years (Nielsen et al., 2006; Cougar Network, 2010), no researchers have yet developed models of potential habitat for cougars in North America's interior. Furthermore, relatively few applications of multi-criteria evaluation modelling exist for carnivores (Clevenger et al., 2002; Doswald et al., 2007; Singh et al., 2009). We previously modelled potential dispersal corridors for cougars into the Midwest based on expert opinion surveys within the AHP modelling framework; much of our discussion regarding these techniques are provided in LaRue and Nielsen (2008). The objectives of the present paper are to

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0304-3800/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.ecolmodel.2010.11.017

(1) quantify the amount and distribution of potentially favorable cougar habitat in the Midwest based on our previous work (LaRue and Nielsen, 2008); (2) delineate large areas of contiguous, highly favorable habitat; and (3) discuss model utility.

2. Methods

We assessed potential habitat for cougars using the same 9-state midwestern North America study area as in LaRue and Nielsen (2008). We were unable to use empirical data from midwestern cougars because such data were unavailable; confirmation location data (Nielsen et al., 2006; Cougar Network, 2010) from most states were deemed unsuitable, as they were likely dispersing animals and not selecting habitat optimally while dispersing (LaRue and Nielsen, 2008). Briefly, our approach to identify potential habitat was similar to that of Thatcher et al. (2006) and was based on an assessment of biological and anthropogenic influences that would likely define cougar habitat in the Midwest. Our primary emphasis was on using expert knowledge, decision-making techniques, geospatial data, and a GIS to model potential habitat. We created a survey to obtain expert opinion regarding factors potentially affecting cougar habitat and distributed it to 29 wildlife biologists who study cougars or furbearer species for state and federal agencies. Completed surveys ($n = 11$) were analyzed using the analytical hierarchy process (Saaty, 1980) and a consistency ratio was calculated to determine the consistency of answers between our experts (Saaty, 1980, 1987). Final weights of all 5 factors (i.e., land cover, slope, human density, distance to roads, and distance to water) from the surveys were then combined with geospatial data in a GIS to create a model of potential habitat for cougars in the Midwest. Further detail on our modelling process can be found in LaRue and Nielsen (2006, 2008).

We then defined a cut-off percentage for defining “highest favorable” habitat for cougars. Rather than choosing an arbitrary percentage for this purpose, we used the Black Hills region of South Dakota as a guide. Specifically, we determined the average percentage of pixel values within the Black Hills, where a breeding population of cougars already exists (Fecske, 2003; Thompson and Jenks, 2005). The average habitat percentage in the Black Hills region was 75%, thus, we considered pixels with a suitability score ≥75% as highly favorable habitat for cougars.

Following Thatcher et al. (2006), we determined the largest areas of highly favorable habitat for cougars in the region. A grid was overlaid on the habitat map; the grid cell size of 75 km^2 was based upon the smallest female cougar home range in the Black Hills population (Fecske, 2003). We then identified grids that contained ≥50% of the area in ≥75% favorable habitat and delineated areas of contiguous habitat of this percentage that were ≥2500 km^2 in size. This area is in concordance with Beier (1993), who suggested that cougars need areas 1100–2200 km^2 in size to persist in the absence of immigration; and Thatcher et al. (2006), who indicated that Florida panthers required areas ≥2590 km^2 for population viability.

We tested the accuracy of the habitat model using 46 known cougar locations from North Dakota collected during 1990–2006 (Fecske, 2006, personal communication). Cougar locations were associated with verified carcasses, tracks, or photographs recorded at exact map coordinate locations (Cougar Network, 2010; Nielsen et al., 2006). Thirty-five known locations (76%) were within the portion of North Dakota identified by Fecske (2006) as breeding range for cougars. We chose North Dakota locations for model validation because (1) North Dakota contained a breeding cougar population (Fecske, 2006), making confirmation locations most likely of resident animals; and (2) confirmation locations from other midwestern states were likely of dispersing animals, given lack of breeding populations throughout much of the study region. We overlaid cougar confirmations from North Dakota onto the habitat map and determined the mean percentage of habitat favorability at the section (259 ha) associated with each confirmation. We also created 1000 random locations statewide in North Dakota and compared percentage of habitat favorability associated with random locations versus confirmation locations.

Table 1
Weights, standard deviation, and consistency ratios for variables used in development of the habitat suitability model for cougars in the Midwest. Weights were calculated using the Analytical Hierarchy Process (Saaty, 1980) and represent the averaged, relative scores of importance to potential cougar habitat in the Midwest.

Variable	Weight	Standard deviation	Consistency ratio[a]
Land cover	1.84	0.59	0.10
Human density	1.22	0.82	0.06
Distance to roads	0.86	0.45	0.01
Slope	0.61	0.56	0.00
Distance to water	0.47	0.26	0.02

[a] Values of ≤0.10 indicate a consistent survey (Saaty, 1987) of the opinions of all 11 experts.

3. Results and discussion

We provide the first large-scale assessment of potential cougar habitat in midwestern North America based on the collection and analysis of ecological data used for model building and validation. Of the 11 expert surveys returned (38% return rate), results were consistent among biologists surveyed, and indicated that land cover, specifically mixed and deciduous forest cover, was the most influential factor for potential habitat for cougars in the Midwest (Table 1). Distance to water was considered the least important factor (Table 1). Approximately 8% of the Midwest contained highly favorable habitat for cougars; the states with the largest proportion of highly favorable habitat were Arkansas (19%) and Missouri (16%) (Table 2, Fig. 1). However, large, contiguous areas of highly favorable habitat only represented 3% of the region, and were patchily distributed (Fig. 1). Since the small, patchily distributed areas are likely not large enough to potentially maintain a viable population (Beier, 1993; Thatcher et al., 2006), but are still suitable for cougars, these smaller areas of habitat may provide dispersal corridors for cougars traveling through the Midwest (LaRue and Nielsen, 2008). Much of this potential dispersal habitat runs along major rivers in the region (e.g., Missouri River, Platte River) and it is well known that cougars use river corridors for travel (Beier, 1993, 1995).

We identified 6 large sites of contiguous, highly favorable habitat for cougars; these areas ranged in size from 2500 km^2 in the Black Hills, to 15,000 km^2 in the Ouachita National Forest (Table 3, Fig. 1). In addition to the Black Hills and Badlands of North Dakota, which are known to contain breeding populations (Fecske, 2003, 2006; Thompson and Jenks, 2010), portions of Missouri, Arkansas,

Table 2
Percent and total area of potential cougar habitat (expert-assisted scores ≥75%) for midwestern North America.

State	Percent (%) of highest suitable habitat	Total area of the state (km^2)
Arkansas	19.0	26,029
Missouri	16.0	28,928
Minnesota	11.0	24,071
North Dakota	5.6	10,267
Oklahoma	5.1	9243
South Dakota	4.8	9913
Nebraska	4.3	8609
Kansas	3.6	7661
Iowa	2.6	3787
Entire Midwest region	7.7	128,608

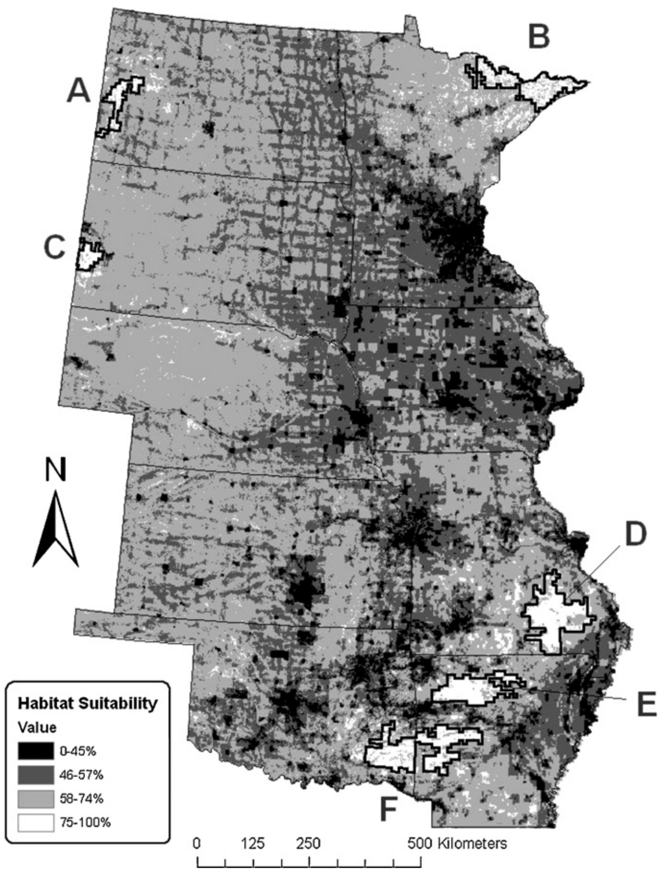

Fig. 1. Expert-assisted scores for potential cougar habitat in midwestern North America. Six large areas of contiguous, highly suitable habitat were identified: A. North Dakota Badlands region, ND; B. Northeastern Minnesota region, MN; C. Black Hills region, SD; D. Mark Twain National Forest region, MO; E. Ozark National Forest region, AR; and F. Ouachita National Forest region, AR and OK.

Table 3
Summary statistics for large areas (>2500 km^2) of contiguous potential habitat for cougars in midwestern North America.

Label[a]	Location	Area (km^2)[b]	Percent (%) of state area[b]
A	Badlands, ND	3,825	2.1
B	Northeastern Minnesota, MN	11,100	5.1
C	Black Hills, SD	2,625	1.3
D	Mark Twain National Forest, MO	12,150	6.7
E	Ozark National Forest, AR	9,000	6.6
F	Ouachita National Forest, AR and OK	15,000	5.5 (AR); 4.1 (OK)
	Entire Midwest region	53,700	3.2

[a] Defined in Fig. 1.
[b] Amount of area of contiguous (≥2500 km^2), highly suitable (≥75%) habitat for cougars in the Midwest.

and southeastern Oklahoma appear to be very promising potential cougar habitat because of rugged topography, thick forest cover, and relatively low human densities (Table 4). Compared to statewide values (LaRue and Nielsen, 2008), potential cougar habitat contained proportionately more forest cover and less agricultural and developed cover types.

Our habitat model appeared relatively accurate when (1) validated with an independent set of cougar confirmation locations, (2) compared to a null data set, and (3) compared to other studies (Fecske, 2003; Thatcher et al., 2006). In North Dakota, average habitat favorability for sections containing cougar confirmations was 74%, which corresponded with the minimum threshold we considered to be highly favorable habitat. These confirmation locations were in areas with 17% higher habitat favorability as compared to statewide, where the mean favorability score was 57%. This indicates that cougar confirmations and suitable habitat did not occur at random on the North Dakota landscape. Fecske (2006) also found that the Badlands were good habitat for cougars and those results overlap ours almost entirely. Arkansas was the only state of overlap between Thatcher et al. (2006) and our study; we both found the Ozark National Forest and Ouachita National Forest to be highly suitable for *Puma*.

However, our model failed to identify contiguous cougar habitat in northwestern Nebraska, which appears to sustain a small resident cougar population of likely dispersers from the Black Hills population (Cougar Network, 2010; Thompson and Jenks, 2010; Wilson et al., 2010). We suggest cougars can certainly persist in areas with <75% habitat suitability or in areas of contiguous suitable habitat <2500 km^2 such as we modelled, especially in areas being recolonized by a nearby source population. We believe our model should be viewed as a rather conservative estimate of cougar habitat for the region.

4. Model utility

The modelling framework we employed was useful for identifying potential habitat for cougars in midwestern North America and provides an example approach for modelling potential habitat for large carnivores in the region and elsewhere. Gray wolves (*Canis lupus*) and black bears (*Ursus americanus*), have recolonized and increased their distribution in several midwestern states during the past decade (Gehring and Potter, 2005; Bales et al., 2005; Beringer, 2008). These top-tier trophic species will have a variety of ecological and socioeconomic effects in the states in which they are expanding, and wildlife conservation agencies will benefit from proactive planning efforts to focus management of unfamiliar species (Davenport et al., 2010).

More specifically, our model provides valuable baseline information for further analyses regarding cougar occupancy potential in the Midwest. In addition to dispersal corridor modelling (LaRue and Nielsen, 2008), analyses of re-colonization potential or population viability may now be possible for cougars in the Midwest, given in our work. It is unknown whether cougars will eventually re-colonize the Midwest, but dispersal of subadults into the region has occurred (Thompson and Jenks, 2005, 2010). Should cougars

Table 4
Mean values of habitat variables used in an expert-assisted model to identify potential habitat for cougars in midwestern North America.

Label[a]	Location	Human density (persons/km^2)	Road density (m/km^2)	Forest (%)	Agriculture (%)	Developed (%)
A	Badlands, ND	0.5	37.4	36.0	3.7	0.1
B	Northeastern Minnesota, MN	3.5	20.3	68.9	0.6	0.1
C	Black Hills, SD	21.8	65.2	87.5	2.0	0.2
D	Mark Twain National Forest, MO	16.0	106.0	88.2	9.8	0.1
E	Ozark National Forest, AR	10.7	167.0	88.5	9.9	0.1
F	Ouachita National Forest, AR and OK	9.3	112.0	89.1	7.2	0.1

[a] Defined in Fig. 1.

re-colonize the interior of North America, our model may be useful for predicting the potential proximity of cougars to humans (Beier, 1991; Kadesky et al., 1998; McKee, 2003), livestock (Torres et al., 1996), and important prey populations harvested by humans (e.g., white-tailed deer, *Odocoileus virginianus*). Wildlife biologists and natural resource planners could then use our model as an educational and planning tool to proactively address potential human–cougar conflicts, or other conflicts with potentially re-colonizing large carnivores in the Midwest (Beier, 2010).

Acknowledgements

We thank the Summerlee Foundation, Shared Earth Foundation, Cougar Network, and Graduate School and Cooperative Wildlife Research Laboratory at Southern Illinois University Carbondale for project funding. Thanks to C. Anderson, P. Beier, C. Christianson, G. Koehler, D. Onorato, H. Quigley, T. Ruth, H. Shaw, S. Wilson, A. Wydeven, and J. Young for evaluating and returning our expert-opinion survey. T. Oyanna and P. McDonald provided considerable support with GIS. Thanks to D. Fecske for providing data regarding cougar locations used for model validation. We also acknowledge C. Anderson, M. Dowling, K. Miller, H. Shaw, and B. Wilson of the Cougar Network for facilitating our research and providing helpful guidance. Finally, thanks to P. Beier and an anonymous reviewer who provided comments that improved earlier drafts of this manuscript.

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