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Research Article

Cougars Are Recolonizing the Midwest: Analysis of Cougar Confirmations During 1990–2008

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ABSTRACT Although cougars (*Puma concolor*) were extirpated from much of midwestern North America around 1900, hard evidence of cougar presence has increased and populations have become established in the upper portions of the Midwest during the past 20 years. Recent occurrences of cougars in the Midwest are likely due to dispersal of subadult cougars into the region from established western populations, and may be indicative of further recolonization and range expansion. We compiled confirmed locations of cougars (i.e., via carcasses, tracks, photos, video, and DNA evidence) collected during 1990–2008 in 14 states and provinces of midwestern North America. We separated our study area into 2 regions (east and west), calculated number and types of confirmations, and assessed trends in confirmations during the study period. We recorded 178 cougar confirmations in the Midwest and the number of confirmations increased during the study period ($r = 0.79$, $P \leq 0.001$). Confirmations by state or province ranged from 1 (Kansas, Michigan, and Ontario) to 67 (Nebraska). Carcasses were the most prevalent confirmation type ($n = 56$). Seventy-six percent of known-sex carcass confirmations were males, consistent with predominantly male-biased dispersal in cougars. More confirmations ($P = 0.05$) were recorded in the western region ($\overline{x} = 19.9 \pm 22.8$/yr) than the eastern region ($\overline{x} = 4.3 \pm 3.1$/yr). Seventy-nine percent of cougar confirmations occurred within 50 km of highly suitable habitat (i.e., forest areas with steep terrain and low road and human densities). Given the number of cougar confirmations, the increasing frequency of occurrences, and that long-distance dispersal has been documented via radiocollared individuals, our research suggests that cougars are continuing to recolonize midwestern North America. © 2012 The Wildlife Society.

KEY WORDS cougar, dispersal, Midwest, *Puma concolor*, recolonization.

Cougar (*Puma concolor*) populations have been largely absent from eastern and midwestern North America since the early 1900s, because of direct persecution and declining prey populations (Sunquist and Sunquist 2002). Since then, cougars have been restricted to the American west, except for the critically endangered Florida panther (*P. c. coryi*; Maehr et al. 2002). When cougars were reclassified from a bountied predator to a managed game species in the 1960s and 1970s, populations in the western portions of the continent rebounded significantly (Pierce and Bleich 2003). Now, cougars may be expanding into the Midwest from western source populations (Nielsen et al. 2006, Thompson and Jenks 2010, Cougar Network 2011).

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Currently, 3 breeding populations of cougars exist in the Midwest within 400 km of established cougar range (Fig. 1), all of which were likely recolonized naturally from the West. The Black Hills population became viable in the 1990s (Fecske 2003, Beier 2010, Thompson and Jenks 2010), and has been a primary source for new (post-2005) breeding populations in the North Dakota Badlands (North Dakota Game and Fish Department 2007, Fecske et al. 2008) and western Nebraska (Hoffman and Genoways 2005, Wilson et al. 2010). Long-distance dispersal (Thompson and Jenks 2005, Stoner et al. 2008, Henaux et al. 2011) has facilitated recolonization and range expansion of cougar populations. Recently a male cougar from the Black Hills (its origin was verified through genetic analysis) dispersed >2,900 km through Minnesota, Wisconsin, and New York before being killed by a vehicle in Connecticut (Cougar Network 2011). The establishment of new breeding populations and

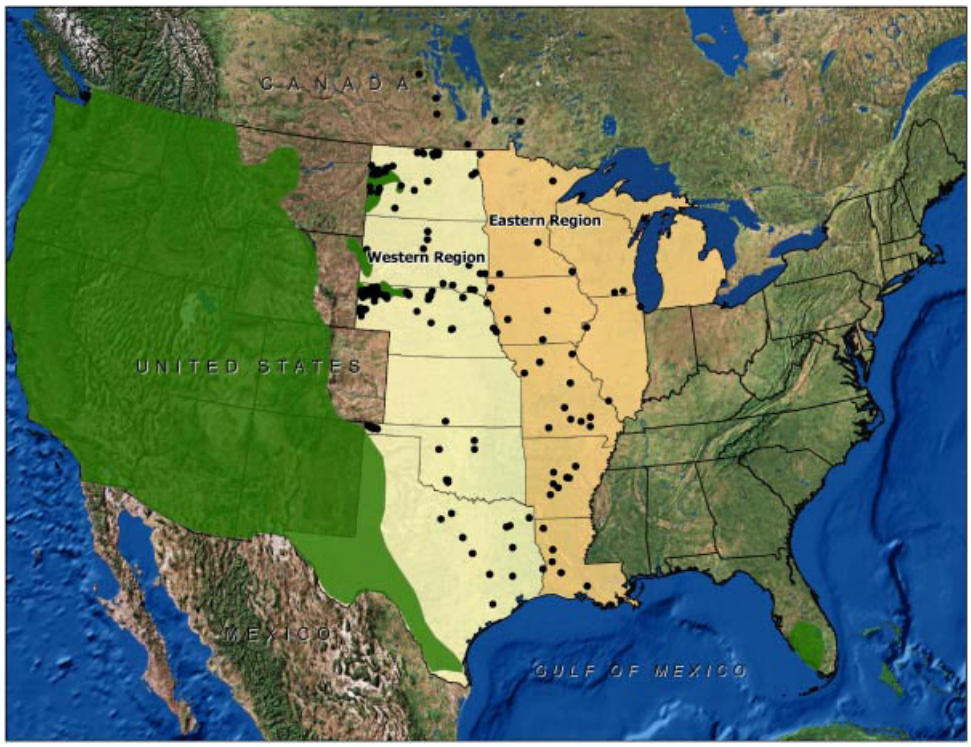

Figure 1. Confirmed cougar locations ($n = 178$) in midwestern North America during 1990–2008. Dark-shaded represent the population in western United States and established cougar populations in the Black Hills, South Dakota, the Badlands, North Dakota, and northwestern Nebraska.

documented instances of long-distance dispersal has provided credibility to the notion that cougars are indeed moving into portions of their historic range in the Midwest.

Since the 1990s, cougar occurrences (hereafter cougar confirmations) have been confirmed in the Midwest every year (Nielsen et al. 2006, Cougar Network 2011). This phenomenon has spawned research into potential dispersal corridors and paths (LaRue and Nielsen 2008, Henaux et al. 2011), habitat suitability (LaRue and Nielsen 2011), and human dimensions associated with cougar expansion in the Midwest (Davenport et al. 2010). These analyses suggest that 8% of the Midwest contains highly suitable cougar habitat, suitable dispersal corridors are indeed present, and the public is generally supportive of cougar presence in the region. However, questions remain regarding the number, type, and habitat associations of cougar confirmations in the Midwest, and what insight those confirmations may provide into the issue of potential recolonization.

The Cougar Network, a non-profit organization dedicated to monitoring cougar presence east of their range, compiled all known, definitive occurrences of cougars outside their established range since 1990 (Nielsen et al. 2006, Cougar Network 2011). These data in conjunction with previous research (LaRue and Nielsen 2008, 2011; Thompson and Jenks 2010; Henaux et al. 2011), may lend considerable insight into the issue of cougar recolonization and range expansion throughout Midwest. We analyzed records of cougar confirmations in the Midwest collected by the Cougar Network during 1990–2008. Our specific objectives were to 1) summarize cougar confirmation records by number, type, and region; 2) characterize trends in cougar confirmations over time; and 3) assess habitat suitability (LaRue and Nielsen 2008, 2011) associated with cougar confirmation locations.

METHODS

We compiled cougar confirmations recorded during 1990–2008 in a 3,200,000-km^2 portion of midwestern North America. Our study area included North Dakota, South Dakota, Minnesota, Wisconsin, Michigan, Illinois, Iowa, Nebraska, Kansas, Missouri, Arkansas, Louisiana, Texas, Oklahoma, and the Canadian provinces of Ontario and Manitoba. Confirmation data were provided and verified by state and/or federal wildlife agencies, and included the county and state where the confirmation was located, date, confirmation type, verifying source, and pertinent notes. When finer-scale location data were available, we included specific latitude and longitude coordinates of a confirmation. We only considered tangible, physical evidence of a cougar when evaluating potential confirmations, accepting only those verified by qualified wildlife professionals (Nielsen et al. 2006, Cougar Network 2011). Cougar sighting data and animals known to be released captives were not included in our dataset. We classified confirmations into 6 different categories: carcass, video, photo, DNA, tracks, or other tangible, physical evidence of cougar presence, such as wildlife or domestic animal depredation.

We carefully excluded confirmation data that were not verifiable or were inappropriate given the lack of uniform treatment (i.e., cougar harvest) over the study area. Given their status as containing breeding populations, we excluded confirmations from the Black Hills entirely and

confirmations from western North Dakota from 2006 to 2008 (North Dakota Game and Fish Department 2007, 2010; Fecske et al. 2008). We also excluded confirmations from the North Dakota and South Dakota harvests (North Dakota Game and Fish Department 2010, South Dakota Department of Game, Fish, and Parks 2010).

We calculated the total number and type of confirmations per state or province and within the entire study area during 1990–2008. For carcass confirmations, we calculated percentage of males versus females, as this was the only source of definitive sex information from our dataset. We further separated our study area into 2 regions (Fig. 1) to address spatial trends in areas near established cougar range (i.e., the western region; ND, SD, NE, KS, OK, TX, and Manitoba) versus areas farther away from established cougar range (i.e., the eastern region; MN, IA, MO, AR, LA, WI, MI, IL, and Ontario). We calculated Pearson's correlation coefficient ($\alpha = 0.05$ throughout) to assess trends in confirmations over time (years) for the each region and for the entire study area. We determined the correlation between confirmations in the eastern regions versus western regions to assess differences in the spatial extent of potential recolonization. We used a 1-tailed Student's t-test to examine regional differences in 1) the total number of confirmations and 2) the number of carcass confirmations.

We used habitat suitability information for cougars in the Midwest from LaRue and Nielsen (2008, 2011) to determine the proportion of confirmations within highly suitable habitat (i.e., forested areas with steep terrain, and low road and human densities), and to calculate the average suitability of habitat at cougar-confirmation locations. We resampled the habitat suitability map from LaRue and Nielsen (2011) to 1-km resolution to account for the size of the study area and potential inaccuracies in spatial locations of confirmations. We did not calculate habitat suitability scores for Canadian provinces because geospatial datasets needed for our model were not concurrent with existing data for the United States. We also calculated average distance to confirmations from habitat patches in the Black Hills, North Dakota Badlands, and the easternmost habitat patches within the entire range of established cougar populations. The easternmost patches were defined as highly suitable (>75%) habitat (LaRue and Nielsen 2011) that were >64 km^2, which represents the smallest post-parturition home range of a female cougar (Ross and Jalkotzy 1992); effectively the smallest area that could contain breeding individuals. Patches ranged from North Dakota to Texas (LaRue and Nielsen 2008, 2011). We determined the center of each of the aforementioned habitat patches using ArcGIS 9.3 (ESRI Inc., Redlands, CA) and calculated the distance from the center point of each patch to each cougar confirmation location. We then calculated the average distances from cougar confirmations to the Black Hills, North Dakota Badlands, and easternmost habitat patches separately. We also buffered highly suitable habitat patches throughout the study area by 20 km and 50 km to determine the number of confirmations in proximity to highly suitable habitat. We used distances of 20 km and 50 km to account for potential inaccuracies in location data and because cougars can travel approximately 10–11.5 km/day (Hemker et al. 1984, Dickson et al. 2005). A cougar confirmation within 20–50 km of a suitable habitat patch represents an animal that had likely been using suitable habitat, but our location accuracy (i.e., at the county level) was unable to capture finer detail.

RESULTS

We recorded 178 cougar confirmations occurring in the Midwest during 1990–2008 (Table 1; Fig. 1). The number of confirmations increased through time ($r_{17} = 0.79$, $P \leq 0.001$), with the most annual cougar confirmations ($n = 32$) occurring during the final year of the study (Fig. 2). Nebraska had the most cougar confirmations ($n = 67$) through the study period; Kansas, Michigan, and Ontario reported the fewest ($n = 1$ each; Table 1). Carcasses were the most prevalent confirmation type ($n = 56$) and video and live animal captures were least common (Table 2). Of the 38 known-sex carcasses, 76% ($n = 29$) were male.

More confirmations ($t_{14} = 1.76$, $P = 0.03$) were recorded in the western region ($\overline{x} = 19.9 \pm 22.8$/yr; SD throughout) than the eastern region ($\overline{x} = 4.3 \pm 3.1$/yr). We found a positive correlation ($r_{17} = 0.61$, $P = 0.001$) in the number of confirmations between the 2 regions; number of confirmations increased through time in both regions (Fig. 3). More carcass confirmations occurred in the western region ($\overline{x} = 6.4 \pm 5.3$/yr) than the eastern region ($\overline{x} = 2.2 \pm 1.1$/yr; $t_{11} = 2.59$, $P = 0.05$).

Mean habitat suitability at cougar confirmation locations (at the 1-km^2 scale) throughout the study area was 65 ± 2%; habitat suitability for all counties in the study area containing ≥1 confirmation was similar (66 ± 2%). Average suitability of habitat in counties where confirmations were found was 63 ± 3% and 75 ± 2% in the eastern and western regions, respectively. Approximately 62% ($n = 110$) of confirmations

Table 1. Number of cougar confirmations (i.e., photo, video, tracks, carcass, or DNA evidence) per state or province in midwestern North America during 1990–2008. These data excluded confirmations within established populations in the Black Hills, confirmations in the Badlands after 2006, and all legally harvested animals.

State	*n*	% of Total
Nebraska	67	37.6
North Dakota	31	17.4
Oklahoma	12	6.7
Texas	12	6.7
South Dakota	11	6.2
Missouri	10	5.6
Arkansas	8	4.5
Louisiana	5	2.8
Manitoba	5	2.8
Minnesota	5	2.8
Iowa	4	2.2
Illinois	3	1.7
Wisconsin	2	1.1
Kansas	1	0.6
Michigan	1	0.6
Ontario	1	0.6
Total	178	100.0

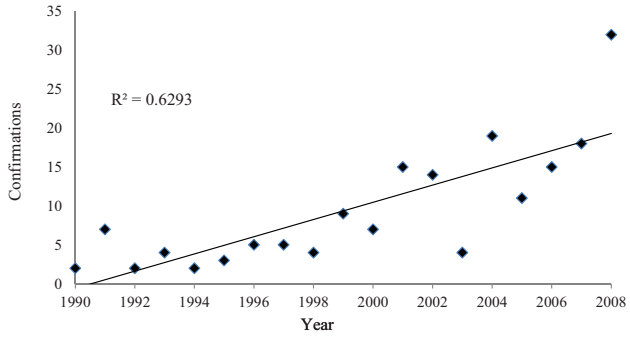

Figure 2. Confirmed cougar locations per year in midwestern North America during 1990–2008, excluding legally harvested animals and confirmations occurring within the Black Hills or in the Badlands after 2006. Confirmed cougar locations included carcasses, live animals, tracks, photographs, video, and DNA evidence verified by wildlife professionals.

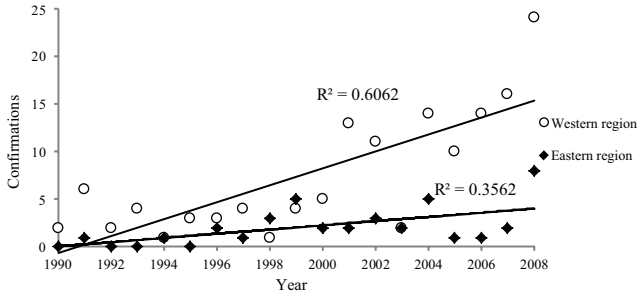

Figure 3. Annual number of cougar confirmations per region in midwestern North America during 1990–2008. The western region included North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. The eastern region was comprised Minnesota, Iowa, Missouri, Arkansas, Louisiana, Illinois, Wisconsin, and Michigan.

were within 20 km of a highly suitable habitat and 79% ($n = 140$) were within 50 km of suitable habitat. Average distance of confirmations from the Black Hills was 664 ± 503 km and average distance from the centroids of the 20 patches of habitat within the established range to 178 confirmations in the Midwest was 997 ± 507 km (Table 3).

DISCUSSION

Our findings lend further credence to Thompson and Jenks (2010), suggesting that cougars are likely recolonizing and expanding their range in the Midwest. We provide 3 novel pieces of evidence to support this conclusion. First, cougar confirmations increased significantly in the study area during the last 2 decades, and many of these animals are likely dispersing from the Black Hills. Indeed, genetic and isotopic evidence (Henaux et al. 2011), and data from radiocollared animals (Thompson and Jenks 2010) support this hypothesis. Second, states with the greatest number of confirmations outside the Black Hills were North Dakota and Nebraska, consequently where breeding populations have recently become established (Fecske et al. 2008, Wilson et al. 2010).

Table 2. Confirmations of cougars by confirmation type in midwestern North America during 1990–2008. Carcass confirmations consisted of the body of a dead cougar present in the study area; tracks were verified by a state or federal wildlife biologist; camera confirmations were photographs verified by a state or federal wildlife biologist; the designation of "other" for confirmations consisted of wildlife or domestic animal depredations verified as being attributed to a cougar; scat was verified by a state or federal wildlife biologist; the "animal" designation was considered a live animal that was trapped and later released elsewhere; and video confirmations consisted of videographic evidence of a cougar that was verified by a state or federal wildlife biologist.

Confirmation type	*n*	% of Total
Carcass	56	31.5
Tracks	40	22.5
Camera	37	20.8
Other	19	10.7
Scat	10	5.6
Animal	8	4.5
Video	8	4.5
Total	178	100.0

Third, the majority of carcass confirmations (76%) were male. Cougars are capable of traveling long distances (e.g., Oklahoma male: 1,067 km [Thompson and Jenks 2005], Utah female: 1,341 km [Stoner et al. 2008]), and males are the primary dispersers in cougar populations (Ross and Jalkotzy 1992, Sweanor et al. 2000, Logan and Sweanor 2001). Combined, these findings suggest a continued recolonization and range expansion event of cougars from the West into midwestern North America.

Because we found more confirmations in the western regions than the eastern regions of the Midwest, our results provide further evidence that cougar recolonization of the Midwest appears to be proceeding via stepping-stone dispersal. Stepping-stone dispersal adheres to island biogeography theory (MacArthur and Wilson, 1967), such that a matrix of suitable and unsuitable habitat exists for a dispersing individual, whereby the largest, closest patches are most likely to be inhabited first. Specifically, a stepping-stone disperser moves out of a density-dependent population, stopping at the closest patch of available habitat and examining its surroundings for suitability (e.g., mates and prey) before moving on. For a population to expand its range, both males and females need to disperse from the source (e.g., the Black Hills). Habitat patches that intersect dispersal paths of both males and females is where populations are likely to expand first; cougars likely fit the stepping-stone dispersal model because females are far more philopatric, dispersing at lower rates, and distances than males (Lopez-Gonzalez 1999, Sweanor et al. 2000, Maehr et al. 2002, Anderson et al. 2004, Thompson and Jenks 2010). Given this, areas closest to the Black Hills should be recolonized first, as our results indicate.

Table 3. Mean distances to cougar confirmations in midwestern North America during 1990–2008 from established populations in the Badlands, North Dakota, Black Hills, and South Dakota, and to the 20 easternmost patches of habitat in the west (LaRue and Nielsen 2008, 2011); *n* corresponds to the number of distance calculations determined per established population.

Established habitat patch	*n*	$\bar{x}$ Distance (km)	SD
Badlands	178	864	582
Black Hills	178	664	503
Western range	6,230	997	507

We found the majority of confirmations were within or relatively close to highly suitable habitat, defined as areas comprised primarily forest cover, containing steep slopes, and with low road and human densities (LaRue and Nielsen 2008, 2011). However, we recognize that areas of less-suitable habitat in the study area likely consisted of row crops, which could actually provide suitable cover for dispersing individuals for a few months per year. Our study area contained approximately 8% highly suitable habitat for cougars (LaRue and Nielsen 2011); 62% of all confirmations in our study area were within 20 km of suitable habitat patches and 79% of confirmations were within 50 km of suitable habitat. We are aware of potential inaccuracies in the location data; therefore, we calculated the number of confirmations in proximity to highly suitable habitat patches. Given that cougars are known to use less suitable habitat during dispersal (Beier 1995, Dickson et al. 2005, Thompson and Jenks 2005), it was not surprising that we did not find a closer association of confirmations with highly suitable habitat.

We recognize several limitations to our study given the nature of the confirmation data. As aforementioned, all potential cougar confirmations were rigorously reviewed by wildlife biologists (Nielsen et al. 2006). Besides carcasses, no confirmation data could be analyzed for sex, age, or DNA information to verify potential sources, and DNA and age of most carcasses were not analyzed. Regardless, we contend these animals were likely dispersers from established populations, and not merely released captives. We also acknowledge that video and camera confirmations may very well represent multiple counts of the same animal moving through the region. For example, the cougar killed recently in Connecticut was definitively documented in >5 instances (via individual markings in remote camera photos and DNA analysis) in Minnesota, Wisconsin, and New York prior to its vehicle-caused mortality event (Cougar Network 2011). However, given the quality of the carcass data alone, we feel confident that other types of confirmation data are likely representative of what was found in the carcass data (i.e., primarily subadult males likely dispersing from the Black Hills or other established breeding populations).

MANAGEMENT IMPLICATIONS

Range expansion of top predators is a relatively new phenomenon in North America, but is not unique to cougars (Thompson and Jenks 2010), as grizzly bear (*Ursus arctos*), wolf (*Canis lupus*), coyote (*Canis latrans*), and black bear (*Ursus americanus*) populations throughout North America have experienced recent range expansions (Pletscher et al. 1997, Wydeven et al. 1998, Gompper 2002, Pyare et al. 2004). The implications of large carnivores recolonizing portions of North America have been discussed elsewhere and include impacts on trophic dynamics and carnivore-human conflicts (Mladenoff et al. 1997, Mladenoff and Sickley 1998, Gehring and Potter 2005, Rice et al. 2007, Thompson and Jenks 2010). Perhaps the most important concern to wildlife managers regarding cougar recolonization in the Midwest is how the public will respond, given that people have been living without large carnivores there for nearly a century. Studies generally suggest that humans have learned to live with long-established predators (Riley and Decker 2000, Teel et al. 2002, Zinn and Pierce 2002, Casey et al. 2005). In contrast, human attitudes regarding cougars in the Midwest are just beginning to be investigated (Davenport et al. 2010). We agree with Beier (2010) and Thompson and Jenks (2010) that enough information exists for wildlife professionals to begin thinking about public awareness campaigns in areas likely to encounter dispersing cougars. Successful conservation strategies will almost certainly require an integrated approach involving management across state boundaries (Sinclair et al. 2001) and careful thought will be needed to accurately inform the public of cougar recolonization in the Midwest (Davenport et al. 2010). Mountain lion response plans are already in place in Nebraska and Missouri (Nebraska Game and Parks Commission 2004, Cougar Network 2011, Wilson et al. 2010), and we suggest that states even farther east consider doing the same.

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