Distribution of American black bear occurrences and human–bear incidents in Missouri

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Abstract: American black bears (*Ursus americanus*) were nearly extirpated from Missouri (USA) by the early 1900s and began re-colonizing apparent suitable habitat in southern Missouri following reintroduction efforts in Arkansas (USA) during the 1960s. We used anecdotal occurrence data from 1989 to 2010 and forest cover to describe broad patterns of black bear re-colonization, human–bear incidents, and bear mortality reports in Missouri. Overall, 1,114 black bear occurrences (including 118 with dependent young) were reported, with 95% occurring within the Ozark Highlands ecological region. We created evidentiary standards to increase reliability of reports, resulting in exclusion of 21% of all occurrences and 13% of dependent young. Human–bear incidents comprised 5% of total occurrences, with 86% involving bears eating anthropogenic foods. We found support for a northward trend in latitudinal extent of total occurrences over time, but not for reported incidents. We found a positive correlation between the distribution of bear occurrences and incidents. Twenty bear mortalities were reported, with 60% caused by vehicle collisions. Black bear occurrences have been reported throughout most of Missouri's forested areas, although most reports of reproduction occur in the southern and eastern Ozark Highlands. Though occurrence data are often suspect, the distribution of reliable reports supports our understanding of black bear ecology in Missouri and reveals basic, but important, large-scale patterns important for establishing management and research plans.

Key words: American black bear, distribution, incident, Missouri, mortality, nuisance, re-colonization, *Ursus americanus*

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Introduction

The range of American black bears (*Ursus americanus*) contracted throughout much of the early 20th century in the United States (Laliberte and Ripple 2004), mostly from habitat loss, forest fragmentation (Hellgren and Maehr 1992), and unregulated hunting (Hristienko and McDonald 2007). However, relaxation of these pressures, repatriation efforts, and black bear dispersal via contiguous forest and riparian corridors has facilitated their re-colonization over parts of their historical range in North America (Smith and Clark 1994, Pelton et al.1998, Frary et al. 2011, Simek et al. 2012, Lackey et al. 2013). Likewise, bears in Missouri and surrounding Interior Highlands were thought to be extirpated by the early 1900s (Bennitt and Nagel 1937, Smith and Clark 1994, Schwartz and Schwartz 2001). Following the successful reintroduction of black bears in Arkansas during 1958–1968 (Smith and Clark 1994), populations have expanded throughout much of the Interior Highlands of Arkansas and Oklahoma (Smith et al. 1991, Bales et al. 2005, Gardner-Santana 2007, Faries et al. 2013). Proximity of bear populations in Arkansas and increasing occurrences and nuisance reports in southern Missouri also suggested that black bears started expanding northward into the Ozark region of Missouri (Missouri Department of Conservation [MDC] 2008). Recent genetic evidence has demonstrated both the persistence of a remnant population and expansion of Arkansas' bear population into Missouri following their reintroduction (Faries et al. 2013).

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Large carnivores often exist at low densities (Lofroth and Krebs 2007, Sollmann et al. 2011, Sunarto et al. 2013) and monitoring their distribution over space and time presents many logistical and statistical challenges (Gese 2001, Bjornlie et al. 2013). The validity of anecdotal occurrence data (McKelvey et al. 2008) collected from numerous sources (e.g., sightings, photographs, tracks) to estimate distribution is often unreliable, and can be spatially and temporally biased (Kucera et al. 1995, Gese 2001, Hellgren et al. 2005, Lee et al. 2010). Inference from these sources is further confounded by nonrandom or non-independent observations, locational uncertainty, and habitat changes over long sampling periods (Agee et al. 1989, Stoms et al. 1993, Palma et al. 1999). Considerable attention has been given to improving the reliability of using anecdotal data for conservation decision-making (Aubry and Jagger 2006, McKelvey et al. 2008, Frey et al. 2013, van Strien et al. 2013). Nonetheless, more rigorous sampling methods spanning both the extensive spatial distribution of large carnivores and temporal scales necessary to elucidate trends in their distribution are often logistically impossible to implement for such wide-ranging and elusive species (Braunisch and Suchant 2010).

Black bear presence in southern Missouri has now been documented throughout much of the Ozark Highlands plateau and negative interactions with humans are of increasing concern for wildlife managers. Many ecological and anthropogenic factors influence re-colonization by large carnivores (Mladenoff et al. 1999, Onorato and Hellgren 2001, LaRue and Nielsen 2008, Frary et al. 2011), and understanding patterns of re-colonization is important for developing conservation and management strategies (Swenson et al. 1998, Carroll et al. 2001, Bales et al. 2005). Our objectives were to use historical occurrence data and forest cover to characterize broad patterns of black bear re-colonization in Missouri, and summarize bear incident (Hopkins et al. 2010) reports to describe their distribution, frequency, and type of incident occurrence over time. We hypothesized that the distribution of occurrences would follow the distribution of forest cover, occurrence reports would follow a northward trend over time, and the distribution of bear incidents would follow a similar spatio-temporal pattern and be correlated with location of occurrences.

Study area

Missouri (35°57′–40°35′N, 89°8′–95°46′W) comprises 180,472 km^2 and includes 37% forest, 51% crop and pasture, 2% grassland, and 7% developed areas (Fry et al. 2011). Of the 66,390 km^2 of forest in Missouri, 80% occurs in the Ozark Highlands ecological region and is predominantly upland oak–hickory (*Quercus* spp., *Carya* spp.) and oak–pine (*Pinus* spp.; Raeker et al. 2010). Land ownership in the Ozark Highlands includes private homesteads and farms and public lands (e.g., Mark Twain National Forest, Ozark National Scenic Riverways). Elevations in Missouri range from 70 m to 540 m, with the greatest elevations found in the Ozark Highlands (Nigh and Schroeder 2002, United States Geological Survey 2009).

Methods

We used statewide public bear occurrence data obtained through MDC's Report a Bear Sighting system (MDC 2013) from 1989 to 2010 to examine distribution and potential range expansion of bears throughout Missouri. This system collected bear occurrences by phone, email, and mail-in observation forms, until it was made available online in 2008 (MDC 2008). Public requests for bear occurrences by MDC were opportunistic and commonly solicited at MDC offices, in MDC's magazine *Missouri Conservationist,* and in local newspapers. Type of occurrences from this data set included direct observations, sign (e.g., track or scat), vehicle collisions, illegal harvests, and bear incidents. Records included date, location, description of occurrence, and number of adult bears and dependent young observed. We created evidentiary standards (McKelvey et al. 2008) using 6 categories (i.e., bear mortality, nuisance complaint, observation, photograph, sign, and no data) based on descriptions provided for each occurrence record. To improve reliability of occurrences, we excluded all records with no data describing the occurrence and sign records based on insufficient evidence (e.g., unconfirmed scat). We also excluded occurrences that lacked geographic coordinates. Given the large size of black bears and lack of similar species in Missouri, we considered all other categories to be reliable sources of bear occurrence.

We used ArcGIS 10.0 (Environmental Systems Research Institute, Redlands, California, USA) to map reported bear occurrences in relation to forest cover. We used Landsat-based, 30-m-resolution

land-cover data from the 2001 National Land Cover Database (Homer et al. 2007) to describe distribution of forest cover (i.e., deciduous, evergreen, and mixed forests).

To examine whether occurrence data may reveal any northward trend in re-colonization over time, we regressed annual maximum latitude of occurrence on year of occurrence record ($\alpha = 0.05$). If there were <10 occurrences in a year, we omitted that year from analysis to minimize any effect of small sample size. We used simple linear regression using function lm in Program R (R Development Core Team 2013).

We summarized reported nuisance complaint records by incident type (anthropogenic food consumption , food consumption and property damage, property damage, and attack on domestic animal), and described sources of human-caused bear mortalities from 1989 to 2010. We used linear regression to test for a similar northward trend in reported bear incidents over time by regressing annual maximum latitude of incident on year of incident report. We also tested for correlation between number of incidents and number of observations by county ($\alpha = 0.05$) using Pearson's product-moment correlation (function cor.test; R Development Core Team 2013).

Results

Distribution of occurrences

Total occurrences from the MDC Report a Bear Sighting system included 1,114 reports occurring in 79 of 114 counties, including 118 reports of dependent young in 34 counties, from 1989 to 2010. Overall, most (61%) reports were direct observations; 8% were sign; 5% were bear incidents; 5% were photographs of bears; 2% were bear mortalities, and 19% lacked adequate data to categorize. We excluded 211 records lacking adequate descriptions, 17 records based on inconclusive evidence from sign, and 10 records lacking observation date. This resulted in 876 reliable occurrences, including 103 of dependent young (Fig. 1). The distribution of all reports was bimodal across years, with the first peak in 1993 ($n = 158$) and the second in 2009 ($n = 142$). The distribution remained bimodal following exclusion of unreliable records, with peak occurrences in 2009 ($n = 134$) and 2010 ($n = 110$; Fig. 1). Occurrences excluded due to poor reliability were greatest in 1992 ($n = 29$) and 1993 ($n = 50$), and averaged 11 each year (SD = 13). For regression analysis of total occurrences, we excluded

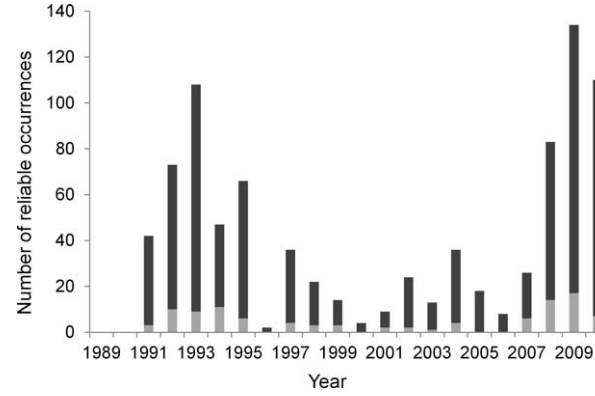

Fig. 1. Number of reliable American black bear occurrence reports with (light gray) and without (dark gray) dependent young, Missouri, USA, 1989–2010.

an additional 14 records without spatial data and 24 records from years with <10 occurrences. This resulted in the loss of 5 years (1989, 1996, 2000, 2001, 2006) from the data set, with 838 occurrences (75% of total) considered reliable for analyses.

Most bear occurrences (95%) were located in the Ozark Highlands and concentrated in the forested southern and eastern regions, with occurrences of dependent young following a similar spatial distribution (Fig. 2). We detected a significant positive effect of year of occurrence on annual maximum latitude of occurrence ($\beta_1 = 0.083$, SE = 0.027, $R^2 = 0.408$, $P = 0.008$; Fig. 3). Although the earliest reported occurrence north of the Ozark Highlands was in 1991, most (76%) occurred after 2000. In addition, occurrences north of the Ozark Highlands continued to increase during 2000–2010, with 75% reported from 2006 to 2010. Only one occurrence of dependent young was reported north of the Ozark Highlands in 2001, although no details of the observation were recorded.

Human–bear incidents

Reported bear incidents from the Report a Bear Sighting system ($n = 58$; 2 records without observation date) averaged 2.5 reports/year (SD = 3.2) from 1989 to 2010, with a maximum of 11 reports in 1995. Of these reports, 60% involved bears eating anthropogenic food, 26% involved anthropogenic food and property damage, 10% involved property damage, and 4% involved a bear purportedly attacking or killing a domestic animal. We did not find support for a relationship between maximum annual latitude

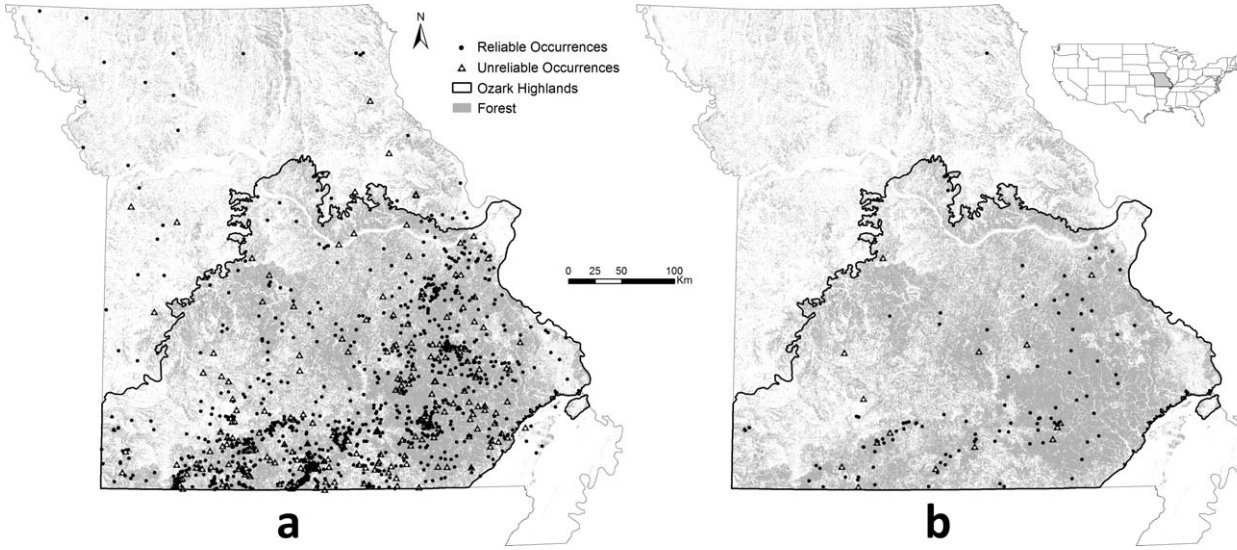

Fig. 2. Distribution of all American black bear occurrences (a) and occurrences of dependent young (b) during 1989–2010 in Missouri (USA), including locations of unreliable bear occurrences ($n = 238$).

and year of reported incident ($\beta_1 = 0.013$, SE = 0.032, $R^2 = 0.014$, $P = 0.685$). Number of incidents by county was positively associated with number of bear occurrences per county ($r_{77} = 0.76$, $P < 0.001$).

Twenty human-caused black bear mortalities were reported during 1989–2010 (1 record without observation date, 5 records without location). Mortalities were greatest in 2008 and 2009, with 4 mortalities each year. Mortalities resulted from vehicle collisions ($n = 12$), illegal harvest ($n = 3$), bear incidents ($n = 2$), and undetermined causes ($n = 3$). Three records of mortalities from vehicle collisions were not verified.

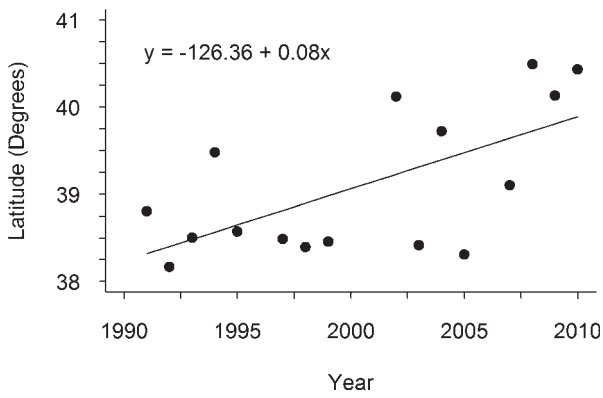

Fig. 3. Linear regression of annual maximum latitude of American black bear occurrence on year of occurrence report ($R^2 = 0.408$, $P = 0.008$) during 1989–2010 in Missouri (USA).

Sex of bears killed was recorded for 5 records comprising 4 males and 1 female. The female mortality was an illegal harvest and the male mortalities were from 2 vehicle collisions, 1 illegal harvest, and 1 undetermined. All bear mortalities with spatial data were located within the Ozark Highlands.

Discussion

Black bears often depend on forest cover for parts of their life history (Herrero 1972, Rudis and Tansey 1995), and as expected, the spatial distribution of both total and dependent young occurrences closely reflected the distribution of forest cover. The Ozark Highlands contain the largest contiguous tracts of forest in Missouri and represent the most suitable black bear habitat in the state (Smith 2013), whereas areas north of this region are primarily agricultural and contain few forests that are highly fragmented (Raeker et al. 2010). Though the current distribution of reports in Missouri reflects the importance of forest cover, it is also important to recognize that the proximity of these forests to source populations in Arkansas has likely also contributed to the underlying distribution of occurrences throughout the state. The current distribution of dependent young reports in Missouri further supports the importance of this relationship and suggests reproducing bears primarily occur in the Ozark Highlands.

Though we did not observe any northward trend in the distribution of reported bear incidents over

time, our results did suggest an overall northward increase in reported occurrences. We recognize that these data are insufficient to confirm any northward expansion of Missouri's black bear population. However, the observed trends generally support known northward dispersal from source populations in Arkansas (Faries et al. 2013), and suggest that this has contributed to bears colonizing or moving through areas of Missouri without known bear occurrences. Although the latitudinal extent of occurrences has apparently increased over time, it is important to note that most bear occurrences and mortalities remained concentrated in the more forested southern and eastern areas of the Ozark Highlands in close proximity to source populations.

The bimodal pattern in annual number of reported black bear occurrences likely reflects MDC requests for public information on black bear occurrences (Hellgren et al. 2005, Danielsen et al. 2009), rather than actual changes in black bear abundance. Reports increased dramatically from 1991 to 1993 following a MDC publicized request for occurrences in 1990 and 1991 (MDC 1993) and during 2008–2010 (J. Beringer, unpublished data). Evolving public attitudes and agency management strategies can also influence trends both within and among bear occurrences and incident reports (Garshelis and Hristienko 2006). Though not quantifiable, we also suggest that in years without MDC requests for occurrences, citizen reporting rates may have declined with decreasing novelty of observing black bears (Hellgren et al. 2005, Danielsen et al. 2009, Lee et al. 2010).

Although variation in MDC and citizen effort may account for much of the observed trends, variability in anthropogenic and natural food abundance can also influence annual variation in bear occurrences and nuisance reports. Availability of anthropogenic food can result in increased attraction by black bears to human settlements (Hristienko and McDonald 2007, Merkle et al. 2013). It is important to recognize that the likelihood of reporting occurrences or nuisance behavior is closely associated with proximity of bears to human settlements. Therefore, the positive correlation between bear occurrences and incidents is expected, but further illustrates the attractiveness of anthropogenic food to bears (Lyons 2005). Disturbance of garbage and anthropogenic food sources was the most common human–bear incident reported in Missouri, and the most common incident reported to other state and provincial wildlife agencies (Spencer et al. 2007).

Sources of human-caused bear mortalities were similar to other regions without a bear hunting season, with vehicle collisions and illegal harvests being greatest (Pelton et al. 1998, Williamson 2002, Simek et al. 2012). The 2 bears killed because of nuisance activity were both associated with apiary damage, with 1 being shot by the property owner.

Increasing interest in managing Missouri's bear population has led to greater efforts by MDC to standardize and improve reporting of bear occurrences. Our exclusion of unreliable occurrences did not influence the overall spatial or temporal distribution of occurrences and we suggest that verified public reports of black bears in Missouri are suitable as broad-scale data on bear observations. Moreover, broad-scale patterns of the distribution of occurrences relative to source populations in Arkansas and general land-cover associations (i.e., forests) corroborate our understanding of black bear ecology. Nonetheless, anecdotal reports of wildlife occurrences should be evaluated under species- and status-specific evidentiary standards (McKelvey et al. 2008), and inferences based on anecdotal data must be sensitive to potential spatial and temporal inconsistencies. For low-density, wide-ranging species such as black bear in Missouri, anecdotal occurrence records are often the only statewide data available and provide a low-cost approach to understanding basic distribution and habitat association patterns (Palma et al. 1999, Woolf et al. 2002, Hartin et al. 2007, Lackey et al. 2013). Therefore, we suggest this database revealed basic, but important, information on statewide bear occurrences and human–bear incident patterns, which will be useful for establishing future research and management plans in Missouri.

Black bears appear distributed throughout most of Missouri's forested areas. Although land conversion and habitat fragmentation may ultimately limit recovery and range expansion (Larivière 2001), distribution of occurrences indicates that black bears have potential to occupy large portions of Missouri. As black bears in Missouri continue to re-colonize historical range, understanding large-scale spatial and temporal changes in their distribution and interactions with humans will help managers better assess research and management objectives.

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