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Carnivores, urban landscapes, and longitudinal studies: a case history of black bears

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***Abstract*:** As urban landscapes expand across the globe, it becomes imperative to understand how these landscapes affect large carnivore populations. We examined the effects of human-altered landscapes on age-specific fecundity and life history parameters for female black bears (*Ursus americanus*) in urban and wildland regions in the northern Sierra Nevada Mountains of Nevada, including the Lake Tahoe Basin. We followed 12 marked female bears in an urban environment and 10 females in wildland habitats from 1997–2006. Our results show that female bears in urban areas have higher age-specific fecundity rates. Despite this difference, female bears in urban areas never realized this putative gain in fitness because they experienced higher age-specific mortality rates, leading to the creation of sinks (λ = 0.749). Urban bears of the Lake Tahoe Basin are unable to repopulate vacated wildland areas.

K*ey words*: black bears, human–wildlife conflicts, life tables, source sink, urban interface, *Ursus americanus*

Human activities associated with urban areas impact the viability of carnivore populations. Impacts include altering (1) behavior of individuals (Mattson 1990, Baker and Timm 1998, Beckmann and Berger 2003*a*), (2) distributions of populations (Craighead et al. 1995, Beckmann and Berger 2003*b*, Prange et al. 2004), (3) movements of individuals and use of corridors or linkage areas (Torres et al. 1996, Prange et al. 2004), (4) disease ecology of populations (Frolich et al. 2005), (5) diets (Craighead et al. 1995, Burgess 2000, Beckmann and Berger 2003*b*), and (6) mortality (Woodroffe and Ginsberg 2000, Grinder and Krausman 2001). Most impacts of human activities on these parameters have been investigated singly in separate, independent studies that have focused mainly on behavioral or ecological changes. Hence, little is understood about the impacts of human-altered landscapes on entire life histories of individuals in a population, especially for large carnivores.

Ecologists use population-modeling tools, such as minimum viable population (MVP) analyses and island biogeography theory to predict the likelihood of populations of various sizes surviving into the future (Ferreras et al. 2001). Many studies have focused on the theoretical basis of population viability, by modeling differing scenarios of mortality, reproductive rates, and migration under various hypothetical environmental conditions (e.g., Tiedemann et al. 2000). Many of these models are not based on empirical data from the field because one of the most challenging tasks facing population biologists who focus on large mammals is accurately estimating the number of individuals in a population and calculating age-specific survivorship and fecundity schedules (Millar and Zammuto 1983). As humans continue to expand their distribution into regions that contain carnivores, there will be a more pressing need for temporal data sets examining changes not only in behavioral parameters of carnivores, but in life history parameters, as well. Currently, such information exists for only a handful of carnivore species and rarely in urban settings. Such broad gaps in knowledge of the temporal impacts of human perturbations on large carnivores make conservation of these species difficult.

Despite the relatively simple calculations involved, life history tables potentially can be one of the most useful tools to examine the impacts of various environmental conditions and changes in land-use patterns on a species (Millar and Zammuto 1983). However, for most long-lived species with extended generation times, collecting adequate data to calculate age-specific fecundity, mortality, survivorship, and basic reproductive rates requires a data set over several years or decades. Because the vast majority of ecological field studies on mammals are only 3 to 5 years in duration, calculating life

tables is rarely done (Millar and Zammuto 1983).

We summarize a 10-year data set on black bears in western Nevada to examine the impact of humans on life history traits of a large carnivore in areas where contact rates between humans and bears are high. The primary question is whether exposure to human activities and altered food resources in the form of garbage affect bear life history patterns. We are unaware of any studies on urban carnivore populations that have estimated age-specific fecundity rates or life tables and compared them to populations existing in less human-disturbed environments. The ability to carry out this type of analysis is invaluable to understanding how individuals and, ultimately, populations respond to altered ecological regimes.

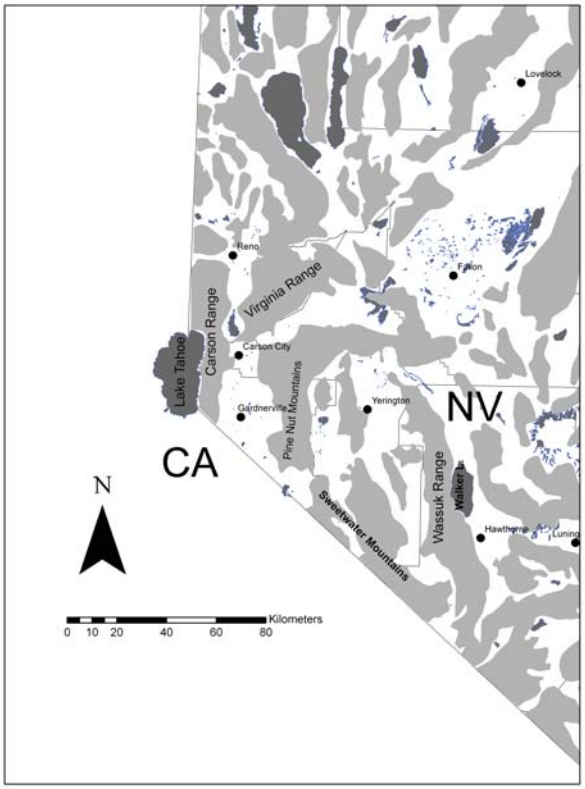

Figure 1. The region of western Nevada with mountain ranges containing black bears (*Ursus americanus*). Black bears are currently found in the Carson Range of the Sierra Nevada Mountains along the eastern shore of Lake Tahoe; the Pine Nut Range east of Carson City, Nevada; the Sweetwater Range that extends from California into Nevada; and the Wassuk Range located on the western shore of Walker Lake.

Methods

Our study was conducted in western Nevada where bears are restricted to the Carson Range of the Sierra Nevada Mountains, Sweetwater Range, Pine Nut Range, and the Wassuk Range in extreme western Nevada (Goodrich 1990; Figure 1). The current population estimate is 200–400 bears, the lowest of any western state (Beckmann and Berger 2003*b*). We specifically targeted 2 different types of bears: those in urban areas and those in wildland areas. From 1997 to 2006, 165 individuals were marked and released. Detailed procedures on capture, handling, and classification (urban versus wildland) for bears are found in Beckmann and Berger (2003*b*) and Beckmann and Lackey (2004). *A priori* individuals for which ≥90% of their location points were inside urban areas (defined by town and city delineation on coverage maps in ArcView 3.2) were defined as urban. Such sites in western Nevada were Carson City, Incline Village, Glenbrook, Stateline, Minden, and Gardnerville. South Lake Tahoe, California, was also considered an urban center in density calculations. Based upon our operational definition, there never was a case where it was questionable whether a bear was an urban or wildland bear. Urban bears always had >90% of their location points within urban areas, whereas wildland bears almost always had 100% of their location points outside urban areas (Beckmann and Berger 2003*b*).

To estimate fecundity and life table parameters, we followed 12 marked females in an urban environment and 10 females in wildland habitat from 1997–2006. These 22 bears were chosen because they were females we captured prior to their achieving reproductive maturity (<3 years of age), and collared. Thus, we could follow them throughout their entire lives. We estimated age-specific fecundity (m_x), age-specific mortality rates (q_x), and the finite rate of increase (λ) using the methods of Andrewartha and Birch (1954). Life tables were calculated

using Survival 6.0 Life Table program.

Our calculations of the finite rate of increase (λ) assumed a closed population, an assumption likely to be violated because of the close proximity of black bears in the northern Sierra Nevada Mountains of California. However, in the absence of genetic data from the California population, we were unable to estimate immigration rates. We note up-front several limitations to our analyses. (1) Our sample sizes are small relative to studies conducted under more controlled laboratory conditions because black bears are a long-lived, low-density species with extended generation times. However, we feel that our sample sizes for urban and wildland females are adequate to examine the impacts of human-altered landscapes on life history traits of this large carnivore. (2) We collapsed the final age-class of wildland bears into a >10-year-old group because all urban females included in this analysis were dead by age 10. This led to a conservative estimate of the finite rate of increase (λ) of wildland bears because no female cubs produced by wildland females >10 years of age are included in our calculations. (3) We have detected female bears up to 20 years of age in our study area. Therefore, the discrepancy in the finite rate of increase between the 2 populations is likely greater than what is reported here, with the actual λ for wildland bears being higher than that reported. Despite these potential limitations, our approach remains valuable.

Results

Age-specific fecundity (m_x = number of female cubs/female) of urban bears was higher during the early reproductive years (ages 4 and 5) and again in the prime reproductive years (ages 8–9) compared to wildland conspecifics (Figure 2). Urban female bears also had an earlier age of first reproduction (age 4) compared to that of wildland female bears (age 7) in this xeric environment (Figure 2). Fecundity rates generally increased for both groups as age increased, especially between ages 7 and 10. Age-specific mortality rates (q_x) were dramatically higher in the first 2 years of life for urban females (q_x = 0.58 and 0.20 respectively) compared to wildland conspecifics (q_x = 0 in both years; Figure 3). Both groups had similar age-specific mortality rates from age 2–7, although there was a lack of dispersal-related mortality in urban female bears at ages 2–3 as seen in wildland female bears (Figure 3). Urban female bear mortality surpassed that of wildland females again at age 8 (Figure 3). All 12 urban female bears were dead by age 10

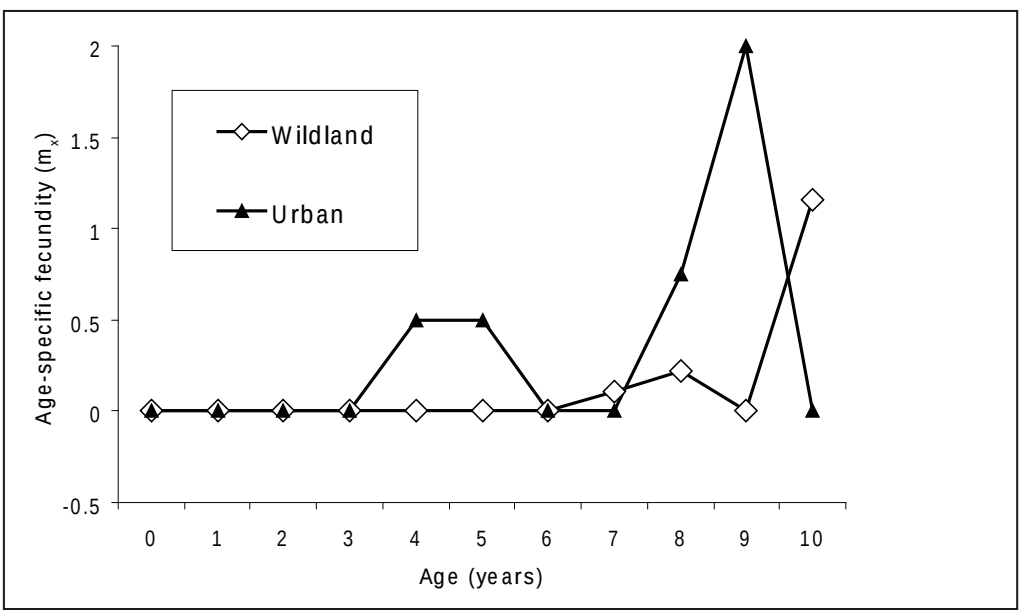

Figure 2. Age-specific fecundity (m_x = female cubs/female) rate for urban and wildland American black bears (*Ursus americanus*) in the northern Sierra Nevada Mountains of western Nevada, USA. Values are based on 12 marked female bears in urban areas and ten in wildland areas from 1997–2006.

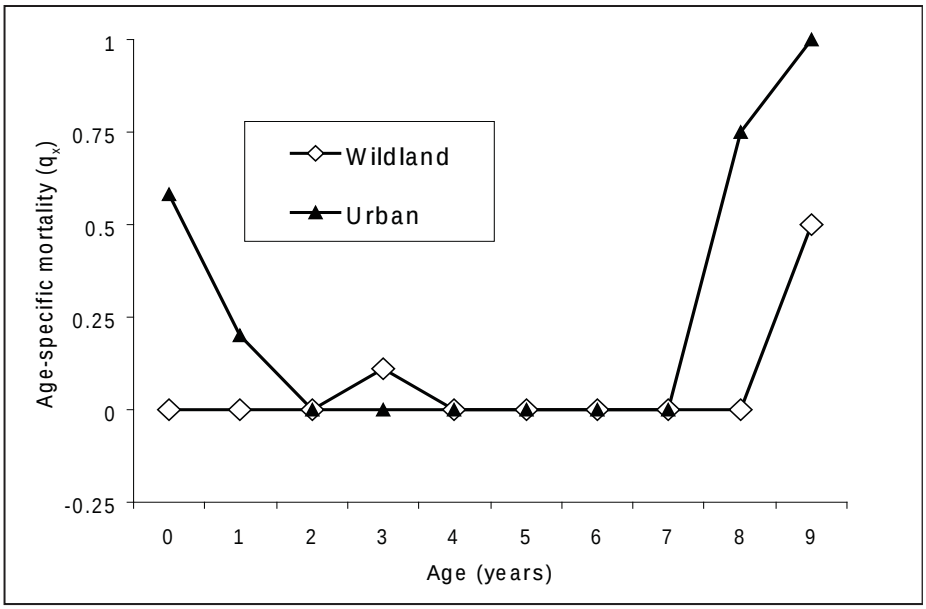

Figure 3. Age-specific mortality (q_x) rate for urban and wildland American black bears (*Ursus americanus*) in the northern Sierra Nevada Mountains of western Nevada, USA. Values are based on 12 marked female bears in urban areas and ten in wildland areas from 1997–2006.

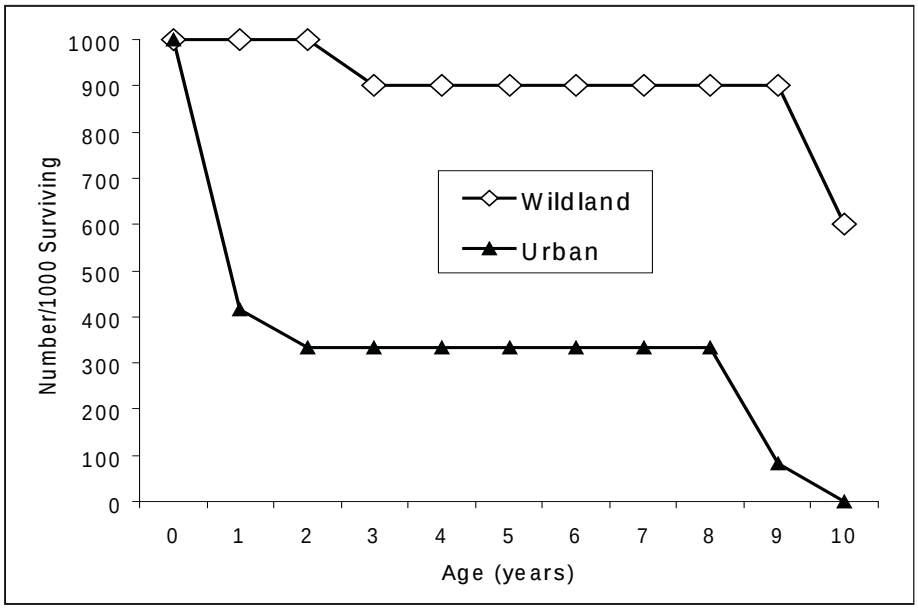

Figure 4. Age-specific survivorship curves for urban and wildland American black bears (*Ursus americanus*) in the northern Sierra Nevada Mountains of western Nevada, USA. Values are based on 12 marked females in urban areas and ten in wildland areas from 1997–2006.

due of collisions with vehicles. Our subsequent truncation of the data set at age 10 resulted in an age-specific mortality of 1.0 for wildland female bears at that age despite the fact that six were still alive.

Based on our data, higher levels of bear mortality in urban areas have led to the creation of sinks in urban centers as evidenced by the low finite rate of increase (λ = 0.75) in urban centers (λ = 1 represents a stable population). In contrast, wildland bear numbers in western Nevada are near the replacement rate (λ = 1.0). Survivorship curves demonstrate the high level of mortality among urban female bears,

particularly during the first 2 years of life (Figure 4). The chronic high level of juvenile mortality in this urban population has led to a Type III survivorship curve that is generally seen for species that produce many offspring but provide little or no parental care. This urban bear population no longer exhibits the Type I survivorship curve generally associated with large mammals that produce few offspring. Over the 10-year study period, we handled a total of 43 female bear cubs ≤24 months of age. Of those, twenty-eight (65%) died before they reached 15 months of age (dispersal age); 78% of deaths were due to collisions with vehicles. During our 10-year study period, we documented 156 bear mortalities; all of the 151 bear deaths with a known cause were due to human activities, despite the continued protected status of bears in Nevada. Of the 151 human-caused bear mortalities, 89 bears were killed by vehicles, twenty-seven by agency management actions for public safety, seventeen for depredating livestock, two due to illegal killing, and sixteen due to other causes (e.g., accidents, euthanized for poor body condition, etc.).

Discussion

Why has an increasing food supply in the form of garbage not led to more bears on the landscape and a subsequent repopulation of wildland areas? As our data make clear, bears in urban areas have experienced elevated levels of mortality that exceed reproductive rates, even though urban bears are more fecund than wildland bears.

In our study site, mortality due to anthropogenic causes have increased in the last few decades. We found that almost 9 bears have been killed annually by vehicles from 1997–2008. This represents a 17-fold increase in bear mortalities due to bear–vehicle collisions since the late 1980s (Goodrich 1993). During the late 1980s, before bears became conditioned to human food, no bears were destroyed because of safety concerns (Goodrich 1990). In contrast, 27 bears were euthanized because of safety concerns during the 10 years of our study.

We found that bear mortality in urban areas are exceeding recruitment rates. The creation of sinks in urban centers has resulted in the situation where bears are unable to repopulate vacated wildland areas following the shift to urban centers and food sources in the early to mid-1990s. In contrast to data collected on bears in the same region in the late 1980s (Goodrich 1990), we have now documented >100 urban bears, a 10-fold increase in the annual number of complaints, and a 17-fold increase in the annual bear mortality rate due to vehicles in the 1990s. In addition, densities have increased by >3-fold over baseline, historical levels (Goodrich 1990, Beckmann and Berger 2003*b*). Changes have been so great that the estimated density of urban bears at our study site is the second highest density of black bears in North America (Beckmann and Berger 2003*b*). In contrast, the historical densities for our study population were low to intermediate relative to those elsewhere in North America, due to the xeric climate of our study site.

We believe that bears are being drawn out of wildland areas by a clumped food resource in urban areas (as evidenced by the positive change in body mass, Beckmann and Berger 2003*b*) and concentrated into urban areas; stomachs of necropsied bears were filled with human garbage, and garbage was concentrated in urban areas. For example, in the Lake Tahoe Basin bears were historically found throughout the entire Carson Range (Goodrich 1990). However, due to the redistribution of bears in the landscape in the 1990s we were unable to capture any bears in the Carson Range outside of urban areas except at one small site (Little Valley, a 7-km^2 area). These findings reaffirm our supposition of dramatic and rapid decadal ecological shifts.

While discrepancies in age-specific fecundity, mortality, and the finite rate of increase between urban and wildland bears are striking, they are based on very conservative calculations. Because we truncated the data set at age 10 when all urban females were dead, we underestimated the true finite rate of increase for wildland bears, as six of them were still alive at age 10. None of their subsequent female cubs wasincluded in our calculations. In reality, λ was likely even higher for wildland bears, making the difference between urban and wildland females even more extreme.

Bears in the Tahoe Basin are likely functioning in a source-sink dynamic, with urban areas acting as sinks for bears produced in both urban areas and wildland source areas. Further,

given the near-replacement level of production in wildland areas and the sink in urban areas, the stable-sized population of bears in western Nevada over the past 15 years likely is the result of bear immigration from neighboring areas of the Sierra Nevada Mountains in California.

Management and conservation implications

Without the empirical foundation that can be provided only by long-term life history studies, the permutations of assumed life history trait values in models for species such as black bears are infinite. The ability to place realistic boundaries on trait values based on field data is extremely important in cases in which management decisions may be based on projections from population modeling (Crouse et al. 1987, Congdon and Dunham 1997). This is also true when a conflict exists between harvesting and conserving a species.

High levels of bear mortality in urban areas have led to the creation of sinks in urban centers, and bears of the Lake Tahoe Basin currently are unable to repopulate vacated wildland areas following a shift to urban centers and urban food sources (Beckmann and Berger 2003*b*). If anthropogenic sources of mortality could be reduced in the region, it is likely that the bear population in the Lake Tahoe Basin and western Nevada would slowly start to increase due to reproductive rates in wildland source areas. At the same time, densities would likely redistribute across the landscape. Given that long-lived species such as black bears have limited ability to respond to high levels of juvenile mortality (Congdon et al. 1993), the current levels of mortality of young females in urban areas makes the long-term viability of this bear population tenuous.

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