

Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food

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(Accepted 10 April 2003)

Abstract

Many areas have experienced disproportionate increases in the number of conflicts between large carnivores and humans, and this is especially true in western North America where urban sprawl has encroached into regions that have historically contained large carnivores. Yet, globally there is a paucity of studies of temporal changes in behavioural and ecological parameters of carnivores associated with human-induced perturbations at the same location. We capitalized on the extent to which human population growth and its coincident food stores offer a quasi-experimental setting to test hypotheses about the impact of novel food resources. Using black bears *Ursus americanus* and garbage, measures of behaviour and ecology were contrasted between individuals living in urban–wildland interface (‘experimental’) and in wildland (‘control’) settings at the interface of the Sierra Nevada Range and the Great Basin Desert in the western United States. A temporal dimension was included by comparing our data to those from the same population lacking areas of human encroachment 10–15 years earlier. Specifically, an examination was made of the impacts of garbage on bear time budgets, patterns of activity, and den chronology. Individuals at urban interface areas relative to wildland conspecifics were: (1) active for significantly fewer h per day (8.5 vs 13.3 h; $P < 0.01$); (2) shifted their activities to nocturnal periods ($P < 0.001$); (3) entered dens significantly later and remained in them for significantly fewer days ($P < 0.05$). Our results are contrasted with selected carnivores from sites where attendant changes in behaviour and ecology have accompanied landscape changes associated with human activity. Our findings suggest alterations in carnivore ecology may be rapid and occur within shorter periods than had been previously assumed.

Key words: *Ursus americanus*, behaviour, human-altered landscapes

INTRODUCTION

As the world’s human population increases, the resulting patchwork of urban sprawl and modified environments will dominate most landscapes (Western, 2001). The maintenance of biological diversity at the urban–wildland interface will be a challenge because for some taxa, including carnivores, populations tend to decrease as human influences increase (Vucetich & Creel, 1999; Woodroffe & Ginsberg, 2000). Little information is available about how carnivores co-exist with humans and the extent to which, if any, behavioural adjustments occur. This is particularly true if we restrict our analyses to situations not associated with livestock as the disturbance.

In some places, perturbations have compromised the viability of wildlife populations. Corbett (1995) reported that domestic dogs associated with human encroachment into areas of Australia have threatened dingoes *Canis lupus dingo* through hybridization. The introduction of domestic livestock and pets has led to an increase in diseases in some carnivore populations (e.g. Gascoyne *et al.*, 1993; Roelke-Parker *et al.*, 1996). In western North America for example, the presence of garbage in suburbs has led to a tremendous recent increase in the number of conflicts between humans and black bears *Ursus americanus* (e.g. Beckmann, 2002; Beckmann & Berger, 2003). Additionally, bears in Yellowstone have taken advantage of garbage for > 100 years (see Craighead, Sumner & Mitchell, 1995). Further, the supplemental feeding of deer in some areas of western North America has concentrated animals near urban centres. As a result, humans may be inadvertently, but rapidly, altering the distribution of cougars *Puma concolor*, an issue that clearly

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warrants further attention. A comprehensive understanding of the impacts of urban sprawl on carnivores will not only require information on spatial and demographic parameters of populations (e.g. Torres *et al.*, 1996; Ferreras *et al.*, 2001), but also data on the behaviour of individuals living inside and adjacent to these urban areas.

Effects of urban environments on the home-range size and activity patterns of meso-carnivores, most notably coyotes *Canis latrans*, have been determined (Andelt & Mahan, 1980; Shargo, 1988; Quinn, 1995; Grindler & Krausman, 2001). For larger carnivores, shifts in behaviour for species such as brown bears *Ursus arctos* in areas with high rates of contact with humans have been documented (Mattson, Knight & Blanchard, 1987; Mattson, Blanchard & Knight, 1992; Olson, Gilbert & Squibb, 1997; Gibeau *et al.*, 2002). Bears avoided areas with high road densities, salmon streams near lodges during extended lodging seasons, and mortality rates were significantly higher in areas of contact with humans.

Black bears are generally thought to shift to crepuscular and nocturnal activity when daylight activities are disrupted (Reimchen, 1998). The principal factors currently thought to promote this shift are the presence of either humans or brown bears and the role of food. Although ecologists have suggested that shifts in behaviour and activity patterns occur for black bears in areas with high levels of human activity, most of the evidence is anecdotal and few, if any, comparative studies exist or have been published.

The effect of a novel food resource (i.e. garbage) on the behaviour of black bears was assessed in urban interface areas in two ways: (1) using both spatial and temporal contrasts; (2) focusing on contact zones involving black bears and humans at the Sierra–Great Basin interface in Nevada in western North America.

As urban food resources are being exploited for the first time, changes in behaviour and ecology may occur because garbage alters the abundance and distribution of food at a landscape level. In an area where food is limited, introduction of garbage should result in shorter periods of foraging activity on a daily basis, and shorter periods in dens (Schooley *et al.*, 1994). Garbage is a good resource for bears because: (1) it is always available regardless of season or environmental conditions; (2) it is predictable in both space and time (i.e. trash cans were always set out the same day of the week); (3) it is highly clumped (e.g. in residential areas) so that little energy is required to move from patch (i.e. dumpster) to patch; (4) it is always replenished after use. We assumed, a priori, that urban interface areas would not be food or resource limited, whereas surrounding wildlands would be. We predicted that urban bears would shift to nocturnal activity owing to disruption of activities by humans during diurnal periods.

Study area and species

Black bears are large (50–200 kg) carnivores that have the capacity to kill ungulates, but primarily survive as omnivores subsisting on vegetation. Their current

distribution in Nevada is restricted to the Carson Range of the Sierra Nevada, Sweetwater Range, Pine Nut Range, and the Wassuk Range in extreme western Nevada. These four mountain ranges cover an area of *c.* 1400 km² and are characterized by steep topography with high granite peaks, deep canyons and are separated by desert basins that range from 15 to 64 km across (Grayson, 1993). These desert basins are often large areas of unsuitable desert habitat (e.g. large expanses of sagebrush *Artemisia* spp.) that bears do not use in the western Great Basin Desert (Goodrich, 1990; Beckmann, 2002). However, bears will occasionally make relatively short movements through areas comprised of sagebrush to reach patchily distributed suitable habitat (e.g. cone-producing trees) in this arid landscape. Historically, black bears in Nevada enter dens in mid-November and emerge from March to April (Goodrich, 1993).

MATERIALS AND METHODS

Bears were captured in culvert traps (Teton Welding, Chateau, Montana) from 1 July 1997 to 1 April 2002 and tranquilized with a mixture of Telazol/Xylazine. Each bear was weighed and radio-collars with mortality sensors were attached to adults (Advanced Telemetry Systems, Isanti, Minnesota). Age was estimated from annuli of the first upper premolar (PM₁), the tooth that is routinely removed for age analysis in black bears (Matson's Laboratory, Milltown, Montana; Stoneberg & Jonkel, 1966) and animals were classified as cubs (< 1.5 years), juveniles (1.5–3 years) or adults (> 3 years). All research was conducted under the University of Nevada, Reno Animal Care and Use Protocol no. A99/00–02. Bears wore radio-collars from 1 July 1999 until they were removed in June 2002.

Animals were located weekly, weather permitting, from a Cessna 206 fixed-wing airplane from 1 July 1999 to 1 April 2002, and from the ground. Most flights occurred from 05:00 to 16:00 Pacific Standard Time. Universal Transverse Mercator coordinates were assigned to each location from a global positioning system unit on-board the aircraft.

A priori bears were considered urban individuals if $\geq 90\%$ of their location points were inside urban areas (defined by town and city delineation on coverage maps in ArcView 3.2 software) and wildland bears if $\geq 90\%$ of their locations were outside urban areas (Carson City, Incline Village, Glenbrook, Stateline, Minden, and Gardnerville, Nevada and South Lake Tahoe, California). Urban bears were captured in each of these cities, while wildland bears were trapped in the 4 adjacent mountain ranges (see above) outside of city limits. Trapping was specifically designed to catch 2 different types of bears, those entirely in urban areas and those outside urban areas. Based upon our operational definition, there was never a questionable case whether a bear was an urban or wildland individual. As evidence of this, urban bears almost always had 100% of their location points within urban areas, whereas wildland bears almost always had 100% of their

location points outside urban areas (Beckmann & Berger, 2003). Urban bears were truly urban, as 6 of them denned under the decks of homes in the Lake Tahoe basin and 29 urban bears denned within 100 m of a building structure inside city limits.

Patterns of activity and time budgets

Ten adult urban and 10 adult wildland bears were followed for 24-h and the number of active hours recorded at 30-min intervals (beginning at 05:00) for a total of 48 data points per individual. Twenty individual bears were followed for 24 h each resulting in 480 h of observations (20 individuals \times 24 h). Of the 20 bears, 5 were urban males, 5 urban females, 5 wildland males, and 5 wildland females. If a bear was lost during a 24-h sampling period, the data were discounted and a new 24-h sampling period begun; this happened 4 times. Bears were considered active at the beginning of each hour in which a movement was first recorded. For example, if a bear moved between data collection points at 09:30 and 10:00, then the bear was considered to have begun activity during the 09:00 h.

If a bear remained in the same spot for > 2 h and it could not be seen, no activity was assumed at the time of the first location at the spot. Thus, activity was defined solely as movement between successive 30-min intervals, while inactivity was defined as no movement for > 2 h. It is possible that the period of activity for bears that foraged in a small area for several hours was underestimated, especially if activity could not be confirmed visually. A bear foraging in a small area for several hours would not move enough distance to be detected as active by telemetry alone, thus their activity would be underestimated. However, it was assumed that the direction of error (i.e. underestimating activity) was consistent across bears. Further, keeping visual contact with bears in urban areas foraging in dumpsters was relatively easy owing to their shorter movements, greater illumination, and more open terrain (e.g. parking lots behind fast food restaurants and shopping centres). Because wildland bears tended to travel more, it is probable that their activity levels were not underestimated, and although urban bears moved short distances between garbage dumpsters in a given night, the ability to establish visual contact minimized error when estimating their activity levels. Artificial light from a 1.5 million candle-watt spotlight was occasionally used for brief periods (< 30 s) to try to visually locate bears during sampling. Observations were made as far away as possible from bears (> 50 m), especially in urban areas, while maintaining visual contact, to avoid influencing their behaviour. It was never obvious that observations disturbed their natural foraging, as bears were used to feeding in garbage with some attendant level of human disturbance and because they continued to feed. Keeping constant visual contact was impossible, even in urban areas, so standard triangulation methods were heavily relied upon (Heezen & Tester, 1967; Hupp & Ratti, 1983; Samuel & Fuller, 1994) to determine an individual's location and movement and thus its activity.

Data were recorded from 25 July 2001 (late summer) to 23 September 2001 (early autumn) because these dates coincide with the stage of the annual cycle when bears have maximum caloric intake requirements as they prepare to enter dens for the winter (Brody & Pelton, 1988). Thus, any differences in either their level of activity or their use of resources would be most pronounced during this time, making it easier to detect any differences that might exist in the use of these 2 types of food resources. While data on foraging activities were gathered for 480 h during autumn, they were not gathered in spring, although supplemental food probably has a marked effect during that time as well. However, since bears achieve their maximum body masses in autumn before entry into winter dens, data gathered during this hyperphagic period was assumed to be representative of periods when individuals elect to forage most, including spring.

Den chronology

Den entry and emergence dates were estimated during 3 winters (1999–2000, 2000–1, 2001–2) as midway between the first location at the den and the previous location, and the date midway between the last location at the den and the following location. The time period between these locations never exceeded 2 weeks. Means ± 1 SD and Wilcoxon paired-sample tests (t) or Wilcoxon rank-sum tests (W) were used for contrasts. Alpha was set, a priori, at 0.05 for all statistical comparisons.

RESULTS

Patterns of activity

The mean hour that urban bears began activity ($19:00 \pm 2.33$ h) differed from that of wildland bears ($08:00 \pm 1.62$, $t = 55$, $P = 0.0007$; Fig. 1). Similarly, mean activity rate (number of hours active) differed between urban bears ($\bar{X} = 8.50 \pm 2.64$) and wildland bears ($\bar{X} = 13.3 \pm 2.67$, $t = 145$, $P = 0.0037$; Fig. 1). Urban bears generally began their activity during the evening and during nocturnal periods, while wildland bears were more diurnal. However, because bears in both areas spent several h active, overlap in activity occurred during crepuscular periods (Fig. 1).

Den chronology

Of 38 urban bears, five (13%) never denned, whereas all wildland bears did. For urban bears, mean Julian date of entry into hibernacula was 1 January vs 4 December for wildland conspecifics (day 338, $P < 0.0001$; Table 1). The pattern of urban bears entering dens on average 1 month later held for both sexes, but for females there was not a statistical difference (Table 1), although this result probably had reduced power owing to a small sample size.

Table 1. The mean Julian date of entry into dens for urban interface and wildland black bears *Ursus americanus* and the mean number of days in dens for bears in the two study areas in western Nevada. Julian dates > day 365 correspond to the equivalent Julian date the subsequent year. Urban interface bears are those that were located > 90% of the time inside urban areas. Wildland bears are those that were located < 10% of the time inside urban areas. All comparisons were made using the non-parametric Wilcoxon rank-sum test (*W*)

Sex	Urban-interface bears		Wildland bears		<i>W</i>	<i>P</i> -value
	Sample size	Mean \pm 1 SD	Sample size	Mean \pm 1 SD		
Mean Julian date of entry into den						
Males	29	367.55 \pm 13.85	17	337.06 \pm 16.28	196	0.0001
Females	4	356.75 \pm 16.26	9	340.44 \pm 19.75	36.5	0.1194
Combined	33	366.24 \pm 14.34	26	338.23 \pm 17.24	454.5	0.0001
Mean number of days in den						
Males	19	76.74 \pm 19.62	9	109.00 \pm 21.85	193.5	0.0024
Females	3	74.33 \pm 27.39	6	132.00 \pm 27.51	7	0.0444
Combined	22	76.41 \pm 20.05	15	118.60 \pm 25.91	418.5	0.0001

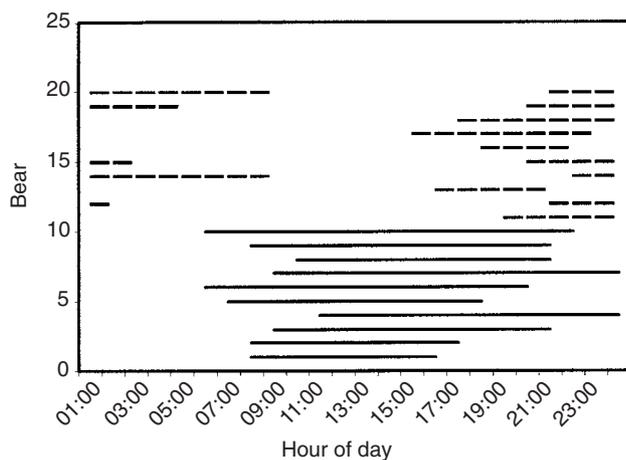


Fig. 1. The number of hours active and the patterns of activity for 10 adult (≥ 3 years) urban interface (dashed lines) black bears *Ursus americanus* and 10 adult wildland (solid lines) bears in western Nevada. Urban interface bears are those that were located > 90% of the time inside urban areas. Wildland bears are those that were located < 10% of the time inside urban areas. Five males and five females were followed for 24 h in both urban and wildland areas during late summer and early autumn 2001.

Den exit dates were similar. As a result, urban bears ($n = 22$) spent, on average, 42 days fewer in dens than wildland bears ($n = 15$, $P = 0.0001$; Table 1). This pattern held true for both males and females ($P < 0.05$; Table 1). Mean age of urban and wildland bears monitored for this analysis did not differ ($\bar{X}_{\text{urban}} = 6.95 \pm 3.67$, $\bar{X}_{\text{wildland}} = 7.95 \pm 4.59$, $W = 700.5$, $P = 0.2829$).

DISCUSSION

To maintain populations of large carnivores adjacent to urban areas, city planners must become more knowledgeable about biological diversity, and carnivores in

particular, so that issues pertaining to wildlife resources can be considered before development, such as the expansion of sub-divisions or addition of roads that encroach into wildland areas. The problem of urban expansion or appropriation of previously undeveloped habitat is widespread globally, including many regions throughout the western United States such as California, Arizona, Colorado, Montana, and Nevada. Contributing to the conflicts between carnivores and humans is a lack of ordinances, laws, or other forms of regulation prohibiting the deliberate or non-intentional feeding of wildlife. The result of the availability of urban food resources is the current situation where black bears in the western U.S.A. and other parts of North America are becoming increasingly reliant upon food sources supplied by humans in the form of garbage.

Our findings underscore consistent variation between urban and wildland bears in three behavioural parameters: (1) pattern of daily activity; (2) amount of daily activity; (3) denning chronology. These differences do not seem to be random, but the result of an underlying difference in resource availability. In addition, other rapid behavioural and ecological changes were documented that have occurred during the past 10–15 years owing to the presence of garbage.

The following points are noted at our specific study area relative to earlier work on the same population (Goodrich, 1990, 1993; Goodrich & Berger, 1994). Whereas urban bears were absent 10–15 years ago, they now not only occur but, relative to wildland bears, urban bears experience: (1) 70–90% reductions in home-range size; (2) an average 30% increase in body mass; (3) > threefold increases in densities relative to baseline levels (e.g. 10–15 years ago) (Beckmann, 2002; Beckmann & Berger, 2003). Additionally, (4) a rapid depopulation of bears from wildland areas owing to profitable foraging in urban areas has occurred with a coincident 10-fold decrease in wildland bear densities (20–40 bears/100 km² a decade ago vs 3.2 bears/100 km² currently); (5) sex ratios skewed heavily towards males in urban areas (4.25 times more skewed vs wildland areas); (6) changes have occurred in female reproductive success (see Beckmann, 2002;

Beckmann & Berger, 2003). Understanding these behavioural and ecological changes associated with human-induced perturbations is essential if we are truly to understand the impact of human activity on carnivore populations.

Shifts in patterns of activity and time budgets

Black bears are generally thought to shift to crepuscular and nocturnal activity when daylight activities are disrupted (Reimchen, 1998), and it was assumed that shifts in the patterns of activity towards crepuscular and nocturnal activity during this study were the result of human activities in urban areas. Our data offer an empirical verification of the assumption that shifts in patterns of activity occur when black bears are in urban areas. These data also suggest that shifts in behaviour, at least as assayed by time budgets, are owing not only to direct disruption from human activities, but also to anthropogenic sources of food. Our data further suggest that garbage was not a limiting resource because urban bears were active for 36% less time compared to wildland bears in late summer to early autumn. At this period of the annual cycle, black bears are achieving their maximum caloric intake (Brody & Pelton, 1988), and our analyses suggest that urban bears were meeting their caloric intake requirements more quickly than wildland bears. Further, urban bears became satiated and stopped foraging even though garbage was still available.

Changes in den chronology

Goodrich (1990) found that 10 wildland bears that he monitored in this region, hibernated by 5 December, and all collared bears entered dens, though date of entry was unknown for several bears. Bears in the Carson Range typically entered dens earlier than bears in the more xeric Pine Nut and Sweetwater Ranges, probably owing to higher snowpack depths and earlier snowfall (Goodrich, 1990). In contrast, during this study, urban bears, primarily from the Carson Range, entered dens later than wildland bears in the Carson, Pine Nut, and Sweetwater Ranges. This was a complete reversal of the situation a decade ago, despite deeper and earlier snowpack in the Carson Range than in the other Great Basin mountain ranges (USDA, 2002).

Although den entrance dates have shifted for urban bears over baseline levels in the past decade, the exit dates for urban bears were similar to wildland bears during this study and during Goodrich (1990) and Goodrich & Berger's (1994) studies. Adult males exited dens first in March to early April and adult females with cubs of the year exited last from early April to May. Similarly, Shideler & Hechtel (2000) documented four brown bears feeding on anthropogenic foods who entered dens a month later than bears of similar age that fed on wildland foods at the Prudhoe Bay, Alaska oil fields.

Temporal datasets and conservation

As humans continue to expand their distribution globally into regions that have historically contained carnivores, there will be a more pressing need for temporal datasets examining changes in both behavioural and ecological parameters of carnivores. Currently, such information exists for only a handful of carnivore species at the same location. Such broad gaps in knowledge of the temporal impacts of human perturbations on large carnivores makes conservation of these species difficult. Without long-term datasets, conservationists generally do not have a good idea of the patterns of population change, both in terms of numbers or distribution at landscape levels. However, certain attributes of carnivores can be used as major predictors for what species are likely to change. Obviously, large-bodied species that range over extensive areas and that are ecological specialists (e.g. Siberian tigers *Panthera tigris altaica*) are more likely to be negatively impacted. In contrast, generalist carnivores, such as black bears and coyotes, may actually profit in many ways through commensal relationships with humans in altered landscapes. Without baseline levels of behavioural and ecological parameters, biologists are often left guessing as to the targets of recovery for many large carnivore species. If biological diversity that includes a large mammalian carnivore is to be retained, more must be done about both education and policy to move traditional wildlife management towards conservation and at levels that involve not only citizens but public officials across multiple jurisdictions. We suggest that an effective strategy to reduce human–bear conflicts in western North America is to begin extensive public education, similar to that carried out in numerous areas, states, and parks. Also, areas that contain black bears should pass laws, ordinances, and regulations against the intentional or non-intentional feeding of bears or any wildlife that may inadvertently bring bears into an area. These areas should pass ordinances requiring private landowners and businesses to obtain and use bear-proof garbage containers.

Acknowledgements

We thank the University of Nevada, Nevada Agriculture Experiment Station, the Nevada Division of Wildlife, the National Science Foundation, and the Wildlife Conservation Society for support. We are extremely grateful to Carl Lackey with the Nevada Division of Wildlife for his countless hours of effort – physical, emotional, and intellectual. We also thank the numerous people who assisted with data collection, specifically Amy Beckmann, Jim Nelson, Misty Thompson, Sean Shea, and Gregg Bracket. Mike Wiklanski, John Kelly and the entire staff at El Aero Services in Carson City, Nevada committed many hours of safe flight. We thank Drs Bill Longland, Mary Peacock, Peter Brussard, and Stephanie Livingston for helpful comments and insight. We also thank the two reviewers for their insights that helped strengthen this paper.

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