Evaluation of deterrent techniques and dogs to alter behavior of "nuisance" black bears

Jon P. Beckmann, Carl W. Lackey, and Joel Berger

Abstract The general public often prefers nonlethality when dealing with problem black bears (*Ursus americanus*). We evaluated the efficacy of nonlethal deterrent techniques on 62 bears in the Lake Tahoe Basin of the Sierra Nevada range. We contrasted animals randomly assigned to a control (no treatment) group (n = 21), an experimental (treatment) group (n = 21), or a treatment + dog group (n = 20). Experimental bears were pepper-sprayed, shot with 12-gauge rubber buckshot and a rubber slug, and exposed to cracker shells. Bears in the treatment + dog group were chased by hounds in addition to the combination of other deterrents. We tested and modeled the effectiveness of deterrents and dogs using a survival analysis with Cox proportional hazards and ANOVA. Relative success was evaluated by the latency of time (days) between treatment and return to the urban patch (RUP). Predictor variables in the saturated model included age, weight, season, sex, distance moved, and treatment. Only treatment remained in the most parsimonious model. However, mean number of days until RUP did not vary among the 3 treatment levels (ANOVA, P = 0.55). In all but 5 of 62 cases, bears eventually returned to the urban patch in which they were captured; 33 of 62 bears (53%) returned within 1 month and 70% (n = 44) of all bears returned in ≤40 days. We conclude that in the Lake Tahoe Basin the most common nonlethal deterrents, used by agencies responsible for black bear management, are not very effective at altering bear behavior over periods of time >1 month.

Key words black bears, deterrents, dogs, Lake Tahoe, Sierra Nevada, *Ursus americanus*

During the last 10–20 years, many areas have experienced an increase in the number of conflicts between black bears (*Ursus americanus*) and humans, and such conflicts have been disproportional to human population growth (Beckmann 2002, Beckmann and Berger 2003*a*). This is especially true in western North America, where rapid urban sprawl has encroached into areas adjacent to United States public lands that have historically contained large carnivores. In Nevada, as in other areas of western North America, human–bear interactions involve loss of pets, localized predation on livestock, property damage, and even human deaths (approximately 40 from black bears since 1900 in North America; Herrero 2002). Many state and federal agencies seek nonlethal solutions (i.e., deterrents) for dealing with "nuisance" carnivores, especially black bears. Deterrents such as lithium chloride, protection collars, and loud noises have been tested on other species of carnivores, mostly coyotes (*Canis latrans*) (Giffiths et al. 1978, Burns 1983, Jelinski et al. 1983, Burns et al. 1996). Yet there is a paucity of rigorous study on the effectiveness of common deterrent techniques that man-

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agement agencies currently use to alter behavior of “nuisance” bears, although exceptions clearly exist (Gilllin et al. 1994, Ternent and Garshelis 1999, Clark et al. 2002).

A survey conducted by the Virginia Department of Game and Inland Fisheries in 2001 revealed that 33 states currently manage black bears and respond to citizen complaints about “nuisance” bears (D. Kocka, Virginia Department of Game and Inland Fisheries, personal communication). Of those, 26 (79%) administer deterrent techniques with the aim of behavioral alteration of “nuisance” individuals. The use of deterrent techniques, although not a new management tool, has been increasing rapidly in both Canada and the United States, primarily in response to the public's request for nonlethal bear management near urban–wildland interface areas. This is particularly true given the large increase in human–bear conflicts over the past 10–15 years (Beckmann and Berger 2003*a*). Fifteen of 26 states that currently use deterrents began doing so in the 1990s (D. Kocka, Virginia Department of Game and Inland Fisheries, personal communication). In contrast, only 4 states administered deterrents in the 1960s and 1970s. The 6 most common techniques used on trapped bears according to the 33 states surveyed were 1) rubber buckshot, 2) rubber slugs, 3) pepper spray, 4) cracker shells, 5) dogs, and 6) loud noises (D. Kocka, Virginia Department of Game and Inland Fisheries, personal communication). Although many states and other entities such as national parks (e.g., Yosemite National Park, Calif.) spend many dollars annually for such deterrents, to date no research has rigorously analyzed the efficacy of these deterrents.

We capitalized on the extent to which human population growth and coincident food stores in the Lake Tahoe Basin in the Sierra Nevada Range in western Nevada offer an experimental setting in which to examine the effectiveness of deterrent techniques on behavior of black bears. From 1990–2000 the human population in the Lake Tahoe Basin increased by 26% and the number of complaints by citizens concerning black bears increased by >10-fold (Beckmann 2002, Beckmann and Berger 2003*a*). Our goal was to examine the effectiveness of the 6 most common deterrents used on black bears.

Methods

Black bear distribution in Nevada is restricted to the Sierra Nevada and nearby mountains that include the Sweetwater, Pine Nut, and Wassuk ranges (Goodrich 1990), all of which were the focus of our work. These Great Basin Desert mountain ranges contain areas with high granite peaks and deep canyons (Goodrich 1990). Desert floors that can be greater than 64 km wide separate mountain ranges in which bears occur. Further, desert basins often are large areas of unsuitable desert habitat (e.g., large expanses of sagebrush [*Artemesia* spp.]) that bears do not use (Goodrich 1990, Beckmann 2002, Beckmann and Berger 2003*a*). However, bears occasionally will make relatively short movements through areas of sagebrush to reach patchily distributed suitable habitats, consisting mainly of lodgepole (*Pinus contorta*) and Jeffrey pine (*Pinus jeffreyi*) forests in this arid landscape (Grayson 1993). The human population inside the Lake Tahoe Basin was >50,000 people, with an additional 350,000 people living in the study area along the eastern front of the Sierra Nevada in Reno and Carson City, Nevada. Bears in this region are at the eastern edge of their known range in the Great Basin, with the closest population to the east being about 750 km away in Utah. Although black bears are listed as a game species in Nevada, there has never been a legal harvest.

We captured bears in culvert traps (Teton Welding, Choteau, Mont.) and tranquilized and immobilized them with a mixture of Telazol–Xylazine from 1 July 1997 to 1 April 2002. We weighed each bear and fitted each adult with a mortality-sensing radiocollar (Advanced Telemetry Systems, Isanti, Minn.). We determined age from annuli of the first upper premolar (PM_1), the standard tooth for age analysis in black bears (Matson's Laboratory, Milltown, Mont.; Stoneberg and Jonkel 1966), and we classified animals as cubs (<1.5 years), juveniles (1.5–3 years), or adults (>3 years). At time of capture and administration of deterrents, the history of each bear was unknown due to a lack of recent study of the population immediately preceding onset of this study. However, subsequent monitoring and data collection indicated that all 62 truly were “nuisance” bears, as all of them were inside urban areas multiple times (Beckmann and Berger 2003*a*). We also documented rapid changes in the ecology and behavior of urban bears as a consequence of their foraging almost entirely on garbage (Beckmann and Berger 2003*b*).

We tested the effectiveness of the 6 most common deterrents used by state agencies in the

United States (D. Kocka, Virginia Department of Game and Inland Fisheries, personal communication). We randomly assigned 62 collared bears captured in urban areas in the Lake Tahoe Basin of the Sierra Nevada to 1 of 3 groups: experimental group, which received deterrents ($n=21$); experimental+dog group, which were chased by dogs in addition to receiving other deterrents ($n=20$); or control group, which did not receive deterrents ($n=21$). Experimental treatment consisted of bears being hit with pepper spray, 12-gauge rubber buckshot, and a rubber slug, and exposed to cracker shells and yelling. Our methods did not allow examination of each deterrent individually. We were interested only in the combination of these methods. Bears in the treatment+dog group were chased by hounds in addition to other deterrents. Each bear was chased by the same hounds to standardize the treatment. We released control bears in a "silent" manner, with no physical or audible deterrents. Clark et al. (2002) suggested that the capture and handling experience also should be considered an aversive agent. Because all bears in our analyses were captured and handled in the same manner, we assumed that this would not bias the data. We moved individual bears varying distances from the capture site to administer deterrents. Distance moved ranged from 1–75 km, and distance was included as a continuous variable in the model.

We measured effectiveness as time (in days) required for the bear to return to the urban patch (RUP) after treatment application, or "silent" release in the case of controls. We located animals weekly, weather permitting, from a Cessna 206 fixed-wing airplane (Cessna Aircraft Company, Wichita, Kans.). Most flights occurred from 0500–1600 Pacific Standard Time. We assigned Universal Transverse Mercator coordinates to each location from a Global Positioning System unit onboard the aircraft. We entered all locations into coverage maps and defined urban areas by town and city delineation (incorporated city limits) in ArcView 3.2. We considered an individual to have returned (RUP) the first time we located it inside the same urban patch from which it had been removed. If an individual returned to the urban area in the weeklong time period between flights, we averaged date of return.

Statistical analyses

We modeled deterrent effectiveness using a multivariate survival analysis with a Cox proportional hazards model (PROC PHREG in SAS statistical software; SAS Institute 2001). This analysis is a log likelihood model and produces a hazard ratio: the conditional probability that the event of interest (RUP) occurs in the given time interval (Schoenfeld 1980, Klein and Moeschberger 1997, Song and Lee 2000, Persson 2002). Analysis of survival data, in this case RUP (i.e., "failure" or "death"), requires special techniques because data are almost always incomplete and parametric assumptions may be unjustifiable. For example, 5 individuals failed to RUP by the time of our analyses; thus their status was "unknown." The problem is onerous because the 5 bears may never come back, or they could return at any unknown future time. These 5 survival times (8% of the observations) were censored. The remaining 57 bears had known survival times, referred to as event times. Methods for survival analysis must account for both censored and noncensored data. The Cox proportional hazards model is an excellent tool for making inferences on the population average effect of covariates with incomplete failure time data (Schoenfeld 1980, Klein and Moeschberger 1997, Song and Lee 2000, Persson 2002).

Predictor variables in the saturated 2-way interactive model included age, weight, season, sex, distance moved, and treatment (3 levels). We assigned categorical predictor variables dummy variables for the proportional hazard regression model. We compared potential models, beginning with the saturated 2-way interactive model, using information-theoretic methods to direct model selection. We calculated Akaike's Information Criterion (AIC) and adjusted these for small sample sizes (AIC_c) as suggested by Hurvich and Tsai (1989) and Anderson et al. (1994). We used these values (ΔAIC_c) to compare candidate models to select the most parsimonious model that accurately represented the data (Anderson et al. 2000).

We ran these complex models to try and develop a predictive model for managers to assess when application of deterrents is most likely to be successful. We included 6 ecological and biological parameters of individuals that we believed to be a priori relevant. We also analyzed RUP data using a more simplistic analysis of variance (ANOVA) model to compare treatment levels. The ANOVA model also had the added benefit of not censoring data, as the Cox proportional hazards regression model had done. For the 5 cases in which bears had not returned (RUP) at the time of the analysis, we used number of days they had been gone.

Means±SD are presented unless otherwise noted.

Results

In 57 of the 62 cases (92%), bears returned to the urban patch where they were captured. Of the 62 bears, 33 (53%) returned in less than 30 days, 17 (27%) returned between 31 and 180 days, 7 (11%) returned between 181 and 365 days, and 5 (8%) had not returned in >365 days (Table 1). Mean number of days for RUP was not significantly different between the 3 treatments (ANOVA; $F_{2,59}$=0.61, *P*= 0.5468). However, mean RUP for the treatment+ dog group was 154±202 days compared to 88.4± 76.5 days for the treatment-only group and 64.6± 103.9 days for the control group. Only the treatment level was selected in the most parsimonious model (hazard $\text{ratio}_{\text{treatment}}$=0.454; *P*=0.0061; Table 2) when analyzing data using Cox proportional hazards regression. Thus, an individual was 0.454 less likely to RUP in the presence of deterrents than in their absence, and treatment level alone predicted RUP. Dogs chased individuals in 4 of the 5 cases in which they had yet to RUP. Mean number of days elapsed between application of the deterrent and time of analysis for the 5 bears that had not RUP was 481 days (range 424–641 days; Table 1). In all models no other predictor variables or any interactions accounted for significant variation in RUP.

Table 1. Time period (days) and number of black bears (*Ursus americanus*) that returned to the urban patch (RUP) from which they were captured in western Nevada from July 1997 to April 2002 following 3 different treatment levels of deterrents. Control bears were released without any deterrents; treatment bears were released after exposure to pepper spray, 12-gauge rubber buckshot, a rubber slug, and cracker shells and yelling; and treatment + dog bears were released after being exposed to the other deterrents and chased by hounds.

Days to RUP	Control (*n* = 21)	Treatment (*n* = 21)	Treatment+dog (*n* = 20)
<30	16	9	8
31-180	2	9	6
181-365	3	2	2
>365	0	1	4

Discussion

We evaluated 6 ecological and biological parameters of bears we believed might prove relevant to deterring "nuisance" bears from returning. We found that 92% of the time, black bears returned to the urban patch from which they were removed. Although it would be ideal if treated bears did not return to urban areas, thus eliminating human–bear conflicts in those regions, the more realistic issue is not whether bears return but when. Our data indicate that 70% (*n*=44) of the bears returned in ≤40 days. Based on assessment of 6 ecological and biological parameters, we were unable to produce a model that predicted which individuals and under what circumstances this combination of deterrents would be a useful management strategy. However, deterrents did have a positive effect on model selection: only treatment was left in the most parsimonious model, and change in AIC was≥2.0 versus the next best model (Burnham and Anderson 1998; Table 2). However, a majority of bears generally returned within 1 month, suggesting that deterrents were not very effective at altering behavior of bears based on RUP data.

Bears chased by hounds did return slightly later on average than bears not chased by dogs, either in the control group or in the treatment-only group. However, differences were not statistically significant. Further indication that dogs may not be an effective deterrent was the tremendous variation in RUP for bears chased by dogs (range: 5–641 days). In fact, bears within all groups showed tremendous variation in RUP (overall range: 1–641 days). This extreme within-group variance suggested that effectiveness of deterrents was likely based on individual variation among bears and how they

Table 2. Multi-model inference of behavioral responses of bears (*Ursus americanus*) captured in western Nevada from July 1997 to April 2002 to deterrent techniques. The best model for each of the respective number of parameters is presented. Overall, the model containing only treatment was the most parsimonious.

Model[a] Number of days to return to urban area	# parameters	ΔAIC[b]	AIC weight
{T}	1	0	0.542
{T, Dis}	2	2.56	0.330
{T, S, Dis}	3	4.13	0.071
{T, S, W, Dis}	4	5.94	0.027
{T, S, G, W, Dis}	5	10.21	0.018
{T, A, S, G, W, Dis}	6	13.40	0.0115

[a] T = treatment (control, deterrent, deterrent + dog); A = age; S = season (spring, summer, winter, fall); G = sex (male, female); W = weight; Dis = distance moved from capture site to where deterrents were administered.

[b] ΔAIC is the rank of each model by rescaling the model with a minimum AIC value to zero (ΔAIC = AIC_i – minAIC). AIC weights are the likelihood of the model given the data (Akaike weights).

responded to such disturbances. Our models did not allow us to incorporate individual variation in the level of "boldness" or "shyness" of each bear.

There are obvious limitations in approaches to studying large wild carnivores. First, although 62 collared individuals may be a reasonable sample, larger sample sizes are needed for adequate power to detect the true effectiveness of some deterrents. Second, with 62 bears we were unable to establish a group that received only dogs without the other deterrents. This would have created too many categories for the limited sample. Additional research should examine the effectiveness of each deterrent individually.

Management implications

We recommend that any group dealing with "nuisance" black bears conduct a cost–benefit analysis to decide whether monetary investments in deterrents are worth it. If agencies define success of deterrents a priori as never having to deal with a "nuisance" bear again, our data suggest that this objective will most likely always fail. If the goal is to establish positive public relations or to avoid dealing with an individual bear for several weeks or months, then deterrents may be an effective management tool. The Nevada Division of Wildlife has had fewer negative responses from the local media and public in the Lake Tahoe Basin about using nonlethal deterrents compared to the 5-year period before these techniques were in use (C. Healy, Nevada Division of Wildlife, personal communication). Use of nonlethal deterrents may have the added benefit of increasing public awareness of human–bear conflicts created by availability of urban food sources. For example, 2 homeowner associations and a private campground on the south shore of Lake Tahoe spent a combined $100,000 on 350 bear-proof garbage containers in response to the use of nonlethal deterrents on bears in Nevada (M. Paulson, Tahoe Village Homeowners Association, personal communication).

Our results indicate that the most commonly used deterrents to alter behavior of "nuisance" black bears are not effective when used in combination. Use of dogs and other deterrents provided limited evidence for a longer time period before bears returned to the urban area, although due to extreme within-group variance this difference was not significant. Further, even use of dogs in combination with other deterrents was not very effective at altering bear behavior beyond 1 month. Our study suggests that bears that were human-food (i.e., garbage) conditioned and habituated to living near or in urban–wildland interface areas were unlikely to alter their behavior in response to the deterrent techniques currently adopted by most state and federal agencies.

A more effective strategy to reduce human–bear conflicts may be aggressive public education, as is being done in numerous areas, states, and parks (Beckmann 2002). Areas that contain black bears should pass laws, ordinances, and regulations against intentional or unintentional feeding of bears or other wildlife that may inadvertently attract bears. These areas should pass ordinances requiring private landowners and businesses to obtain and use bear-proof garbage containers. For example, the combination of an aggressive public outreach campaign through a bear working group consisting of state and federal agencies, empirical data, and county ordinances requiring bear-proof dumpsters has led to the first decline since 1994 in the number of complaints concerning bears in Nevada from 2002–2003. In 2002 Juneau, Alaska created several ordinances requiring bear-proof dumpsters that have resulted in fewer conflicts (D. Garcia, City of Juneau, personal communication). Additionally, an aggressive public education campaign and citation program in Yosemite National Park, California reduced the monetary damage caused by bears by >70% since 1998 (S. Matthews, Wildlife Conservation Society Yosemite Program, personal communication). In these instances, a combination of ordinances and public education has been successful in reducing the number of conflicts between bears and humans. Future research should focus on the effectiveness of such public education campaigns and bear-proof garbage containers in reducing conflicts.

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