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EVALUATION OF DETERRENT TECHNIQUES ON ALTERING BEHAVIOR OF BLACK BEARS

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Abstract: The general public often prefers non-lethality when dealing with problem black bears (*Ursus americanus*). We evaluated the efficacy of bear deterrent techniques in the Lake Tahoe Basin of the Sierra-Nevada range by contrasting animals randomly assigned to an experimental (treatment) or to a control (no treatment) group. Experimental bears were pepper sprayed, shot with 12-gauge rubber buckshot and a rubber slug, and exposed to cracker shells. Additionally, half the bears that received the treatment were chased by both hounds and Karelian bear dogs. We modeled the effectiveness of deterrents using a survival analysis utilizing Cox proportional hazards. Relative success was evaluated by the latency of time between treatment and return (days) to the urban patch (RUP). Predictor variables in the model included: age, weight, season, gender, distance moved, treatment/control, dogs, and prior experience with the treatment. Only the use of dogs remained in the most parsimonious model. The mean number of days (154) until RUP after being chased by dogs was three times that for bears lacking the dog treatment (55 days). Nevertheless, in all but 5 cases of 62 possible, bears eventually returned to the urban patch and 33 of 62 bears (53%) returned within 1 month. We conclude that in the Lake Tahoe Basin the most common deterrents, other than dogs, currently used by agencies responsible for the management of black bears are not effective at altering their behavior over periods of time >1 month.

Key words: black bears, deterrents, Karelian 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 and humans, and such conflicts have been disproportional to human population growth. This is especially true in western North America where rapid urban sprawl has led to encroachment into areas adjacent to U.S. public lands that have historically contained large carnivores. In Nevada, as in other areas of western North America, human-bear interactions involve the loss of pets, localized predation on livestock, property damage, and even human deaths (approximately 40 from black bears since 1900 in North America). Many state and federal entities seek non-lethal 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 of the effectiveness of the most common deterrent techniques management agencies currently use to alter the behavior of 'nuisance' bears, although exceptions clearly exist (*e.g.,* 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 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 USA, primarily in response to the public's request for non-lethal management of bears near urban-wildland interface areas. Fifteen of 26 states that currently utilize deterrents began 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, are: 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, California), spend many dollars on an annual basis 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 their 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 during the same time period. Our goal here is modest, 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 near-by mountains that include the Sweetwater, Pine Nut, and Wassuk Ranges (Goodrich 1990), all of which were the focus of our work. 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.

Bears were captured in culvert traps (Teton Welding, Chateau, Montana) and by tranquilizing free-ranging individuals from 1 July 1997 to 1 April 2002 and immobilized 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 (PM_1), the standard tooth for age analysis in black bears (Matson's Laboratory, Milltown, Montana;

Stoneberg and Jonkel 1966) and animals were classified as cubs (<1.5 years), juveniles (1.5-3 years) or adults (> 3 years).

We tested the effectiveness of the 6 most common deterrents utilized by state agencies across the USA (see above). Sixty-two collared bears captured in urban areas in the Lake Tahoe Basin of the Sierra-Nevada were randomly assigned to an experimental group, which received deterrents (treatment), or to a control group (no treatment). The experimental treatment consisted of bears being hit with pepper spray, 12-gauge rubber buckshot and a rubber slug, and being exposed to cracker shells and yelling. In addition, half the bears in the treatment group were chased by hounds or Karelian bear dogs. Individual bears were moved varying distances from the capture site for the administration of deterrents. These distances ranged from zero km (on-site release) to 75 km and distance was included as a continuous variable in the model.

We measured effectiveness as time (in days) required between treatment and for the bear to 'return to urban patch', designated as RUP. Animals were located weekly, weather permitting, from a Cessna 206 fixed-wing airplane, and from the ground ($\overline{X}_{\text{number of locations per individual}} \pm 1\text{SD} = 105 \pm 39$). Most flights occurred from 0500 to 1600 Pacific Standard Time. We assigned Universal Transverse Mercator coordinates to each location from a global positioning system unit on-board the aircraft. All locations were entered into coverage maps and urban areas were defined by town and city delineation in ArcView 3.2. If an individual's RUP was separated by the approximately weeklong interval between flights, we averaged date of return. The time interval between flights never exceeded two weeks.

Statistical analyses

We modeled the effectiveness of deterrents using a multivariate approach that included a survival analysis utilizing a Cox proportional hazards model (through PROC PHREG in SAS statistical software; SAS Institute 2001). The analysis of survival data, in this case time to return (*i.e.,* 'failure' or 'death'), requires special techniques because the data are almost always incomplete, and thus parametric assumptions may be unjustifiable. For example, in our case, 5 individuals failed to RUP at the time of our analyses and thus, beyond that time 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, which comprised 8% of the observations, were censored. The remaining 57 bears were non-censored survival times and were referred to as event times. Methods for survival analysis, such as the proportional hazard regression model reported here, must account for both censored and non-censored data. The Cox proportional hazards model is an excellent tool for making inferences on the population average effect of covariates on incomplete failure time data.

Predictor variables in the full model included: age, weight, season, gender, distance moved, treatment/control, dogs, and previous number of experiences with the treatment. Categorical predictor variables were assigned dummy variables for the purpose of the proportional hazard regression model. All possible models for each number of parameters (*i.e.,* 8,7,6,5,4,3,2, and 1) were examined. We compared 255 potential models beginning with the saturated 2-way interactive model using information-theoretic methods to direct model selection. For each model we calculated Akaike information criteria (AIC) and adjusted these for small sample sizes (AIC_c) as suggested by Hurvich and Tsai (1989) and Anderson et al. (1994). These values (AIC_c) were used to compare candidate models to achieve the most parsimonious one that accurately represented the data (Anderson et al. 2000). We also utilized the application of a bootstrap technique in PROC PHREG (SAS Institute 2001) to estimate the survival curve of individuals 1) in treatment versus controls; and 2) within the treatment that were chased by dogs and were not. Means $\pm$ 1SD are presented unless otherwise noted.

Results

In 57 of the 62 cases that bears were released, the individuals returned back to the urban patch by the point in time of the analysis. Of the 62 bears, 33 (53%) returned in less than 1 month (30 days), 17 (27%) returned between 31 and 180 days, 7 (11%) returned between 181 and 365 days, and 5 (9%) were gone for >365 days. The latency of RUP varied significantly, but only the use of dogs fit in the most parsimonious model (hazard $\text{ratio}_{\text{dogs}} = 0.454$; $P = 0.0061$; Figure 1; Table 1). RUP was greater when chased by dogs ($\overline{X}_{\text{days}} = 154 \pm 202$; range 5-641 days) than in their absence ($\overline{X}_{\text{days}} = 55 \pm 83$; range 1-283 days). Dogs chased individuals in 4 of the 5 cases in which they had yet to 'fail' (*i.e.*, return) at time of the analysis. The mean number of days that had elapsed between the deterrent and time of analysis for the 5 bears that had not yet 'failed' was 481 days (range 224-641 days). In all 255 possible models, none of the other predictor variables or any interactions accounted for a significant amount of the variation in RUP. However, mean RUP was slightly greater when deterrents were given ($\overline{X}_{\text{days}} = 104 \pm 165$; range 1-641 days) than that for the control group ($\overline{X}_{\text{days}} = 71 \pm 102$; range 2-283 days; Figure 2).

Discussion

In our analyses, we included 8 ecological and biological parameters of individuals that, *a priori*, we believed might prove relevant. Our analysis revealed that 92% of the time, black bears exposed to deterrents returned to the urban patch. Although ideally, it would be wonderful if treated bears did not return, the more realistic issue is not whether bears return but when. Our data indicate that 70% of the bears returned in <40 days. Based on our assessment of 8 ecological and biological parameters, we were unable to produce a model that allowed us to predict which individuals and under what circumstances deterrents would be a useful management strategy. However, the use of deterrents did slightly shift the probability curve for not failing (*i.e.,* not returning) for bears by delaying the time until RUP (Figure 2).

The only significant variable that affected RUP was the use of dogs. Bears chased by either hounds or Karelian bear dogs returned approximately 100 days later on average than bears that were not chased by dogs. The use of dogs in combination with the other 6 deterrents did significantly alter the 'return curve' (RUP) (Figure 1). However, an indication that even dogs may not be an effective deterrent is that of the tremendous variation in RUP.

There are obvious limitations in approaches that involve study of large wild carnivores. First, although 62 collared individuals may be a decent sample, larger ones will have to be used to have 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, as this would have created too many categories for the limited sample. Additional research in the area of deterrents on black bears should examine the effectiveness of dogs when used alone.

We recommend that any group that deals with 'nuisance' black bears conduct a serious cost/benefit analysis to decide if monetary investments in deterrents are worth it. If, *a priori*, agencies define success of deterrents as never having to deal with a 'nuisance' bear again, then our data suggest that this objective will most likely always be met with failure. If the goal is to establish positive public relations or not having to deal with an individual bear for several weeks or months, then the use of deterrents may be an effective management tool. The Nevada Division of Wildlife has had far fewer negative responses from the local media and public in the Lake Tahoe Basin as the result of the use of non-lethal deterrents compared to the time period before these techniques were in use in their management of bears (C. Healy, Nevada Division of Wildlife, personal communication). The use of non-lethal deterrents may have the added benefit of increasing public awareness of human-bear conflicts that are created through the availability of urban food sources in the form of garbage. For example, two homeowner associations and a private campground at the south shore of Lake Tahoe spent a combined $100,000 on 350 bear-proof garbage containers in response to the use of non-lethal deterrents on bears in Nevada (M. Paulson, Tahoe Village Homeowners Association, personal communication).

Management implications

Our results indicate that the most commonly used deterrents to alter the behavior of 'nuisance' black bears: 1) rubber buckshot; 2) rubber slugs; 3) pepper spray; 4) cracker shells; and 5) loud noises, are not effective at altering the behavior of bears. The only significant factor in RUP was the use of dogs. We recommend that management agencies that deal with 'nuisance' black bears pursue non-lethal strategies or programs by incorporation of hounds, Karelian bear dogs, or both. Bears that are both human-food (*i.e.,* garbage) conditioned and habituated to living near or in urban-wildland interface areas are 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 is to begin aggressive public education, as is being done 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.

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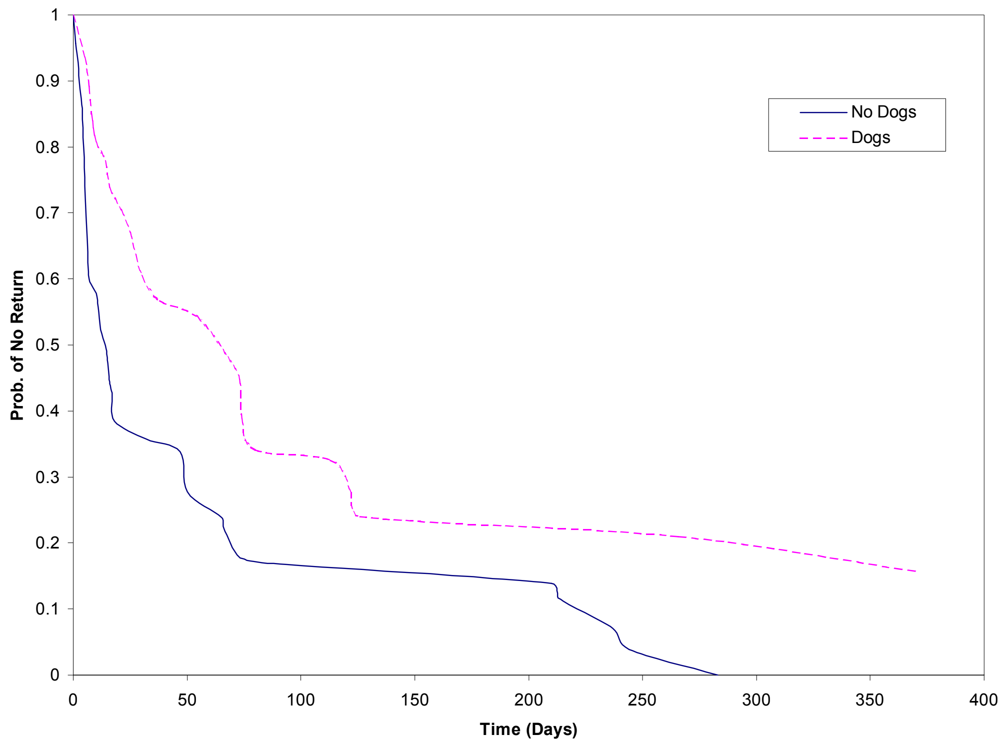
Figure 1. Probability curves for failing to return to an urban patch *(i.e.,* success) over time following the administration of deterrents for adult black bears (*Ursus americanus*) that were either chased (dashed line) or not chased (solid line) by dogs. A bear that returned to an urban area was equivalent to ‘failure’ or ‘death’ in the survival analysis.

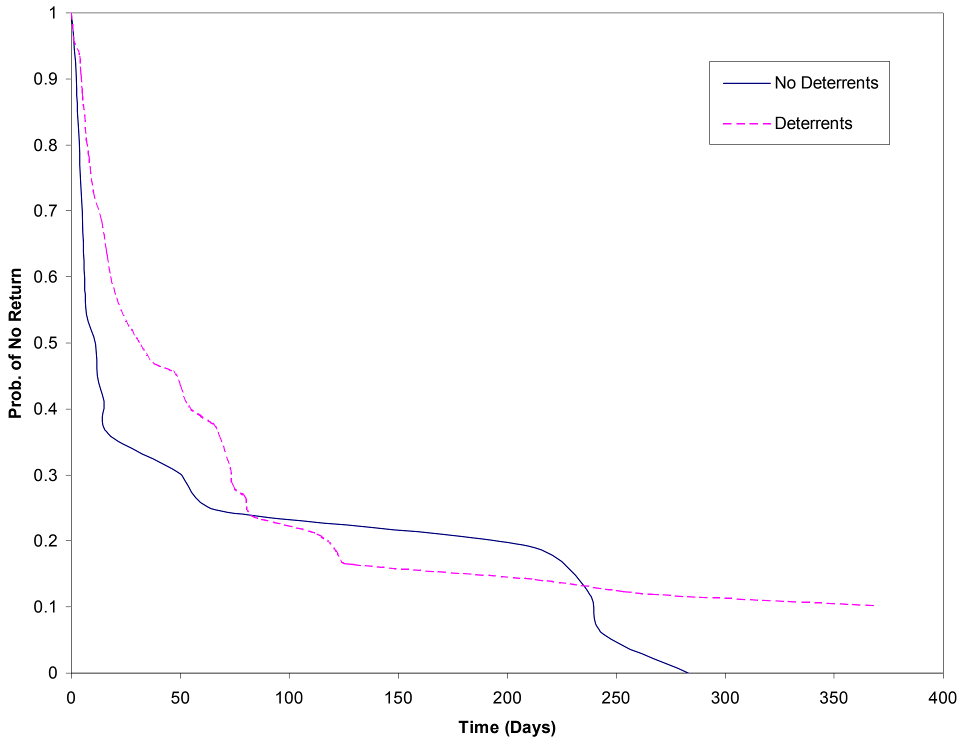
Figure 2. Probability curves for failing to return to an urban patch (*i.e.,* success) over time for adult black bears (*Ursus americanus*) that were either exposed (dashed line) or not (solid line) to deterrents. A bear that returned to an urban area was equivalent to ‘failure’ or ‘death’ in the survival analysis.

Table 1. Multi-model inference of behavioral responses of bears to deterrent techniques. All 255 possible models across all number of parameters were examined. The best model for each of the respective number of parameters is presented as examples. Overall, the model containing only the use of dogs was the most parsimonious. ΔAIC is the rank of each model by rescaling the model with a minimum AIC value to zero ($\Delta AIC = AIC_i - minAIC$). AIC weights are the likelihood of the model given the data (Akaike weights).

Model[i]	# parameters	ΔAIC	AIC weight
Number of Days to Return to Urban Area			
{D}	1	0	0.529
{D, Det}	2	1.631	0.234
{D, S, Dis}	3	2.811	0.130
{D, S, W, Dis}	4	4.133	0.067
{D, S, E, W, Dis}	5	5.944	0.027
{D, S, G, E, W, Dis}	6	8.151	0.009
{D, Det, S, G, E, W, Dis}	7	10.691	0.002
{D, Det, A, S, G, E, W, Dis}	8	13.309	0.0005

[i] D = Dogs (chased, not chased), Det = deterrent (yes, control), A = age, S = season (spring, summer, winter, fall), G = gender (male, female), E = experience (number of previous times treatment has been administered), W = weight, Dis = distance moved from capture site to where deterrents were administered.


No Dogs
Dogs
Prob. of No Return
Time (Days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400


No Deterrents
Deterrents
Prob. of No Return
Time (Days)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400