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Management and Conservation Note

Does Aversive Conditioning Reduce Human–Black Bear Conflict?

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ABSTRACT Aversive conditioning (AC) has the potential to temporarily reduce conflicts between humans and black bears (*Ursus americanus*). From 2002 to 2005, I evaluated the effectiveness of projectiles with varying impact intensities, pepper spray, and chasing on approximately 150 bears in Sequoia National Park. Aversive conditioning was successful in keeping bears that were not food-conditioned from becoming food-conditioned. For the bears that were already food-conditioned, 17 of 29 bears subjected to AC abandoned unwanted behaviors, 6 required continual treatments, and 6 were killed or relocated. Success with food-conditioned bears was highest when AC was applied soon after bears obtained human food. Aversive conditioning was less successful on yearlings than adults. Rubber slugs were slightly more effective than lower impact projectiles.

KEY WORDS aversive conditioning, black bear, hazing, nonlethal wildlife management, nuisance wildlife, Sequoia National Park, *Ursus americanus*.

The occurrence of food-conditioned black bears (*Ursus americanus*) is increasing, as are human–black bear conflicts, resulting in property damage and occasional human injuries (Beckmann et al. 2004). Conflicts are often resolved by killing nuisance animals (Sillero-Zubiri and Laurenson 2001). Although lethal control is more efficient than nonlethal means of managing these animals and may sometimes be the method of choice, public protests against killing bears, especially in protected areas such as Yosemite National Park, California, USA, are increasing (Grossi 2001). Furthermore, except in extreme circumstances, lethal control is not permitted with threatened populations, as in the case of the Louisiana black bear (*Ursus americanus luteolus*; Leigh 2007).

Operant conditioning is a form of learning in which a reward or punishment modifies some voluntary behavior (Dugatkin 2004). Often an animal learns to associate a previously neutral stimulus with reward or punishment, so the stimulus itself evokes the voluntary behavior. Food-conditioning, as used here, is a form of operant conditioning where a bear learns to associate humans or human-occupied areas with the high-caloric food that humans consume. Food-conditioned bears are, thus, bears that approach humans, or frequent human-occupied sites, in search of food, potentially creating human–bear conflicts.

Aversive conditioning (AC) is an operant technique that uses a negative stimulus to cause pain, avoidance, or irritation in an animal engaged in an unwanted behavior (Brush 1971, Mason et al. 2001, Shivik et al. 2003, Beckmann et al. 2004). In the case of bears, if AC is successful, bears will learn to associate humans, human food, and human developments with the negative stimulus and avoid them. Habituation is the loss of avoidance behaviors (i.e., muted response) after either repeated exposure to a stimulus or the lack of a negative stimulus. Bears may habituate to AC for those reasons, or because the rewards simply overwhelm the effects of the negative stimulus. Ideally, abandonment of unwanted behaviors will be permanent, but bears may later resume foraging on human foods, so one must distinguish between short-term and long-term behavior change.

Published accounts of common aversive stimuli indicate a wide range in effectiveness and feasibility. Illness-inducing chemicals have been used to create a conditioned taste aversion (Garcia et al. 1974, Burns 1983, Ternent and Garshelis 1999), but it is successful only in getting bears to stop eating specific foods in specific packaging for limited periods (Hastings et al. 1981, McCarthy and Seavoy 1994, Ternent and Garshelis 1999). Electrification of human food has kept bears away, but some bears did not generalize the experience to nonelectrified food (Breck et al. 2006). Both captive and wild bears wearing electric-shock collars terminated problem behaviors only until the shock ceased (Mason et al. 2001; H. Werner, National Park Service, personal communication), and shocking is fraught with ethical and safety issues and technical difficulties (Gillin et al. 1995, Andelt et al. 1999, Shivik et al. 2003). Some managers trap bears in developed areas using culvert traps and hold them in place so the bears will learn to associate the area with the discomfort of the trap (Clark et al. 2002). This association can be strengthened with a hard release employing dogs, noisemakers, or rubber slugs as the bear leaves the trap (Beckmann et al. 2004). There is evidence that trapping causes some bears to avoid an area (Chi et al. 1998, Clark et al. 2002), but most food-conditioned bears do return (Beckmann et al. 2004, Leigh 2007). Those that return tend to be cautious and stay farther from humans (Leigh 2007). This improves human safety, but also makes the bears harder to catch (Leigh 2007). Trapping can be counterproductive if bears associate the trap with a bait reward, and trapping is costly in time and money.

An ideal AC method makes a strong connection between humans and an aversive stimulus, allows for multiple trials, and is cost-effective and safe. The use of a firearm to shoot painful but nonlethal projectiles at a free-ranging bear has

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this potential. Anecdotal evidence of success has raised its popularity with the public and wildlife agencies, but little critical evaluation of effectiveness has been published. Controlled studies of polar bears (*Ursus maritimus*; Stenhouse 1983) and black bears (Wooldridge 1984) show that rubber or plastic slugs get bears to leave an area temporarily. Follow-up studies provide some evidence of short-term success, but sample sizes have been small and study periods limited (Gillin et al. 1995). In one study, results were confounded by the availability of human garbage (McCarthy and Seavoy 1994). Studies with longer time frames, preferably over years, and larger samples are needed (Beckmann et al. 2004, Leigh 2007). Pepper spray also has the potential to be a useful AC method based on its success as a deterrent in preventing bear injuries to humans (Smith et al. 2006).

I compared rubber slugs, projectiles with less impact, and pepper spray for their short- and long-term success in aversively conditioning black bears at Sequoia National Park, California (hereafter Sequoia) from 2002 to 2005. I tested for reduction in the recruitment of wild bears into the food-conditioned population and elimination of unwanted behaviors of existing nuisance bears at multiple time scales. I predicted that success would be correlated with the type of projectile, amount of human food available, and length of time that a bear had used human food.

STUDY AREA

Sequoia covers 1,645 km^2 on the western slope of the Sierra Nevada in California. Sequoia ranges in elevation from 418 m in the low western foothills to 4,417 m on the crest of the Sierra, and is composed largely of rugged, mountainous terrain. Vegetation types, including chaparral, oak woodland and savannah, upland hardwood forest, conifer forest, woodland, meadows, and alpine plant communities, make up 68% of the park. The region's Mediterranean climate was characterized by wet, snowy winters and long, dry summers (Stephenson 1988). Over 960,000 people visited Sequoia each year. Developed areas included 7 campgrounds with 559 campsites, 3 visitor centers, and 7 developed picnic areas. Roughly 70% of the Park was federally designated wilderness. Sequoia annually recorded over 100 human–bear conflicts and thousands of dollars in property damage (National Park Service 2008).

METHODS

Between June 2002 and September 2005, I annually supervised a team of 5 bear-management personnel, who subjected all bears encountered within 50 m of a developed area to an AC treatment. To ensure consistency, all team members attended safety and protocol training. Aversive conditioning treatments included chasing (without dogs); 3 projectiles of varying impact intensity: rock-throwing, slingshots, and rubber slugs (Strike II, Margo Supplies, Alberta, Canada); and pepper spray (Counter Assault; Kalispell, MT). Team members shot rubber slugs from a 12-gauge shotgun at a distance of 30–50 m from the target bear. We accompanied all AC treatments by yelling at the bear to reinforce the association with humans.

The causal effects of different aversive treatments are ideally evaluated with a randomized experimental design (Mitchell 2001); however, field conditions often dictate deviations from this ideal (Conroy and Nichols 1996). We did not strictly randomize treatments in the present study, although management personnel did strive for random assignment. The major impediment, in roughly half of events, was the proximity of the bear to visitors, which precluded using any potentially hazardous treatment or noxious pepper spray. Occasionally, when urgent action was required, rubber slugs or slingshots were unavailable. As a result, we used chasing and rock-throwing more frequently than other treatments.

The team located bears by patrolling developed areas every day between 0700 hours and 0200 hours, using radiotelemetry to find collared bears, and visitor reports. It is unlikely that we missed many instances of bears entering developed areas for human food because these events are usually reported multiple times. When bears were reported in developed areas when no staff was working, the team immediately shifted hours to ensure there was coverage when bears were present. We classified as food-conditioned all bears that we observed foraging on human food ≥ 3 times. We classified all other bears as wild. I use the term wild following prior usage (Mazur and Seher 2008) to designate bears that are not food-conditioned. It is possible that we sometimes counted the reappearance of an unmarked bear as 2 different bears; we minimized this potential source of bias by the AC team being familiarized with most bears in the area. It is also unlikely that these same bears moved undetected to other developed areas, because employees in those areas would have notified the team about a bear appearing in another area.

The AC team caught and marked 24 of the 36 food-conditioned bears used in this study (National Park Service 1992). We captured bears in a culvert trap, immobilized them with 4.4 mg/kg Telazol (Fort Dodge Animal Health, Fort Dodge, IA), and marked them with colored and numbered ear tags (Allflex International, Dallas, TX). We did not trap 12 food-conditioned bears because they were identifiable by distinct markings or injuries such as ripped ears, limps, or distinctly patterned chest blazes. The effect of on-site trapping on food-conditioned bears is short-lived (Beckmann et al. 2004), but some bias between the 2 groups may have occurred. To minimize trapping effects, we did not use any AC on bears upon release. For each trial, we recorded the type of location (campground, natural areas and roadsides, picnic area, or employee housing), the AC treatment, and the bear's response.

The main differences among locations were the consistency of human presence and the amount of unguarded food. In campgrounds, humans were usually present with their food. In picnic areas, humans were present only at mealtimes, but despite intensive education and enforcement efforts, they often left unattended trash, food scraps, and dirty grills that bears lick. Natural areas (within 50 m of a development) and roadsides presented sporadic opportunities for bears to obtain food scraps and garbage that lead to food-conditioning. In employee housing, humans were often present due to variable work schedules and food was generally stored properly as per park housing policy.

For food-conditioned bears, the team recorded each bear's behavioral response to the AC treatment in 4 time frames: immediate, within the first hour, for the remainder of the season, and multiyear. We also recorded age class (cub, yearling, subad–ad) and sex for all tagged bears. For wild bears, all unmarked, the team recorded only immediate and first-hour behavioral responses.

We coded responses differently for each time frame. We ordered a bear's immediate response, ranging from mild to strong aversion, as approaches observer, remains in area, climbs a tree, walks away, and runs away. We measured responses within the first hour by the length of time the bear stayed out of developed areas, in 15-minute increments, up to 1 hour. We measured responses for the remainder of the season by the number of days that a bear apparently stayed away from developed areas after treatment.

Nonparametric methods are helpful when data have a ranking but no clear numerical interpretation. The bear's immediate response to hazing can be unambiguously ranked from mild (bear approaches observer) to strong (bear runs away), but these different responses have no clear numerical values. Similarly, responses during the first hour can be brief (returns within 15 min) or long (stays away ≥ 45 min), but again these rankings have no clear numerical interpretation as a continuous time measurement would. Because food-conditioned bears received all or nearly all 5 treatments in both the immediate and 1-hour time frames for each bear, the treatments can be ranked according to their efficacy. For example, bear A may have run away when shot with a rubber slug but stayed in the area when pepper sprayed. The rubber slug is ranked as more effective than pepper spray in evoking an immediate response from that bear. The ability to rank the efficacy of the 5 treatments for each bear makes it convenient to use the Friedman test (Siegel and Castellan 1988) to detect differences in treatments across multiple food-conditioned bears. To minimize pseudo-replication (Hurlbert 1984), and to avoid potential effects of bears habituating (i.e., muting their response) to treatments, we included only the first trial of each treatment on each known bear. We then used a Friedman test with ranked responses blocked by bear to compare the immediate and first hour effectiveness of the 5 AC treatments (Sokal and Rohlf 1995). We included 2 additional independent variables, location type and age class, to assess their role as predictors of success. Each wild bear presumably received only one treatment, precluding any ranking of treatments. Therefore, for wild bears, which provided more numerous events, we used one-way and 2-way analysis of variance tests (Zar 1996).

We measured the result for the remainder of the season, called time to return (TTR), for food-conditioned bears only, by the number of days it took a bear to return to a developed area. When bears did not return by the end of the visitor season (30 Sep), we had no way of knowing whether they ceased to be problems or returned later in the autumn. The most conservative approach is to treat these data as incomplete by censoring them (Der and Everitt 2002). Therefore we analyzed TTR with a Cox proportional hazards model (Hosmer and Lemeshow 2000). The Cox model is an appropriate tool for this analysis because it accounts for both censored and uncensored data (Beckmann et al. 2004). The hazard ratio is the conditional probability that the TTR occurs in a given time interval. For this hazard model, predictor variables included the bear's identity, age, and location type. The number of previous treatments is also included to measure habituation to treatment. Because individual bear behavior was expected to influence the TTR, I kept all bears in the model.

For multiyear data on food-conditioned bears, we used a Fisher's exact test to compare the demographics of bears that were treated frequently and infrequently (Zar 1996). We completed all analyses using SAS statistical software (version 9.1; Cary, NC). We considered statistical comparisons significant at $\alpha = 0.05$.

RESULTS

There were 1,050 AC events on >150 bears during the 4 years of the study. Of these, 729 events involved 36 identifiable food-conditioned or habituated bears (we tagged 24 of these bears). The remaining 321 events involved wild bears that we assumed to be separate animals, though we cannot guarantee that there was no double-counting of the same bears. We differentiated unmarked bears by their color, chest blazes, obvious injuries, size, and home range. The team used chasing in 549 trials, rock-throwing in 249 trials, sling shots in 70 trials, pepper spray in 82 trials, and rubber slugs in 100 trials. We used chasing and rock-throwing disproportionately more than other methods due to safety concerns associated with working near visitors. We hazed bears from campgrounds 537 times, from roadsides 184 times, from picnic areas 166 times, from natural areas 148 times, and from employee housing 15 times.

With wild bears, immediate responses differed across the 5 treatments ($F_{4,316} = 9.55$, $P = 0.001$). Those shot with rubber slugs or chased were about twice as likely to run away as those given moderate treatments (rocks, slingshots) or pepper sprayed. Rubber slugs were slightly more effective than chasing (Fig. 1). Among the 36 food-conditioned bears, rubber slugs had far more immediate success than other treatments, causing animals to run away 92% of the time. Every other treatment caused bears to run in fewer than half of the trials. It is noteworthy that chasing was not as effective on food-conditioned bears as on wild bears (Fig. 1). With the small number of food-conditioned bears, the overall difference among treatments was not significant ($F_{4,57} = 1.11$, $P = 0.363$). However, the difference was significant in dichotomous tests between rubber slugs and every other treatment.

When we included location type as an independent variable, food-conditioned bears were more likely to immediately run from natural areas and roadsides, then campgrounds, and finally from picnic areas ($F_{2,55} = 6.56$, $P = 0.003$), perhaps reflecting the different availability of human food and level of

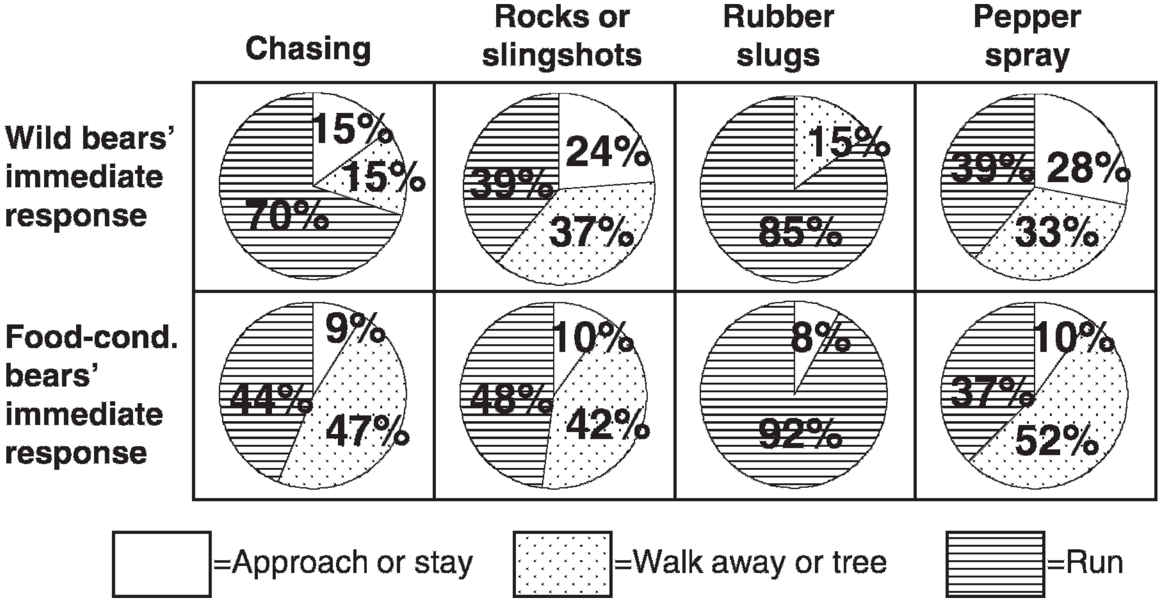

Figure 1. Immediate responses of wild and food-conditioned (food-cond.) black bears to various aversive conditioning treatments administered at Sequoia National Park, California, USA, 2002–2005.

conditioning. Taking age as an independent variable, cubs were most likely to immediately run, then adults, and finally yearlings ($F_{2,56} = 5.07$, $P = 0.01$).

Wild bears' responses within the first hour differed by treatment ($F_{4,218} = 3.34$, $P = 0.011$). Those shot with rubber slugs, chased, or pepper sprayed were more likely to stay away for at $\geq$1 hour than those hit with rocks or slingshots (Fig. 2). Chasing was nearly as effective as rubber slugs or pepper spray. Location type did not significantly affect first-hour response to AC.

Surprisingly, rubber slugs were not superior to other treatments in keeping food-conditioned bears away for an hour ($F_{4,42} = 1.30$, $P = 0.286$). Location type made little difference ($F_{2,40} = 2.12$, $P = 0.133$). Yearlings again were most resistant to AC, being most likely to return within 1 hour ($F_{2,41} = 2.92$, $P = 0.065$).

The Cox proportional hazards model, used to test which variables predict the number of days it took food-conditioned bears to return after hazing, showed no significant effect of AC treatment. Only location type and number of previous treatments during the year significantly predicted a bear's return. Bears took longer to return after AC from employee housing than from all other locations (hazard ratio = 0.259, $P = 0.026$). Bears that had previously received the most AC treatments also took longer to return (hazard ratio = 0.992, $P = 0.016$). These results should be

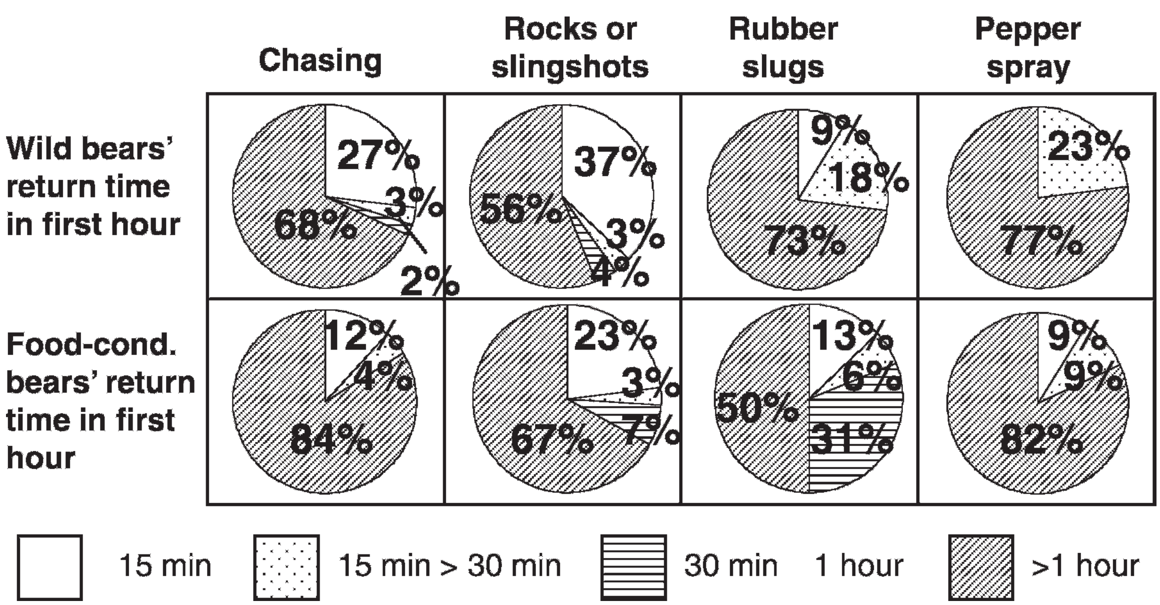

Figure 2. Short-term responses of wild and food-conditioned (food-cond.) black bears to various aversive conditioning treatments administered at Sequoia National Park, California, USA, 2002–2005.

Table 1. Multiyear outcomes for 36 black bears that we subjected to aversive conditioning treatments at Sequoia National Park, California, USA, 2002–2005.

Outcome	Bears treated infrequently (<14 times, $n = 25$)	Bears treated frequently (>23 times, $n = 11$)	Total
Treated for the first time in 2005	7	0	7
Food-conditioned before study began	2	5	7
Became food-conditioned during study	23	6[a]	29
Ceased entering developed areas in posttreatment yr	16	1	17
Required continued treatments annually, but changed behavior	2	4	6
Killed or relocated for safety	0	6	6

[a] Of these 6 bears, 5 were the offspring of the other bears in this group.

interpreted with caution; the behavior of individual bears seemed to strongly influence the TTR. During this study, 6 bears were either killed or relocated due to their potentially dangerous behavior; all had hazard ratios above one ($\bar{x}$ = 1.7, SD = 0.3), indicating a relatively fast return after AC. Hazard ratios for other bears ranged from 0.471 to 1.458 ($\bar{x}$ = 0.9, SD = 0.4).

Finally, we recorded the annual progress of the 36 food-conditioned bears over the 4 years of the study (Table 1). These bears fell into 2 natural groupings: those we treated infrequently because they were less persistent in seeking human food, and those very persistent bears that we treated frequently. Numerically, we treated 25 bears fewer than 14 times each, while we treated 11 bears >23 times each. These 11 bears accounted for 90% of all hazing events.

Of the 25 infrequently treated bears, 2 were food-conditioned before the study began, and the other 23 became food-conditioned during this study. Among these relatively less persistent animals, we treated 16 for $\geq$1 years and they then ceased to enter developed areas (we observed all in natural areas in subsequent yr), and 2 required hazing treatments every year. Another 2 changed their behavior from that deemed unacceptable (e.g., snatching food from attended tables), to acceptable by park management in terms of human safety (e.g., taking food from unattended tables at night when reporting parties were $\geq$50 m away). We treated 7 bears in this grouping for the first time in 2005, the last year of the study, so their multiyear fate is unknown.

Of the 11 persistent and, therefore, frequently treated bears, only one completely stopped entering developed areas; 4 changed their behavior but required treatments every year, and 6 became so persistent and potentially dangerous that they were killed or relocated by management.

Of these 11 most persistent bears, 6 were food-conditioned at the start of the study (2 were killed during the study). The other 5 were their offspring (4 were killed or relocated during the study). One food-conditioned female abandoned human food while raising her cub, but continued coming to within 50 m of developed areas, despite receiving 24 AC treatments. Her cub did not learn about human food from his mother, but he was continually in close proximity to visitors who approached and fed him. He soon became food-conditioned and a danger, and was killed as a yearling.

There were significant age differences between the 2 groupings (Fisher's exact test, $P = 0.022$). The infrequently treated group included 52% cubs, 8% yearlings, and 40% adults. The frequently treated group was 9% cubs, 36% yearlings, and 54% adults. The gender difference between the 2 groups was not significant (Fisher's exact test, $P = 0.677$).

DISCUSSION

Aversive conditioning reduced but did not eliminate the occurrence of bears entering developed areas to forage on human food and trash in Sequoia National Park. Aversive conditioning was most effective on wild bears. With food-conditioned bears, effectiveness was related to how quickly bears received AC after first receiving human food. Aversive conditioning was least effective on yearlings. Overall, rubber slugs were only slightly more effective than other methods, and some bears became food-conditioned despite all treatments.

Aversive conditioning was most effective if bears had never, or rarely, obtained human food. The challenge for managers is that it requires constant vigilance to treat all wild bears before they obtain human food or garbage. During this study, $\geq$29 previously known wild bears obtained human food. Bears likely got this food at night from overflowing garbage cans, roadside trash, by entering picnic areas to retrieve scraps from grills, or were fed by visitors (National Park Service 2008). The likelihood of bears entering developments for human food or trash increases when bears are habituated to human presence (Clark et al. 2002). Bears that spend time near human developments are more likely to be killed in motor vehicle collisions than wild bears (Mazur and Seher 2008), a strong argument for using AC to keep bears away from human developments regardless of whether or not human food is available.

The mixed success of AC on food-conditioned bears was related to how quickly a bear received an AC treatment after obtaining human food. During this study, animals receiving AC treatments immediately after they received human food for the first time required fewer treatments than food-conditioned bears, and were more likely to abandon their nuisance behaviors. Most of these bears ceased to enter developed areas after being treated between one and a dozen times. The team had less success with bears that were already food-conditioned, and with cubs of food-conditioned females. One of these bears did stop entering human developments, and some became less persistent or aggressive, but 6 became so persistent, aggressive, or caused so much damage that they were removed from the area or destroyed by management.

Rubber slugs were slightly more effective than other AC treatments in getting all bears to leave developed areas immediately. Pepper spray and chasing were about as effective as rubber slugs in keeping wild bears away during the first hour after AC. This may be due to the lingering effect of pepper spray, which may serve as an attractant. Other methods were useful in encouraging bears to leave developed areas, but the bears left more slowly. The most persistent bears did not leave until rubber slugs were used, and in the cases of the 6 bears that were killed or relocated, they would run when shot, but immediately return and resume their foraging. The long-term results show these same 6 bears to be among those most likely to return quickest (measured in days) after AC. They may have become habituated to the treatments and muted their reactions to obtain human food, or they may have been energetically stressed (Lima 1998).

The cost of firearms, ammunition, and training for AC and lethal control are roughly comparable at about US$400/year. Bear-management personnel are employed full time by the National Park Service to assist with all aspects of bear management (including education and enforcement) at a cost of US$42,000/year. Because about 10% of their time was spent on AC, this prorates to US$4,200/year. The cost of personnel for lethal control at Sequoia runs between US$2,000/year and US$20,000/year, depending on how many bears are killed and how difficult they are to catch. For lethal control, each bear must first be caught and marked to make a positive identification, and then caught again for destruction.

Management Implications

When bears do obtain human food, projectiles or chasing can drive them from the area regardless of whether or not long-term AC has been achieved. Aversive conditioning can prevent nuisance behaviors in many wild bears if it keeps them away from developed areas. For bears that are already food-conditioned, AC can drive most bears away from developed areas, but the success is often short-lived. The main utility of AC with these bears is to 1) modify unacceptable behaviors to those deemed acceptable for human safety, 2) keep them out of developed areas long enough to install bear-proof facilities, and 3) keep females with cubs out of developed areas so the cubs do not learn nuisance behaviors from their mother.

Aversive conditioning, like lethal removal, will not be an effective management strategy if human food remains in the area. Before AC is attempted, adequate food-storage facilities must be available, along with an outreach and enforcement program that ensures these facilities are used. In areas where bears require access to critical habitats, the best management option may be to seasonally exclude humans, rather than bears. This will allow bears access without putting humans at risk of encounters, injuries, or property damage, and without putting bears at risk of habituating to humans or receiving a food reward (Herrero et al. 2005).

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