2018

Assessing Ecological and Social Outcomes of a Bear-Proofing Experiment

Heather Johnson
USGS, heatherjohnson@usgs.gov

David L. Lewis
Colorado Parks and Wildlife

Stacy A. Lischka
USGS

Stewart W. Breck
USDA National Wildlife Research Center

The Journal of Wildlife Management 82(6):1102–1114; 2018; DOI: 10.1002/jwmg.21472

Featured Article

Assessing Ecological and Social Outcomes of a Bear-Proofing Experiment

HEATHER E. JOHNSON,[1,2] *Colorado Parks and Wildlife, 415 Turner Drive, Durango, CO 81303, USA*
DAVID L. LEWIS, *Colorado Parks and Wildlife, 415 Turner Drive, Durango, CO 81303, USA*
STACY A. LISCHKA,[3] *Colorado Parks and Wildlife, 317 West Prospect Ave., Fort Collins, CO 80526, USA*
STEWART W. BRECK, *U.S. Department of Agriculture National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA*

ABSTRACT Human-black bear conflicts within urban environments have been increasing throughout North America, becoming a high priority management issue. The main factor influencing these conflicts is black bears foraging on anthropogenic foods within areas of human development, primarily on residential garbage. Wildlife professionals have advocated for increased bear-proofing measures to decrease the accessibility of garbage to bears, but little research has been conducted to empirically test the effectiveness of this approach for reducing conflicts. Between 2011 and 2016, we conducted a before-after-control-impact experiment in Durango, Colorado where we distributed 1,110 bear-resistant trash containers, enhanced education, and increased enforcement to residents in 2 treatment areas, and monitored 2 paired control areas. We examined the ecological and social outcomes of this experiment, assessing whether bear-resistant containers were effective at reducing conflicts; the level of public compliance (i.e., properly locking away garbage) needed to reduce conflicts; whether the effectiveness of bear-resistant containers increased over time; and if the distribution of bear-resistant containers changed residents' attitudes about bear management, support for ordinances that require bear-proofing, or perceptions of their future risk of garbage-related conflicts. After the bear-resistant containers were deployed, trash-related conflicts (i.e., observations of strewn trash) were 60% lower in treatment areas than control areas, resident compliance with local wildlife ordinances (properly locking away trash) was 39% higher in treatment areas than control areas, and the effectiveness of the new containers was immediate. Conflicts declined as resident compliance with wildlife ordinances increased to approximately 60% (by using a bear-resistant container or locking trash in a secure location), with minor additional declines in conflicts at higher levels of compliance. In addition to these ecological benefits, public mail surveys demonstrated that the deployment of bear-resistant containers was associated with increases in the perceived quality of bear management and support for ordinances that require bear-proofing, and declines in the perceived risk of future trash-related conflicts. Our results validate efforts by wildlife professionals and municipalities to reduce black bear access to human foods, and should encourage other entities of the merits of bear-proofing efforts for reducing human-bear conflicts and improving public attitudes about bears and their management. © 2018 The Wildlife Society.

KEY WORDS bear-resistant containers, black bear, Colorado, human-black bear conflict, human-wildlife interaction, management, perceived risk, public perceptions, public survey, *Ursus americanus*.

Human-black bear (*Ursus americanus*) conflicts within developed environments have increased throughout North America, becoming a high priority management issue (Hristienko and McDonald 2007). The main factor influencing these conflicts is black bears foraging on anthropogenic foods within areas of human development, primarily on residential garbage (Barrett et al. 2014, Lewis et al. 2015). Anthropogenic food subsidies not only alter the behavior of bears (Baruch-Mordo et al. 2014; Johnson et al. 2015, 2018) but can result in increased human-caused bear mortality and reduced population growth rates (Beckmann and Berger 2003, Hostetler et al. 2009, Baruch-Mordo et al. 2014), while also creating situations where bears cause property damage and threaten human safety (Treves et al. 2010). Despite the trajectory of increasing human-black bear conflicts (i.e., human-bear conflicts), and the severe consequences of these interactions for bears and people, best management practices for reducing conflicts have largely remained unclear.

Received: 20 October 2017; Accepted: 2 March 2018

[1]*E-mail: heatherjohnson@usgs.gov*
[2]*Present Address: U.S. Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, AK 99508, USA.*
[3]*Present Address: U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Ave, Fort Collins, CO 80526, USA.*

To address rising human-bear conflicts, wildlife management agencies have invested resources in a variety of techniques. These techniques include the removal of conflict-causing individuals by translocation or culling (Alldredge et al. 2015, Voyles et al. 2015), various forms of hazing and aversive conditioning (Beckmann et al. 2004, Breck et al. 2006, Mazur 2010), increased harvest (Treves et al. 2010, Obbard et al. 2014), and education (Gore et al. 2008, Baruch-Mordo et al. 2011). Although these strategies are commonly employed, they can be expensive, time-consuming, short-term, and have the potential to reduce bear population sizes, while often resulting in minimal declines in human-bear conflicts. Most importantly, they are proximal solutions that do not address the ultimate problem of accessible garbage and other human food resources attracting bears into developed environments.

Given that bears are attracted to anthropogenic foods, eliminating the availability of this resource should reduce bear foraging activity around human development, and thus, conflicts (Peine 2001, Beckmann et al. 2004, Lyons 2005, Spencer et al. 2007). Although this strategy has had success within national parks (Gniadek and Kendall 1998, Schirokauer and Boyd 1998, Greenleaf et al. 2009) and anecdotally in some communities (Tavss 2005, Barrett et al. 2014), the implementation of wide-scale bear-proofing (i.e., reducing the availability of anthropogenic foods to bears) has rarely been applied in municipalities facing increases in human-bear conflicts. In part, this is because bear-proofing measures (e.g., distribution of bear-resistant garbage containers, increased enforcement) can be expensive and logistically difficult to implement. It is also because municipalities control local waste management and enforcement practices but are not typically responsible for reducing human–bear conflicts. Meanwhile, wildlife agencies are typically mandated to address conflicts yet have no control over public waste management practices.

To test the utility of urban bear-proofing efforts for reducing conflicts, Baruch-Mordo et al. (2013) used a theoretical model of black bear foraging behavior. Like other wildlife, black bears make foraging decisions based on perceived trade-offs, weighing the benefits of acquiring human food against the risks associated with human activity (Frid and Dill 2002, Johnson et al. 2015). Bears are known to perceive the benefits of additional food resources around development but also appear to recognize increased risks associated with human activity and infrastructure (Ordiz et al. 2011, Johnson et al. 2015). Using a patch selection model depicting changes in forage-risk trade-offs, Baruch-Mordo et al. (2013) found that reducing the availability of human foods to bears (i.e., the forage benefit) by 55–70% was predicted to significantly reduce bear use of urban development, and thus, the risk of human-bear conflict.

Studies of bear conflicts and bear behavior suggest that bear-proofing measures should reduce human-bear conflicts, but studies of people suggest that bear-proofing measures may also have social benefits (Gore et al. 2009). Indeed, the implementation of certain management actions increases public trust in agencies, as long as people believe the actions will achieve goals that align with their own concerns (Rudolph and Riley 2014). Because residents have reported that bear-resistant garbage containers are likely to reduce human-bear conflicts and are an acceptable management approach (Barrett et al. 2014), the application of bear-proofing infrastructure may significantly improve resident satisfaction with wildlife management agencies. Strengthening this trust is critical, particularly in the management of human-carnivore interactions, where the potential for social conflict is high and can result in contentious interactions between the public and wildlife agencies (Decker et al. 2016).

Given the significant financial and logistical resources required to bear-proof a community, municipalities and wildlife agencies need definitive evidence that such efforts are effective at reducing conflicts to implement this approach. To better understand the effects of urban bear-proofing on human-bear conflicts and resident attitudes, we conducted a large-scale experiment in Durango, Colorado, USA, a community that regularly experiences high rates of human-bear conflicts (Baruch-Mordo et al. 2008). Using a before-after-control-impact (BACI) design, we deployed bear-resistant containers, enhanced education, and increased enforcement in 2 treatment areas, and compared changes in conflicts and public attitudes relative to 2 paired control areas. Our experimental design, and mixed methods approach to data collection, enabled us to understand the ecological and social outcomes of wide-scale urban bear-proofing by assessing whether bear-resistant containers were effective at reducing human-bear conflicts; the level of public compliance (i.e., properly locking away garbage) needed to significantly reduce conflicts; whether the effectiveness of bear-resistant containers increased over time; and if the distribution of bear-resistant containers changed residents' attitudes about bear management, support for wildlife ordinances, and perceptions of their future risk of garbage-related conflicts.

STUDY AREA

The city of Durango is located along the Animas River in southwest Colorado (37.2753° N, 107.8801° W; Fig. 1) and consists of approximately 18,000 residents (U.S. Census Bureau 2014). Lands surrounding Durango range between 1,930 m and 3,600 m in elevation and are largely owned and managed by city, county, state, and federal entities. The area is generally characterized as having mild winters and warm summers that experience monsoon rains. During the past 10 years in Durango, the average high and low temperatures in winter (Dec–Feb) were 5.7°C and −10.2°C, respectively, and the averages for summer (Jun–Aug) were 28.6°C and 10.3°C, respectively (http://climate.colostate.edu/data_access.html). Over the same period, mean annual snowfall and precipitation was 108.5 cm and 42.8 cm, respectively. The vicinity of Durango is considered high quality bear habitat (Johnson et al. 2015) and is dominated by ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*), aspen (*Populus tremuloides*), pinyon pine (*Pinus edulis*), juniper (*Juniperus* spp.), and mountain shrubs such as chokecherry (*Prunus virginiana*) and wild crabapple (*Peraphyllum ramosissimum*). Other large

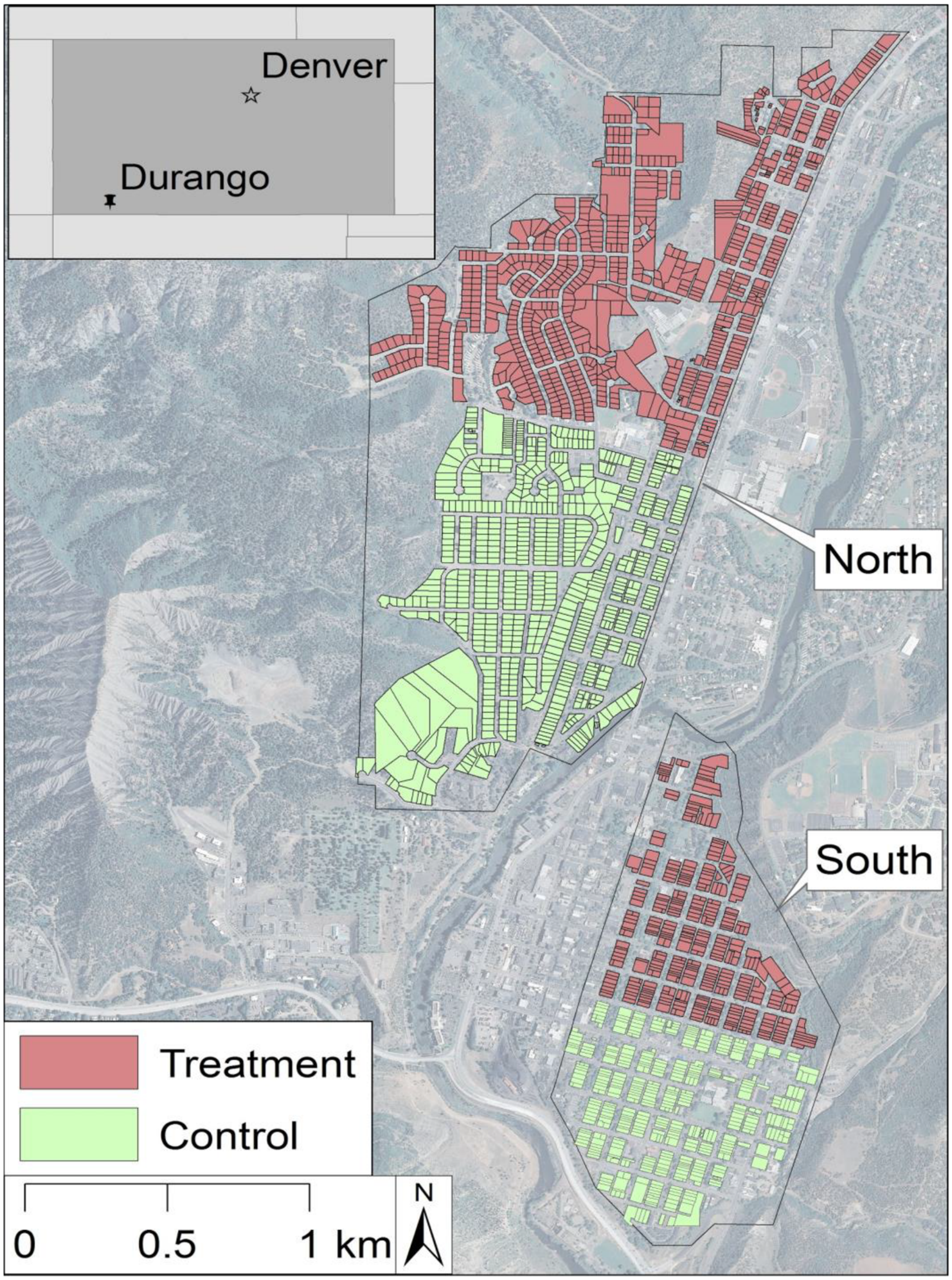

Figure 1. Residential parcels within treatment and control areas of our experimental units (north and south) in Durango, Colorado, USA.

carnivores in the vicinity of Durango are cougars (*Puma concolor*) and coyotes (*Canis latrans*), and the primary ungulate prey are mule deer (*Odocoileus hemionus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*). Durango has experienced higher human population growth rates than the rest of Colorado (from 1970–2010 growth in Durango was 67%; statewide it was 57%; U.S. Census Bureau 2014), with residential housing sprawling into previously undeveloped bear habitat.

The City of Durango manages all residential garbage within city limits. Prior to the implementation of our experiment, residents were provided regular garbage containers, and could pay a voluntary additional fee for a bear-resistant container. When we initiated our study (summer 2011), approximately 10% of residences voluntarily paid for bear-resistant containers. The City of Durango has an ordinance requiring residents to keep their garbage in either a locked wildlife-resistant container or a secure location (e.g., garage or shed; www.durangogov.org/index.aspx?NID=668). The only time that homeowners are allowed to have their garbage accessible (in an unlocked container outside of a garage or shed) is on their scheduled garbage pick-up day between 0600 and 1900.

METHODS

Experimental Design

To conduct our experiment, we identified 2 treatment areas and 2 paired control areas within the residential core of Durango (Fig. 1). In all experimental units, we collected pre-treatment data during summers 2011–2012 and post-treatment data during 2013–2016. One experimental unit was designated in the north part of the city (1,485 residences), and another in the south (784 residences), separated by the Animas River (Fig. 1). We randomly assigned treatment and control areas within each experimental unit and selected areas with approximately the same number of homes (north treatment = 783, north control = 701, south treatment = 362, south control = 422). The north unit consisted primarily of single-family dwellings, most of which had garages (allowing for secure trash storage), on larger lots and with larger home sizes (http://co.laplata.co.us/cms/one.aspx?portalId=1323753&pageId=3061574). The south unit also consisted primarily of single-family homes but contained more rental properties; fewer homes had garages and homes and lot sizes were generally smaller than those in the north unit. All homes in the southern unit were located along alleys, where trash containers were placed for storage and waste removal; only 14% of homes in the north were situated along alleys.

During March–June 2013, we worked with the City of Durango to distribute bear-resistant garbage containers, at no cost, to all residences within treatment areas. We focused our efforts on reducing the accessibility of garbage because this is the primary food attractant to bears within developed landscapes (Lewis et al. 2015). We replaced regular 242-liter and 360-liter trash containers with bear-resistant ones of the same size (Solid Waste Systems Equipment, Parker, CO, USA), which had 2 latches on the lid that had to be manually locked. Although self-locking containers would have been preferable, when we initiated our study, no such cans were certified as bear-resistant (certification by the Living with Wildlife Foundation) that were available for bulk purchase and compatible with Durango's existing waste management equipment. Although our intention was to replace all regular containers within treatment areas, a field survey in August 2013 revealed that 11% of residences in the north and 27% of residences in the south still had regular trash containers. To improve our bear-proofing treatments we distributed additional containers in spring 2014 to ensure that all residences in treatment areas had bear-resistant cans (1,110 cans total). Additionally, each summer, we replaced any regular containers that were found within treatment areas with bear-resistant containers. Field monitoring conducted during August 2014–2017 confirmed that ≥97% of trash containers in the north and ≥95% of containers in the south were bear-resistant.

In addition to providing bear-resistant containers, we also increased education and enforcement at homes within treatment areas. During early July each year (2013–2016), the time when conflicts generally increase, we canvassed homes after 1700 to remind residents to lock their bear-resistant containers and to request that they remove or secure all other outside food attractants (e.g., bird feeders, pet food). In addition to talking with residents, we distributed a flyer that contained standard information from Colorado Parks and Wildlife (CPW) about bear-proofing homes and specific information about Durango's wildlife ordinance and the importance of locking bear-resistant trash containers. Additionally, we increased enforcement of the city wildlife ordinance. We surveyed each home within treatment areas on the morning of trash pick-up and if strewn garbage was visible, we would attach a warning to the can, citing the ordinance and the associated fines. If a residence received >1 warning during the summer sampling period, Durango City Code Enforcement was notified to issue a fine. No canvassing or enforcement occurred in control areas.

Measuring Ecological Outcomes of the Experiment

Monitoring human-bear conflicts, public compliance, and natural food availability.—To assess the effectiveness of the treatment for reducing trash-related conflicts, we collected data on the frequency and locations of strewn garbage. Between July and September 2011–2016 (months when human-black bear conflicts peak; CPW, unpublished data), we patrolled each street and alley within the study area on the morning of garbage pick-up (when maximum human food was assumed available to bears). We conducted patrols from 0500–0700 and recorded the location (i.e., parcel) and container type (regular or bear-resistant) where there was evidence that wildlife had obtained garbage (e.g., strewn trash; i.e., trash conflicts). We assumed that trash conflicts were caused by black bears, as they typically consisted of a large container (242 or 360 liter) knocked over on the ground with trash bags dragged out of the can and strewn nearby, but we cannot dismiss the possibility that other animals caused the conflict. We collected pre-treatment data on trash conflicts during 2011 and 2012, and post-treatment data during 2013–2016.

After we distributed bear-resistant containers within treatment areas (2013–2016), we also collected data on human behavior, monitoring whether individual residences complied with Durango's wildlife ordinance. The bear-resistant containers we deployed were only effective if they were manually locked, which required resident cooperation. To collect data on compliance, we monitored residences between 0500 and 0600 on the morning of garbage pick-up. Logistical constraints restricted us from monitoring all homes within the study area, so we randomly selected 40 blocks in each treatment and control area (160 blocks), where we monitored compliance at every residence each year. We monitored 86% of the blocks in the smaller south experimental unit, and 56% in the larger north unit. We surveyed homes in these blocks once per month during July, August, and September, except in 2013, when surveys only occurred during August and September. In accordance with the ordinance, we considered a residence to be compliant if both latches on their bear-resistant container were locked or the container was not visible (suggesting it was secured in a garage or shed). We coded residences as non-compliant if their bear-resistant garbage container had one or 2 latches unlocked, or if we observed a regular garbage container or trash outside of a secure structure.

In addition to monitoring trash conflicts and human compliance, we also monitored the annual abundance of natural foods available to bears in the study area. Human-black bear conflicts increase during years when natural foods are scarce (Zack et al. 2003, Obbard et al. 2014), as bears forage on anthropogenic foods for subsidy (Baruch-Mordo et al. 2014, Johnson et al. 2015, Lewis et al. 2015). To account for variation in natural food conditions, and the subsequent effects on conflicts, we monitored 15 1-km vegetation transects within 10 km of Durango. Following Johnson et al. (2018), we estimated the annual availability of hard and soft mast from Gambel oak, chokecherry, and wild crabapple shrubs along each transect every 2 weeks during August and September. During each survey, on each transect, we estimated the abundance of fruit or nuts for each species as the percentage of plants with no mast (value $= 0$), scarce mast (value $= 25$), moderate mast (value $= 50$), abundant mast (value $= 75$), or a bumper crop (value $= 100$). We then multiplied the percentage of plants in each category by their assigned value (i.e., 0, 25, 50, 75, or 100) to estimate an index of mast abundance for each transect. Each year, we averaged the highest abundance score for each forage species across all 15 transects to calculate an annual mean abundance for each species across the study area. We then calculated the average annual abundance of mast across the 3 different forage species, using this value as an annual index of natural forage conditions (natural food).

Statistical analyses of ecological outcomes.—We used a mixed logistic regression model to investigate whether residential conflicts decreased in response to the treatment. Our response variable was whether each residence was observed with $\geq$1 trash conflict/year. If a residence was observed with $\geq$1 trash conflict during the 13 weekly sampling occasions (Jul–Sep), we coded it as a 1 and if no trash conflicts were observed, we coded it as a 0. We coded responses as binary, rather than as counts, because 94% of residences had no observed trash conflicts/year, 5% had 1 conflict/year, and 1% had $>$1 conflict/year. We analyzed conflict data using a BACI design (Williams et al. 2002), where we tested for a significant interaction between time (pre- vs. post-treatment) and treatment (treatment vs. control). We coded time and treatment as binary variables; the reference class for time was pre-treatment years and for treatment was control areas. Because we suspected that differences between north and south neighborhoods may influence conflict rates (e.g., homes in the south largely stored garbage in alleys that may be more accessible to bears), we also included site as a binary variable with north serving as the reference class. We also included natural food in all ecological models because trash conflicts increased when natural food availability declined (95% CIs excluding 0; $\beta = -0.026 \pm 0.004$ [SE]). To determine whether the treatment affected conflicts, we used a single logistic mixed regression model where we included individual residence as a random effect (accounting for multiple observations at the same properties over time) and time, treatment, site, natural food, and time $\times$ treatment as fixed effects. We considered 95% confidence intervals that excluded zero to indicate the significance of different variables on trash conflicts, and evaluated the effectiveness of the experiment by assessing the time $\times$ treatment interaction.

We determined the relationship between public compliance and conflicts using data from treatment and control areas, as homes across the study area demonstrated a continuum of compliance rates. We assumed that a residence's risk of a conflict was related to the availability of garbage within the vicinity of their home, not just at the residence itself, and calculated compliance at the scale of the city block. During each sampling period, for each block, we divided the number of compliant residential parcels by the total number of residential parcels. We averaged the 3 surveys/block/year to determine the annual compliance rate/block (compliance), and assigned this value to each parcel on the block that year. Compliance was correlated with treatment ($R = 0.53$, $P < 0.001$) and site ($R = -0.62$, $P < 0.001$); compliance was higher in treatment areas and in the north replicate. To avoid issues with multicollinearity, we excluded treatment and site from this analysis. We ran a mixed logistic regression model where the response variable was observed trash conflict at each residence during the year, and the explanatory variables included compliance and natural food as fixed effects, and individual residence as the random effect (we excluded time because we collected compliance data only during post-treatment years). Given that we monitored only a subset of homes for compliance, this analysis included 1,551 residences. We used 95% confidence intervals to assess the significance of compliance rates on trash conflicts.

To examine whether the effectiveness of the experiment changed over the 4-year treatment period, we used a mixed logistic regression model to test whether observed trash conflicts were associated with the number of years post-treatment ($2013 = 1$, $2014 = 2$, $2015 = 3$, $2016 = 4$). We restricted this analysis to residences within treatment areas ($n = 1{,}145$). We included compliance and natural food as fixed effects because both factors changed over time and we wanted to test for a temporal trend in conflicts after accounting for these variables. We treated individual residence as a random effect and used coefficient confidence intervals to test for a temporal trend in conflict rates. We fit mixed logistic regression models with maximum likelihood estimation in program R version 3.2.3 (R Core Team 2013) using the package lme4 (Bates et al. 2013).

Measuring Social Outcomes of the Experiment

Monitoring public attitudes with mail surveys.—To assess the effect of the bear-proofing experiment on resident perceptions, we sent self-administered, mail-back surveys to all residential parcels in experimental areas (treatment and control areas; $n = 2{,}269$) before and after the distribution of bear-resistant containers (2012 and 2016). We obtained names and addresses for mailings from spatially referenced plat maps and tax roll information from the La Plata county assessor's office. We assigned all survey responses to parcels so that responses could be attributed to specific treatment and control areas. We sent questionnaires using a modified version of the tailored design method (Dillman 2014) with 6 mailings (1 pre-notification letter, 2 survey mailings, 2 reminder postcards, and 1 non-respondent postcard) administered at 3-week intervals between January and June. In each mailing, we offered respondents the option to reply via paper survey or online. We assessed non-response bias with a mailed postcard (sent to all non-respondents 4 weeks after the final reminder postcard) containing a sample of 5 questions from the original survey. To quantify bias between survey respondents and community characteristics, we used t-tests to compare the demographic profiles of respondents to information for the city of Durango from the United States Census Bureau (2014). All survey materials and procedures met the approval of Colorado State University's Institutional Review Board (Protocol number 005-17H).

We evaluated changes in resident perceptions about human-bear conflicts and their management using 3 response variables. We asked respondents to score the quality of management of bears and human-bear interactions on a 5-point Likert scale, ranging from excellent to poor with a mid-point of average. We also asked residents about the acceptability of CPW working to establish bear-proofing ordinances in communities, which was also measured on a 5-point Likert scale ranging from very acceptable to very unacceptable, with a midpoint of neither. Finally, we assessed residents' perceived risk of future garbage-related conflicts using 2 survey items that measured cognitive and affective components of perceived risk (Slovic 1980). We assessed cognitive risk by asking respondents to rate how likely they were to have a black bear break into or attempt to break into their garbage in the next year, and assessed affective risk by asking respondents to rate the acceptability of having a black bear break into or attempt to break into their garbage. We measured both components of risk on 5-point Likert scales, where cognitive risk ranged from very likely to very unlikely, and affective risk ranged from very acceptable to very unacceptable. Both scales had a midpoint of neither. We calculated risk as cognitive risk × affective risk, which ranged from 1 to 25. For all Likert response questions, respondents were offered a not sure response option, which we coded as a missing value.

Statistical analyses of social outcomes.—We used linear regression models to determine whether the bear-proofing experiment changed resident attitudes, modeling each of our 3 response variables (management, ordinance, and risk) as functions of the binary variables time (reference = pre-treatment), treatment (reference = control areas), site (reference = north), and the interaction time × treatment. We treated all survey response variables as continuous, and we weighted responses to account for non-response bias (Groves 2006). We fit weighted linear models in R version 3.2.3 (R Core Team 2013).

RESULTS

Ecological Outcomes

Field observations.—Between 2011 and 2016, we observed 810 trash conflicts within the study area. Before the experiment began (2011–2012), 123 conflicts occurred in treatment areas ($\bar{x}$ = 11 conflicts/100 residences), and 133 occurred in control areas ($\bar{x}$ = 12 conflicts/100 residences; Table 1). After implementation of the experiment (2013–2016), 180 conflicts occurred in treatment areas ($\bar{x}$ = 16 conflicts/100 residences), and 374 occurred in control areas ($\bar{x}$ = 33 conflicts/100 residences; Table 1). Despite the fact that the south replicate contained fewer residences (784 residences) than the north (1,485 residences), both replicates experienced similar numbers of conflicts across the study period (south = 410 conflicts, north = 400 conflicts). Trash conflicts were highly variable in the study area across years, with a maximum of 231 in 2015, and a minimum of 30 in 2016. During post-treatment years, we distributed 121 warnings at residences with treatment areas (2013 = 58, 2014 = 16, 2015 = 31, 2016 = 16). These warnings appeared to be effective because we notified City Code Enforcement about only 9 residential addresses that accrued >1 warning/year for subsequent ticketing. Based on field surveys of chokecherry, wild crabapple, and Gambel oak in the study area, the index of natural food availability was highly variable, ranging from a low of 5.6 in 2012 to a high of 30.6 in 2011 (Table 1).

After we applied the treatments, the average proportion of homes within a block that complied with the wildlife ordinance was 0.61 (SD = 0.24), with individual blocks ranging from 0.00 to 1.00 (Table 1). In treatment areas, the average rate of compliance was 0.71 (SE = 0.18) and in control areas, it was 0.51 (SE = 0.24). The north replicate had higher average rates of compliance (0.73; SD = 0.17)

Table 1. The black bear natural food index, the number of trash conflicts/residence, and the ordinance compliance rate/block annually observed in experimental areas between 2011 and 2016, Durango, Colorado, USA. We collected pre-treatment data during 2011–2012 and post-treatment data during 2013–2016. We only collected compliance data during post-treatment years.

		Conflicts/residence				Compliance/block			
		North		South		North		South	
Year	Natural food	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
2011	30.6	0.02	0.06	0.13	0.02				
2012	5.6	0.07	0.09	0.08	0.09				
2013	25.1	0.08	0.07	0.12	0.14	0.69	0.52	0.53	0.28
2014	25.4	0.03	0.05	0.06	0.20	0.83	0.74	0.63	0.37
2015	17.5	0.06	0.10	0.09	0.43	0.85	0.68	0.65	0.49
2016	23.0	0.01	0.01	0.01	0.04	0.86	0.66	0.64	0.45

than the south replicate (0.49; SD = 0.23). Compliance rates were lowest in 2013 (first post-treatment year) and higher in subsequent years (Table 1).

Effects of bear-proofing treatment on conflicts.—After we distributed bear-resistant containers, we detected a significant change in trash conflicts between treatment and control areas (Table 2 and Fig. 2). Although we expected conflicts to decline in treatment areas after the containers were deployed, we found that treatment areas experienced a minor, non-significant decrease in conflicts, whereas control areas experienced a significant increase (Fig. 2); this result was largely influenced by increases in conflicts in the south replicate. After the bear-resistant containers were distributed (post-treatment years), the annual probability of an individual house being observed with a trash conflict during the survey period was 0.02 within treatment areas, and 0.05 within control areas. Conflicts were generally lower in the north replicate than the south, and declined during good natural food years (Table 2 and Fig. 2).

We found that increased compliance with the wildlife ordinance strongly reduced the probability of conflict (Table 2 and Fig. 3). The annual probability of conflict at a house on a block with a compliance rate of 10% was 0.11, whereas for a house on a block with a compliance rate of 90% it was 0.02. Compliance had a strong nonlinear effect on conflict rates, such that the probability of conflict sharply declined as compliance increased to approximately 0.60, and then waned (Fig. 3). After accounting for changes in compliance and variation in natural food availability, conflicts declined across the 4-year study period (Table 2), although the effect was relatively minor (Table 2), decreasing from 0.03 in 2013 to 0.01 in 2016.

Table 2. Coefficients, standard errors, and lower (L95%) and upper (U95%) 95% confidence intervals from mixed logistic regression models assessing 1) whether bear-resistant containers reduced black bear related trash conflicts, 2) the influence of compliance on conflict rates, and 3) whether the effectiveness of bear-resistant containers increased across the 4-year study period in Durango, Colorado, USA. Model parameters represent pre- (2011–2012) and post-treatment years (2013–2016; time; reference = pre-treatment years), treatment areas that received bear-resistant containers (treatment; reference = control), the replicate (site; reference = north), annual natural food availability (natural food), resident compliance with the city wildlife ordinance (compliance), and the number of years since the treatment commenced (ranging from 1 to 4). Estimates are provided on the logit scale.

Parameter	Estimate	SE	L95%	U95%
1) Effect of treatment on conflicts				
Intercept	−3.10	0.15	−3.39	−2.81
Natural food	−0.03	0.01	−0.04	−0.02
Time (post-treatment)	0.62	0.12	0.39	0.85
Treatment	−0.07	0.15	−0.36	0.21
Site (south)	0.75	0.10	0.56	0.94
Time × treatment	−0.75	0.17	−1.08	−0.43
2) Effect of compliance on conflicts				
Intercept	1.52	0.42	0.69	2.35
Natural food	−0.15	0.02	−0.18	−0.12
Compliance	−2.46	0.27	−2.98	−1.94
3) Temporal trend in conflicts				
Intercept	1.58	1.48	−1.31	4.48
Natural food	−0.25	0.05	−0.35	−0.16
Compliance	0.28	0.86	−1.40	1.97
Years post-treatment	−1.23	0.19	−1.60	−0.85

Social Outcomes

Survey responses.—In 2012, prior to the deployment of bear-resistant containers, our adjusted survey response rate (after removing undeliverable addresses) was 50% ($n = 1{,}127$). In 2016, after deployment of the bear-resistant containers, our adjusted response rate was 41% ($n = 918$). Across the experimental units (treatment and control areas), homeowners responded to the survey at higher rates than renters (60% homeowners in 2012 and 62% homeowners in 2016 vs. 49% homeowners in Durango; U.S. Census Bureau 2014). As a result, we chose to weight survey data by homeownership. We found no other significant differences between respondents and non-respondents ($P > 0.05$ for all tests).

Across all experimental units, approximately half of respondents rated management of bears and human-black bear conflicts as either above average or excellent in 2012 (50%) and 2016 (51%; Table 3). After the bear-proofing experiment was implemented, more residents believed ordinances requiring the use of bear-resistant garbage containers were acceptable (86% in 2012 vs. 94% in 2016; Table 3). Residents' perceptions of their risk of garbage-related conflicts slightly increased between 2012 and 2016 ($\bar{x}_{2012} = 10.5$, $n = 732$, SE = 0.2; $\bar{x}_{2016} = 11.6$, $n = 1{,}032$, SE = 0.2).

Effects of bear-proofing treatment on public attitudes.—Attitudes in treatment areas toward management generally became more positive after bear-resistant containers were deployed. During the pre-treatment survey, satisfaction with management was similar among treatment and control areas, but during the post-treatment survey, treatment areas reported higher levels of satisfaction (Tables 3 and 4 and Fig. 4). Before the implementation of the experiment, we found no difference between treatment and control areas in their support of CPW working to establish ordinances requiring bear-proofing. After the experiment commenced, support for ordinances increased in treatment and control areas, but the increase was larger in treatment areas (Tables 3 and 4 and Fig. 4). Finally, although the perceived risk of garbage-related conflicts was similar for residents in treatment areas before and after the distribution of bear-resistant containers, perceived risk markedly increased for residents of the control areas after the experiment commenced (Tables 3 and 4 and Fig. 4), mirroring patterns of observed conflicts.

DISCUSSION

Across North America, a key challenge for wildlife agencies has been to identify effective management strategies to reduce human-bear conflicts. Our results contribute to a growing body of literature that supports the strategy of reducing bear access to garbage and other human food sources; we demonstrated that this approach reduced garbage-related conflicts and improved public

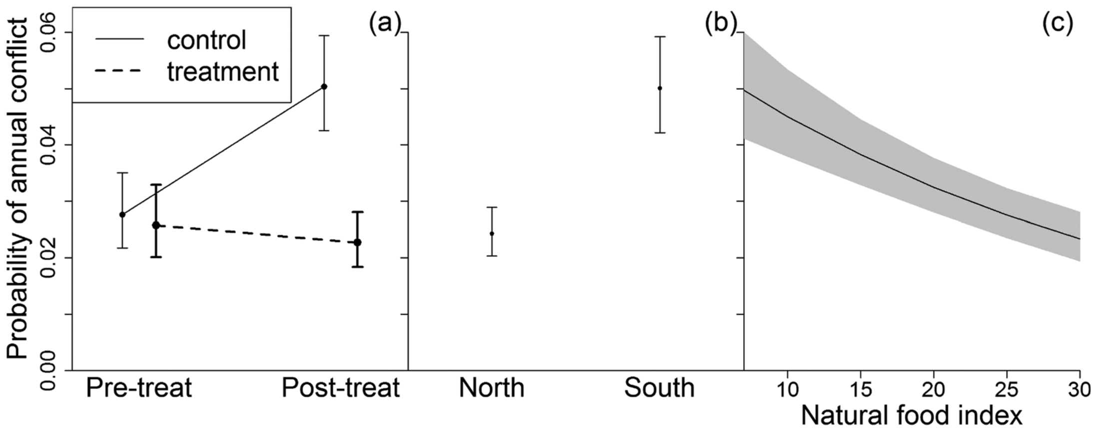

Figure 2. Annual probabilities of a black bear-related trash conflict being observed at an individual residence on the morning of trash pick-up (Jul–Sep) within treatment and control areas a) before and after the distribution of bear-resistant containers, b) in the north and south replicate, and c) based on an index of natural food availability, Durango, Colorado, 2011–2016.

perceptions, yielding both ecological and social benefits. Although the implementation of our BACI design was logistically challenging, expensive, and time-consuming, we can clearly attribute observed ecological and social differences to our treatment. Our results validate efforts by wildlife professionals and municipalities to reduce black bear access to human foods and should encourage other entities of the merits of bear-proofing for reducing human-bear conflicts.

After we deployed bear-resistant containers, trash conflicts in treatment areas were 60% lower than in control areas, a difference that decreased the predicted number of conflicts within our study area and survey period (2,269 homes surveyed on a weekly basis from Jul–Sep) from 113 to 45. These results support previous studies that have examined the utility of bear-proofing efforts for reducing self-reported conflicts (Tavss 2005, Barrett et al. 2014) and decreasing human foods in bear diets (Greenleaf et al. 2009, Hopkins et al. 2014). Indeed, although numerous approaches for reducing human-bear conflicts have been implemented with mixed success (e.g., increased harvest, translocation, hazing), bear-proofing efforts have repeatedly exhibited desired reductions in black and brown bear (*Ursus arctos*) conflicts (Gunther 1994, Gniadek and Kendall 1998, Tavss 2005, Barrett et al. 2014).

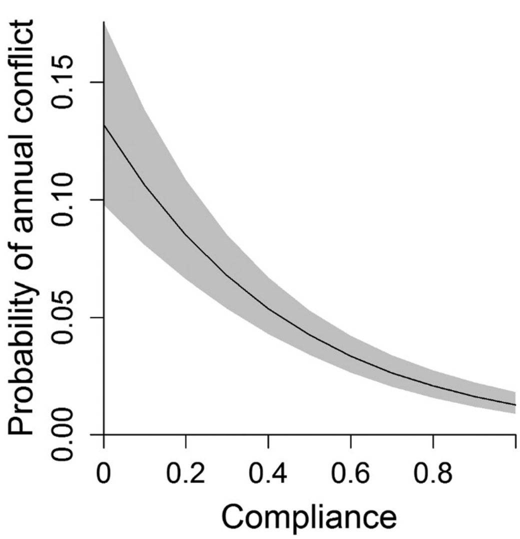

Figure 3. Annual probability of a black bear-related trash conflict being observed at an individual residence on the morning of trash pick-up (Jul–Sep) based on the proportion of homes within the city block that complied with a city ordinance requiring residents to secure their garbage from wildlife in Durango, Colorado, 2013–2016.

Contrary to our expectations, however, the difference in conflicts between treatment and control areas was primarily influenced by an increase in conflicts in control areas between pre- and post-treatment years, rather than by a decrease in conflicts in treatment areas between those periods (Fig. 2). We are uncertain about the mechanisms that generated this pattern but speculate that 2 factors were likely contributors. First, although the intention of the study was to eliminate bear access to garbage in treatment areas, residents frequently left their project-provided garbage containers unlocked. The distribution of bear-resistant containers resulted in a 39% increase in residence compliance with the city ordinance (compliance averaged 0.51 in control areas and 0.71 in treatment areas), but 29% of treatment residences still had accessible garbage, likely minimizing treatment effects. Similar patterns were observed in Aspen, Colorado, where residents were required to have bear-resistant containers, but only 57% of containers were regularly locked (Lewis et al. 2015). Bear-resistant containers are a convenient tool for securing trash, but in the case of the manual locking containers we deployed, their effectiveness is entirely dependent on resident participation. Self-locking or automated bear-resistant containers are becoming more widely available (http://www.igbconline.org), only unlatching in response to a 2-handed release mechanism or when tipped upside-down by a garbage truck. We expect that municipalities that deploy self-locking containers will experience much higher rates of compliance along with sharper declines in conflicts and recommend future work to empirically quantify these potential differences. Second, we suspect that increased conflicts in control areas may reflect changes in bear behavior as bears near town learned to forage in neighborhoods that

Table 3. Changes in the perceived quality of black bear management, acceptability of Colorado Parks and Wildlife (CPW) supporting bear-proofing ordinances, and perceived risk of future trash-related conflicts with bears, reported by residents in treatment and control areas, before (2012) and after (2016) the deployment of bear-resistant containers in Durango, Colorado, USA. We used a 5-point Likert scale to measure quality of management (5 = excellent and 1 = poor), acceptability of ordinances (5 = very acceptable and 1 = very unacceptable). We combined very and somewhat acceptable responses into a single category, and combined very and somewhat unacceptable responses. Risk perceptions ranged from 1–25 (1 = low perceived risk and 25 = high perceived risk).

		2012				2016			
		Control		Treatment		Control		Treatment	
Survey question	Survey response	North	South	North	South	North	South	North	South
Overall, how would you rate management of black bears and bear-human interactions in the area where you live?	Above average	48%	57%	51%	47%	46%	31%	55%	50%
	Average	40%	36%	32%	42%	33%	48%	36%	29%
	Below average	12%	7%	17%	11%	22%	21%	10%	21%
How acceptable is it to you that CPW supports city ordinances that require citizens to use bear-resistant garbage containers?	Acceptable	74%	80%	79%	75%	89%	95%	98%	96%
	Neither acceptable, nor unacceptable	14%	15%	11%	19%	7%	1%	1%	4%
	Unacceptable	12%	6%	10%	6%	5%	4%	1%	0%
Perceived risk of having a black bear break in or attempt to break into your garbage	Mean	11.2	8.9	10	11.5	12.3	13.2	10.1	11

predominantly had regular trash containers. Johnson et al. (2015) reported that bears increase their use of anthropogenic foods as they age, and presumably gain more experience with this resource. This pattern suggests that bear use of development is likely to increase over time, potentially contributing to increased conflicts in control areas during post-treatment years.

Despite the dramatic increase in the distribution of bear-resistant containers (~10% of homes in treatment areas had them at the start of the study and ≥95% had them post-2013), the most influential factor for reducing trash conflicts was compliance with the city wildlife ordinance, whether compliance was the result of locking a bear-resistant container or storing trash in a secure location (i.e., garage or shed). Indeed, some blocks within control areas were highly compliant with the ordinance (residents secured trash without free bear-resistant containers), whereas some blocks within treatment areas had low compliance, despite their new containers. Regardless of where blocks were located, conflicts sharply declined as compliance increased. This effect was nonlinear, where the greatest reductions in conflicts occurred as compliance increased to approximately 60%, and then tailed-off (Fig. 3). Although previous studies reported that reduced bear access to human food results in fewer human-bear conflicts (Gniadek and Kendall 1998, Barrett et al. 2014), our study is the first to empirically quantify a rate of conflict reduction. Our findings closely corroborate the theoretical model developed by Baruch-Mordo et al. (2013). They reported that bears generally avoided urban development when forage benefits had been reduced by ≥55% and avoided urban-wildland interface development when forage benefits had been reduced by ≥70%. Given empirical and theoretical evidence, wildlife agencies and municipalities may want to target management efforts toward those

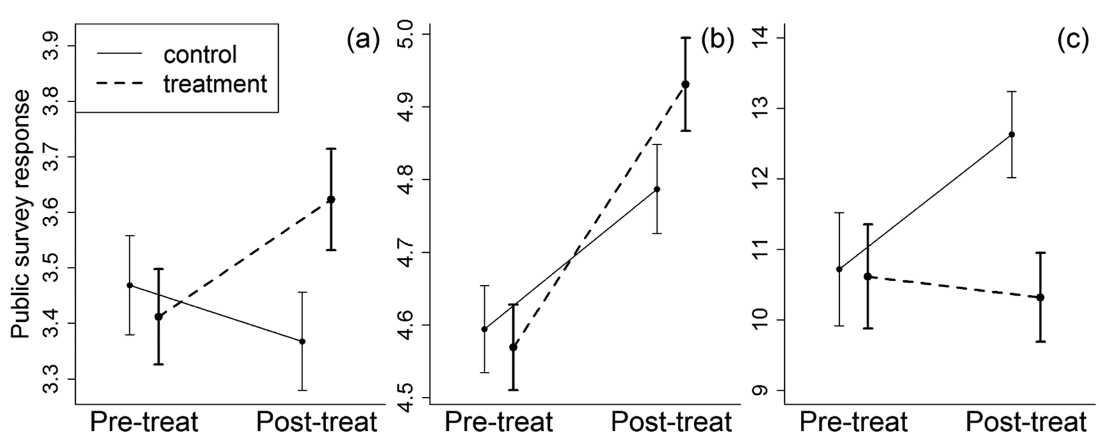

Figure 4. Modeled changes in the a) perceived quality of the management of black bears and human-bear conflicts, b) acceptability of Colorado Parks and Wildlife to support ordinances requiring bear-proofing, and c) perceived future risk of garbage-related conflicts, by residents in treatment (received bear-resistant containers) and control areas before (pre-treat; 2012) and after (post-treat; 2016) the distribution of bear-resistant containers in Durango, Colorado, USA. Quality of management ranged from 5 (excellent) to 1 (poor), acceptability of ordinances ranged from 5 (very acceptable) to 1 (very unacceptable), and risk perceptions ranged from 1 (low perceived risk) to 25 (high perceived risk).

Table 4. Coefficients, standard errors, and lower (L95%) and upper (U95%) 95% confidence intervals from linear models assessing public perceptions before (2012) and after (2016) the deployment of bear-resistant containers in Durango, Colorado, USA. We asked residents to score the 1) quality of management of black bears and human-bear conflicts, 2) the acceptability of Colorado Parks and Wildlife supporting bear-proofing ordinances, and 3) their perceived risk of future bear-related trash conflicts. Model parameters represent pre- and post-treatment surveys (time; reference = pre-treatment survey), treatment areas that received bear-resistant containers (treatment; reference = control), and the replicate (site; reference = north).

Survey question	Estimate	SE	L95%	U95%
1) Quality of bear management				
Intercept	3.472	0.048	3.379	3.566
Treatment	−0.057	0.063	−0.181	0.067
Time (post-treatment)	−0.101	0.064	−0.226	0.024
Site (south)	−0.013	0.048	−0.107	0.081
Treatment × time	0.312	0.090	0.135	0.489
2) Support for ordinances				
Intercept	4.578	0.032	4.515	4.642
Treatment	−0.025	0.043	−0.109	0.059
Time (post-treatment)	0.193	0.044	0.107	0.278
Site (south)	0.057	0.033	−0.008	0.121
Treatment × time	0.169	0.062	0.047	0.291
3) Perceived risk of future conflict				
Intercept	10.570	0.419	9.748	11.392
Treatment	−0.105	0.556	−1.196	0.986
Time (post-treatment)	1.912	0.515	0.902	2.923
Site (south)	0.529	0.369	−0.196	1.253
Treatment × time	−2.208	0.715	−3.610	−0.806

neighborhoods where compliance is <60% because reducing access to garbage and other anthropogenic foods in these areas is likely to yield the greatest reductions in human–bear conflicts.

Our results suggest that black bears foraging on garbage weigh the perceived benefits of accessing anthropogenic foods against the risks associated with human activity and infrastructure. When garbage is abundant and easily accessible, the forage benefit likely outweighs the risk, and bears use residential development. As bear-proofing measures decrease the forage benefit, however, bears should reach a tipping point where the risk simply outweighs the reward and they avoid development. Although we measured this tipping point to be when approximately 60% of residences secured their trash, we expect this value to be dynamic within and across years based on natural food conditions, anthropogenic food availability (e.g., ripe non-native fruit), bear physiological state (e.g., hyperphagia, reproductive status), and previous experience (Merkle et al. 2013, Johnson et al. 2015, Lewis et al. 2015). Indeed, even within our study area we found that trash conflicts were highly spatially and temporally variable; conflicts were higher in the south neighborhood (where there were fewer garages and more alleys) and during poor natural food years (Fig. 2). The predicted probability of conflict for homes in the south was approximately twice that of homes in the north, and predicted probabilities of conflict were 2–4 times as high for homes in poor natural food years than good years, depending on whether the home was in a treatment or control area during pre- or post-treatment years. Given the dynamic nature of forage-risk trade-offs, we expect that bear-proofing efforts will be less effective during poor natural food years, and particularly during severe natural food shortages. Under these circumstances, bears should be willing to forage in neighborhoods with relatively little anthropogenic food available because the forage benefit will more readily outweigh the associated risks. Municipalities and wildlife agencies need to recognize the dynamic nature of these forage-risk trade-offs and how they are likely to influence the efficacy of management efforts under different scenarios.

We expected that the effectiveness of the bear-proofing treatment would increase across the study period as bears slowly learned to avoid neighborhoods with bear-resistant containers. Although we did detect a statistically significant temporal trend (Table 2), with conflict activity decreasing over time, the effect was relatively small. The probability of observing a trash conflict at a residence within a treatment area during the first year of the treatment was 0.03, and by the last year of the study it was 0.01. This result suggests that bears learned to recognize differences between treatment and control areas relatively quickly, increasing their foraging in neighborhoods where anthropogenic foods were more readily abundant (Fig. 2). This result also suggests that the deployment of bear-resistant containers should have relatively swift effects within residential communities.

The distribution of bear-resistant containers also altered residents' perceptions about bear management and the acceptability of bear-proofing ordinances. Residents in treatment areas felt that the quality of bear management improved with the distribution of bear-resistant garbage containers, whereas residents in the control areas reported decreased satisfaction with management. For treatment residents, this trend likely resulted from an increase in their real and perceived ability to minimize conflicts (e.g., keeping garbage secured in a supplied garbage container), which had positive effects on broader perceptions of management agencies (Gore et al. 2006, Triezenberg et al. 2014, Harper et al. 2015). For control residents, we suspect their dissatisfaction may have arisen from not receiving a free container because most residents were aware of the experiment through media coverage and could observe the new containers in neighboring areas. After the experiment commenced, residents of both the control and treatment areas were more likely to report that it was acceptable for CPW to pursue ordinances requiring bear-resistant containers, although the pattern was stronger for treatment residents (Fig. 4). We suspect this shift may have resulted from residents throughout Durango becoming more familiar with the new containers. Evidence from patterns of acceptance of other wildlife-related regulations similarly indicate that support for ordinances can increase with exposure to the regulation (Schroeder et al. 2014).

Survey data also indicated that resident perceptions of their risk of garbage-related conflicts with bears closely mirrored patterns of their real risk of conflict; treatment residents reported a minor decline in risk perceptions during post-treatment years, whereas control residents reported substantial increases in risk perceptions. This alignment between real and perceived risk indicates that perceptions of risk may be a useful proxy for monitoring changes in human–bear conflicts, especially given that management strategies are often employed to reduce both real and perceived risks (Gore et al. 2009). Similar to processes influencing changes in perceptions of management, we suspect that the increase in perceived risk in control areas may have also resulted from frustration of residents that they did not receive a free container. Survey comments reflected this perspective; many residents felt that their exclusion from the treatment increased their risk of conflicts with bears. Perceptions of control are a primary factor influencing risk perceptions, and individuals are likely to assign high-risk perceptions to those issues over which they feel little control (Slovic 1980; Gore et al. 2006, 2009; Dickman 2010).

We were able to use field observations of trash conflicts to assess the effectiveness of bear-resistant containers, but given financial and logistical constraints, this information is rarely available to management agencies. As a result, agencies typically rely on voluntary public reports to monitor spatio-temporal variation in human-bear conflict activity (Spencer et al. 2007, Howe et al. 2010). Although these voluntary reports are commonly collected and used, they can be biased by resident experiences and attitudes (Wilbur et al. 2018). Originally, we had intended to use both observed and reported conflicts as response variables in our analyses, but inconsistent procedures for recording public calls inhibited our ability to use that data type. In Durango, residents reported black bear conflicts to various entities (i.e., state wildlife agency, city code enforcement, local non-profit organization), all of which collected different types of information, and whose data procedures changed over the course of our study. Given that conflict management decisions are typically informed by reported conflicts, we recommend that entities collect congruent information, and work toward having a single entity collecting data (Voyles et al. 2015). By ensuring the systematic recording of reported conflicts, wildlife agencies will have greater power to assess the effectiveness of different management actions intended to reduce human-bear conflicts.

Management agencies often take multiple approaches to reduce human-bear conflicts, targeting bears and people (Can et al. 2014). Although actions that target bears, such as increased harvest, hazing, and translocation, are commonly employed, they often have limited success (Beckmann et al. 2004, Mazur 2010, Obbard et al. 2014, Alldredge et al. 2015, Voyles et al. 2015). Meanwhile, empirical evidence suggests that approaches that target the behavior of people are likely to be more effective at reducing conflicts, especially those approaches that reduce the availability of human food (Gniadek and Kendall 1998, Peine 2001, Baruch-Mordo et al. 2009, Baruch-Mordo et al. 2013, Barrett et al. 2014). Such approaches are also likely to have added benefits, such as improving public attitudes about management agencies, increasing support for conservation (Worthy and Foggin 2008), and reducing inadvertent management effects on bear survival (Gniadek and Kendall 1998, Newsome et al. 2015). Although a shift in focus from managing bears to managing people requires new skill sets and techniques, reallocations of resources, and a better understanding of human behavior (Schultz 2011), it should address the key factor influencing human-bear conflicts: the accessibility of anthropogenic food.

MANAGEMENT IMPLICATIONS

We strongly recommend that municipalities within or adjacent to bear habitat implement bear-proofing measures. Human-bear conflicts significantly declined when people properly secured their garbage, regardless of whether residents locked trash in a bear-resistant container or in a garage or shed. We suggest that bear-proofing efforts could take a variety of forms, from the provisioning of bear-resistant garbage containers, to the implementation of bear-proofing ordinances or regulations, to increased enforcement of existing ordinances, just as long as the accessibility of anthropogenic foods within residential development is substantially reduced. We recommend that management agencies work to ensure that $\geq$60% of residences properly store their trash because that decline in food availability has empirical and theoretical support for reducing conflicts. Although wildlife agencies can encourage bear-proofing efforts, their implementation will largely depend on action from local municipalities directly responsible for waste management practices. For municipalities investigating bear-resistant container designs, we recommend the deployment of self-locking or automated cans because they should result in higher rates of public compliance and greater reductions in human-bear conflicts. If municipalities implement major changes in waste management practices (e.g., distributing bear-resistant containers), we suggest that they partner with wildlife agencies to increase education, enforcement, or other efforts that may maximize their voluntary use. Our compliance data suggest that such efforts may be particularly important in the first year of implementation as residents learn to use new equipment. Although we recommend that agencies collect systematic data on human–bear conflicts, we also suggest that they invest resources in monitoring human behavior and the social outcomes of management actions. As management efforts to reduce human-wildlife conflicts increasingly shift toward a focus on people, information on human behavior (and factors that elicit desired behavior) will allow agencies to assess the effectiveness of different management actions and improve efforts in the future (Baruch-Mordo et al. 2009).

ACKNOWLEDGMENTS

We thank the City of Durango, R. Petersen, J. Medina, and D. Cogswell, as their support and cooperation made this work possible. We also thank all the people that collected field data and entered survey data: C. Anton, G. Colligan, S. Coons, T. Day, R. Dorendorf, E. Dowling, A. Groves, C. Jager, J. Johnson, P. Lundberg, L. Mengak, S. Ogden, J. Peterson, M. Preisler, L. Vander Vennon, A. Welander, R. Wilbur, and L. Willmarth. Our manuscript was greatly improved by R. Conrey, D. Johnston, L. Larson, and 2 anonymous reviewers. This work was funded by CPW, the

USDA National Wildlife Research Center, the International Association for Bear Research and Management, and the Summerlee Foundation.

LITERATURE CITED

Alldredge, M. W., D. P. Walsh, L. L. Sweanor, R. B. Davies, and A. Trujillo. 2015. Evaluation of translocation of black bears involved in human-bear conflicts in South-Central Colorado. Wildlife Society Bulletin 39:334–340.

Barrett, M. A., D. J. Telesco, S. E. Barrett, K. M. Widness, and E. H. Leone. 2014. Testing bear-resistant trash cans in residential areas of Florida. Southeastern Naturalist 13:26–39.

Baruch-Mordo, S., S. W. Breck, K. R. Wilson, and J. Broderick. 2009. A tool box half full: how social science can help solve human–wildlife conflict. Human Dimensions of Wildlife 14.3:219–223.

Baruch-Mordo, S., S. W. Breck, K. R. Wilson, and J. Broderick. 2011. The carrot or the stick? Evaluation of education and enforcement as management tools for human-wildlife conflicts. PLoS ONE 6:e15681.

Baruch-Mordo, S., S. W. Breck, K. R. Wilson, and D. M. Theobald. 2008. Spatiotemporal distribution of black bear-human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

Baruch-Mordo, S., C. T. Webb, S. W. Breck, and K. R. Wilson. 2013. Use of patch selection models as a decision support tool to evaluate mitigation strategies of human-wildlife conflict. Biological Conservation 160: 263–271.

Baruch-Mordo, S., K. R. Wilson, D. L. Lewis, J. Broderick, J. S. Mao, and S. W. Breck. 2014. Stochasticity in natural forage production affects use of urban areas by black bears: implications to management of human-bear conflicts. PLoS ONE 9:e85122.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2013. lme4: linear mixed-effects models using Eigen and S4. R package version 1. 0-5. http://CRAN.R-project.org/package=lme4. Accessed 10 Jan 2013.

Beckmann, J. P., and J. Berger. 2003. Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. Journal of Zoology 261:207–212.

Beckmann, J. P., C. W. Lackey, and J. Berger. 2004. Evaluation of deterrent techniques and dogs to alter behavior of "nuisance" black bears. Wildlife Society Bulletin 32:1141–1146.

Breck, S. W., N. Lance, and P. Callahan. 2006. A shocking device for protection of concentrated food sources from black bears. Wildlife Society Bulletin 34:23–26.

Can, Ö. E., N. D'Cruze, D. L. Garshelis, J. Beecham, and D. W. Macdonald. 2014. Resolving human-bear conflict: a global survey of countries, experts, and key factors. Conservation Letters 7:501–513.

Decker, D., C. Smith, A. Forstchen, D. Hare, E. Pomeranz, C. Doyle-Capitman, K. Schuler, and J. Organ. 2016. Governance principles for wildlife conservation in the 21st century. Conservation Letters 9:290–295.

Dickman, A. J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. Animal Conservation 13:458–466.

Dillman, D. A. 2014. Internet, phone, mail, and mixed-mode surveys: the tailored design method. Fourth edition. Wiley, Hoboken, New Jersey, USA.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Ecology and Society 6:11.

Gniadek, S. J., and K. C. Kendall. 1998. A summary of bear management in Glacier National Park, Montana, 1960-1994. Ursus 10:155–159.

Gore, M. L., B. A. Knuth, P. D. Curtis, and J. E. Shanahan. 2006. Stakeholder perceptions of risk associated with human-black bear conflicts in New York's Adirondack Park campgrounds: Implications for theory and practice. Wildlife Society Bulletin 34:36–43.

Gore, M. L., B. A. Knuth, C. W. Scherer, and P. D. Curtis. 2008. Evaluating a conservation investment designed to reduce human-wildlife conflicts. Conservation Letters 1:136–145.

Gore, M. L., R. S. Wilson, W. Siemer, H. Wieczorek Hudenko, C. E. Clarke, P. Sol Hart, L. A. Maguire, and B. A. Muter. 2009. Application of risk concepts to wildlife management: special issue introduction. Human Dimensions of Wildlife 14:301–313.

Greenleaf, S. S., S. M. Matthews, R. G. Wright, J. J. Beecham, and H. M. Leithead. 2009. Food habits of American black bears as a metric for direct management of human-bear conflict in Yosemite Valley, Yosemite National Park, California. Ursus 20:94–101.

Groves, R. M. 2006. Nonresponse rates and nonresponse bias in household surveys. Public Opinion Quarterly 70:646–675.

Gunther, K. A. 1994. Bear management in Yellowstone National Park, 1960-93. Bears: Their Biology and Management 9:549–560.

Harper, E. E., C. A. Miller, and J. J. Vaske. 2015. Hunter perceptions of risk, social trust, and management of chronic wasting disease in Illinois. Human Dimensions of Wildlife 20:394–407.

Hopkins, J. B., III., P. L. Koch, J. M. Ferguson, and S. T. Kalinowski. 2014. The changing anthropogenic diets of American black bears over the past century in Yosemite National Park. Frontiers in Ecology and the Environment 12:107–114.

Hostetler, J. A., J. W. McCown, E. P. Garrison, A. M. Neils, M. A. Barrett, M. E. Sunquist, S. L. Simek, and M. K. Oli. 2009. Demographic consequences of anthropogenic influences: Florida black bears in north-central Florida. Biological Conservation 142:2456–2463.

Howe, E. J., M. E. Obbard, R. Black, and L. L. Wall. 2010. Do public complaints reflect trends in human-bear conflict? Ursus 21:131–142.

Hristienko, H., and J. E. McDonald Jr. 2007. Going into the 21st century: a perspective on trends and controversies in the management of the American black bear. Ursus 18:72–88.

Johnson, H. E., S. W. Breck, S. Baruch-Mordo, D. L. Lewis, C. W. Lackey, K. R. Wilson, J. Broderick, J. S. Mao, and J. P. Beckmann. 2015. Shifting perceptions of risk and reward: dynamic selection for human development by black bears in the western United States. Biological Conservation 178:164–172.

Johnson, H. E., D. L. Lewis, T. L. Verzuh, C. F. Wallace, R. M. Much, L. K. Willmarth, and S. W. Breck. 2018. Human development and climate affect hibernation in a large carnivore with implications for human-carnivore conflicts. Journal of Applied Ecology 55:663–672.

Lewis, D. L., S. Baruch-Mordo, K. R. Wilson, S. W. Breck, J. S. Mao, and J. Broderick. 2015. Foraging ecology of black bears in urban environments: guidance for human-bear conflict mitigation. Ecosphere 6:141.

Lyons, A. J. 2005. Activity patterns of urban American black bears in the San Gabriel mountains of southern California. Ursus 16:255–262.

Mazur, R. L. 2010. Does aversive conditioning reduce human-black bear conflict? Journal of Wildlife Management 74:48–54.

Merkle, J. A., H. S. Robinson, P. R. Krausman, and P. Alaback. 2013. Food availability and foraging near human developments by black bears. Journal of Mammalogy 94:378–385.

Newsome, T. M., J. A. Dellinger, C. R. Pavey, W. J. Ripple, C. R. Shores, A. J. Wirsing, and C. R. Dickman. 2015. The ecological effects of providing resource subsides to predators. Global Ecology and Biogeography 24:1–11.

Obbard, M. E., E. J. Howe, L. L. Wall, B. Allison, R. Black, P. Davis, L. Dix-Gibson, M. Gatt, and M. N. Hall. 2014. Relationships among food availability, harvest, and human-bear conflict at landscape scales in Ontario, Canada. Ursus 25:98–110.

Ordiz, A., O. G. Støen, M. Delibes, and J. E. Swenson. 2011. Predators or prey? Spatio-temporal discrimination of human-derived risk by brown bears. Oecologia 166:59–67.

Peine, J. D. 2001. Nuisance bears in communities: strategies to reduce conflict. Human Dimensions of Wildlife 6:223–237.

R Core Team. 2013. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Rudolph, B. A., and S. J. Riley. 2014. Factors affecting hunters' trust and cooperation. Human Dimensions of Wildlife 19:469–479.

Schirokauer, D. W., and H. M. Boyd. 1998. Bear-human conflict management in Denali National Park and Preserve, 1982-94. Ursus 10:395–403.

Schroeder, S. A., L. Cornicelli, D. L. Fulton, and M. D. Grund. 2014. What predicts support for antler point restrictions? Human Dimensions of Wildlife 19:301–318.

Schultz, P. W. 2011. Conservation means behavior. Conservation Biology 25:1080–1083.

Slovic P. 1980. Perception of risk. Science 236:280–285.

Spencer, R. D., R. A. Beausoleil, and D. A. Martorello. 2007. How agencies respond to human- black bear conflicts: a survey of wildlife agencies in North America. Ursus 18:217–229.

Tavss, E. A. 2005. Correlation of reduction in nuisance black bear complaints with implementation of a) a non-violent program and b) a hunt. Final Report. New Jersey Public Hearing on the Comprehensive Black Bear Management Policy. Rutgers, the State University of New Jersey, New Brunswick, New Jersey, USA.

Treves, A., K. J. Kapp, and D. M. MacFarland. 2010. American black bear nuisance complaints and hunter take. Ursus 21:30–42.

Triezenberg, H. A., M. L. Gore, S. J. Riley and M. K. Lapinski. 2014. Perceived risk from disease and management policies: an expansion of zoonotic disease information seeking and processing model. Human Dimensions of Wildlife 19:123–138.

U.S. Census Bureau. 2014. United States Census Bureau. 2014. Durango, Colorado QuickFacts. https://www.census.gov/quickfacts/table/BZA115214/0822035,08067. Accessed 25 Mar 2016.

Voyles, Z., A. Treves, and D. MacFarland. 2015. Spatiotemporal effects of nuisance black bear management actions in Wisconsin. Ursus 26: 11–20.

Wilbur, R. C., S. A. Lischka, J. R. Young, and H. E. Johnson. 2018. Experience, attitudes and demographic factors influence the probability of reporting human-black bear interactions. Wildlife Society Bulletin 42:22–31.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego, California, USA.

Worthy, F. R., and J. M. Foggin. 2008. Conflicts between local villagers and Tibetan brown bears threaten conservation of bears in a remote region of the Tibetan Plateau. Human-Wildlife Conflicts 2:200–205.

Zack, C. S., B. T. Milne, and W. C. Dunn. 2003. Southern oscillation index as an indicator of encounters between humans and black bears in New Mexico. Wildlife Society Bulletin 31:517–520.

Associate Editor: Lincoln Larson.