

DISSERTATION

INTEGRATING SOCIAL AND ECOLOGICAL PREDICTORS OF HUMAN-
WILDLIFE INTERACTIONS TO GUIDE CONSERVATION AND
MANAGEMENT

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ABSTRACT

INTEGRATING SOCIAL AND ECOLOGICAL PREDICTORS OF HUMAN- WILDLIFE INTERACTIONS TO GUIDE CONSERVATION AND MANAGEMENT

There is growing recognition that interdisciplinary approaches that account for both ecological and social processes are necessary to successfully address human-wildlife interactions. However, such approaches are hindered by challenges in aligning data types, communicating across disciplines, and applying social science information to conservation actions. My dissertation builds on emerging efforts to address these challenges by proposing a conceptual model for integration of social and ecological information to understand human-wildlife interactions, and reports empirical data which tests the impact of an experimental effort to reduce human-black bear (*Ursus americanus*) conflicts on tolerance for bears and residential bear-proofing behavior. The conceptual model I propose adopts a social-ecological systems approach and identifies multiple, nested levels of influence on human and animal behavior. I applied this model in an exploration of the drivers of human tolerance for black bears, an important determinant of their persistence. I measured tolerance for black bears in the vicinity of Durango, Colorado, USA and monitored changes resulting from a bear-proofing experiment designed to reduced garbage-related conflicts in the community. Residents who reported higher perceptions of benefits associated with bears and more positive impacts from interactions with them had increased tolerance. Residents who reported higher perceptions of risks, more negative impacts, higher trust in managers, domination wildlife value orientations, and older age were

associated with decreased tolerance. Conflicts with bears were not an important predictor, supported by our finding that changes in conflicts resulting from our experiment did not affect tolerance. While conflicts may not affect tolerance for bears, many communities struggle to reduce conflicts in residential settings. The motivators for a key method to do so, bear-proofing of residential garbage, are poorly understood, yet information about them is key to designing successful efforts to increase this behavior. I observed use of bear-resistant containers at 383 households in 2014 and 2016 and used surveys to determine the drivers of this behavior. Most residents used bear-resistant containers irregularly (containers were locked on 44% of observations); 33% of households were never compliant across observations. I found residents increased their use of containers when rates of conflicts per residential block were higher. Further, when respondents were more trusting of the management agency and perceived more benefits from bears, they used containers less often. Approaches which integrate social and ecological information to understand and manage human-wildlife conflicts could assist conservation practitioners in reducing these conflicts and their negative outcomes for wildlife and people.

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TABLE OF CONTENTS

ABSTRACT.....	II
ACKNOWLEDGEMENTS.....	IV
LIST OF KEYWORDS	IX
A CONCEPTUAL MODEL FOR THE INTEGRATION OF SOCIAL AND ECOLOGICAL INFORMATION TO UNDERSTAND HUMAN-WILDLIFE INTERACTIONS.....	1
SUMMARY.....	1
INTRODUCTION.....	2
SES MODEL OF HUMAN-WILDLIFE INTERACTIONS	4
CASE STUDY: APPLYING THE CONCEPTUAL MODEL TO UNDERSTAND DRIVERS OF HUMAN-BLACK BEAR CONFLICTS	10
BACKGROUND.....	10
DEFINING COMPONENTS OF THE MODEL.....	12
LESSONS LEARNED FROM THE CASE STUDY.....	15
LESSON 1: INTEGRATE SOCIAL SCIENCE THROUGHOUT THE RESEARCH PROCESS.	16
LESSON 2: ALIGN THE SCALE OF SOCIAL AND ECOLOGICAL DATA.....	18
LESSON 3: CONSERVATION MEANS HUMAN AND ANIMAL BEHAVIOR	19
CONCLUSIONS	21
REFERENCES	24
UNDERSTANDING AND MANAGING HUMAN TOLERANCE FOR A LARGE CARNIVORE	27
SUMMARY.....	27
INTRODUCTION.....	28
METHODS.....	32
STUDY AREA.....	32
DATA COLLECTION.....	33
MEASUREMENT AND ANALYSIS	34
RESULTS.....	38
SURVEY RESPONSE.....	38
TOLERANCE MODELING.....	39
DISCUSSION.....	44
CONCLUSION	46
REFERENCES	48
UNDERSTANDING THE MOTIVATIONS FOR RISK-REDUCING BEHAVIORS TO LIMIT HUMAN-BLACK BEAR CONFLICT	51
SUMMARY.....	51
INTRODUCTION.....	52
METHODS.....	56
STUDY AREA.....	56
DATA COLLECTION.....	57
SURVEY WEIGHTING	61
DATA ANALYSIS	61

RESULTS	63
RESPONDENT CHARACTERISTICS	63
COMPLIANCE MODELING	65
DISCUSSION.....	68
REFERENCES	74
APPENDIX 1	77
SUPPORTING INFORMATION ON CALCULATION OF PREDICTOR VARIABLES FOR MODELS OF <i>TOLERANCE</i>	77
APPENDIX 2.....	85
SUPPORTING INFORMATION ABOUT MODELING OF <i>COMPLIANCE RATE</i>	85

LIST OF KEYWORDS

social-ecological systems

black bears

social science

human-bear conflict

Colorado

human behavior

tolerance

bear-proofing

A CONCEPTUAL MODEL FOR THE INTEGRATION OF SOCIAL AND ECOLOGICAL INFORMATION TO UNDERSTAND HUMAN-WILDLIFE INTERACTIONS¹

Summary

There is growing recognition that interdisciplinary approaches that account for both ecological and social processes are necessary to successfully address human-wildlife interactions. However, such approaches are hindered by challenges in aligning data types, communicating across disciplines, and applying social science information to conservation actions. To meet these challenges, we propose a conceptual model that adopts a social-ecological systems approach and integrates social and ecological theory to identify the multiple, nested levels of influence on both human and animal behavior. By accounting for a diverse array of influences and feedback mechanisms between social and ecological systems, this model fulfills a need for approaches that treat social and ecological processes with equal depth and facilitates a comprehensive understanding of the drivers of human and animal behaviors that perpetuate human-wildlife interactions. We apply this conceptual model to our work on human-black bear conflicts in Colorado, USA to demonstrate its utility. Using this example, we identify key lessons and offer guidance to researchers and conservation practitioners for applying integrated approaches to other human-wildlife systems.

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Introduction

In his prescient work, *Wilderness*, Aldo Leopold (1949: 188) stated that “One of the anomalies of modern ecology is the creation of two groups, each of which seems barely aware of the existence of the other. The one studies the human community, almost as if it were a separate entity, and calls its findings sociology, economics and history. The other studies the plant and animal community and comfortably relegates the hodge-podge of politics to the liberal arts. The inevitable fusion of these two lines of thought will, perhaps, constitute the outstanding advance of this century.” This refrain has become common in the conservation sciences since Leopold’s plea (e.g., Mascia et al. 2003), yet researchers and practitioners still struggle to work across disciplinary boundaries to achieve conservation success. Although there is growing recognition that approaches that integrate social and ecological knowledge should lead to more effective and sustained conservation solutions, difficulties in aligning data types, challenges of communicating across disciplines, and misperceptions about the quality and utility of social science information continue to plague these efforts (Fox et al. 2006, Pooley et al. 2014). Nonetheless, the potential for this integration remains a critical advance for the next century of conservation (Tallis & Lubchenco 2014).

The need for social-ecological integration is readily apparent in the management of human-wildlife interactions (HWIs), defined as the spatial and temporal juxtaposition of human and wildlife activities where humans, wildlife, or both are affected (Leong 2010, Peterson et al. 2010). Although HWIs are the direct result of human and/or animal behavior, numerous social and ecological factors contribute to the conditions shaping those behaviors, defying single-discipline explanations of causal mechanisms (Dickman 2010). Understanding the complexity of drivers of HWIs is critical, as the value people place on these interactions ultimately provides the

foundation for wildlife conservation and management, whether people want to see interactions enhanced (e.g., increased hunting opportunity, recovery of endangered species) or reduced (e.g., property damage; Riley et al. 2003).

Whereas a number of recent papers have called for integrated approaches to understanding HWIs, particularly in the context of human-wildlife conflict (e.g., Dickman 2010, Redpath et al. 2013), progress in this area will be facilitated by a comprehensive framework to guide investigations of the diverse array of social and ecological drivers of HWIs. In response to this need, we propose a conceptual model of HWIs that adopts a social-ecological systems (SES) approach. SESs are systems of biophysical and social factors that interact at multiple spatial, temporal, and organizational scales and whose flow is regulated in dynamic and complex ways (Redman et al. 2004). Our model integrates theory from the social and ecological sciences, building upon recent advances applying a systems approach to understand the human dimensions of conservation (e.g., Manfredo et al. 2016). We add to existing frameworks aimed at addressing SES questions (Binder et al. 2013), including previous applications of SES concepts to HWIs (e.g., Morzillo et al. 2014, Carter et al. 2016), by treating social and ecological systems in equal depth, acknowledging the bidirectional influence of social and ecological processes, and considering both individual-level and broad, external influences on human and animal behavior. In doing so, we provide a heuristic framework to assist researchers and practitioners in understanding the relationship between social and ecological drivers of HWIs and foster interdisciplinary approaches to addressing them. We apply the model to our work on human-black bear (*Ursus americanus*) conflicts to illustrate the benefits of our approach and conclude with a set of lessons learned, offering guidance for applying integrated approaches to other human-wildlife systems.

SES Model of Human-Wildlife Interactions

In the simplest form, HWIs can be conceptualized as the result of two distinct, but interacting systems: social and ecological (Fig. 1.1a). Although human and animal behaviors are the proximate drivers of HWIs, the context shaping those behaviors is defined by multiple, nested levels of external social and ecological influences (Fig. 1.1b) and attributes of individual humans and animals (Fig. 1.1c). When viewed through a single disciplinary lens, these systems may appear to operate independently; however, the ecological and social systems often overlap spatially, and feedbacks among social and ecological drivers (represented by curved arrows in Fig. 1.1b) are critical determinants of HWIs.

Within the ecological system, wildlife activities are influenced by a suite of internal and external factors occurring across hierarchical levels (Fig. 1.1b; see Table 1.1 for definitions of *italicized* terms). These levels of decreasing organizational complexity – ranging from ecosystems to individuals (Krebs 2001) – provide the framework within which wildlife activities occur and the context for HWIs. At the broadest level of external influence, *ecosystems* define interactions between organisms and their abiotic and biotic environment, and prescribe the nature, direction, and distribution of the flow of energy and nutrients. At the next level, ecological *communities* determine interactions among species through processes such as predation and competition, further constraining the distribution and behavior of individual animals. The last tier of external influence occurs at the *population* level, where local dynamics influence the abundance, density, survival, and reproduction of individuals, which in turn, can strongly affect animal behavior. In addition to these external influences, *individual behavior* is the consequence of various individual attributes of animals (Fig. 1.1c). Attributes such as demographic characteristics (e.g., age, sex), reproductive status, *physiological condition*, *social*

status, temperament, previous experience, and genes can all shape animal behavior directly or indirectly (Davies et al. 2012).

Table 1.1. Definitions of selected terms in the conceptual model of human-wildlife interactions. From ^aLeong 2010, ^bPeterson et al. 2010, ^cKrebs 200, ^dDavies et al. 2012, ^eManfredo et al. 2014, 2016, ^fManfredo 2008.

<i>Term</i>	<i>Definition</i>	<i>Case study examples</i>
Human-Wildlife Interactions _{a,b}	Spatial and temporal juxtaposition of wildlife and human activities where humans, wildlife, or both are affected	Black bears forage on unsecured human garbage; Humans see black bear while walking in a city park
<i>Ecological system^{c,d}</i>		
Ecosystem	Interacting biotic and abiotic components of the environment	Climate conditions and vegetation types that influence habitat for black bears
Community	Suite of species that populate a given area and interact through activities such as competition and predation	Availability of key plant species that provide natural foods for bears
Population	Members of a single species that interact and interbreed	Survival, reproduction, immigration, and emigration rates that influence bear abundance and distribution
Individual behavior	Actions of individual animals that provide the opportunity to interact with humans	Foraging of black bears in urban development for anthropogenic foods
Physiological condition	Mechanical, physical, and biochemical processes that affect survival and reproduction	Increased caloric intake by bears in preparation for hibernation (e.g., hyperphagia)
Social status	Ranking system created when members of a social group interact	Differential access to natural food sources based on dominance
Temperament	Within species differences in behavioral tendencies that are consistent over time and correlated across contexts	Behaviors such as boldness that make bears more likely to explore novel habitats (i.e., human-dominated areas)
<i>Social system^{e,f}</i>		
Society	Broad social forces that act on large groups of humans such as culture, language and patterns of human migration	Technological advances that allow remote work
Institutions	Formal and informal decision-making processes that distribute power and allocate resources	City ordinances that require trash to be secured from bears and other wildlife
Groups	Formal and informal associations among humans that define and reinforce norms	Groups interested in and affected by wildlife-human conflict issues such as homeowners associations
Individual behavior	Actions of individual humans that provide the opportunity to interact with wildlife	Storage of garbage and other food attractants

Attitudes	Directional evaluation of a specific object or event, based on memory	Support for management actions to euthanize conflict-causing bears
Values	Fundamental, stable goals and principles that transcend situations and guide human behavior	Belief that wildlife are deserving of rights and care
Norms	Rules that define acceptable behaviors in social life; Enforced directly by group members or by personal perceptions of group expectations	Expectations about how neighbors should store their garbage
Emotions	Short duration feeling states elicited by a specific situation and that occupy conscious thought	Fear elicited when a person encounters a bear near home

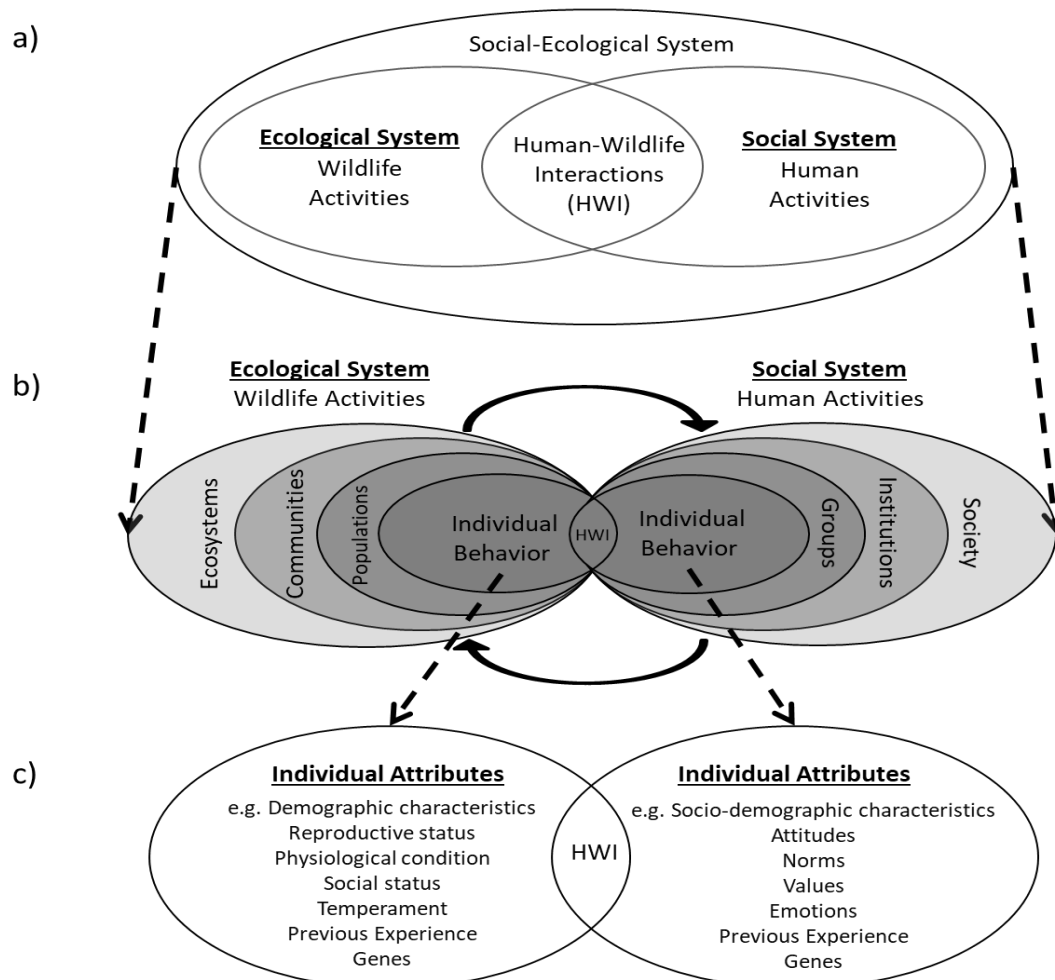


Figure 1.1. SES model of Human-Wildlife Interactions. Selected concepts from this figure are defined in Table 1. Panel a) describes the overall SES model of HWIs, while panel b) describes external influences on individual behavior and panel c) describes individual attributes which also affect behavior. Curved arrows in b) indicate feedback among all levels of the social and ecological systems.

Mirroring the multilevel conceptualization of the ecological system, human activities are affected by external and internal influences within the social system (Manfredo et al. 2014, 2016; Fig. 1.1b, 1.1c; Table 1.1). At the broadest level, patterns in *society*, such as language, culture, economic development, and human migration, shape the context within which people live and interact with the natural environment. *Institutions* and governance structures, such as decision-making authority, policies, and methods for public engagement, comprise the next level of external influence and affect people's perceptions and expectations about decision-making processes, power, and resource allocation. At the finest level of external influence, *groups*, such as community organizations and other affiliations with which people identify, impose and reinforce *norms* for acceptable behavior in relation to one's social and environmental surroundings. *Individual behavior* is also driven by various individual attributes (Fig. 1.1c), ranging from general (*values*) to specific (*attitudes*, *personal norms*) cognitive influences, as well as socio-demographic characteristics, *emotions*, previous experience, and genes. Although traditional approaches to understanding conservation-related behaviors have assumed that rational choice and cognitive influences guide individual actions, recent advances call for greater attention to non-cognitive (e.g., *emotions*) and broader-level (e.g., *groups*, *institutions*) factors captured by our model (Manfredo et al. 2014, 2016).

By explicitly acknowledging the suite of external and internal factors operating within both the social and ecological systems, researchers are better able to identify the relative roles of each in driving HWIs, and importantly, account for spatial overlap and feedbacks within and between the two interacting systems (Redman et al. 2004, Manfredo et al. 2016). For example, *ecosystem* characteristics, such as the location of rivers and streams, can affect animal distribution, as well as patterns of human migration and residential development, which are

societal-level drivers. *Institutional* influences, such as decisions to reintroduce a threatened species, can alter predator-prey dynamics within ecological *communities* and affect human *attitudes* by impacting people's wildlife-related experiences. In addition to these top-down and cross-system effects, individual human and animal behaviors can scale up through both social and ecological systems to affect processes occurring at higher levels. For example, collective human actions can affect institutional response, as when voting behavior on state referenda limits the methods that wildlife agencies can use to manage species. As illustrated in the case study below, our model can serve as a conceptual map to facilitate conversations across disciplines about information gaps, research questions, and management strategies that better account for the complex and dynamic nature of HWIs.

Case Study: Applying the Conceptual Model to Understand Drivers of Human-Black Bear Conflicts

Background

Although interactions between humans and black bears can be positive, they often result in threats to human property and safety (e.g., bears breaking into vehicles), nuisances (e.g., spilled trash; Gore et al. 2006a), and increased bear mortality (e.g., lethal removal; Treves & Karanth 2003). As human development has encroached on bear habitat, conflicts resulting from bears foraging for anthropogenic food near human development (e.g., garbage and fruit trees; Lewis et al. 2015) have increased (Hristienko & McDonald 2007), becoming a major management challenge for wildlife agencies. Although wildlife agencies have invested significant resources in a variety of approaches to reduce conflicts, such as translocation, education, and harvest, these efforts have generally yielded limited success in reducing conflicts in residential settings (Gore et al. 2006b, Treves et al. 2010, Baruch-Mordo et al. 2011).

Investigators recognize that both ecological and social factors contribute to human-bear conflicts (Baruch-Mordo et al. 2009), yet few studies have attempted to integrate both types of information to guide management.

As part of a large-scale study to better understand both the ecological and social factors associated with increases in human-bear conflicts, several authors of this paper conducted an experiment in Durango, Colorado (2011-2106), a community that regularly experiences high human-bear conflict rates (Baruch-Mordo et al. 2008). Because conflicts typically occur when bears use human development to forage on garbage (Lewis et al. 2015), we tested the effectiveness of wide-scale urban bear-proofing for reducing human-bear conflicts (Johnson et al. 2018). Using a before-after-control-impact study design, we distributed 1,110 bear resistant garbage containers to all residents of two treatment areas within Durango, and paired these with two control areas where residents did not receive containers. We then monitored garbage-related conflict rates with direct observations of spilled garbage, human attitudes with mail surveys, and human behavior (i.e., appropriate use of the garbage containers) with direct observations. Using this design, our goals were to evaluate the effectiveness of distributing bear-resistant containers for reducing human-bear conflicts, identify the social and ecological factors contributing to conflicts, and assess the outcomes of this action on human behaviors and attitudes (Johnson et al. 2018). Our experiences planning and executing this project, as well as conversations with colleagues working on similar projects in other ecosystems, led to development of the conceptual model presented in this paper. Our successes and failures helped us refine the components of the model and serve as a meaningful example of the ways its application can foster a broad understanding of the drivers of human-wildlife conflicts.

Defining Components of the Model

Within the *ecological system*, a suite of external factors and *individual attributes* shape bear *behaviors* that contribute to garbage-related conflicts between people and bears (see Table 1.1 for case study examples). The *ecosystems* around Durango are diverse, with widely varying elevations, climate conditions, and vegetation types, dominated by ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*), aspen (*Populus tremuloides*), pinyon pine (*Pinus edulis*), juniper (*Juniperus* spp.), and mountain shrubs (e.g., *Prunus virginiana*, *Amelanchier alnifolia*). The resulting ecological *communities* provide a diversity of plants and animals that produce natural foods for black bears, such as grasses, forbs, berries, acorns, and insects. Natural food abundance is highly variable across years due to annual variation in weather (e.g., drought conditions, late freezes), and scarcity in natural foods can cause bears to increase their use of human development (Johnson et al. 2015, 2017). For example, during a poor natural food year in 2012, bears around Durango increased their use of development and the *population* was estimated to have declined in association with high rates of human-caused mortality (e.g., vehicle collisions, harvest, lethal removals of conflict-involved individuals; Laufenberg et al. 2018). In addition to these external factors, several *individual attributes* are known to influence bear foraging behavior around human development, and thus, their probability of accessing human foods and interacting with people. For example, Johnson et al. (2015) found that female bears that were older, had limited access to natural foods, and were experiencing hyperphagia (the period of increased foraging prior to hibernation) selected more strongly for human development.

Individual human *behaviors* also contribute to human-bear interactions, especially those related to the storage of garbage and other food attractants (Table 1.1; Johnson et al. 2018).

Societal forces around Durango, a rapidly growing, mid-sized city in southwest Colorado, affect patterns of residential development. Durango is surrounded by public lands popular for outdoor recreation, which attracts many new residents. The resulting development, aided by technological advancements in communications that allow people to live farther from traditional workplaces, has occurred within areas that were high-quality bear habitat (Johnson et al. 2015), increasing the availability of human foods on the landscape. *Institutional* factors include actions taken by local, state, and federal authorities to reduce conflicts and alter the distribution of bears. Wildlife managers have increased bear harvest in response to high rates of reported conflict, and the city implemented an ordinance requiring people to secure trash from bears and other wildlife (<http://www.durangogov.org/index.aspx?NID=668>). Based on our systematic observations of bear-resistant garbage containers distributed as a part of the project, we found that resident use of the containers was highly variable. On some blocks, all residents kept garbage secured in provided containers, while on other blocks, few to no residents did so (Johnson et al. 2018), indicating that social *norms* (i.e., perceived social pressure to behave in a certain way) about garbage storage may also be variable. A suite of individual attributes (e.g., *values*, *attitudes*, personal *norms* [i.e., personal expectations about how one ought to behave]) also play a role in determining human behaviors related to garbage storage. For example, using mail survey data, we found that individuals who believe that the state wildlife management agency is trustworthy and capable of addressing negative interactions between people and bears, representing positive *attitudes* toward the agency, are less likely to take individual action (e.g., bear-proofing garbage) to reduce their risk of human-bear interactions (Colorado Parks and Wildlife, unpublished data). In contrast, residents with negative *attitudes* toward the agency believe that their own individual action is required to reduce human-bear conflicts, and, therefore, are more likely to keep their

garbage secured. Additional influences, such as fearful *emotions* elicited from encounters with bears, may also motivate bear-proofing behaviors (Wieczorek Hudenko 2012).

The Durango system also illustrates how spatial overlap of social and ecological drivers, and feedback between them, can affect the likelihood of interactions between humans and bears. For example, feedback between social and ecological dynamics can perpetuate garbage-related conflicts, complicating efforts to reduce negative interactions while maintaining sustainable bear populations along the wildland-urban interface. Most notably, *individual human behaviors* that make garbage and other food sources accessible to bears can directly alter the *behavior* of individual bears by providing abundant, alternate food sources. Interestingly, as bears increased their use of human food in Durango, they decreased their hibernation and were thus awake to interact with people for more time during the year (Johnson et al. 2017), further illustrating how *human behavior* can alter *bear behavior* and the potential for conflict. Foraging in human-dominated areas can also increase mortality risks to bears from vehicle collisions, conflict removals, and other sources (Beckmann & Berger 2003, Hostetler et al. 2009). For example, Laufenberg et al. (2018) detected a 57% decline in the female bear *population* surrounding Durango following a year of poor natural food conditions. This decline was primarily driven by increased mortality from bear-vehicle collisions as bears increased foraging within development, and resulted in dramatic changes to the distribution of bears in areas near Durango. Further, tolerance, an *attitude* which is often used to describe social acceptance of wildlife species (Bruskotter & Wilson 2014), is determined by both positive and negative interactions with individuals of the species (Zajac et al. 2012, Lischka et al. 2008). Because bear behavior changes with the abundance of natural foods, these changes also have the potential to impact where and how often people interact with bears. If reductions in positive interactions occur, feedback

between the social and ecological systems may yield lower tolerance for bears among residents, ultimately affecting support for bear conservation (Bruskotter & Wilson 2014). Feedback between the social and ecological systems can also result from efforts to reduce garbage-related conflicts. For example, increasing the rate of bear-proofing within residential areas (*individual human behavior*) appears to cause a decrease in the amount of time bears spend foraging in town (*individual bear behavior*; Johnson et al. 2018). This reduction can motivate *institutional* actions, such as occurred in Durango when the city government decided to provide no-cost bear-resistant containers to residents in a larger area of town, following completion of this project.

Lessons Learned from the Case Study

Our Durango research team experienced several challenges in our attempts to execute an integrated SES investigation of human-bear conflicts. As research progressed, we realized that a conceptual framework could assist us in addressing many of these challenges, so we developed model presented herein. As we modified and executed research plans to achieve a more fully integrated study, we identified ways that its application could help us in understanding the system and refined the model. The model helped us identify areas where we could improve the project and its outcomes, albeit sometimes in hindsight, and we learned several valuable lessons as we worked toward an integrated social-ecological study. The lessons described below are not unique to HWIs, SES efforts more broadly (Pooley et al. 2014), or even to measuring the concepts we describe in this model, but, rather, are common to interdisciplinary studies that combine social and ecological data. We hope that the lessons we learned will help other multidisciplinary research teams better anticipate and resolve such challenges and thereby foster more effective integration of social and ecological information, no matter the conservation context.

Lesson 1: Integrate social science throughout the research process.

The success of integrated approaches to understanding and managing HWIs is dependent on the extent to which they adequately address social factors (Dickman 2010), yet wildlife research and management typically focus on actions that modify animal populations (Morzillo et al. 2014). Because ecologists may lack familiarity with how the social sciences can contribute to conservation, social science experts are often not included on research teams or not incorporated sufficiently early in the process (Pooley et al. 2014). Further, on such a team, a single social scientist may be expected to represent a variety of disciplinary specialties, as ecologists may not recognize distinct specializations within the broader field (Bennett et al. 2016). However, as with the ecological realm where there are specialized disciplines, theory, and expertise at each of the scales from individual to ecosystem, the same is true within the social realm. Including representatives on the project team from a variety of social science disciplines would help ensure that the appropriate theories, processes, and impacts are considered and addressed, across the levels of influence identified by the model.

Even when social and ecological scientists collectively design research objectives, teams often separate into discipline-specific groups to collect and analyze data and disseminate results. Although it requires a significant investment of time and effort and a willingness to make continued adjustments to approaches along the way, the outcomes of truly integrated work can have surprising results that independent efforts would otherwise miss. For example, although our conceptual model recognizes the importance of social and ecological factors in driving HWIs, our Durango study was initially designed to solely investigate the influence of distributing bear-resistant garbage containers on rates of garbage-related human-bear conflicts. Initially, there was no plan to explicitly understand human behavior or the internal or external influences affecting

behaviors. The original research team assumed that the primary impediment to bear-proofing was the cost of bear-resistant garbage containers, and that once residents received a free container, they would use it appropriately. As a result, the primary response variable that was going to be monitored was rates of garbage-related conflicts. After initial study plans were developed, however, social scientists were added to the team. They advocated for monitoring whether residents were using containers properly (manually locking the containers) as well as motivations for doing so. After observing human behavior at >700 residences that received free bear-resistant containers, we learned that <50% of residents properly locked their containers (Colorado Parks and Wildlife, unpublished data). It became clear that simply measuring conflict rates was not adequate to determine the effect of distributing bear-resistant containers, and that understanding human behavior would be imperative to translating research results into management recommendations. The early inclusion of social science expertise was therefore critical to identify solutions to conflicts that account for both human and animal behavior.

It is not sufficient, however, to simply quantify patterns in human behaviors to supplement understanding of ecological processes. To truly understand and address the dynamics of SESs, researchers must strive for greater depth and integration of findings across the ecological and social realms. In particular, we have faced difficulty identifying the best approach to describe both social and ecological patterns to potentially unfamiliar audiences within publications. Broadening communications to discuss both social and ecological outcomes exposes specialists to the utility of considering multidisciplinary approaches to addressing HWIs. Yet, even within our team, communicating concepts, methods, and findings across disciplines at times proved challenging. Prior work has described similar challenges in applying multidisciplinary approaches to conservation and identified the importance of employing

concrete processes to anticipate and address these issues (e.g. Heemskerk et al. 2003, Fox et al. 2006, Pooley et al. 2014). Specifically, we feel that group model development, long-term investment of time and resources in collaborations, and frequent communication with collaborators across disciplines could facilitate the success of integrated projects.

Lesson 2: Align the scale of social and ecological data

The default extent and resolution of data collected in social and ecological studies often do not match, leading to difficulties in integrating findings across data types (Heemskerk et al. 2003, Pooley et al. 2014). This issue can be especially challenging for wide-ranging animals, such as large carnivores. For example, in our case study, researchers fit individual bears with GPS telemetry collars to understand habitat selection and space use with respect to human development (Johnson et al. 2015, 2017). Ideally, as a part of our experiment, we would have provided free bear-resistant garbage containers across the same area inhabited by our collared sample of bears to quantify the effects of bear-proofing on bear behavior and garbage-related conflicts. However, financial and logistical constraints hampered our ability to execute the experiment at this scale, primarily due to the large size of bear home ranges and the high cost of bear-resistant containers. As a result, our bear-proofing study was constrained to track the effect of the new containers on conflict rates and human behaviors within the core residential area of Durango. Although this study area was small from an ecological perspective, we were able to concurrently investigate the social and ecological drivers of human and bear behavior that produced conflicts at a spatial scale relevant to HWIs. This scale enabled us to understand feedback mechanisms between human and animal behavior and describe the complex interplay of social and ecological forces that perpetuate conflict.

In addition to aligning the spatial extent of our measures of human and animal behavior, we also modified our plans to assess the motivations for bear-proofing behavior. Initially, we had planned to distribute mail surveys to a random sample of Durango residents to summarize attitudes and behaviors at the scale of the community. However, we recognized that the practice of relying on a random sample to generalize findings to the entire community, a common approach in survey research, would have limited our ability to explore resident motivations at finer degrees of resolution, at the same locations where we were observing bear-proofing behavior and garbage-related conflicts. We also recognized that the experience of garbage-related conflict is heterogeneous across the landscape, likely due to differences in garbage storage behaviors and proximity to bear habitat, and we wanted to understand how ecological factors identified in the conceptual model (e.g., ecosystem, community-level influences) affected human attitudes and behaviors. To address this, we modified social science research plans to sample at a much higher rate, contacting all residents within the community. Furthermore, we recorded survey responses with respect to specific parcel locations, so that we could spatially link them to locations of conflicts, compliance, and ecological variables. Increasing the intensity of our data collection enabled us to model human behavior at a fine resolution and thereby relate the same set of explanatory variables (e.g., distance to riparian habitat) to bear behaviors, human behaviors, and rates of bears accessing garbage. Efforts such as these that match the scale and resolution of data types prior to the start of data collection can overcome common challenges of SES research and yield greater opportunities for integration of results (Pooley et al. 2014).

Lesson 3: Conservation means human and animal behavior

In his influential paper, *Conservation Means Behavior*, Schultz (2011) argued that conservation success is dependent on efforts to understand and affect human behavior. We agree

that these efforts are critical, and further suggest that they be combined with investigations of the drivers and consequences of animal behavior to yield more comprehensive and effective management actions (Blumstein & Fernandez-Juricic 2010). For this reason, the intersection of human and animal behaviors are the primary focus of the conceptual model presented here (Figure 1).

Wildlife managers have often used rates of HWIs as an indicator of the size of wildlife populations (Morzillo et al. 2014). Consequently, management actions to reduce conflict, such as increased harvest, are frequently aimed at decreasing wildlife population size. Unfortunately, these efforts are rarely successful as conflict rates do not necessarily reflect numerical changes in populations (Treves et al. 2010, Obbard et al. 2014), particularly when animals shift their behavior in response to changing environmental conditions (Wong & Candolin 2015). For example, in our case study, bear foraging behavior has been found to be highly dynamic, as bears increase their use of anthropogenic foods in poor natural food years and decrease it in good natural food years, as a function of changing forage-risk trade-offs (Johnson et al. 2015). Baruch-Mordo et al. (2013) suggested that managers may be able to reduce forage benefits around development by securing garbage and other attractants. As a result, managers may be able to tip the balance of the forage-risk trade-off, discouraging bears from using human development and reducing garbage-related conflict. In Durango, human-bear conflicts decreased as compliance with the bear-proofing ordinance increased, with reductions in conflict leveling out once 60% of residents complied with the ordinance (Johnson et al. 2018). This suggests that reductions in forage benefits for bears can indeed have significant effects on nuisance bear behavior. Further, an understanding of how the temperament of individual bears (e.g., degree of boldness) affects use of anthropogenic foods could offer novel approaches to managing HWIs (Blackwell et al.

2016). We suggest that understanding and managing the behavior of individual animals responsible for conflict may be an important improvement in addressing HWIs.

Similarly, social science research on HWIs could benefit from greater attention to quantifying individual human behaviors. Data collection in this area has often relied on passive means of behavioral assessment, including surveys of behavioral intentions or self-reported activities as proxies for actual behavior (Baumeister et al. 2007). While these methods are cost-efficient and can be used to collect information from a large sample of residents, such data may not accurately reflect the frequency of human behaviors (Miller & Anderson 2002, Wilbur et al. 2018). Direct observation of behaviors can provide more accurate and reliable measures of the prevalence of activities contributing to and resulting from HWIs (Baruch-Mordo et al. 2009), yet are more difficult to collect and are only feasible for behaviors generally observable to the public. In the first year of data collection, we observed that only 50% of Durango residents appropriately used project-supplied garbage containers, while >70% of survey respondents reported doing so (Colorado Parks and Wildlife, unpublished data). By collecting data on bear-proofing behaviors through direct observations of garbage containers, rather than relying on self-reports, we were able to quantify rates of over-reporting and better understand the volume of garbage available to bears. As a whole, our experience indicates that accurate information about both animal and human behavior is needed to pinpoint the various drivers of HWIs and identify options for successful management intervention.

Conclusions

The conceptual model presented herein offers an integrated, multilevel approach to understanding HWIs that acknowledges the critical role of both social and ecological drivers as well as feedbacks among system components. While a number of studies have investigated

human-black bear conflicts (e.g., Don Carlos et al. 2009, Kretser et al. 2009, Merkle et al. 2011, Beckmann & Berger 2003), prior efforts have largely focused on either the social or ecological aspects of conflict and rarely integrated both information types to gain a holistic understanding of the system. This is typical of other HWI systems, where attempts to simultaneously examine both human and animal drivers are rare (Dickman 2010). By understanding the relative role of social and ecological factors affecting HWIs, as facilitated by the conceptual model we propose, researchers will be in a better position to inform management actions focused on the most critical drivers, whether those are social, ecological, or both.

An additional benefit of taking an SES approach to HWIs is the explicit focus on feedbacks within and across the social and ecological systems. The application of our model to the study of human-black bear conflicts in Durango led to the identification of relationships and feedback mechanisms that had been previously unexplored. We realized that we could not fully evaluate the efficacy of a bear-proofing effort by only tracking changes in human-bear interactions. To more completely assess the effectiveness of changes in waste management practices, we needed to also investigate the importance of natural food conditions, resident compliance with the city bear-proofing ordinance, and the factors motivating those behaviors. Further, by examining the social and ecological systems in tandem, we were able to better understand the social and ecological outcomes of human-bear conflicts, such as changes in bear behavior caused by garbage-storage practices and how the experience of conflict affects tolerance for bears. While resulting recommendations will still require institutional support to be put into practice, we hope that this integrated approach will yield improved mitigation of human-bear conflict in the future.

We recommend applying this model to other assessments of HWIs to guide interdisciplinary communication and research efforts that can more adequately address the complex and dynamic nature of human-wildlife relationships. Moreover, applying this framework to a diverse suite of HWI systems, such as illegal wildlife harvest or damage to agricultural products, will contribute to our overall understanding of the relative importance of social and ecological drivers in perpetuating conflict situations, yielding a broader suite of management actions that modify both human and animal behaviors. Our hope is that employing this model and adapting it for use across systems and contexts will move the practice of conservation one step closer to achieving Leopold's (1949) vision of an integrated field of social-ecological inquiry

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UNDERSTANDING AND MANAGING HUMAN TOLERANCE FOR A LARGE CARNIVORE²

Summary

Human tolerance for interactions with large carnivores is an important determinant of their persistence, yet the relative importance of factors affecting tolerance is not fully understood. Further, the impact of management efforts on tolerance has not been adequately assessed. We employed a longitudinal survey to measure tolerance for black bears (*Ursus americanus*) in the vicinity of Durango, Colorado, USA. We tested a suite of predictors, including conflicts, outcomes of interactions with bears, perceptions of benefits and risks from bears, trust in managers, perceived similarity with the goals of managers, personal control over risks, value orientations towards wildlife, and demographic factors. In addition, we monitored changes in tolerance resulting from a bear-proofing experiment designed to reduced garbage-related conflicts in the community. Residents who reported higher perceptions of benefits associated with bears and more positive impacts from interactions with them had increased tolerance. Residents who reported higher perceptions of risks, more negative impacts, higher trust in managers, domination wildlife value orientations, and older age were associated with decreased tolerance. Conflicts with bears were not an important predictor, supported by our finding that changes in conflicts resulting from our experiment did not affect tolerance. In contrast to conventional approaches to increasing tolerance, which focus on decreasing conflicts,

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communication efforts emphasizing the benefits and positive impacts of living with carnivores are likely to be more effective.

Introduction

The conservation of mammalian carnivores can be complex and challenging, particularly in systems dominated by humans (Chapron et al. 2014). Frequent and intense interactions between people and carnivores are the root cause of many of these challenges (Woodroffe et al. 2005). While some of these interactions can be positive, conflicts between humans and wildlife can lead to intolerance of species among people who face real and perceived impacts related to their health, safety, livelihoods, and property (Kansky and Knight 2014). Intolerance has the potential to affect the long-term sustainability of carnivore populations, especially when manifest as illegal killing or support for large-scale efforts to reduce populations (Treves and Bruskotter 2014). As a result, management actions focused on increasing tolerance can help create landscapes with enhanced social support for conservation, and ultimately, carnivore persistence (Bruskotter and Wilson 2014).

Tolerance is defined as an individual's or group's acceptance of negative effects and desire for positive effects arising from human-wildlife interactions (Decker and Purdy 1988, Carpenter et al. 2000). Therefore, an individual who has a high tolerance for a species will state a preference for a large population, whereas an individual with a tolerance will prefer a smaller population (Carpenter et al. 2000). Fundamentally, tolerance is a measure of attitudes toward wildlife. However, in practice, the term is sometimes used describe both attitudes (e.g., favorable beliefs about the outcomes of conservation) and behaviors that result from them (e.g., illegal killing, voluntary donations to support conservation; Bruskotter et al. 2015). Although this attitude can allow managers to quantify human desires for wildlife populations and account for

these desires in management, there is little information about the factors that affect tolerance and the influence of different management actions on it. As a result, managers have had limited success in applying the concept in the field (Gigliotti et al. 2000, Bruskotter et al. 2015).

Researchers have attempted to measure and predict attitudes associated with tolerance for a variety of species globally (Riley and Decker 2000, Lischka et al. 2008, Carter et al. 2012, Zajac et al. 2012, Inskip et al. 2016, Kansky et al. 2016, Struebig et al. 2018), resulting in studies of a variety of explanatory variables which draw widely from existing knowledge about the factors affecting attitudes more generally (Figure 2.1). Early efforts to understand the drivers of tolerance drew primarily from the experiences of wildlife managers. Based on input from stakeholders, managers typically assumed that the experience of conflicts with wildlife was the most important determinant of an individual's tolerance of a species (Conflict Model, Figure 2.1; Decker and Purdy 1988). While a focus on conflicts gave managers a specific set of interactions to attempt to mitigate, it failed to recognize the potential influence of positive human-wildlife interactions on this attitude. To address this issue, Riley et al. (2002) proposed a broader measure of the outcomes of interactions with wildlife, termed impacts (Impacts Model, Figure 2.1), which are defined as the important cognitive and emotional outcomes of both positive and negative human-wildlife interactions. For example, potential impacts resulting from seeing wildlife near home might be excitement, fear, or confidence in wildlife management efforts. Impacts have been shown to be an important predictor of tolerance (Lischka et al. 2008), providing a mechanism to account for both positive and negative outcomes of human-wildlife interactions.

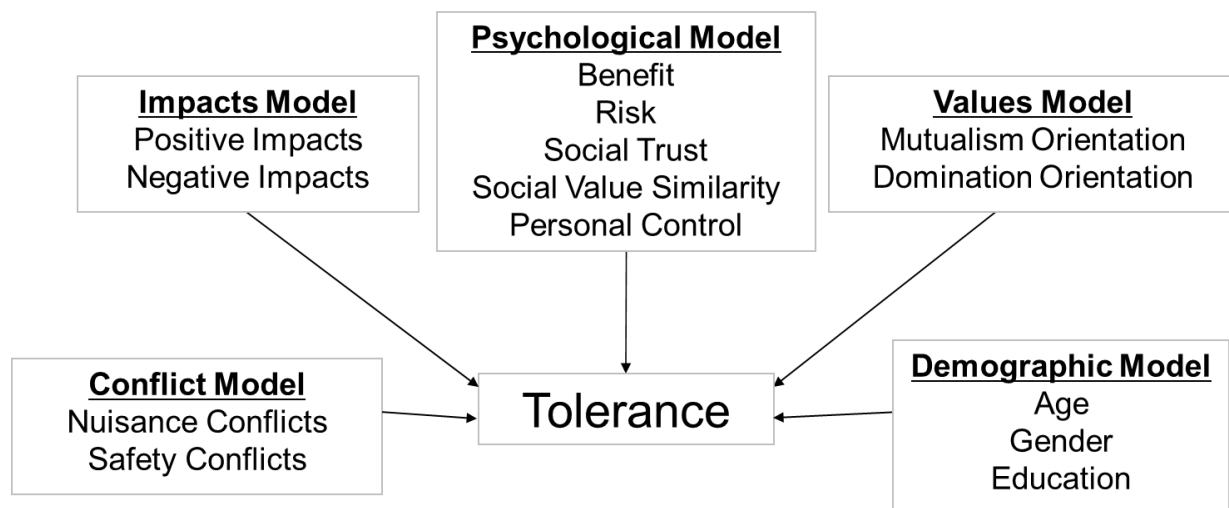


Figure 2.1. *A priori* models assessed to understand tolerance for black bears, including the Conflict Model (Decker and Purdy 1998), Impacts Model (Riley et al. 2002), Psychological Model (Zajac et al. 2012; Bruskotter and Wilson 2014); Values Model (Zinn 2000), and Demographic Model (Kansky and Knight 2014).

While these measures (impacts and conflicts) were based on perceptions of wildlife managers, they are not strongly rooted in theory (Gigliotti et al. 2000). To address this need, researchers applied hazard acceptance theory to examine the influence of a suite of psychological variables (risks and benefits from wildlife species, trust in managers, perceived similarity with management agencies, and personal control over risks) on tolerance (Zajac et al. 2012, Bruskotter and Wilson 2014). This approach (Psychological Model, Figure 2.1) demonstrated that perceptions of the general risks and benefits resulting from a species (e.g., the species improves ecosystem health, encounters with the species may cause human deaths) were the primary proximate drivers of tolerance, and higher-order influences, including trust in management agencies and perceived personal control over risks, affected tolerance indirectly through their influence on perceived benefits and risks. In contrast to measures of impacts and conflicts, which reflect the outcomes of direct interactions with wildlife, measures of perceived

risks and benefits describe more general perceptions of the consequences of living with wildlife and the value gained from their existence (Kansky et al. 2016).

Other factors drawn from social science theory have also proven useful in understanding tolerance. For example, wildlife value orientations (WVOs), defined as sets of basic beliefs about wildlife that provide contextual meaning to more general values, explain variation in a wide range of attitudes, including tolerance (Values Model, Figure 2.1; Zinn et al. 2000, Teel & Manfredi 2009). While WVOs may explain patterns in tolerance, we expect that specific and salient attitudes about species and interactions (impacts and benefits/risks) would have a stronger direct effect (Zinn et al. 2000).

In addition, demographic characteristics such as gender and age are commonly explored in assessments of attitudes toward wildlife (Kansky and Knight 2014; Demographic Model, Figure 2.1). Like WVOs, the explanatory power of demographics is likely to be lower because they may reflect latent influences, such as when gender reflects differences in individuals' power to employ risk-reducing behaviors rather than actual differences in attitudes toward carnivores (Carter et al. 2014).

Although researchers have identified a variety of predictors of tolerance for different species and in different systems, these factors have not been simultaneously tested to identify their relative importance (Gigliotti et al. 2000). To better understand the relative influence of these factors, we employed a longitudinal mail-back survey measuring tolerance for black bears (*Ursus americanus*) in the vicinity of Durango, Colorado, USA. Specifically, we explored the influence of conflicts, outcomes of human-bear interactions, perceptions of bear-related benefits and risks, trust in managers, perceived similarity with the goals of managers, personal control over risks, wildlife value orientations, and demographics (Figure 2.1). Further, we monitored

changes resulting from a bear-proofing experiment designed to reduce garbage-related conflicts in the community. Conflicts and interactions between people and black bears have been increasing across the U.S. (Hristienko and McDonald 2007), yet black bears are highly valued by urban and rural residents alike (Morzillo et al. 2010, Lowery et al. 2012), making them an excellent case study for understanding tolerance. By identifying important predictors of tolerance and assessing the influence of management actions on tolerance, we hope to inform efforts to increase support for maintaining bear populations in increasingly human-dominated landscapes.

Methods

Study area

The city of Durango is located in southwest Colorado, along the Animas River, at an elevation of 1,988 m. The city is surrounded by mountainous public land and dominated by ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*), pinyon pine (*Pinus edulis*), juniper (*Juniperus spp.*), aspen (*Populus tremuloides*), and mountain shrubs (i.e., *Prunus virginiana*, *Peraphyllum ramosissimum*, etc.) that provide diverse natural food sources for black bears. Durango, with a human population of approximately 18,500 individuals, has grown rapidly since 1970 (U.S. Census Bureau 2017), resulting in increases in anthropogenic foods available to bears. These food sources are concentrated around residential developments, leading to high rates of human-black bear conflicts (Baruch-Mordo et al. 2008, Johnson et al. 2018). In response, the city of Durango implemented an ordinance in 2010 requiring residents to keep garbage in a locked wildlife-resistant container or a secured location such as a garage or shed.

Despite the ordinance, high rates of reported human-bear conflicts motivated us to experimentally test the effect of wide-scale urban bear-proofing on the frequency of garbage-related human-bear conflicts from 2011 to 2016 (Johnson et al. 2018). In 2013 and 2014, as a

part of this experiment, we distributed bear-resistant garbage containers, free-of-charge, to each household (1,145 residences) in 2 residential sections of the city (1 in the north and 1 in the south). In 2 paired control areas (1,123 residences), we did not distribute containers, and residents could choose whether to use a regular garbage container or a bear-resistant container. To test the effectiveness of this bear-proofing effort, we monitored rates of garbage-related human-bear conflicts from 2011-2016 throughout the treatment and control areas, collecting data for 2 years before the deployment of the containers (2011-2012; pre-treatment) and for 4 years after deployment of the containers (2013-2016; post-treatment). After the deployment of bear-resistant containers, garbage-related conflicts in the treatment areas slightly declined, while conflicts in control areas significantly increased (Johnson et al. 2018).

Data collection

From January to April 2012, 2014, and 2016, we sent self-administered mail surveys to all households within Durango city limits ($n= 5,852$), as well as a random sample of 1,500 residents of near-town areas. Included in this sample were all residents of the experimental area (control and treatment areas). The 2014 survey was designed to measure tolerance for bears, as well as the relative importance of predictors (Figure 2.1), which were assessed for all members of the sample. The 2012 and 2016 surveys were used to evaluate changes in tolerance in relation to changing rates of human-bear conflicts, which were assessed only among residents of the experimental area.

We identified names and addresses for mailings from the La Plata County Assessor's spatially referenced plat maps and tax roll information. We administered the surveys using a modified version of the Tailored Design Method (Dillman et al. 2014) with 5 total mailings including 1 invitation letter, 2 mailings of the printed survey, and 2 postcard reminders.

Respondents were also offered the option to reply via an online survey in each mailing. Non-response bias was assessed with a postcard mailed to individuals who did not return the full survey. The postcard contained a subset of 5 questions to allow for comparison to the full survey and known characteristics of the Durango population from the U.S. Census. All survey materials and procedures met the approval of Colorado State University's Institutional Review Board (Protocol #005-17H).

Measurement and analysis

We measured *Tolerance*, our response variable, by asking respondents to report their preferences for a change in the size of the bear population over a 2-year period, on a 5-point scale from 1 = decrease greatly to 5 = increase greatly (Bruskotter et al. 2015). We assumed that the current bear population was above tolerance for individuals desiring a decrease and below tolerance for those desiring an increase. This value was measured in 2012, 2014, and 2016.

For predictors within the Conflict Model, we measured prior conflict by asking respondents to report the number of times over the past 2 years they experienced a suite of 11 conflicts with bears in the area where they live, on a 4-point scale (0 = 0 times, 1 = 1-2 times, 2 = 3-4 times and 3 = ≥ 5 times; Figure 2.2). Conflicts included interactions likely to result in nuisances for the household (e.g., bear got into my garbage or damaged fruit trees; *Nuisance conflicts*) as well as interactions likely to threaten human or domestic animal safety (e.g., bear attacked or harassed pets or livestock; *Safety conflicts*). For *Nuisance conflicts*, we summed the frequency values for all nuisance-causing conflicts. Because few people reported experiencing *Safety conflicts*, we recoded these into a binary variable (1 = experienced ≥ 1 conflict, 0 = did not experience a conflict; Wilbur et al. 2018).

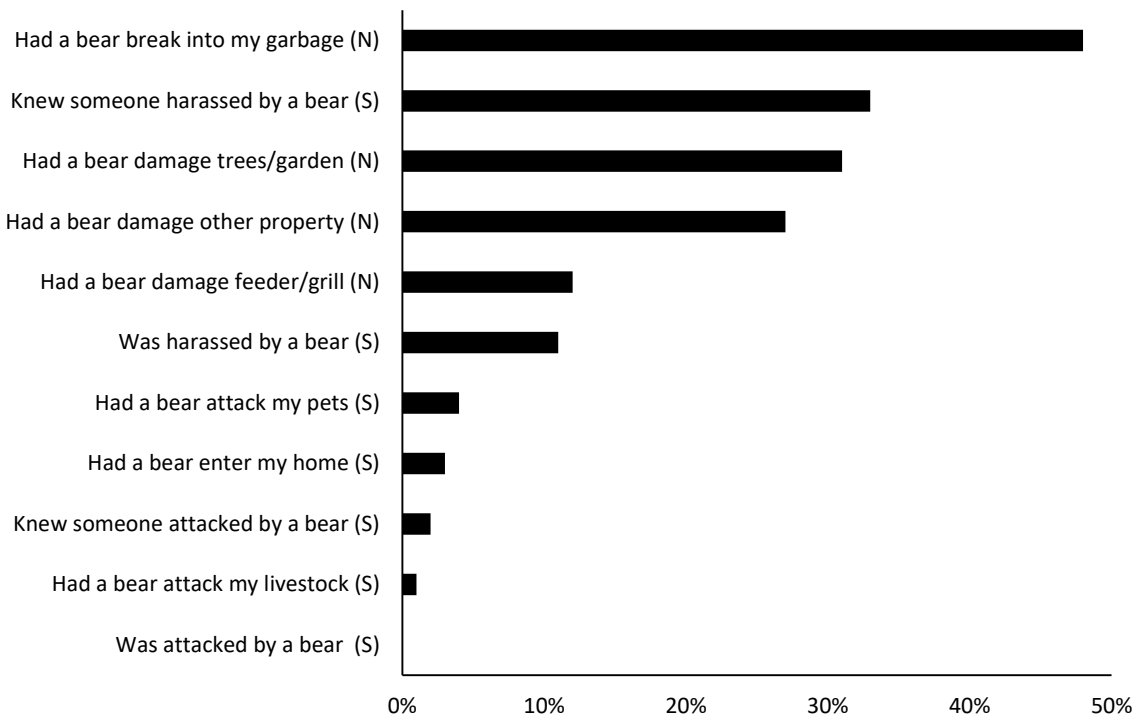


Figure 2.2. Items included in Conflict Model of tolerance for black bears. Bars represent the percent of respondents who had experienced each conflict. Results from “Living with black bears in Durango” survey, conducted January–April 2014 in Durango, Colorado, USA. Individuals were asked to report whether they had experienced each conflict within the previous 2 years. (N) indicates *Nuisance conflicts*, (S) indicates *Safety conflicts*

We followed the methods of Lischka et al. (2008) to quantify predictors in the Impacts Model. We asked respondents to report whether they had experienced a suite of 33 (12 positive, 28 negative) affective (emotion-based) outcomes of interactions with bears over the past 2 years (e.g., feeling fear when they saw a bear, feeling that bears indicated the health of the local ecosystem) and across 3 different settings (i.e., around home, in town, and in natural areas outside of town) where 1 = experienced the outcome and 0 = did not experience the outcome (Appendix A1.1). We also asked respondents to report the importance of each outcome on a 3-point scale from 1 = not at all important to 3 = very important. Because impacts are defined as

outcomes of interactions that are both recognized and important, we retained only impacts that respondents reported having experienced and felt were important. We weighted the retained impacts by responses to a third question rating the respondent's desired change in the frequency at which they experienced the outcome (ranging from 0 = no change to 2 = large change; Lischka et al. 2008). We summed the resulting values across all positive and negative impacts, separately, resulting in a score for positive impacts (*Positive impacts*) and negative impacts (*Negative impacts*).

We measured predictors in the Psychological Model following methods of Zajac et al. (2012). We created scales from multi-item questions measuring respondents' perceived benefits (e.g., The presence of black bears improves the quality of life in Durango; *Benefit*) and risks (e.g., I fear having an encounter with black bears; *Risk*) associated with bears, trust in the management agency (e.g., I am confident CPW can effectively manage black bears; *Social trust*), perceptions of the degree to which the agency shares their values (e.g., I believe CPW shares values similar to mine; *Social value similarity*), and personal control over risks related to bears (e.g., I have the ability to protect my property from wildlife; *Personal control*; Appendix A2). Individual items were measured on a 5-point scale from 1 = strongly disagree to 5 = strongly agree. Because these measures were derived from previously validated scales, we conducted a factor analysis (Principal Axis Factoring) for each scale (5 total) to reduce dimensionality and calculate values for each respondent (Johnson 1998). We assessed scree plots and eigenvalues to determine the appropriate number of factors to retain (Table A1.2; Johnson 1998), factor loadings to denote practical significance (> 0.40 ; Devellis 2012), and reliability analysis (Cronbach's α) to test the internal consistency of each scale (Cortina 1993). To improve scale reliability, we removed several items from the *Risk* and *Personal control* scales (Appendix

A1.2). With these modifications, all scales exhibited acceptable internal consistency ($\alpha > 0.6$, Vaske 2008).

For the Values Model, we measured WVOs following the methods of Teel and Manfredi (2009), modified to a reduced 14-item set (Chase et al. 2016; Appendix A1.3). Respondents rated these items, representing basic beliefs about wildlife and wildlife management, on a 7-point scale from 1 = strongly disagree to 7 = strongly agree. We computed scores on two value orientation scales, domination (view of wildlife that prioritizes human well-being over wildlife and treats wildlife in utilitarian terms; *Domination*) and mutualism (view that places greater emphasis on equality, caring, and compassion for wildlife; *Mutualism*), by averaging responses to corresponding belief items.

For the Demographic Model, we asked respondents to report the year of their birth (to calculate *Age* by subtracting from 2014), gender (*Gender*; Reference class = male), and highest level of education completed (*Education*; Reference class = high school diploma or less; Table 1).

To assess the relative influence of predictors of *Tolerance*, we conducted linear regression modeling using responses to the 2014 survey. We compared the ability of each of the 5 *a priori* models (Conflict, Impacts, Psychological, Values, Demographic) and a global model (including all predictor variables; Figure 2.1) to explain *Tolerance* (Appendix A1.5). We compared models using Akaike's Information Criteria (AIC), where models with the lowest AIC values reflect more empirical support from the data (Burnham and Anderson 2010). We identified important explanatory variables in the global model by determining where 95% confidence intervals (CIs) around standardized regression coefficients did not overlap zero. We only retained survey responses that included data for all predictor variables. Prior to modeling,

we assessed multicollinearity by inspecting bivariate correlations (Pearson's r) among predictor variables (Appendix A1.4). Where $r > 0.50$, we inspected Variance Inflation Factor (VIF) values to identify problematic multicollinearity. If VIF values were > 5 , we removed the variable with the lowest correlation with *Tolerance* (Zar 1999).

We used linear regression to investigate whether *Tolerance* also changed in response to the bear-proofing experiment, using responses from the 2012 and 2016 surveys. We chose to use 2012 and 2016 survey responses to maximize the potential to detect an impact of the experiment and avoid multiple responses from the same residences. We analyzed *Tolerance* using a Before-After-Control-Impact (BACI) design (Williams et al. 2002), where we tested for a significant interaction between *Time* (pre-treatment [2012] vs. post-treatment [2016]; Reference class= pre-treatment) and *Treatment* (treatment vs. control area; Reference class= control). Because we suspected that differences between north and south neighborhoods may influence *Tolerance* (Johnson et al. 2018), we also included site as a binary variable (Reference class = north). We ran a single linear regression model that included *Time*, *Treatment*, *Site*, and *Time* \times *Treatment* as fixed effects. We identified important explanatory variables by determining where 95% CIs around standardized regression coefficients did not overlap zero, and evaluated the impact of the experiment by assessing the *Time* \times *Treatment* interaction. All analysis was conducted in SPSS (version 24.0, Chicago, Illinois).

Results

Survey response

After removing undeliverable addresses ($n_{2012} = 524$, $n_{2014} = 698$, $n_{2016} = 1,117$), our adjusted response rates were 55% in 2012 ($n = 2,944$), 45% in 2014 ($n = 2,316$), and 51% in 2016 ($n = 2,432$). When we assessed potential non-respondent bias, we found that homeowners

responded to the full survey at a rate higher (85% in 2012, 85% in 2014, 83% in 2016) than homeownership rates in Durango (49%; U.S. Census Bureau 2017). Further, *Tolerance* of homeowners was significantly lower than that of renters ($\bar{x}_{\text{own}} = 2.63$, $SE_{\text{own}} = 0.03$, $\bar{x}_{\text{rent}} = 2.99$, $SE_{\text{rent}} = 0.02$, $t_{2326} = -9.64$, $p < 0.001$, Cohen's $d = 0.37$). We found no other statistically significant differences between respondents and non-respondents ($p > 0.05$). As a result, we chose to weight survey data by homeownership to allow for more accurate generalization of study findings to the population (Groves 2006).

Tolerance modeling

From the full respondent pool in 2014, 745 respondents returned surveys with complete data for all predictor variables of *Tolerance*. For our measure of *Tolerance*, more than half (53%) of respondents reported wanting the bear population near their home to stay the same over the next 2 years, while 29% wanted a decrease and 18% wanted an increase. Respondents most frequently reported the conflicts of having had a bear break into their garbage, heard about someone being harassed by a bear, had a bear damage fruit trees or other property (Figure 2.2). Respondents experienced an average of 3.2 *Positive impacts* ($SE = 0.16$, range: 0-24) and 6.7 *Negative impacts* ($SE = 0.31$, range: 0-44) resulting from their interactions with bears (Appendix A1.1). The most common impacts were feeling that the area was good wildlife habitat when seeing bears in natural areas (59%) or in town (51%), feeling connected to nature when seeing bears in natural areas (56%), and feeling excited when seeing bears in natural areas (54%) or near home (54%). Mean scores on the *Domination* scale were moderate ($\bar{x} = 4.17$, $SE = 0.04$, range: 1-7), representing the degree to which respondents held utilitarian value orientations. Mean scores for the *Mutualism* scale were also moderate ($\bar{x} = 4.79$, $SE = 0.05$, range: 1-7), reflecting the degree to which respondents placed an emphasis on compassion for wildlife.

Among the 5 *a priori* models we compared, the Psychological model provided the best fit to *Tolerance* (Appendix A1.5). However, the global model had a ΔAIC value > 30 less than the Psychological Model, indicating strong empirical support from the data. Our global model explained 46% of the variation in *Tolerance*, offering the best fit to the data among all models compared (Appendix A1.5). In this model, *Positive impacts*, *Negative impacts*, *Benefit*, *Risk*, *Social trust*, *Domination*, and *Age* had 95% CIs that did not include zero (Table 2.1). *Positive impacts* and *Benefit* had a positive relationship with *Tolerance*, indicating that people who perceived more positive outcomes of their interactions with bears and assigned greater benefits to them were more tolerant. In contrast, *Risk* and *Negative impacts* had a negative relationship, where individuals who assigned a greater level of risk to bears and who perceived more negative outcomes of interactions had lower tolerance. *Social trust* also had a negative relationship, indicating that residents who reported higher trust in the agency to address interactions with bears were less tolerant of bears. Older respondents and those with *Domination* value orientations, were also less tolerant of bears. Of these 7 factors, the magnitude of effect of *Benefit* and *Risk* was largest (Figure 2.3).

Table 2.1. Linear regression ($n = 747$) of factors affecting tolerance for black bears in the vicinity of Durango, Colorado, USA. Results are from the “Living with Black Bears in Durango” survey, conducted January-April 2014. *Tolerance*, the response variable, was measured as a desired change in the bear population over the next 2 years, on a 5-point Likert scale with 1 = decrease greatly and 5 = increase greatly. R^2 value was 0.464. *Gender* and *Education* were categorical variables, while all other variables were continuous. * indicates 95% CIs that do not overlap zero. † Reference class = Male, ‡ Reference class = High school diploma or less.

Variable	Unstandardized β	Standardized Values			
		β	SE	95% CIs	
				Lower	Upper
Intercept	3.437	2.853	0.027	2.771	2.879
<i>Nuisance conflicts</i>	-0.024	-0.051	0.027	-0.104	0.003
<i>Safety conflicts</i>	0.048	0.030	0.028	-0.026	0.085
<i>Positive impacts</i> *	0.016	0.068	0.027	0.016	0.120
<i>Negative impacts</i> *	-0.014	-0.115	0.032	-0.178	-0.051
<i>Benefit</i> *	0.294	0.289	0.036	0.218	0.361
<i>Risk</i> *	-0.233	-0.229	0.040	-0.307	-0.151
<i>Social trust</i> *	-0.090	-0.098	0.038	-0.164	-0.016
<i>Social value similarity</i>	0.016	0.014	0.041	-0.066	0.095
<i>Personal control</i>	0.066	0.064	0.034	-0.002	0.129
<i>Mutualism</i>	0.030	0.039	0.034	-0.029	0.106
<i>Domination</i> *	-0.098	-0.110	0.034	-0.178	-0.043
<i>Age</i> *	-0.004	-0.059	0.029	-0.117	-0.002
<i>Gender</i> †	-0.085	-0.045	0.030	-0.104	0.014
<i>Education</i> ‡					
Some post-secondary education	0.105	0.046	0.049	-0.050	0.143
Bachelor's degree or higher	-0.041	-0.019	0.048	-0.114	0.076

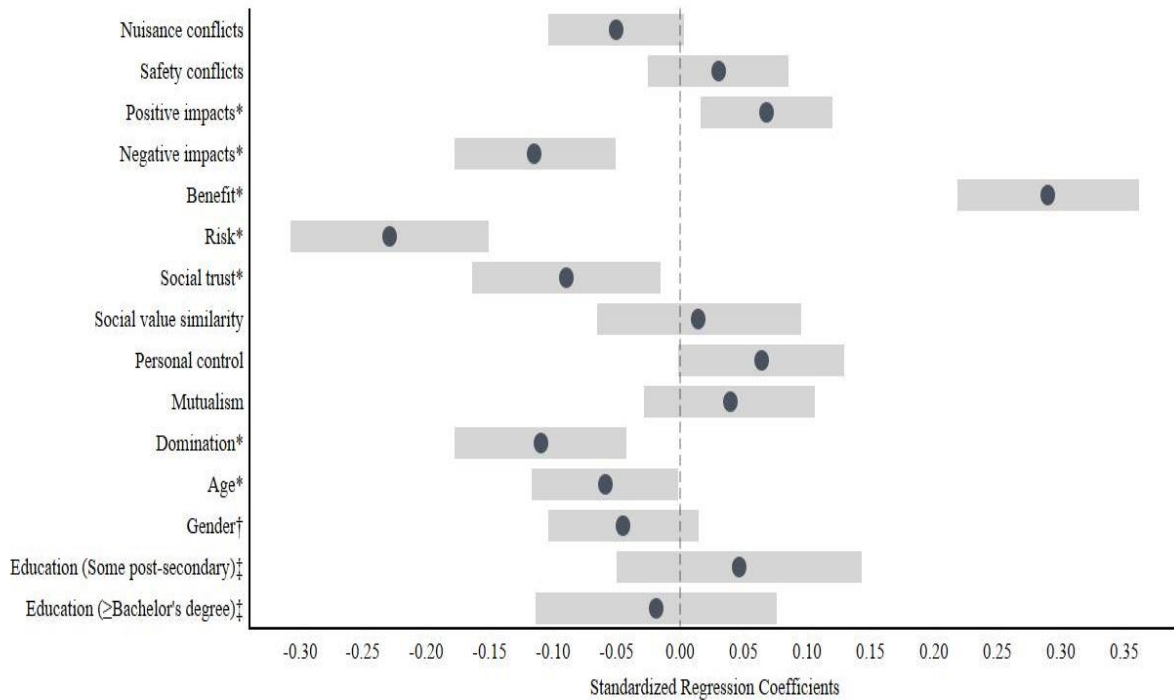


Figure 2.3. Standardized regression coefficients from regression model of factors affecting tolerance for black bears ($n = 747$). Results are from the “Living with Black Bears in Durango” survey, conducted January-April 2014 in Durango, Colorado, USA. Midpoints represent the coefficient values, and error bars show the 95% CIs. * indicates 95% CIs that do not overlap zero

When comparing *Tolerance* before (2012) and after (2016) the bear-proofing experiment, we did not find an impact of the change in conflicts (Table 2.2; Figure 2.4), as mean values remained constant before and after the distribution of bear-resistant containers in the treatment ($\bar{x}_{2012} = 2.78$ [SE = 0.045]; $\bar{x}_{2016} = 2.82$ [SE = 0.05]) and control areas ($\bar{x}_{2012} = 2.95$ [SE = 0.04]; $\bar{x}_{2016} = 2.92$ [SE = 0.05]). *Tolerance* values were slightly higher in control areas and in the south neighborhood during all years, but this pattern did not change in response to shifting patterns of conflicts. Although the management experiment assumed that a reduction in human-bear conflicts in the treatment area relative to the control area would increase tolerance for bears, the *Time × Treatment* effect was not meaningful in modeling (Table 2.2).

Table 2.2. Linear regression ($n = 2,552$) of the impact of the bear-proofing experiment on tolerance for black bears in the vicinity of Durango, Colorado, USA. Results are from the “Living with Black Bears in Durango” survey, conducted January–April 2012 and 2016. *Tolerance*, the response variable, was measured as a desired change in the bear population over the next 2 years, on a 5-point Likert scale with 1 = decrease greatly and 5 = increase greatly. All predictors were categorical variables. * indicates 95% CIs that do not overlap zero. † Reference class = Control, ‡ Reference class = North, and § Reference class = Pre-treatment (2012).

Variable	Unstandardized β	Standardized Values			
		β	SE	95% CIs	
				Lower	Upper
Intercept	2.852	2.853	0.027	2.771	2.879
<i>Treatment</i> ^{†,*}	-0.156	-0.155	0.056	-0.264	-0.046
<i>Site</i> ^{‡,*}	0.090	0.133	0.042	0.050	0.216
<i>Time</i> [§]	-0.017	-0.041	0.055	-0.148	0.067
<i>Treatment</i> \times <i>Time</i>	0.079	0.097	0.079	-0.059	0.252

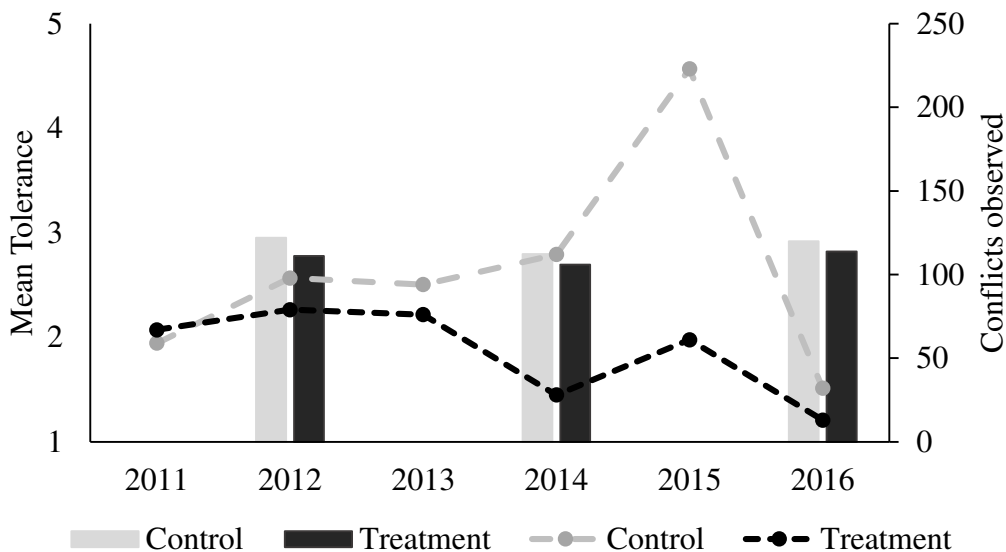


Figure 2.4. Trends in tolerance for black bears and human-bear conflicts in Durango, Colorado, USA (2012–2016). Bars represent the mean values for tolerance among residents of control (black) and treatment (grey) areas in 2012, 2014, and 2016. Dashed lines represent the number of garbage-related conflicts observed in control (black) and treatment (grey) areas. Results from “Living with black bears in Durango” survey, conducted January–April 2012, 2014, and 2016 and annual observations of conflicts (2011–2016) in Durango, Colorado, USA. *Tolerance* was measured as a desired change in the bear population over the next 2 years, on a 5-point Likert scale with 1 = decrease greatly and 5 = increase greatly.

Discussion

For tolerance to become a useful tool in the practice of wildlife conservation, it is critical to understand the factors driving it and how they are affected by conservation action. By testing the relative importance of a suite of predictors posited in prior studies, we provide guidance on the combination of drivers likely to influence tolerance. In contrast to many of the assumptions that underlie management of negative interactions with black bears, our models indicated that experience of safety- and nuisance-related conflicts with bears did not strongly affect tolerance for the species. Notably, we were able to ground-truth our model predictions by testing if tolerance for bears changed as a result of a large-scale bear-proofing experiment designed to reduce human-bear conflicts (Johnson et al. 2018). Despite increases in garbage-related conflict in control areas that did not receive bear-resistant containers, and a reduced bear population in the vicinity of Durango due to a shortage of natural foods in 2012 (Laufenberg et al. 2018), tolerance for bears remained constant between 2012 and 2016. While it is possible that there may be a time lag between changes in conflicts and resulting effects on tolerance, we feel that measuring tolerance 3 years after distribution of the containers reflected a timeframe in which most managers would expect results. Yet, in our experiment, we found that conflict management efforts did not increase tolerance for bears over this time period.

In our modeling, perceived risks and benefits associated with bears were most important in explaining variation in tolerance. Similarly, we found that both the positive and negative outcomes of interactions with bears (i.e., impacts) were important drivers. Further, the contribution of perceived benefits was greater than that of perceived risks and negative impacts, a pattern that may contradict the perceptions of many practitioners. This finding suggests that efforts to modify tolerance for bears and other carnivores may be more successful if designed to

focus on benefits provided by the species in conjunction with risks, rather than focusing on risks alone. Consistent with our conclusions, Slagle et al. (2013) found that exposure of Ohio residents to communication messages describing benefits of bears to people and ecosystems yielded an increase in tolerance, whereas messages focused solely on risks did not. Therefore, we suggest that existing strategies to change attitudes toward bears could also be modified to improve results. For example, standard “BearAware” materials used across the U.S. to encourage strategies for coexistence with bears focus messaging almost exclusively on risks to bears (Gore et al. 2008; Baruch-Mordo et al. 2011). Messages such as “garbage kills bears” commonly comprise the core of such messaging. By modifying content to focus on benefits of living with bears, these materials could be more effective in increasing tolerance. The measures of benefits that we assessed asked respondents to rate the contribution of bears to the quality of life in their community and the health of the environment around Durango. Specifically, our results suggest that communication highlighting the role bears play in a healthy ecosystem and recreational benefits that might accrue from their presence may promote more positive perceptions and thereby increase tolerance.

Surprisingly, individuals who expressed higher trust in the wildlife agency to effectively manage black bears were less tolerant of the species. While agencies often employ a variety of approaches to address human-bear conflict, the approaches that are most notable to the public are frequently those that involve lethal removal of conflict-involved bears. Support for lethal responses to human-wildlife conflict is lowest among people who are most tolerant of the species (Inskip et al. 2014). Although we did not directly explore the relationship between agency trust and specific management actions, we found that residents who desired a large decrease in the number of bears killed by managers reported lower trust scores ($\bar{x} = -0.10$ [SE = 0.06] for those

wanting fewer bears killed) in comparison to residents who felt the number of bears killed was acceptable ($\bar{x} = 0.07$ [SE = 0.06]). We hypothesize that the relationship between social trust, an indicator of perceived capacity of the agency to effectively manage human-bear conflicts, and tolerance may be mediated by whether individuals support the specific actions used by managers to address conflict.

Our model also identified the influence of broader value orientations toward wildlife; people with an orientation prioritizing the needs of humans over wildlife (i.e., domination) were less tolerant of bears. While it may be nearly impossible to alter people's values toward wildlife (Manfredo et al. 2016), understanding how those values influence tolerance may help identify situations where the success of conservation actions will be impacted by social support. For instance, communities with a high prevalence of domination value orientations may be less supportive of efforts to reintroduce and recover carnivores. In such situations, practitioners might face substantial social conflict over conservation interventions, requiring more intensive and targeted efforts to build support (Bruskotter 2013). Regardless of the specific situation or location, information about value orientations can be useful to help frame communication messages that are more likely to resonate with target audiences (Teel and Manfredo 2009).

Conclusion

Local and regional governments, management authorities, and conservation organizations globally are attempting to promote efforts to conserve carnivore species that can cause conflicts with people (Woodroffe et al. 2005). This study was conducted in an area with a high frequency and intensity of conflicts between urban residents and black bears. In fact, a majority (72%) of respondents in our survey had experienced at least some nuisance-related conflicts with bears in the previous 2 years, while 46% reported at least one positive impact from their interactions with

bears. The characteristics of this community provides useful insights into the factors promoting tolerance for a carnivore that may also cause conflicts with people. In addition, the factors that contribute to human-bear conflicts are not likely to decrease in the future, especially given projected changes in land use and climate (Johnson et al. 2015, 2017), making our findings applicable to locations where human-bear conflict is common and variable. Our model explained 47% of variation in tolerance, providing meaningful insight into the concept and its drivers. However, understanding may be further improved by evaluating additional influences. For example, considering the effect of emotions or social group membership may improve understanding of tolerance and its application to carnivore management (Lischka et al. 2018, Struebig et al. 2018). Continuing to refine our understanding of this important concept will be helpful in designing efforts to increase tolerance for carnivores. The development and testing of proactive strategies is a critical next step in the application of the concept to wildlife management and may facilitate carnivore conservation in human-dominated landscapes (Treves and Bruskotter 2014).

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UNDERSTANDING THE MOTIVATIONS FOR RISK-REDUCING BEHAVIORS TO LIMIT HUMAN-BLACK BEAR CONFLICT³

Summary

Local ordinances are viewed as an effective way to motivate human behaviors to address human-wildlife conflicts, yet compliance with ordinances varies. Conservation practitioners commonly employ education efforts to increase compliance with conflict-related ordinances, yet these efforts could be improved by knowledge of the motivations of people who voluntarily employ desired behaviors. To understand factors that motivate one such behavior, appropriate use of bear-resistant garbage containers, we paired observations of household use of these containers with data from a mail survey of residents during a city-wide bear-proofing experiment in Durango, Colorado, USA. We observed use of bear-resistant containers at 383 households in 2014 and 2016 and used surveys to assess the influence of beliefs and attitudes toward bears and bear-proofing, perceived behavioral control, norms, trust in the management agency, and demographics on bear-proofing behavior. Further, we observed garbage-related conflicts throughout the study area to assess the effect of conflict on this behavior. Most residents used bear-resistant containers irregularly (containers were locked and bear-resistant on 44% of observations); 33% of households were never compliant across observations. Garbage-related conflicts with bears were common, with an annual average of 2 conflicts/block observed. In a multivariate model, we found that trust in the management agency, perceptions of benefits

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associated with bears, and the number of conflicts occurring on a resident's block were related to use of containers, while there was no relationship with perceptions of risks associated with bears, home ownership, descriptive norms, gender, or year. Residents increased their use of containers when rates of conflicts per residential block were higher. However, when respondents were more trusting of the management agency and perceived more benefits from bears, they used containers less often. Communication messages highlighting the role of residents' actions in the ability of managers to successfully control conflict and maintain bear populations have the potential to increase the effectiveness of campaigns designed to motivate use of bear-proof containers. Such approaches could assist conservation practitioners in reducing human-bear conflicts by modifying human behavior.

Introduction

Conflicts between people and wildlife are increasing globally due to recovery of previously persecuted species (Chapron et al. 2014), range expansions of some human-adapted species (Ripple et al. 2014), and expansion of human development into wildlife habitats (Woodroffe et al. 2005), with serious consequences for both wildlife and people. Both human and animal behavior contributes to conflicts (Lischka et al. 2018), yet efforts to reduce conflicts generally require human action, including building fences, altering livestock grazing practices, or securing anthropogenic food from wildlife. Local ordinances are often viewed as an effective way to motivate desired human behaviors (Keane et al. 2008). For ordinances to be effective, practitioners often draw on 2 approaches to induce compliance: 1) enforcement actions, such as issuing fines for non-compliance; and 2) passively disseminating educational materials, such as signs or flyers that instruct residents on desired behaviors (Keane et al. 2008). Enforcement, which can be effective at increasing compliance (Baruch-Mordo et al. 2011), is expensive to

execute, may cause only short-term changes in behavior, and can erode intrinsic motivation and trust in management authorities (Keane et al. 2008). Educational materials that target a broad group of residents with general information have proven to yield little success in promoting desired behaviors (Schultz 2011), likely because content is often not based on knowledge of the audiences' motivations for action (St. John et al. 2010). Further, while these efforts are well intentioned and often supported by substantial investments of time and resources, their effectiveness is rarely evaluated (Gore et al. 2008).

Outcomes of both enforcement and education approaches could be improved by understanding the motivations for conflict-reducing behaviors. Several social psychological frameworks provide insight into the factors that motivate human behaviors, increasing the likelihood that behavior change efforts informed by them yield predictable, positive outcomes. The Theory of Planned Behavior (TPB; Fishbein & Ajzen 2010) is a commonly applied theory for understanding individual behavior in conservation (Osbaldiston 2013). This theory posits that intentions to act are determined by attitudes toward a given behavior and beliefs about its outcomes, as well as perceptions of social pressure (norms) and personal control over the behavior (perceived behavioral control). When this theory has been applied to conservation, previous investigators have shown that specific and easily accessible (i.e., salient) attitudes and beliefs predict behaviors better than general attitudes toward conservation and other non-specific objects (St. John et al. 2010) and that activating attitudes toward actions can be an effective way to encourage pro-environmental behaviors (Osbaldiston 2013). The role of norms and social pressure has been relatively underexplored in conservation contexts (St. John et al. 2010), yet has significant potential to motivate behaviors.

Risk perceptions, defined as assessments of the likelihood of an event and the magnitude of negative consequences resulting from it (Slovic 1987), have also proven useful for understanding conservation-related behaviors, particularly in human-wildlife conflict situations (Kahler et al. 2013). Risk perceptions are driven by familiarity with the risk and dread associated with outcomes (Gore et al. 2009), and high levels of perceived risk have been linked, for example, to increased poaching behavior (Kahler et al. 2013), conflict reporting (Hayman et al. 2014), and participation in wildlife disease management efforts (Triezenberg et al. 2014). Risk-based communications are commonly applied in efforts to motivate behavior, yet evaluations of the effectiveness of these efforts in conservation contexts are lacking (Gore et al. 2008, 2009).

While TPB and risk concepts are frequently used to understand and encourage conservation-related behaviors, they assume behavior to be the result of reasoned, rational choices following from a weighing of costs and benefits. Evidence suggests that these individual cognitive pathways make up only part of the decision-making process in humans, with decisions often driven by the effects of non-cognitive and broader-level factors, including emotions, institutional and group-level influences, and heuristics (Manfredo et al. 2014, Lischka et al. 2018). For example, Cialdini et al. (1991) demonstrated the effect of norms, a group-level influence, on littering behavior. When in a littered public environment (indicative of a norm that littering is an acceptable behavior), study participants were more likely to litter than when in a non-littered environment. Similar effects have been found in relation to retaliatory killing of predators (St. John et al. 2015) and commercial fish harvest (Gezelius 2002), where beliefs about the frequency of the behavior among neighbors and important others affected individual actions. As another illustration, research has shown that institutional factors, such as policies guiding the application of lethal removal strategies, can affect people's perceptions of the effectiveness of

conflict management and behaviors such as reporting conflicts (Wilbur et al. 2018) and participation in wildlife disease management programs (Rudolph & Riley 2014). Focusing behavior change efforts on a broader array of factors allows conservationists to draw from a wider suite of potential actions that are likely to be more effective than cognitive-based approaches alone (McKenzie-Mohr 2011).

To advance these efforts, we sought to understand the effect of a range of cognitive, risk-based, and broader-level influences on human behaviors aimed at reducing the risk of human-carnivore conflicts. Specifically, we investigated the relative importance of factors motivating residents of Durango, Colorado to use bear-resistant garbage containers to limit human-black bear conflicts. Conflicts between humans and black bears (*Ursus americanus*), an adaptable and widely distributed carnivore in North America (Scheick & McCown 2014), are increasing across the range of the species (Hristienko & McDonald 2007), yet bears are at the same time highly valued by urban and rural residents alike (Morzillo et al. 2010). Increases in human-black bear conflicts have been attributed, at least in part, to bears foraging on anthropogenic food sources, especially garbage, in human-dominated environments (Lewis et al. 2015). Education and communication campaigns have shown limited success in motivating human behaviors that limit attractants available to bears (Gore et al. 2008; Baruch-Mordo et al. 2011), causing many communities to require residents to keep trash secured from bears by ordinances. Johnson et al. (2018) found that rates of compliance with such ordinances were the primary factor determining their effectiveness at reducing conflicts between people and bears in Durango. In an effort to improve future behavior change initiatives to encourage use of bear-resistant containers (i.e., “bear-proofing”), we investigated the factors affecting their use among a group of Durango residents who were provided free containers to mitigate garbage-related conflict (Johnson et al.

2018). Specific factors of interest included: attitudes and beliefs about bears and bear-proofing behavior, perceived behavioral control over conflicts, previous experience with conflict, perceived risks and benefits assigned to bears, trust in the management agency, norms, and demographic characteristics.

Methods

Study Area

The city of Durango is located in southwest Colorado, along the Animas River, at an elevation of 1,988 m. The city is surrounded by mountainous public land 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 native crabapple (*Peraphyllum ramosissimum*). There is also extensive agricultural land use in the surrounding area. Durango, with a human population of approximately 18,500 individuals, has grown rapidly since 1970 (U.S. Census Bureau 2017), resulting in increases in anthropogenic foods available to bears. These food sources are concentrated around residential developments, leading to high rates of human-bear conflicts (Baruch-Mordo et al. 2008). In response, the city of Durango implemented an ordinance in 2010 to reduce the availability of anthropogenic food attractants to bears and other wildlife (www.durangogov.org/wildlife). This ordinance requires residents to keep garbage in a locked wildlife-resistant container or a secured location (e.g., garage or shed), except between 6:00 am and 7:00 pm on their scheduled day of garbage pick-up.

This study was part of a larger project designed to experimentally assess the effect of bear-proofing behavior on rates of garbage-related human-bear conflicts in Durango (Johnson et al. 2018). The experiment, conducted between 2011 and 2016, provided bear-resistant garbage

containers, free-of-charge, to each residential parcel (783 residences) within a treatment area in a core residential section (148 ha) at the north end of the city. We canvassed treatment neighborhoods one time each year to remind residents to use their bear-resistant containers and, if conflicts were observed with non-compliant containers, issued warnings to residents of the ordinance and associated fines. As part of this larger effort, from January to April 2014 and 2016, we sent self-administered mail surveys to all residential parcels within the Durango city limits (including but not limited to the treatment area, $N = 5,852$) to assess attitudes and beliefs about bears and human-bear conflict. Data from this full survey were analyzed to determine if respondents were representative of Durango residents and if data weighting was necessary to allow for more accurate generalization of study findings to the population (see “Survey Weighting” section below). For the purposes of the remaining analyses in this paper, the study area is composed only of parcels that received project-supplied garbage containers (i.e., treatment area).

Data Collection

We define compliance with the wildlife ordinance, the behavior of interest in our study, as appropriate use of project-provided bear-resistant garbage containers at parcels in the study area. For a bear-resistant container to be compliant, it had to have both latches on the lid locked and all garbage stored inside the container. To monitor compliance, we directly observed use of the bear-resistant containers, rather than depending on survey-reported behavior, to minimize reporting bias and provide an accurate representation of compliance over time (Baruch Mordo et al. 2009). We monitored compliance monthly from July through September in 2014 and 2016 (3 times/year) on a spatially-balanced, random sample of 40 city blocks (393 parcels). Observations occurred between 5:00 and 6:00 am on the morning of garbage collection, when we assumed the

most garbage would be available to bears. During monitoring, investigators noted the garbage container type (bear-resistant or regular) and compliance status of bear-resistant containers at all parcels on each block. Containers that were not visible or for which the latches were not visible were considered missing data. Each year we calculated a value for the parcel *Compliance rate*, our response variable, by dividing the total number of compliant observations by the number of times at least 1 garbage container was observed at each parcel, resulting in a measure of the proportion of times a household was compliant.

We used two methods to measure the location and frequency of garbage-related conflicts, one based on survey-reported conflicts (*Reported conflict*, methods described in the following section) and the other based on systematic field observations of conflicts (*Observed conflict*). To quantify *Observed conflict*, we recorded the location and frequency of bear-caused garbage conflicts between July and September. Because residents could experience conflicts at any time during the period when bears were active (~June-October) but compliance observations were collected at 3 discrete points between July and September, we used the total number of conflicts experienced in the previous year (2013 and 2015) to ensure that only conflicts experienced prior to specific compliance observations were used in our metric of conflict. Beginning at 5:00 am and ending before garbage collection began (~7:00 am), we drove all residential streets and alleys within the study area scheduled for garbage pickup that day, monitoring for conflicts. We then repeated *Observed conflict* monitoring between 5:00 and 7:00 am the day after garbage collection to increase the potential to observe conflicts. When strewn garbage was observed, we recorded GPS coordinates, type of garbage container, and parcel address of the conflict. Conflict location data were entered into ArcGIS 10.4.

To build our model of *Compliance rate*, we used mail survey responses from the treatment area ($n = 783$). We identified names and addresses from the La Plata County Assessor's tax roll information. We administered the survey using a modified version of the Tailored Design Method (Dillman et al. 2014) with six total mailings. Respondents were offered the option to reply via paper survey or online in each mailing. Non-response bias was assessed with a postcard mailed to individuals who did not return the full survey. The postcard contained a subset of 5 questions measuring conflict-related behaviors (e.g., using a bear-resistant container), attitudes toward bears, and demographics. All survey materials and procedures met the approval of Colorado State University's Institutional Review Board (Protocol #005-17H).

We measured several concepts using multi-item scales, which allowed us to assess latent constructs (a construct that is not directly observable; Devellis 2012). We measured perceived behavioral control, perceived risks and benefits, and trust in the management agency following standard survey research practices described in Zajac et al. (2012; Appendix A2.1). *Personal control* represented perceptions of behavioral control over conflicts (e.g., I can protect my personal property from wildlife), and *Risk* and *Benefit* represented perceived risks (e.g., I fear having an encounter with black bears) and benefits (e.g., the presence of black bears improves the quality of life in Durango) associated with bears. Finally, *Agency trust* (referred to in Zajac et al. [2012] as social trust) represented trust in the management agency (e.g., I am confident Colorado Parks and Wildlife [CPW] can effectively manage black bears). Individual items were measured on a 5-point scale from 1 = strongly disagree to 5 = strongly agree.

We asked respondents to report beliefs about the effectiveness of bear-resistant containers at reducing conflicts (*Perceived effectiveness*), on a 5-point scale from 1 = very ineffective to 5 = very effective. We measured overall attitudes toward bears (*Tolerance*) as the

capacity for people to accept wildlife, by asking respondents to report their preferences for a change in the size of the bear population over a 2-year period, on a 5-point scale from 1 = decrease greatly to 5 = increase greatly, with a midpoint of 3 = stay the same (Riley and Decker 2000, Bruskotter et al. 2015, Struebig et al. 2018). We assumed that the current bear population was above tolerance for individuals desiring a decrease and below tolerance for those desiring an increase.

To quantify *Reported conflict*, we asked survey respondents the number of times over the past 2 years they experienced a bear breaking into their garbage, on a 4-point scale from 1 = 0 times to 4 = > 5 times. In addition to garbage-related conflicts, we also asked residents to report whether they had experienced other bear-related conflicts that threatened the safety of humans, pets, or livestock (i.e., had a bear attack or harass pets or livestock, had a bear break into their home, know someone who was attacked or harassed by a bear, or been attacked or harassed by a bear themselves; Severe conflict) in the previous 2 years. We recoded each of these conflict measures into a binary variable (1 = experienced conflict, 0 = did not experience conflict) and summed across all conflict types.

We measured norms (*Descriptive norms*) by asking respondents, on a binary scale (1 = yes, 0 = no), whether they had observed anyone in their neighborhood using a bear-resistant garbage container in the past 2 years. We measured demographic characteristics by asking respondents to report the year in which they were born (to calculate *Age*), their gender (*Gender*; Reference class = male), and the highest level of education they had completed (e.g., high school diploma or less, some post-secondary education, Bachelor's degree or higher), using fixed response categories (*Education*; Reference class = high school diploma or less). We also asked

respondents to report whether they owned or rented their home (*Homeownership*; 1 = own, 0 = rent).

Survey Weighting

After removing undeliverable addresses ($n_{2014} = 698$, $n_{2016} = 1,117$), our adjusted response rate for the full sample (all Durango residents) was 45% ($n = 2,316$) in 2014 and 45% ($n = 2,432$) in 2016. To determine whether respondents to the full survey were representative of Durango residents, we compared survey data to U.S. Census data for Durango and data from the non-respondent survey. We used t-tests ($p < 0.05$ cutoff) to determine where significant differences existed and weighted responses accordingly (Groves 2006). Homeowners responded to the survey at a rate much higher than renters in both survey years (85% in 2014, 83% in 2016 vs. 49% homeowners in Durango; U.S. Census Bureau 2016). Renters had a higher mean level of compliance than homeowners ($\bar{x}_{own} = 0.37$, $SE_{own} = 0.04$, $\bar{x}_{rent} = 0.48$, $SE_{rent} = 0.03$, $t = 2.46$, $p < 0.05$). As a result, we chose to weight survey data by homeownership to allow for more accurate generalization of study findings to the population (Groves 2006). Weights were calculated using the full set of responses to the survey in 2014 and 2016. We found no other statistically significant differences between respondents and non-respondents ($p > 0.05$).

Data Analysis

Because there was little guidance in the literature on the appropriate distance over which to summarize wildlife conflict for examining its effects on human behavior, we tested relationships between *Observed conflict* and *Compliance rate* for 3 different buffer areas (20 m, 40 m, and 80 m from the parcel boundary), chosen to explore 3 possible scales at which conflict could affect resident behavior. The 20 m buffer approximated conflicts at the resident's parcel and directly across the street from the parcel; the 40 m buffer approximated conflicts at the

parcel, across the street, and at the immediate neighbors; and the 80 m buffer approximated conflicts for the resident's block. Before modeling compliance behavior, we compared univariate models of the effect of the number of conflicts at each buffer distance on *Compliance rate*. The count of conflicts occurring within 80 m of parcel boundaries provided the best fit ($\Delta AIC = 4.36$, $w_i = 0.89$; Appendix A2.2) and was thus retained for further modeling.

To reduce dimensionality of multi-item scales and create a single value for respondent, we used factor analysis to calculate values for *Personal control*, *Risk*, *Benefit*, and *Agency trust*. Because these measures were derived from previously validated scales, we conducted Principal Axis Factoring for each scale (Johnson 1998). We assessed scree plots and eigenvalues to determine the appropriate number of factors to retain (Appendix A2.1; Johnson 1998) and used factor loadings > 0.40 to denote practical significance (Devellis 2012). We compared these findings to those of Zajac et al. (2012) to ensure similarity in concept measurement and confirmed internal consistency with Cronbach's α (Cortina 1993).

We conducted linear regression modeling to test the relative ability of the predictor variables to explain variation in *Compliance rate*. Modeling included only treatment parcels that had received a bear-resistant container and for which we had both compliance observations and a survey response. Because we found no effect of survey year on Compliance rate ($n = 171$, $\beta = 0.02$, $SE = 0.03$, $95\% CI = -0.04 - 0.08$), we combined observations and survey data from 2014 and 2016 into a single dataset. To maintain independence among sampling units (parcels), we randomly excluded surveys from either 2014 or 2016 for each household that returned surveys in both years. We then conducted univariate regressions to examine the effect of each predictor variable on *Compliance rate* (Table 3.1). We identified important explanatory variables as those where 95% confidence intervals (CIs) around regression coefficients did not overlap zero. To

further understand the effect of predictor variables on *Compliance rate*, we built a multivariate model including all variables from the univariate analyses that had 80% CIs which did not overlap zero. Prior to this analysis, we assessed multicollinearity among predictor variables by inspecting bivariate correlations (Pearson's r). Where $r > |0.6|$, we retained the variable with the stronger relationship with Compliance rate based on the univariate analysis. All analyses were conducted in SPSS (version 24.0, Chicago, Illinois).

Results

Respondent Characteristics

Our response rate to the mail survey within the treatment area was 47.5% ($n = 372$) in 2014 and 43.8% ($n = 343$) in 2016; 170 of these households also had compliance observations and were included in results reported in the remainder of this paper. On average, respondents were 51 years old (SE = 0.58, range: 16-95), 55% were male, and a majority (70%) had earned at least a Bachelor's degree. The mean number of *Observed conflicts* across parcels was 2.90 conflicts/block (SE = 0.27, $n = 98$, range: 0-9) in 2013 and 1.30 conflicts/block (SE = 0.14, $n = 108$, range: 0-5) in 2015. In our observations of conflict (*Observed conflict*), 34% of households experienced no conflicts, 32% experienced 1-2 conflicts, 21% experienced 3-4 conflicts, and 13% experienced 5 or more. Nearly 1/3 of survey respondents (32%) reported having zero garbage-related conflicts in the past 2 years (*Reported conflict*), while 33% experienced 1-2 conflicts, 15% experienced 3-4 conflicts, and 17% had ≥ 5 conflicts. Most (83%) had not experienced a *Severe conflict*.

More than half (59%) of respondents reported wanting the bear population near their home to stay the same over the next 2 years (*Tolerance*), while 25% wanted a decrease and 16% wanted an increase. Nearly all respondents (98%) reported using a bear-resistant garbage

container at their home in survey responses. However, our observations showed that 34% of households, in 2014 and 2016, were never compliant with use of bear-resistant containers during our monthly observations (Figure 3.1). Only 24% were compliant across all monthly observations. Despite these patterns, 80% of respondents felt that using bear-resistant garbage containers was very effective at reducing negative interactions with bears.

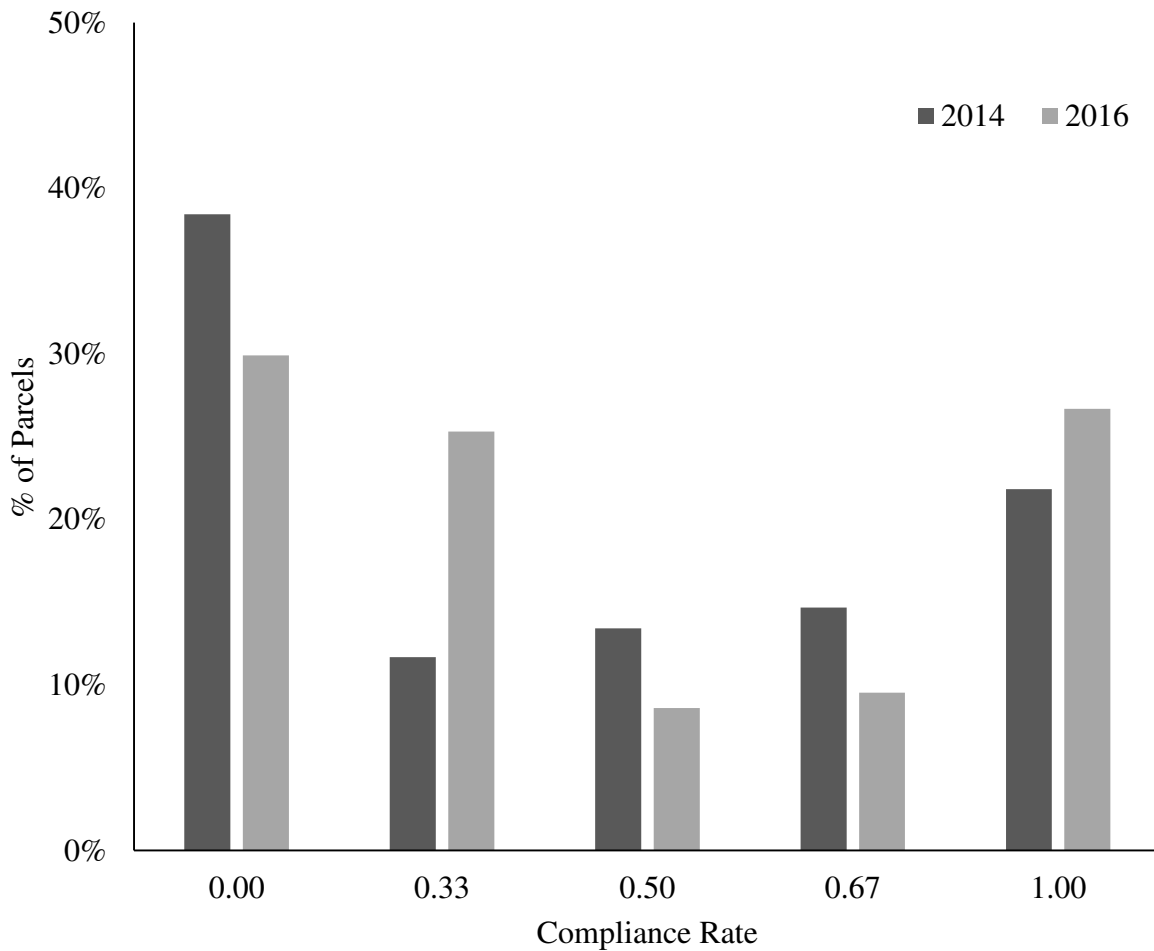


Figure 3.1. Histogram of *Compliance rate* observed in Durango, Colorado, 2014 and 2016 ($n = 206$), calculated as the proportion of compliant a maximum of 3 monthly observations each summer

Compliance Modeling

To improve scale reliability, we removed 2 items from the *Risk* and 3 from the *Personal control* scales (Supplementary Information). With these modifications, all scales except *Personal control* exhibited high internal consistency (Cronbach's $\alpha > 0.60$; Cortina 1993). The factor analysis results offered further confirmation for hypothesized item groupings, with all factor loadings > 0.40 for all scales.

Of the residences where we observed use of bear-resistant containers within the treatment area, 170 households returned surveys in 2014 and/or 2016 ($n = 240$ completed surveys). Where the same residence returned both surveys ($n = 71$), we randomly removed one to maintain independence, for an adjusted total of 169 responses ($n_{2014} = 82$, $n_{2016} = 89$).

In univariate models of *Compliance rate*, we found that *Observed conflict*, *Agency trust*, *Risk*, *Benefit* and *Homeownership* were important predictors (Table 3.1). Individually, these variables explained 3-7% of variation in compliance. Individuals who perceived greater risks associated with bears (*Risk*) and who had experienced more conflicts (*Observed conflict*) had higher rates of compliance. In contrast, homeowners (*Homeownership*), respondents who were more trusting of CPW (*Agency trust*), and those who perceived greater benefits associated with bears (*Benefit*) were less compliant.

Table 3.1. Results of univariate linear regressions of factors affecting compliance with the use of bear-resistant garbage containers in Durango, Colorado, USA¹. ¹ The dependent variable is *Compliance rate*, ² 80% CI does not overlap zero, ³ 95% CI does not overlap zero,⁴ Reference class = Renter, ⁵ Reference class = Male, and ⁶ Reference class = High school diploma or less.

Variable	n	B	S.E.	95% CIs		r ²
				Lower	Upper	
<i>Observed conflicts</i> ^{2,3}	169	0.04	0.01	0.02	0.07	0.07
<i>Agency trust</i> ^{2,3}	125	-0.09	0.03	-0.15	-0.02	0.05
<i>Risk</i> ^{2,3}	136	0.07	0.03	0.01	0.13	0.03
<i>Homeownership</i> ^{2,3,4}	161	-0.17	0.06	-0.29	-0.04	0.04
<i>Benefit</i> ^{2,3}	151	-0.08	0.03	-0.15	-0.02	0.04
<i>Descriptive norm</i> ^{2,3}	160	0.23	0.16	-0.08	0.55	0.01
<i>Gender</i> ^{2,5}	154	0.10	0.06	-0.03	0.22	0.01
<i>Education</i> ⁶	167					0.02
Some post-secondary		0.13	0.10	-0.08	0.34	
Bachelor's degree or higher		0.01	0.10	-0.17	0.20	
<i>Tolerance</i>	150	-0.04	0.04	-0.11	0.03	0.01
<i>Perceived effectiveness</i>	158	-0.05	0.07	-0.19	0.08	0.00
<i>Reported conflict</i>	166	0.02	0.26	-0.03	0.07	0.00
<i>Personal control</i>	142	-0.02	0.03	-0.08	0.05	0.00
<i>Severe conflict</i>	168	0.02	0.08	-0.14	0.17	0.00

Agency trust, Observed conflict, Risk, Benefit, Homeownership, Gender, and Descriptive norms had 80% confidence intervals from univariate regressions that did not overlap zero and were therefore included in the multivariate model of compliance (Table 3.1). Because *Risk* and *Benefit* were correlated ($r = 0.69$, Appendix A2.3), we retained *Benefit*, and excluded *Risk*, in our multivariate model as *Benefit* had the stronger univariate relationship with *Compliance rate*. *Education, Tolerance, Perceived effectiveness, Reported conflict, Personal control, and Severe conflict* had 80% CIs that overlapped zero, and were excluded from the multivariate model.

The multivariate model explained 28% of variation in *Compliance rate*. In this model, *Agency trust*, *Benefits*, and *Observed conflict* had 95% CIs that did not overlap zero, (Table 3.2). Higher levels of trust in the management agency and greater perceived benefits of bears were associated with lower rates of compliance. In response to items in our scale measuring *Agency trust*, more households that were never compliant (84%) agreed that CPW responded appropriately to human-bear conflicts than households that were compliant at least once (68%). Likewise, 82% of households that were never compliant felt that CPW listened to residents regarding bear management, whereas only 63% of compliant respondents felt the same. Similarly, while nearly equal proportions of respondents expressed concern about human-bear conflicts, 57% of respondents who reported higher than average scores *Benefits* rated current management of conflicts as above average or excellent, compared to 28% of respondents who had below average scores on *Benefit*. In contrast, higher compliance rates were related to more *Observed Conflicts* on a respondent's block. Compliant households experienced a mean of 2.43 conflicts/parcel (SE = 0.19, $n = 137$, range: 0-9) while non-compliant households experienced a mean of 1.35 conflicts/parcel (SE = 0.60, $n = 70$, range: 0-9).

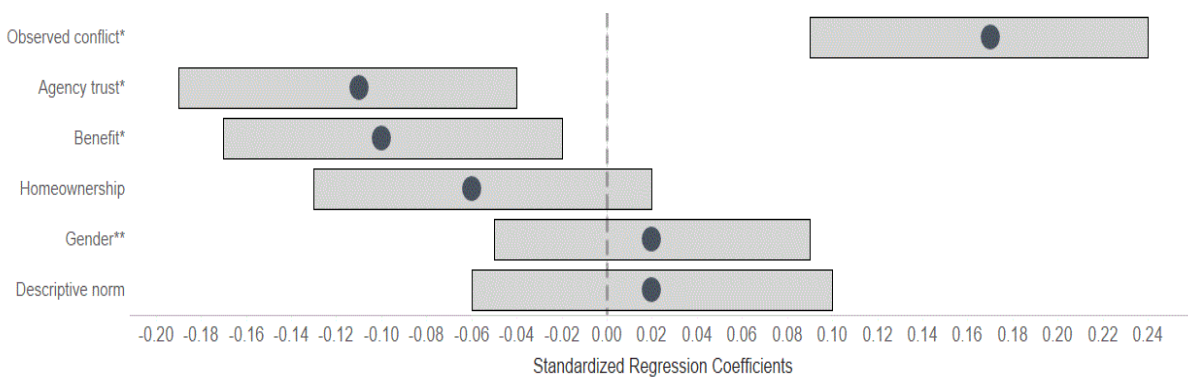


Figure 3.2. Standardized regression coefficients (with 95% CIs) of multivariate model of compliance behavior in Durango, Colorado, USA ($n = 157$)¹. ¹ The dependent variable is *Compliance rate*, and * 95% CI does not overlap zero.

Table 3.2. Model parameters for multivariate model ($n = 107$) of use of bear-resistant garbage containers in Durango, Colorado, USA collected from surveys and behavioral observations in 2014 and 2016.¹ R^2 value was 0.28. ¹ The dependent variable is *Compliance rate*.

² 95% CI does not overlap zero, and ³ Reference class = Male.

Variable	Unstandardized β	Standardized Values			
		β	SE	95% CIs	
				Lower	Upper
Intercept	0.28	0.49	0.04	0.42	0.56
<i>Agency trust</i> ²	-0.11	-0.11	0.04	-0.19	-0.04
<i>Observed conflict</i> ²	0.07	0.17	0.04	0.09	0.240
<i>Benefit</i> ²	-0.10	-0.10	0.04	-0.17	-0.02
<i>Homeownership</i>	-0.12	-0.06	0.04	-0.13	0.02
<i>Gender</i> ³	0.05	0.02	0.04	-0.05	0.09
<i>Descriptive norm</i>	0.09	0.02	0.04	-0.06	0.10

Discussion

Managers and conservation practitioners often suggest that employing education efforts will motivate action to decrease human-wildlife conflicts and strongly advocate for their use (e.g., Marley et al. 2017). These recommendations are typically based on the assumption that if individuals are exposed to messages increasing their knowledge of how to reduce conflicts, they will act accordingly. However, there is considerable evidence that this “knowledge fix” rarely motivates behavior change if not informed by knowledge of the specific audience and context (Schultz 2011). We found that previous conflicts incurred by individuals and their neighbors, beliefs about the benefits of bears, and trust in the management agency affected people’s use of bear-resistant garbage containers. As a result, we suggest that behavior change campaigns which acknowledge and appeal to these motivations will yield greater effects on encouraging bear-proofing behavior (McKenzie-Mohr 2011).

The strongest influence on compliance in our multivariate model was the experience of conflict with bears on one's block, measured by direct observation. More frequent conflicts are likely to increase residents' perceptions of the likelihood of future conflict, which are key to determining perceptions of overall risk of human-bear conflicts, along with beliefs about the outcomes of conflicts for people (Slovic 1987). The outcomes of human-wildlife conflicts can motivate conflict-reducing behaviors (Kahler & Gore 2012, 2013), including reporting human-black bear conflicts to management agencies (Wilbur et al. 2018), and we found a similar pattern in the influence of conflicts on bear-proofing. However, the number of conflicts residents reported on surveys was not an important predictor of use of bear-resistant containers, indicating that exposure to conflict is more important to determining bear-proofing behavior than people's memory of them. To use this information to guide behavior change efforts, nuance in the framing of messages will be necessary. For example, conventional "Bear Aware" messages that focus on the risk to bears of foraging in human-dominated areas have done little to encourage bear-proofing behaviors (Gore et al. 2008, Baruch-Mordo et al. 2011). Our findings suggest that messages emphasizing the role of bear-proofing in limiting negative outcomes of conflicts for people, such as potential threats to human safety, may be more effective than conventional messages at motivating compliance. Evaluation of the outcomes of these changes to messaging will be critical to assessing the effectiveness of these actions (Gore et al. 2008).

We also found that increased trust in the wildlife management agency was associated with reduced rates of compliance. Individuals who reported high levels of trust were more likely to believe that CPW is both capable of and currently executing appropriate management of bears and conflicts. As a result, these individuals may believe that their own actions to reduce conflicts are unnecessary. Therefore, trust may reflect an external locus of control regarding

human-bear conflict, where individuals believe that institutional response is more effective at reducing conflict than individual actions, and that managers are capable of addressing conflicts with institutional actions alone. While we do not advocate that managers attempt to directly modify trust, messages that clarify the critical role of individual action in limiting conflict in residential settings may motivate use of bear-resistant garbage containers. By further tying agency capacity to address conflict to individual actions, the impact of behavior change efforts may be increased.

Previous research exploring bear-proofing behavior has been guided by the Theory of Planned Behavior (TPB) and focused on the importance of attitudes in determining support for risk-reducing behaviors (e.g., Gore et al. 2008, Don Carlos et al. 2009). As predicted by the TPB, we found that perceptions of benefits attributed to bears was associated with appropriate use of bear-resistant containers, although, perhaps surprisingly, we found that individuals who perceived greater benefits from bears were less likely to secure their garbage. Perceptions of benefits were most strongly influenced by the impact of bears on the quality of life for people and the quality of the environment in the area where respondents reside (Appendix 6). Further, perceived benefits have a strong influence on tolerance for bears (Lischka et al. *In review*). Therefore, we suspect that residents with high perceived benefits feel that conflicts are not a major concern for them and may therefore be less motivated to take action to reduce their own probability of conflicts. Modifications of conventional messaging to focus on the potential for reductions in conflict to help maintain the positive benefits of bears to communities and ecosystems (e.g., maintaining bear populations for hunting and viewing, reduced need for lethal removal of bears) may help motivate these individuals to more regularly secure trash from bears.

While we found evidence to support the influence of some attitudes (*Benefits, Agency trust*) on use of bear-resistant containers, we found limited evidence of the influence of other attitudes (*Tolerance, Perceived effectiveness, Personal control*). These findings support recent calls by social scientists to look beyond efforts to change attitudes to modify human behavior, as changes in attitude alone may not be a strong enough influence to cause individuals to act to reduce human-wildlife conflicts (Schultz 2011). Intervening factors such as structural barriers to action (e.g., the cost of bear-resistant containers, living in an apartment building where garbage containers are provided, inability to procure a bear-resistant containers) may curtail behaviors, despite positive attitudes (McKenzie-Mohr 2011). Thus, behavior change efforts that focus on attitudes toward conflict-reducing behaviors may be necessary to increase the number of people willing to bear-proof, but may not be sufficient to improve rates of behavior adoption (Schultz 2011).

Social norms can be a strong influence on behaviors, suggesting that the creation and propagation of norms could be an effective way to modify human action (Cialdini 1991). While our results suggest that conflicts at neighboring parcels affect behavior, our assessment did not identify descriptive norms (observations of others keeping garbage secured from bears) as an important influence. Because norms are less well studied than attitudinal factors (St. John et al. 2010), and measures have been operationalized in different ways across social science disciplines, there is a need for greater clarity on the content of measures used to quantify normative influence. In addition, given our experiment provided bear-resistant containers to residents, there was little variation in whether residents had seen others using bear-resistant containers in our study. Future work would be improved by assessing innovative measures of

broad normative influence, exploring who creates and reinforces those norms, and assessing the ability of these measures to affect behaviors (St. John et al. 2010).

Our effort to explore motivations for bear-proofing behavior offers guidance on how behavior change efforts can be improved. However, additional research is needed to refine our knowledge of motivators, as well as efforts to increase adoption within communities. Our sample size was constrained by the number of households we could actively monitor for compliance behavior before garbage pick-up commenced and by response rates to mail survey, limiting statistical power to examine the influence of some variables such as home ownership. Further, appropriate use of bear-resistant containers was difficult to observe. For example, during 2014 compliance monitoring, there were up to 213 households (of 393 observed) at which garbage containers were not visible during a single round of observations, leaving it unclear whether garbage was stored in a manner that left garbage available to bears, but out of view of observers, or whether garbage was secured from bears in a garage or shed. Efforts to increase survey response or improve methods for behavioral observations may have yielded larger sample sizes and further insights into a more complete range of bear-proofing behaviors. Future research could be improved by assessing the importance of long-term exposure to bear conflicts and habit formation, as well as the influence of perceived responsibility for conflict management. Further, while the number of conflicts on a block was an important motivator for compliance behavior, these data can be expensive and complicated to collect. Widely available spatial and ecological variables that may influence conflict rates, such as distance to water and the wildland-urban interface, may be useful proxies of conflict and, by extension, compliance behavior. Finally, in our work, we removed a significant barrier to bear-proofing by providing bear-resistant garbage containers, free-of-charge, to residents. In many communities facing high

levels of human-bear conflicts, this will not be financially or logistically feasible. Therefore, an exploration of the barriers to securing a container will allow communities to address this critical precursor to bear-proofing.

Using a unique combination of survey and observation data, we were able to evaluate the relative influence of cognitive, risk-based, and broader-level factors hypothesized to influence human behavior. Our assessment provides insights into the drivers of compliance behavior based on psychological theory and observations of human behavior. Approaches to behavior change that use this information to motivate actions will be a critical real-world test of the utility of understanding motivations to increase compliance with local ordinances (Osbaldiston 2013). Given our results, we suggest that management agencies may increase the use of bear-resistant containers using messages that emphasize the role of bear-proofing in limiting negative outcomes of human-bear conflicts to people, link successful management of conflicts to individual actions, and emphasize how reducing conflict could maintain benefits provided by bears. We suggest that application and evaluation of behavior change efforts guided by social science information like that described here will improve the long-term success of efforts to address human-wildlife conflicts.

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APPENDIX 1

Supporting information on calculation of predictor variables for models of Tolerance

Table A1.1. Items included in Impacts model of tolerance for black bears ($n = 747$). Results from “Living with black bears in Durango” survey, conducted January–April 2014 in Durango, Colorado, USA. Respondents were asked to report whether they had experienced the listed impacts, and whether they thought the impacts were important. Tables report settings in which impacts could occur: (a) impacts occurred around home, (b) impacts occurred in town, and (c) impacts occurred in a natural area outside town.

(a) Around home

Impacts	Percent Identified
Positive Impacts	
Feel excited about seeing a wild animal when I see a bear around home.	54%
Feel that the area where I live is good wildlife habitat when I see a bear around home.	51%
Feel connected to nature when I see a bear around home.	50%
Feel confident that black bear hunting in this area will be good when I see a bear around home.	13%
Negative Impacts	
Worry that a black bear will be killed by CPW when I see a bear around home.	48%
Feel concerned that black bears are acting in unnatural ways when I see a bear around home.	35%
Worry that a black bear will be killed by a hunter when I see a bear around home.	23%
Worry about my pets or animals being attacked by a black bear when I see a bear around home.	20%
Worry about me or my family being attacked by a black bear when I see a bear around home.	18%
Feel upset that humans are living in black bear habitat when I see a bear around home.	14%
Worry about the cost of damage to my garden or trees from black bears when I see a bear around home.	14%
Worry about a black bear breaking into my garbage when I see a bear around home.	15%
Worry about the hassle dealing with damage to garden or trees when I see a bear around home.	13%
Worry about the cost of damage to my home, vehicle or property when I see a bear around home.	14%

Worry about hassle of dealing with damage to home, vehicle or property when I see a bear around home.	13%
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(b) In town

Impacts	Percent Identified
Positive Impacts	
Feel excited about seeing a wild animal when I see a bear in town.	50%
Feel that the area near where I live is good wildlife habitat when I see a bear in town.	45%
Feel connected to nature when I see a bear in town.	43%
Feel confident that black bear hunting in this area will be good when I see a bear in town.	13%
Negative Impacts	
Worry that a black bear will be killed by CPW when I see a bear in town.	50%
Feel concerned that black bears are acting in unnatural ways when I see a bear in town.	37%
Worry that a black bear will be killed by a hunter when I see a bear in town.	23%
Worry about me or my family being attacked by a black bear when I see a bear in town.	16%
Worry about my pets or animals being attacked by a black bear when I see a bear in town.	18%
Worry about the cost of dealing with damage to my garden or trees from black bears when I see a bear in town.	15%
Worry about a black bear breaking into my garbage when I see a bear in town.	14%
Worry about the hassle dealing with damage to my garden or trees from black bears when I see a bear in town.	14%
Worry about the cost of dealing with damage to my home, vehicle or property from bears when I see a bear in town.	14%
Worry about the hassle dealing with damage to my home, vehicle or property from bears when I see a bear in town.	13%
Feel upset that humans are living in black bear habitat when I see a bear in town.	15%

c) Natural area outside town

Impacts	Percent Identified
Positive Impacts	
Feel that the area near where I live is good wildlife habitat when I see a bear in a natural area outside town.	59%
Feel connected to nature when I see a bear in a natural area outside town.	56%
Feel excited about seeing a wild animal when I see a bear in a natural area outside town.	54%
Feel confident that black bear hunting in this area will be good when I see a bear in a natural area outside town.	14%
Negative Impacts	
Worry that a black bear will be killed by CPW when I see a bear in a natural area outside town.	22%
Feel concerned that black bears are acting in unnatural ways when I see a bear in a natural area outside town.	17%
Feel upset that humans are living in black bear habitat when I see a bear in a natural area outside town.	16%
Worry that a black bear will be killed by a hunter when I see a bear in a natural area outside town.	12%
Worry about my pets or animals being attacked by a black bear when I see a bear in a natural area outside town.	10%
Worry about me or my family being attacked by a black bear when I see a bear in a natural area outside town.	9%

Table A1.2. Items included in scale measures for Psychological model of acceptance capacity for black bears. Results from “Living with black bears in Durango” survey, conducted January–April 2014 in Durango, Colorado, USA. Items included in *Benefit*, *Risk*, *Social trust*, *Personal control*, and *Social value similarity* variables were measured on a 5-point Likert scale, where 1 = strongly disagree and 5 = strongly agree. Factor analysis was used to calculate single values for each scale variable based on each respondent’s pattern of responses. Cronbach’s $\alpha > 0.60$ indicates high internal consistency in multi-item scales.

Variable	Items in Scale	Factor Loading	Chronbach’s α
Benefit	The presence of black bears improves the quality of life in Durango.	0.87	0.78
	Black bears improve the health of the environment in the Durango area.	0.86	
	Black bears living in this area are an inconvenience. (Reverse coded)	0.73	
	Black bears provide recreational opportunities for many Durango-area residents.	0.64	
Risk	I fear having an encounter with black bears.	0.73	0.70
	Encounters with black bears are likely to result in serious injuries or human deaths.	0.72	
	I am vulnerable to the risks posed by black bears.	0.68	
	Black bears will be more of a problem for Durango in the future.	0.64	
	Conflict with black bears will be reduced if people learn to live with bears. (Reverse coded)	0.59	
	I can prevent conflicts with black bears by making changes around my home. (Reverse coded)	0.43	
	I am not familiar with the risks posed by black bears.	Removed from analysis	
	All residents of Durango are equally exposed to conflicts with black bears.	Removed from analysis	
Social Trust	I am confident CPW knows how to use appropriate methods to manage black bears.	0.94	0.93
	I am confident CPW responds appropriately to black bear conflicts.	0.91	
	I am confident CPW will listen to concerns about black bear management from ordinary people.	0.90	

	I am confident CPW can effectively manage black bears.	0.90	
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Personal Control	I can have an influence on wildlife management decisions.	0.51	0.56
	I have the ability to protect my property from wildlife.	0.43	
	I have very little ability voice my opinions regarding wildlife management. (Reverse coded)	0.41	
	Whether or not I have a conflict with a black bear is mostly a matter of luck.	Removed from analysis	
	Black bear conflicts are not a matter of luck, but rather result from bad personal decisions. (Reverse coded)	Removed from analysis	
Social Value Similarity	When it comes to bear management, I believe CPW shares values similar to mine.	0.97	0.97
	When it comes to bear management, I believe CPW shares opinions similar to mine.	0.97	
	When it comes to bear management, I believe CPW shares goals similar to mine.	0.95	
	When it comes to bear management, I believe CPW takes actions similar to those I would.	0.92	

Table A1.3. Items included in scale measures for Values model of tolerance for black bears. Results from “Living with black bears in Durango” survey, conducted January–April 2014 in Durango, Colorado, USA. *Domination* and *Mutualism* items were measured on a 7-point Likert scale, where 1 = strongly disagree and 7 = strongly agree. Cronbach’s $\alpha > 0.60$ indicates high internal consistency in multi-item scales.

Variable	Items in scale	Cronbach’s α
Domination	<i>Appropriate Use Beliefs</i>	0.76
	Humans should manage wildlife populations so that humans benefit.	
	The needs of humans should take priority over wildlife protection.	
	Wildlife are on earth primarily for people to use.	
	<i>Hunting Beliefs</i>	
	Hunting does not respect the lives of animals. (Reverse coded)	
	People who want to hunt should be provided the opportunity to do so.	
	We should strive for a world where there’s an abundance of wildlife for hunting and fishing.	
	Hunting is cruel and inhumane to animals. (Reverse coded)	
Mutualism	<i>Social Affiliation Beliefs</i>	0.86
	Animals should have rights similar to the rights of humans.	
	I view all living things as part of one big family.	
	Wildlife are like my family and I want to protect them.	
	We should strive for a world where humans and wildlife can live side by side without fear.	
	<i>Caring Beliefs</i>	
	I care about animals as much as I do other people.	
	I feel a strong emotional bond with animals.	
	I value the sense of companionship I receive from animals.	

Table A1.4. Correlations (Pearson’s r) among predictor variables in global model of *Tolerance*. Results from “Living with black bears in Durango” survey, conducted January–April 2014 in Durango, Colorado, USA. Items with $r > 0.5$, were subject to further multicollinearity diagnostics.

	Benefit	Risk	Social Trust	Social Value Sim.	Personal Control	Domin.	Mutual.	Safety Conflicts	Nuisance Conflicts	Positive Impacts	Negative Impacts	Gender	Age	Edu.
Benefit	1													
Risk	-0.61	1												
Social trust	0.24	-0.24	1											
Social value sim.	0.26	-0.31	0.69	1										
Personal control	0.32	-0.37	0.44	0.53	1									
Domin.	-0.30	0.37	-0.06	-0.09	-0.18	1								
Mutual.	0.33	-0.30	0.14	0.24	0.31	-0.56	1							
Safety conflicts	-0.29	0.41	-0.17	-0.28	-0.34	0.21	-0.18	1						
Nuisance conflicts	-0.17	0.26	-0.22	-0.23	-0.21	0.12	-0.06	0.30	1					
Positive impacts	0.17	-0.03	-0.05	0.01	0.08	-0.10	0.09	0.05	0.10	1				
Negative impacts	-0.32	0.44	-0.19	-0.22	-0.24	0.05	-0.02	0.30	0.26	0.23	1			
Gender	-0.08	-0.02	0.06	0.06	0.11	-0.27	0.19	-0.10	0.02	0.04	0.18	1		
Age	-0.26	0.29	0.01	-0.06	-0.10	0.11	-0.08	0.04	-0.01	-0.15	0.02	0.03	1	
Edu.	0.13	-0.07	-0.03	-0.04	0.01	-0.06	-0.02	-0.01	0.05	0.01	0.03	0.05	-0.03	1

Table A1.5. Linear regression models of factors affecting tolerance for black bears in the vicinity of Durango, Colorado, USA ($n=747$). Results are from the “Living with black bears in Durango” survey, conducted January-April, 2014. Response variables were tolerance, measured as the desired change in the bear population in Durango in the next 2 years, where 1 = decrease greatly and 5 = increase greatly. *Gender* and *Education* were categorical variables, while all other variables were continuous. We selected among models based on Akaike’s Information Criterion (AIC) and Pearson’s adjusted R^2 statistics. The Global model explained the greatest proportion of variation (46%) in *Tolerance* and offered the best fit to the data. Of the *a priori* models, the Psychological model (43%), Impacts model (19%), Values model (15%), Conflict model (8%), and Demographic model (6%) had decreasing ability to explain *Tolerance*. For each of these models, Δ AIC values were >30 from the top model, indicating substantially less empirical support for the models. † Reference class = Male, and ‡ Reference class = Less than high school diploma.

Model	Variables	AIC	Δ AIC	R^2
Global	Benefit, Risk, Social value similarity, Social trust, Personal control, Positive impacts, Negative impacts, Domination, Mutualism, Nuisance conflicts, Safety conflicts, Age, Gender, Education	-519.01	0	0.46
Psychological	Benefit, Risk, Social value similarity, Social trust, Personal control	-488.61	30.40	0.43
Impacts	Positive impacts, Negative impacts	-232.99	286.02	0.19
Values	Domination, Mutualism	-203.81	315.20	0.15
Conflict	Nuisance conflicts, Safety conflicts	-141.46	377.55	0.08
Demographic	Age, Gender, Education	-148.91	370.10	0.06

APPENDIX 2

Supporting information about modeling of *Compliance rate*.

Table A2.1. Items included in questionnaires used to develop scale measures for models of compliance behavior. ¹ measured on a 5-point Likert scale, where 1 = strongly disagree and 5 = strongly agree, ² Principal Axis Factoring, ³ Cronbach's $\alpha > 0.6$ indicates high internal consistency, and ⁴ Value presented is Pearson's *r* correlation, appropriate for 2-item scales, rather than Cronbach's alpha.

Variable	Items in Scale ¹	2014		2016	
		Factor Loading ²	Cronbach's α^3	Factor Loading ²	Cronbach's α^3
<i>Benefit</i>	The presence of black bears improves the quality of life in Durango.	0.87	0.78	0.88	0.78
	Black bears improve the health of the environment in the Durango area.	0.86		0.85	
	Black bears living in this area are an inconvenience. (Reverse coded)	0.73		0.72	
	Black bears provide recreational opportunities for many Durango-area residents.	0.64		0.66	
<i>Risk</i>	I fear having an encounter with black bears.	0.73		0.65	
	Encounters with black bears are likely to result in serious injuries or human deaths.	0.72		0.67	
	I am vulnerable to the risks posed by black bears.	0.68		0.68	
	Black bears will be more of a problem for Durango in the future.	0.64		0.63	
	Conflict with black bears will be reduced if people learn to live with bears. (Reverse coded)	0.58		0.59	

	I can prevent conflicts with black bears by making changes around my home. (Reverse coded)	0.42		0.50	
	I am not familiar with the risks posed by black bears.	Removed from analysis		Removed from analysis	
	All residents of Durango are equally exposed to conflicts with black bears.	Removed from analysis		Removed from analysis	
<i>Agency trust</i>	I am confident CPW knows how to use appropriate methods to manage black bears.	0.94	0.93	0.93	0.94
	I am confident CPW responds appropriately to black bear conflicts.	0.92		0.93	
	I am confident CPW will listen to concerns about black bear management from ordinary people.	0.91		0.92	
	I am confident CPW can effectively manage black bears.	0.90		0.91	
<i>Personal control</i>	I can have an influence on wildlife management decisions.	0.81	0.56	0.83	0.38 ⁴
	I have the ability to protect my property from wildlife.	0.70		0.83	
	I have very little ability voice my opinions regarding wildlife management. (Reverse coded)	0.68		Removed from analysis	
	Whether or not I have a conflict with a black bear is mostly a matter of luck.	Removed from analysis		Removed from analysis	
	Black bear conflicts are not a matter of luck, but rather result from bad personal decisions. (Reverse coded)	Removed from analysis		Removed from analysis	

Table A2.2. Model parameters for univariate models ($n = 93$) of the effect of measures of conflicts per parcel on compliance behavior in Durango, Colorado, USA collected conflict and behavioral observations (2013-2016)¹. ¹ The dependent variable is *Compliance rate*, and ² measured from the parcel boundary and including the parcel area.

Buffer distance (m) ²	AIC	ΔAIC	K	w_i	r^2
80 m	-460.97	0	1	0.89	0.04
40 m	-456.61	4.36	1	0.10	0.02
20 m	-452.05	8.92	1	0.01	0.02

Table A2.3. Correlations (Pearson's r) among predictor variables in model predicting *Compliance rate* ($n = 94$).

	Agency trust	Obs. conflict	Risk	Home own.	Benefit	Descr. norm	Education (< HS)	Education (some post-sec.)	Education (> Bachelor)	Gender	Tolerance	Perceived effect.	Reported conflict	Tolerance	Severe conflict
Agency trust	1.00														
Obs. conflict	0.09	1.00													
Risk	-0.03	0.16	1.00												
Home own.	0.02	-0.30	0.17	1.00											
Benefit	0.08	0.13	-0.69	-0.24	1.00										
Descr. norm	-0.04	-0.07	0.25	0.10	0.02	1.00									
Edu. (< HS)	0.14	0.15	0.25	0.00	-0.10	0.04	1.00								
Edu. (some post-HS)	-0.07	0.30	-0.18	-0.11	0.09	-0.26	-0.14	1.00							
Edu. (> Bach.)	0.01	-0.35	0.04	0.07	-0.04	0.22	-0.34	-0.86	1.00						
Gender	-0.05	0.05	0.12	-0.12	0.01	0.12	0.12	-0.43	0.35	1.00					
Tolerance	-0.07	0.02	-0.57	-0.28	0.62	-0.02	-0.20	0.07	0.02	-0.09	1.00				
Perceived effect	0.00	-0.05	-0.15	-0.07	0.14	-0.07	0.09	-0.25	0.19	0.15	0.11	1.00			
Reported conflict	-0.27	-0.18	0.01	0.01	-0.07	0.05	-0.18	-0.09	0.18	-0.17	0.12	0.15	1.00		
Personal control	0.34	-0.08	-0.30	-0.30	0.28	0.13	-0.15	-0.34	0.38	0.30	0.24	0.21	0.01	1.00	
Severe conflict	-0.01	-0.06	0.26	0.21	-0.18	0.06	0.00	-0.09	0.05	-0.20	-0.15	-0.09	0.21	0.13	1.00