University of Alberta

Applications of learning theory to human-bear conflict: the efficacy of aversive conditioning and conditioned taste aversion

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

Master of Science

in

Ecology

Department of Biological Sciences

Spring 2011
Edmonton, Alberta

Examining Committee

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ABSTRACT

I tested the efficacy of aversive conditioning (AC) and conditioned taste aversion (CTA) on American black bears (*Ursus americanus*) in Whistler, British Columbia. Black bears subjected to 3-5 day AC programs responded by increasing their wariness toward humans, while control bears habituated. Bears were located closer to human developments during daylight hours after AC treatments. However, there was no difference in the proportion of utilization distribution that overlapped with developed areas in control or AC-treated bears. CTA may be effective for managing specific attractants that are difficult to secure from bears. Bears appeared to distinguish between baits treated with thiabendazole and baits that were not treated, but by using a protocol that caused severe illness and left the source of illness in doubt, I induced taste aversions to apples in 4 bears. Using both AC and CTA may help wildlife managers mitigate human-wildlife conflicts non-lethally more effectively.

ACKNOWLEDGEMENTS

This project was possible through the support of many people and organizations. The BC Conservation Officer Service, BC Conservation Foundation, Get Bear Smart Society, Resort Municipality of Whistler, Mountain Equipment Coop, Whistler-Blackcomb, Carney's Waste Systems, Ziptrek Ecotours, Bee-Maid Honey, NSERC, Whistler Community Fund, Shell Friends of the Environment, and TD Canada Trust supported the project financially or with in-kind donations.

Several people stand out for their dedication to this project. I thank my supervisor, Colleen Cassady St. Clair, for her ideas, wisdom and friendship. Thanks also to my committee members, Andrew Derocher and Peter Hurd. Many people assisted with field support, including Claire Edwards, Nicola Brabyn and Mary von der Porten. Conservation officers, Rob Groeger, Dean Miller, Drew Milne and Simon Gravel and full-time officers Chris Doyle and Dave Jevons captured bears and participated in aversive conditioning programs. I also thank Tony Hamilton from the government of BC, Sandra Smith and Heather Beresford from the Resort Municipality of Whistler, and Sylvia Dolson from the Get Bear Smart Society. Charlene Nielson helped immensely with GIS analysis, and Carrie Hunt provided the basis for bear shepherding practices.

I am especially grateful for the support of my parents, Reid and Jean Homstol. I also thank my dog, Sisko, for helping us catch bears by scent tracking when they refused to enter culvert traps. Lastly, I thank my study animals, especially those who lost their lives due to human-bear conflict

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CHAPTER ONE: INTRODUCTION

OVERVIEW OF HUMAN-WILDLIFE CONFLICT AND APPLICATIONS OF LEARNING THEORY

Human-wildlife conflict is a conservation and economic issue around the globe. Conflicts between humans and wildlife occur any time the actions of humans or wildlife inflict a negative impact on the other (Conover 2002). Conflicts with wildlife can be costly for humans when wildlife spread disease, kill livestock, compete with people for game animals, raid crops, and when they attack (Thirgood *et al.* 2005). However, conflicts are usually more costly to wildlife than to humans due to loss of habitat as land is developed, and through lethal control, especially with large predators (Woodroffe *et al.* 2005).

In North America, conflicts between large carnivores and humans have been increasing as human population grows (Spencer *et al.* 2007). Bear managers in British Columbia kill approximately 850 black bears (*Ursus americanus*) and 50 grizzly bears (*Ursus arctos*) annually because of human-wildlife conflict (M. Badry, BC Wildlife Conflicts Prevention Coordinator, personal communication.). Despite this, lethal management of bears can be problematic. The general public is often unsupportive of lethal bear management, and increasingly requests that non-lethal management is attempted before resorting to lethal means (Beckman *et al.* 2004**,** Koval and Mertig 2004). Additionally, lethal management may be inappropriate for species or populations that are endangered or in decline.

Although black bears are not a conservation concern in British Columbia, in some parts of their range, particularly in the southern United States and northern Mexico, black bears are a protected species (IUCN 2010).

Regardless of conservation status, reducing human-bear conflicts is important for human safety. Bears often adapt to high levels of human activity through habituation, decreasing their response to those activities that have no negative consequences (Herrero *et al.* 2005). Bears benefit from habituation through increased available habitat, but habituation can be detrimental by increasing the risk of food conditioning and subsequent removal by managers (Herrero *et al.* 2005). Once a bear is food conditioned, it has learned a positive association between humans and food, and human safety becomes a concern (Hopkins *et al.* 2010). Wildlife managers usually remove the bear either by translocating it or killing it; however, many jurisdictions are making efforts to manage bears non-lethally (Koval and Mertig 2004, Spencer *et al.* 2007).

One of the more common non-lethal management tools is aversive conditioning (AC). AC typically uses punishment to reduce an undesirable behaviour (Blood *et al*. 2007). Following specific guidelines can maximize the effectiveness of AC: punishment is most effective when it is applied immediately, consistently, more intensely initially, and without contingencies signaling its application (Domjan 2006). Additionally, rewarding alternative behaviour and ensuring the punishment is evolutionarily relevant improve efficacy (Domjan 2006). Research on other mammals has shown that animals easily form associations between pain stimuli and a sound cue, and between taste stimuli and nausea (Garcia *et al.* 1974). However, mammals do not easily form associations between stimuli that are not evolutionarily relevant such as between sound and nausea, or between food and pain (Garcia *et al.* 1974).

This principle, termed the Garcia Principle, would predict that using pain stimuli (e.g. rubber bullets fired from a shotgun) should not deter bears from eating garbage or other attractants, but could make bears more wary of humans. For bears to learn to avoid food items, the Garcia Principle would support the use of conditioned taste aversion (CTA), which occurs when an animal consumes a nausea-inducing emetic concealed in a bait and subsequently avoids that bait due to illness (Baker *et al.* 2005). Our goals, therefore, were to use an emetic to reduce the attractiveness of specific food items to black bears, and to increase the efficacy of AC by following Domjan's (2006) guidelines for effective punishment.

STUDY AREA

Our study area encompassed the Resort Municipality of Whistler (RMOW) in the Coast Mountains of southern British Columbia. The Biogeoclimatic Ecosystem Classification (Pojar and Mackinnon 1983) put Whistler in the Coastal Western Hemlock zone. Western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*) dominate valley bottoms, and mountain hemlock (*Tsuga mertensiana*), amabilis fir (*Abies amabilis*) and yellow cedar (*Chamaecyparis nootkatensis*) predominate at higher elevations. Shrub species important for bears include huckleberry (*Vaccinium membranaceum*) and blueberry (*V. ovalifolium* and *V. alaskensis*), as well as highbush cranberry (*Viburnum trilobum*), Saskatoon berry (*Amelanchier alnifolia*) and sitka mountain ash (*Sorbus sitchensis*).

Whistler is home to approximately 10,000 permanent residents (Tourism Whistler 2006) and host to about 1.8 million visitors per year (Tourism Whistler 2006). Approximately 100 black bears share the same space, a density of about 1 bear per square kilometer (Appleton 2006). The habitat to support this density of bears was originally of high quality, and was enhanced by Whistler's logging history, ski hills, golf courses and the availability of anthropogenic food sources (Appleton 2006).

Whistler has made a commitment to reducing human-bear conflict by participating in the voluntary Bear Smart Community initiative with the province. This program requires communities to address the root problems of their human-bear conflict issues including: conducting a bear hazard assessment, drafting a human-bear conflict management plan, committing to implement a bear-resistant solid waste management system, supporting ongoing education programs, enacting bylaws requiring animal-resistant waste storage practices, and including initiatives intended to reduce human-bear conflict into the Official Community Plan.

PURPOSE AND OBJECTIVES

The purpose of my thesis was to reduce human-bear conflict in the Resort Municipality of Whistler, for applications in the Conservation Officer Service throughout British Columbia, and other jurisdictions where human-wildlife conflict is a concern. I accomplished this by conducting two experiments.

In Chapter 2, I subjected radio-collared black bears to 3-5 day AC programs. My objectives were to:

1. Document whether bears increased the distance at which they tolerate humans and changed their behavioural responses to humans after being subjected to rubber bullets fired from a shotgun and marbles fired from a slingshot.
2. Examine the influence of AC on bears' spatial use of human developments, including the proportion of utilization distribution overlap with developed areas and the distance of bear relocations to the nearest development.
3. Determine whether I could teach bears to associate a whistle with pain stimuli.

If successful, community members could use whistles to increase bear wariness toward humans and deter bears from conflict situations that contribute to high human tolerance and often lead to food conditioning, until conservation officers arrive.

In Chapter 3, I used an emetic, thiabendazole, to induce nausea in bears when they ingest particular attractants. Specifically, I had two objectives:

1. Determine whether thiabendazole could induce a CTA to specific attractants that are difficult to secure from bears and contribute to local human-bear conflict.

2. Test for bears' ability to detect thiabendazole in baits to help explain variability in the scientific literature of the success of thiabendazole in inducing taste aversions.

Bears are usually managed lethally when they are both human habituated and food conditioned (Hopkins *et al.* 2010). These two experiments address both issues: aversive conditioning to address high human tolerance and help prevent food conditioning, and conditioned taste aversion to address food conditioning to specific attractants that are difficult to secure. Many of my methods may be applied to other wildlife-human conflicts around the world as a part of efforts to reduce anthropogenic impacts on wildlife.

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CHAPTER TWO

SHOTGUNS AND SLINGSHOTS INCREASE WARINESS IN AMERICAN BLACK BEARS

INTRODUCTION

Human-wildlife conflict is a management and conservation issue around the globe. Conflicts between humans and wildlife occur any time the actions of either impose a negative impact on the other (Conover 2002). When conflicts involve large carnivores such as Ursidae, which can pose risks to human safety, officials often resort to lethal management (Conover 2002, Spencer *et al.* 2007). Negative interactions between humans and American black bears (*Ursus americanus*) and complaints of urban black bear activity have been increasing in recent decades (Siemer *et al.* 2009, Spencer *et al.* 2007), as has the rate of injuries to humans caused by bears (Herrero and Higgins 1999).

Bears are usually managed, lethally or non-lethally, near urban or residential areas when they threaten human safety (Spencer *et al.* 2007). The most common complaint involving black bears in most jurisdictions in North America stems from food conditioned bears, followed by general sightings (Spencer *et al.* 2007). Food conditioned bears have made a positive association between humans and food (Smith *et al.* 2005) and reinforce the association by continuing to access human developments in search of food (Hopkins *et al.* 2010).

Food conditioned bears are also usually habituated to humans, dampening their response to humans due to neutral outcomes in previous encounters, but human habituation and food conditioning are different processes and a bear may be either habituated or food conditioned, or both (Hopkins *et al.* 2010).

Tolerance for humans (sometimes but not always through the habituation process) may be necessary for bears to survive in areas with varying levels of human activity, and there is evidence that human-habituated bears display less aggression toward humans than wary bears (Jope 1983, Aumiller and Matt 1994, Herrero *et al.* 2005). However, human-habituated bears are also much more likely than wary bears to be killed by poaching, vehicle and train collisions (Zager *et al.* 1983, Benn and Herrero 2002), and food conditioned bears in particular pose a higher risk to human safety than do wary bears (Herrero 1989, Gunther 1994). The challenge for bear managers, therefore, is to keep habituation to humans in bears below a threshold that maximizes human safety during encounters, but minimizes the likelihood of bears becoming food conditioned or killed due to human activities.

Wildlife managers using non-lethal tools to reduce bear tolerance of humans may include aversive conditioning in their approach (Spencer *et al.* 2007). Aversive conditioning (AC) is a form of operant conditioning used to reduce undesirable behaviour using physical or psychological discomfort (Shivik *et al.* 2003). Its applications to bears involve the administration of negative stimuli, the goal of which is usually to teach the bear to associate humans, human developments and human food sources with negative stimuli and subsequently avoid them.

I distinguish AC from the similar practice of hazing, which typically involves removing a bear from an immediate conflict situation with deterrents including rubber bullets but without follow-up action (Hopkins *et al.* 2010).

METHODS

Conservation officers captured bears by culvert trap or free-range darting with the BC Conservation Officer Service and I fit them with a Lotek (Newmarket, Ontario, Canada) 4400S model GPS or Telonics (Mesa, Arizona, USA)VHF radio-collar. Conservation officers used teletamine-zolazepam hydrochloride combination (Telazol®) at a concentration of 100-300 mg/ml injected intramuscularly. After immobilization, bears recovered inside the culvert trap for at least 4 hours until their release, either onsite or nearby if the capture site was unsuitable for release due to human activity.

After release, I located bears using a three-element Yaegi antenna mounted on the roof of a half-ton truck. I noted the bear's location Universal Transverse Mercator (NAD 83), behaviour, and any anthropogenic attractants the bear accessed. I categorized the bear as in conflict with humans if it accessed or attempted to access anthropogenic attractants, or if it displayed a lack of wariness to humans in urban or residential areas (e.g. walking through a residential area in daylight).

I measured bear wariness by approaching them and measuring response distances and categorizing behavioural responses to my approach. I began my approach by measuring the initial distance between myself and the bear (start distance). I included this measurement because in other species, an animal's response distance (e.g. flight distance) to an approaching threat varied by the start distance of the approach (Blumstein 2003). I then measured the distance at which I noticed that the bear had overtly noticed me: the Overt Reaction Distance (ORD). ORD is believed to be an accurate measure of a bear's tolerance of humans, and should vary depending on the situation the bear is in (Herrero *et al.* 2005). I also measured the distance the bear displaced from humans, if it did (Displacement distance; DD). Due to the multiple factors that could influence a bear's ORD and DD, I only measured a bear's wariness if it was between 1 and 50 meters from security cover (that obscures the bear from human view), if the bear was not attempting to access or accessing anthropogenic attractants such as garbage or other human foods, and if there were no other humans or bears in the immediate vicinity. I recorded bear behavioural response as *leaves at a run*, *leaves at a walk*, or *does not displace*. For safety reasons, I did not approach closer than 10 metres.

I alternately assigned bears I categorized as conflict animals to one of three treatment groups: control, AC with sound, or AC without sound. For the AC with sound group, I blew a whistle one or two seconds before hitting the bear with either rubber bullets fired from a shotgun or marbles fired from a slingshot. Conservation officers used pump action 12-guage shotguns to fire deer thumper bean bag rounds and strike 2 rubber bullets (both from Margo supplies, High River, Canada). Officers fired bean bag rounds from distances ranging from 5 m – 15 m, and rubber bullets from distances ranging from 15 m – 30 m. I used two types of slingshots both on foot and from inside the truck at distances of 1 m – 20 m: one slingshot was laser-sighted (Precision shots PS52 model, Addison, USA) and the other was a straight metal slingshot (Home hardware model 303). I used slingshots in addition to shotguns to help make punishment non-contingent on officer and shotgun presence, as anecdotal evidence in Whistler strongly suggested that bears recognize shotguns and may only flee from persons carrying shotguns or objects resembling shotguns.

I compared the force of a marble fired from a slingshot to that of a rubber bullet impacting a bear at 10 m. To calculate ft-lbs of energy in a marble, I set the marble density at 2.7 g/cm^3 (Cobb 2004) and used density to calculate marble volume using the formula: volume = $4/3 \times \pi \times$ radius. I used volume and density to calculate marble mass using the formula: mass = volume × density. I used the average velocity of 136 m/s (Barrie 2003) in the formula: acceleration = velocity / time, assuming the time for a marble to travel 10 m is reasonably 0.5 seconds. Finally, I used the formula: force = mass × acceleration to calculate the ft-lbs of energy for a marble impacting a bear.

If a bear's conflict with humans escalated at some point after an AC program, I reassigned it to another treatment group. I considered these treatments to be independent since the bear's responses to humans were at pre-treatment levels (e.g. *does not displace*). I also considered bears treated in different years to be independent because bear-to-human habituation seems to be generalized from bear-to-bear habituation (Herrero *et al.* 2005), and bear-to-bear habituation increases over the summer as bears spend more time in close proximity to each other (Stonorov and Stokes 1972, Smith *et al.* 2005). Thus, bears are likely more wary of humans each spring after denning for the winter. Statistical analyses also included bear as a random effect to account for re-using animals. I did not apply AC programs to bears in the control group, but approached bears to record their wariness in the same way as both AC treatment groups.

AC programs generally ran for 3-5 days from dawn to dusk, or later if the bear was using a high human-use area after dark. Although I did not expect 3-5 days of AC to mitigate human-bear conflict, I needed short AC programs to increase sample size. I closely followed the target bear, and conservation officers shot the bear in the rump with projectiles whenever the bear displayed conflict behaviour. When conservation officers were not available, I fired marbles from a slingshot.

I recorded the bear's reaction as *does not displace*, *leaves at a walk*, or *leaves as a run* to both the whistle (if it was in the sound treatment group) and the projectile. To optimize learning for bears in the sound treatment, I also signaled the end of punishment by ringing a bell, intended as a positive reward for appropriate behaviour, if the bear moved into appropriate security cover (out of sight). I set the context for the bell by ringing it as I retreated from a bear after measuring its pre-treatment wariness. The University of Alberta animal welfare committee approved all field methods (protocol 542905).

I measured how AC influenced bear use of human developments spatially and temporally using ArcGIS 9.3 (Redlands, CA, USA) by comparing hourly GPS collar relocations in a pre-treatment monitoring period 3 days before an AC program began, and in a post-treatment monitoring period 3 days after it ended. For control bears, I determined the start date of the 3 day pre-treatment period for each bear using a random number generator.

I used SPSS (version 17, Chicago, Illinois, USA) for most statistical analyses, running Generalized Linear Models with bear identification as a random effect to compare ORD and DD in time periods across treatment groups. To compare bear response to projectiles I used logistic regression using bear as a random effect. For the spatial data, I combined both groups of AC treated bears that wore GPS collars (5 bears) to compare with GPS-collared controls (4 bears). I created a *Development* polygon for Whistler by combining road and residential layers supplied by the Resort Municipality of Whistler. For each bear relocation datapoint, I used ArcGIS to calculate the distance to the development polygon. I used script coded in R statistical software (R development core team 2008) and the KS package (Duong 2008) to estimate the 95% contour for utilization distributions for each bear using fixed kernel analysis (Worton 1989) with the plug-in method to determine smoothing factor (Gitzen *et al.* 2006). I separated data temporally into day and night categories based on sunrise and sunset times. Because data included zeros I log transformed it and used a generalized linear model.

RESULTS

I treated 12 bears in 15 AC programs in 2007 and 2008. Eight bears were in the sound treatment, 7 were in the no sound treatment and 8 animals were controls that I did not treat with AC (Table 2-1). Due to varying availability of conservation officers, 8 bears only received pain stimuli in the form of marbles fired from a slingshot.

Response to whistle

Bears did not respond differently to researchers blowing a whistle versus researchers who did not (χ^2 = 1.48, df = 1, P = 0.22). None of the bears displaced when I blew a whistle within projectile range. Two of the 8 bears in the sound treatment displaced from the sound of the whistle in the first sound-pain pairing during AC programs, and 2 bears responded by leaving at a run the first time I blew a whistle during the AC program.

Wariness

I subjected bears to pain stimuli 245 times: 47 times using rubber bullets and 198 times using marbles during their AC programs and from isolated hazing events by conservation officers. Projectiles fired from slingshots similar to the model I used reached velocities ranging from 112 km/h -144 km/h (Barrie 2003). A bear 10 m away experienced approximately 13 ft-lbs of force at impact for marbles fired from slingshots (my calculation), and 57 ft-lbs for rubber bullets (Margo n.d.). However, bears were as likely to run from marbles fired from a slingshot as they were from rubber bullets fired from a shotgun ($\chi^2 = 3.07$, df = 2, $r^2 = 0.49$, $P = 0.22$).

After conditioning, more bears displaced from approaching humans ($\chi^2 = 60$, df = 6, $P < 0.001$; Figure 2-2), and more bears left at a run than before treatment ($\chi^2 = 38.5$, df = 6, $P < 0.001$; Figure 2-3). Bears subjected to AC programs were more wary in the seven days post-treatment than in pre-treatment compared to control animals (interaction effect $\chi^2 = 6.17$, df = 2, $P = 0.05$ for ORD; $\chi^2 = 121.54$, df = 2, $P < 0.001$ for DD; Figures 2-4 and 2-5). In post-hoc pairwise comparisons for least significant difference for ORD, bears in the no sound treatment group were more wary in post-treatment than control bears were in later approaches ($P = 0.04$), as were bears in the sound treatment ($P = 0.004$). Bears in the no sound treatment were not more wary in post-treatment compared to pre-treatment ($P = 0.16$), but bears in the sound treatment were ($P = 0.007$). For DD, bears in both no sound and sound treatments were more wary of approaching humans in post-treatment than control bears ($P = 0.002$ for bears in the no sound treatment, $P = 0.001$ for bears in the sound treatment). Bears in the no sound treatment were more wary of approaching humans in post-treatment than they were in pre-treatment ($P < 0.001$), as were bears in the sound treatment ($P = 0.001$).

Concern about using animals in more than one treatment group prompted me to rerun the analysis removing the pseudoreplicated data (n = 91), and the results were similar (interaction effect $\chi^2 = 45.18$, df = 2, $P < 0.001$ for ORD; $\chi^2 = 97.72$, df = 2, $P < 0.001$ for DD. In post hoc pairwise comparisons for least significant difference for ORD, bears in the sound treatment were more wary in post-treatment compared to pre-treatment ($P = 0.03$). For DD, post hoc comparisons revealed that bears in the both the no sound treatment and sound treatment were more wary in post-treatment compared to pre-treatment ($P < 0.001$ for both groups).

Bears displayed increased wariness toward approaching humans more than three weeks after their AC program ended for ORD ($\chi^2 = 10.81$, df = 4, $P = 0.03$) but not for DD ($\chi^2 = 4.78$, df = 4, $P = 0.31$). For ORD, post hoc comparisons (least significant difference) revealed that control animals were less wary of approaching humans by week 3 than they had been in the week 1 ($P = 0.02$). In contrast, after AC treatments, bears in the sound group were more wary of approaching humans than controls in the same time category ($P = 0.03$ for week 2 and $P = 0.002$ for week 3; Figure 2-6).

I used start distance as a covariate because linear regressions of ORD and DD on start distance revealed significant correlations (ORD $P < 0.001$, $r^2 = 0.70$; Figure 2-7 and DD $P < 0.001$, $r^2 = 0.18$; Figure 2-8).

Use of Human Developments

Nine bears wore GPS collars on an hourly relocation schedule; 4 bears were control animals and 5 were subjected to AC programs. M23 died in a vehicle collision in the early hours before monitoring began on day 3 of his AC program and I did not have post-treatment GPS data in analysis, although I had taken some measures of wariness during his AC program.

Bears subjected to AC may use the landscape somewhat differently after their AC programs compared to control animals (interaction effect $\chi^2 = 58.78$, df = 7, $P < 0.001$). Pairwise comparisons revealed that the relocations of GPS collared AC-treated bears were closer to human developments after AC programs during the day ($P = 0.05$), but not during the night ($P = 0.82$). Control animals showed no such differences over time between day ($P = 0.26$) and night locations ($P = 0.82$; Figure 2-9). The utilization distributions of AC-treated bears, however, did not overlap with human developments differently compared to controls ($\chi^2 = 13.33$, df = 7, $P = 0.06$). Utilization distributions of AC-treated bears overlapped as much with developed areas during daylight hours in post-treatment as they had in pre-treatment ($P = 0.83$), with similar results for controls ($P = 0.47$). The only significant effect in this model was bear identification ($P < 0.001$).

DISCUSSION

Aversive conditioning appeared to alter some aspects of bear behaviour that contribute to human-bear conflict. Bears subjected to AC using either slingshots or shotguns increased their wariness toward humans, while control animals habituated to humans. Other authors using AC to reduce human-wildlife conflict report similar results: habituated elk (*Cervus elaphus)* increased flight distance from approaching humans after AC programs (Kloppers *et al.* 2005), black bears reduced nuisance activity (Madison 2008**,** Mazur 2010), and grizzly bears increased wariness toward humans (Gillin *et al.* 1992, Honeyman 2008).

While ORD and DD increased in post-treatment for AC-treated bears, the opposite was true for control animals. The habituation of control animals was partly the reason that 4 animals were used in more than one treatment group. If bears exhibited behaviour considered threatening to human safety, conservation officers required me to subject the bears to AC. The result was some bias toward less wary animals in pre-treatment of AC groups. My second analysis, removing pseudoreplicated data, confirmed the increase of wariness of the sound-treated AC group in post-treatment.

Aversive conditioning increased bear response distances (ORD and DD measurements), and it also changed the behavioural response to approaching humans. Madison (2008) described comparable results in Yosemite National Park. Bears in Yosemite National Park continued to use developed areas after AC, but they caused less damage and accessed less food per incident than they had in pre-conditioning. Although I did not measure amounts of garbage bears accessed, I noted that bears that did not displace from humans in pre-treatment were more likely to leave at a run in post-treatment.

Bears subjected to AC appeared to spend more time closer to human developments during the day in post-treatment. This may be due to the short length of AC programs; I ended the programs based on time constraints of 3-5 days and not based on behaviour suppression. After being denied access to developed areas, bears may have capitalized on my absence in post-treatment by increasing their use of the developed areas.

Partial spatial effects may be expected from AC. Elk reduced grazing pressure in the short term but did not restore lost migratory behaviour (Spaedtke 2009). While GPS collared bear locations were closer to human development in Whistler during the day in post-treatment, I did not see a similar result with the proportion of overlap into human development of utilization distributions. This may be partly caused by the short number of days I could analyze in post-treatment (3), which limited the number of points I used in calculating utilization distributions. The error rate of a utilization distribution calculated with 20 points instead of the recommended 50 points increases by 20% (Gitzen *et al.* 2006). The mean number of relocations I used to calculate utilization distributions was 26.5 and ranged from a low of 6 to a high a 50.

Bears subjected to AC appeared to retain some, but not all post-treatment wariness toward humans for at least 3 weeks following an AC program. Similarly, most AC-treated black bears in Nevada took over a month to return to urban areas and conflict after a single AC treatment using multiple deterrents (Beckman *et al.* 2004). Because the most significant effect in the utilization distribution model was bear identification, variation in the response of individual bears to AC may be the most influential factor in the success of an AC program, an observation supported by Beckman *et al.* (2004).

Bears responded to being hit by both marbles fired from a slingshot and rubber bullets fired from a shotgun by leaving at a run, with 4 exceptions. The exceptions were all from the same bear, M34, a large adult male, and were all very early in his AC program. Using a small, non-registered weapon such as a slingshot to deliver pain stimuli in addition to shotguns may be effective partly due to the ease with which slingshots were concealed from bears, making it more likely the bears would generalize a wariness response to the public because punishment is no longer contingent on the presence of a shotgun. Bears likely ran from marbles fired from a slingshot because 13 ft-lbs was enough force to cause pain.

It is unlikely that external pain stimuli can be used to teach animals to avoid food sources. Pinnipeds did not disperse from aquaculture structures or decrease salmonid consumption in response to pyrotechnics, rubber bullets and acoustic deterrent devices (Wright *et al.* 2007). White-tailed deer (*Odocoileus virginianus*) did not decrease foraging on feed stations after experiencing electric shock (Gallagher and Prince 2003). Cattle (*Bos primigenius*) wearing shock collars did not learn to avoid preferred forage, and resumed grazing in undesired locations when the collars were removed (Cibilis *et al.* 2004). Wolves (*Canis lupus*) resumed predation when no longer wearing shock collars (Shivik *et al.* 2003, Hawley *et al.* 2009). Food conditioned black bears were more likely than non food conditioned bears to return to conflict after AC (Beckman *et al.* 2004, Leigh and Chamberlain 2008, Mazur 2010). Animals do not appear to be capable of making associations between food and externally applied pain (Garcia 1974).

Animals do associate aversive events easily to auditory cues, however, more so than visual ones (Shapiro *et al.* 1980). Control bears that heard a whistle blast within projectile range never reacted to the sound. However, 6 of the 8 bears in the sound treatment easily learned to associate the whistle with pain stimuli, reacting to the whistle as if they had been hit with a projectile after the first sound-pain pairing. In fact, the two bears in the sound treatment I had an opportunity to test nearly one year later reacted to the blast of a whistle by leaving at a run. It may be possible, since intense and persistent fears (phobias) resemble conditioned learning during traumatic events in animals (Thompson and Madigan 2005), to use the whistle-pain association to induce a phobia in bears.

MANAGEMENT IMPLICATIONS

Wildlife managers can effectively use AC as a non-lethal tool to increase bear wariness toward humans and to increase human safety, but short AC programs are unlikely to deter bears from using human developments. Using slingshots or other easily concealed weapons to deliver the punishment in addition to shotguns also increases wariness toward humans. Given the ease with which bears learned to associate a sound cue with pain stimuli, exploiting this association using volunteer stewards could help deter bears from human-bear conflict situations before conservation officers can arrive.

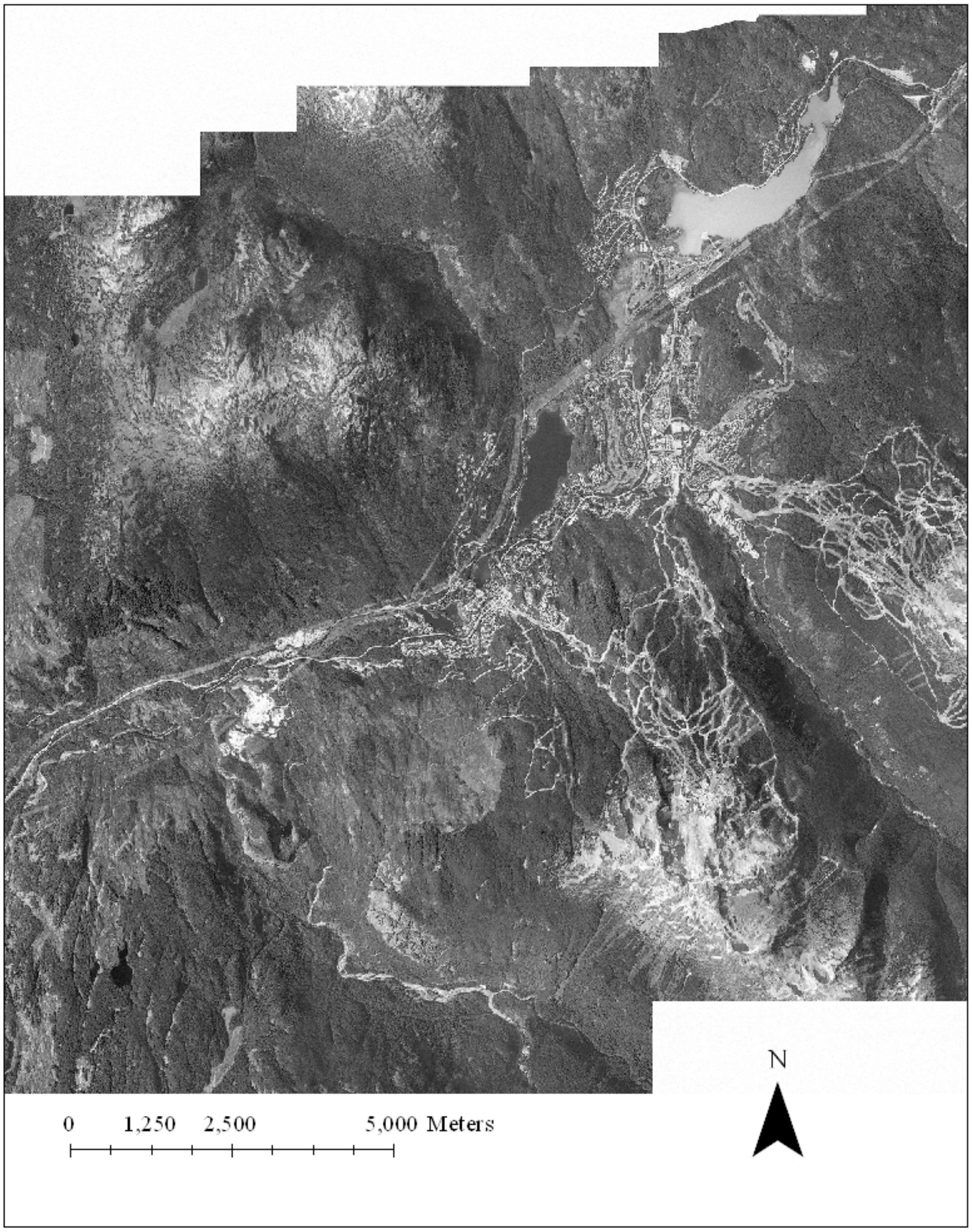

Figure 2-1. Aerial photo of the Resort Municipality of Whistler, with Whistler Mountain and Blackcomb Mountain ski hills at the lower right and residential subdivisions scattered along Highway 99.

Table 2-1. Summary of mean wariness (Start Distance, Overt Reaction Distance and Displacement Distance) of radio-collared American black bears (*Ursus americanus*) in Whistler, British Columbia. Overt Reaction Distance (ORD) was the distance the animal overtly noticed an approaching researcher, and Displacement Distance was that distance the bear displaced out of sight from the researcher into cover. Wariness was measured with a range finder and compared pre- and post-treatment of aversive conditioning using both marbles fired from a slingshot and rubber bullets (rb) fired from a shotgun. Bears were assigned to 3 treatment groups: aversive conditioning with sound (a whistle paired with a rubber bullet fired from a shotgun or a marble fired from a slingshot), aversive conditioning with no sound (no whistle used) and controls.

Bear	Year	Time	Treatment	n	Start(m)	ORD(m)	DD(m)	rb	marbles
F01	2008	pre	Sound	3	39.3	31.3	12.0	0	19
F01		post	Sound	2	53.0	40.0	30.0		
F04*	2008	pre	No Sound	3	27.3	20.3	15.3	0	18
F04*		post	No Sound	3	57.3	48.3	28.7		
F05	2007	early	Control	2	122.0	114.0	16.0	n/a	n/a
F05		late	Control	2	43.0	29.0	15.0		
F05*	2008	early	Control	3	60.7	45.3	16.7	n/a	n/a
F05*		late	Control	3	92.7	44.0	22.7		

F07	2007	pre	No Sound	2	59.5	53.0	14.0	3	10
F07		post	No Sound	3	59.4	40.7	22.0		
F10	2007	early	Control	5	56.6	39.2	22.4	n/a	n/a
F10		late	Control	6	25.0	19.7	18.5		
F10*	2008	pre	Sound	1	30.0	26.0	20.0	0	21
F10*		post	Sound	2	43.0	41.0	23.5		
F12*	2008	early	Control	2	28.5	28.0	10.0	n/a	n/a
F12*		late	Control	2	32.5	22.5	12.5		
F13*	2008	pre	No Sound	2	30.0	27.0	18.5	4	46
F13*		post	No Sound	3	50.0	40.3	35.3		
F18	2009	early	Control	1	66.0	26.0	42.0	n/a	n/a
F18		late	Control	1	40.0	35.0	10.0		
M05	2007	early	Control	1	35.0	20.0	10.0	n/a	n/a
M05		late	Control	1	45.0	12.0	10.0		
M17*	2007	pre	Sound	3	20.7	13.3	10.0	0	5
M17*		post	Sound	4	38.3	19.0	16.8		
M21*	2007	early	Control	3	78.7	32.0	23.3	n/a	n/a
M21*		late	Control	3	46.0	17.4	15.3		
M23*	2007	pre	Sound	2	113.0	76.0	18.0	5	8
M23*		post	Sound	4	39.0	29.5	26.5		
M25	2007	pre	No Sound	5	14.0	14.0	11.4	5	7
M25		post	No Sound	6	18.8	24.0	15.0		
M28*	2007	pre	Sound	3	29.3	14.0	11.3	0	8

M28*		post	Sound	3	38.0	29.7	16.3		
M29	2007	pre	No Sound	1	34.0	14.0	10.0	1	7
M29		post	No Sound	2	30.0	15.0	15.0		
M32	2007	pre	Sound	2	25.0	12.5	12.5	8	18
M32		post	Sound	4	31.5	24.3	13.8		
M32	2008	pre	No Sound	2	81.0	55.0	16.0	0	11
M32		post	No Sound	5	82.8	47.6	28.6		
M38	2008	pre	Sound	2	26.0	12.0	10.0	0	11
M38		post	Sound	1	25.0	25.0	20.0		
M39	2008	early	Control	2	45.0	33.0	20.0	n/a	n/a
M39		late	Control	2	18.5	12.0	10.0		
M39	2008	pre	No Sound	2	16.0	15.5	10.0	0	15
M39		post	No Sound	2	25.0	25.0	21.0		
M39	2008	pre	Sound	2	25.0	24.0	12.0	4	111
M39		post	Sound	3	32.3	29.3	28.7		

*denotes bears wearing GPS collars with hourly relocation schedules

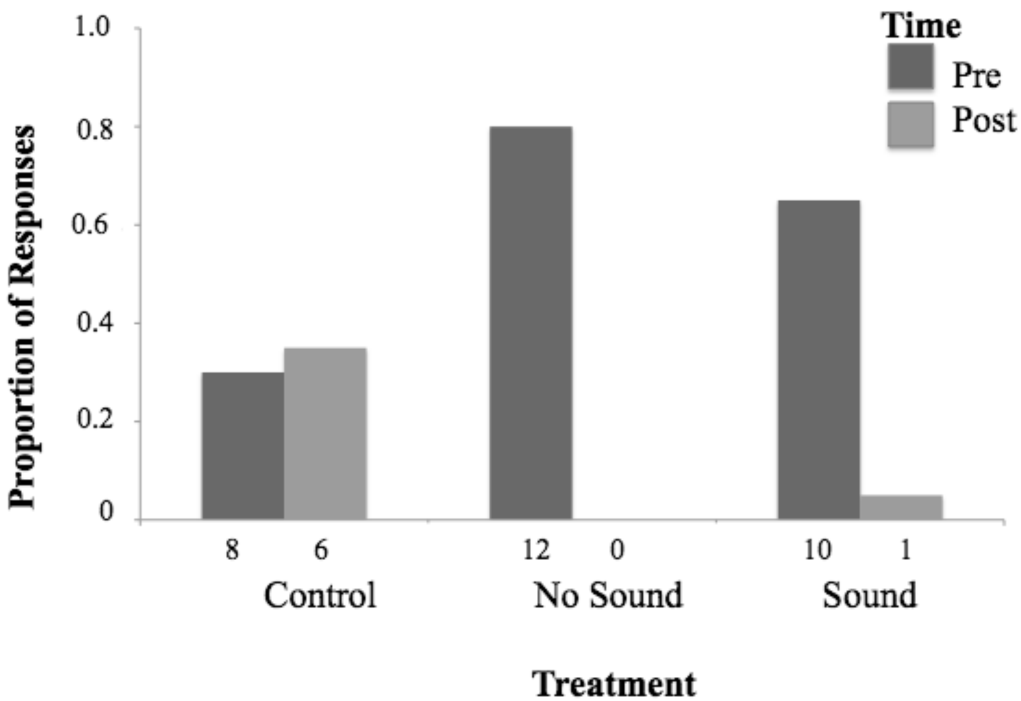

Figure 2-2. Black bear (*Ursus americanus*) response of *does not displace* from approaching humans before and after aversive conditioning programs in Whistler, British Columbia. Behavioural responses to approaching researchers were compared between 3 treatment groups before (pre) and after (post) aversive conditioning using marbles fired from a slingshot and rubber bullets fired from a shotgun. Bears were alternately assigned to 3 treatment groups: aversive conditioning with sound (a whistle paired with a rubber bullet or a marble), aversive conditioning with no sound (no whistle used) and controls.

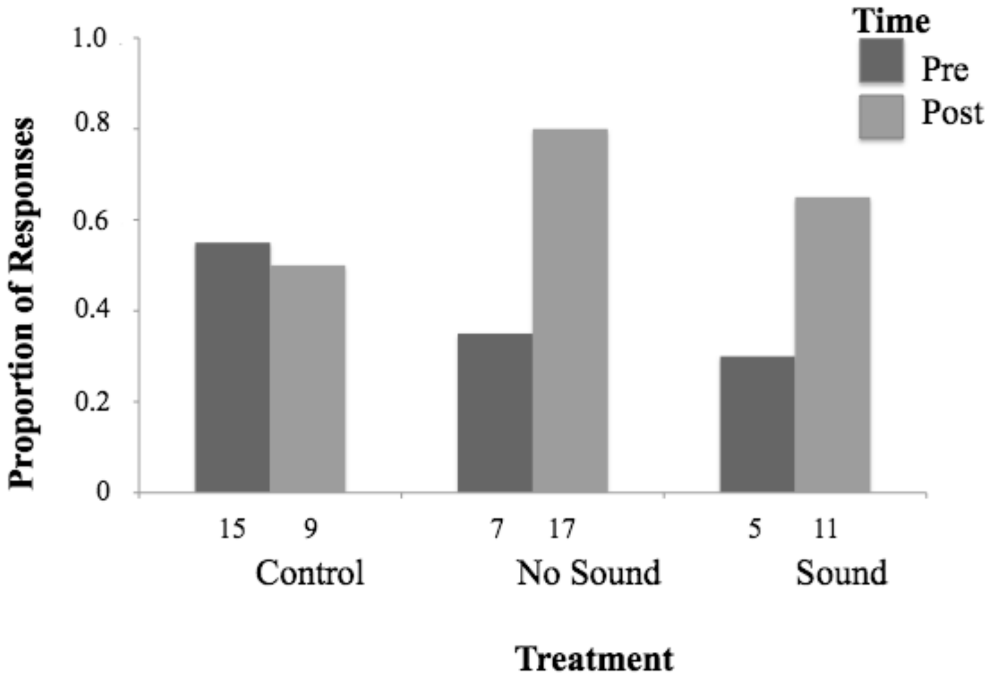

Figure 2-3. Black bear (*Ursus americanus*) response of *leaves at a run* from approaching humans before and after aversive conditioning programs in Whistler, British Columbia. Behavioural responses to approaching researchers were compared between 3 treatment groups before (pre) and after (post) aversive conditioning using marbles fired from a slingshot and rubber bullets fired from a shotgun. Bears were alternately assigned to 3 treatment groups: aversive conditioning with sound (a whistle paired with a rubber bullet or a marble), aversive conditioning with no sound (no whistle used) and controls.

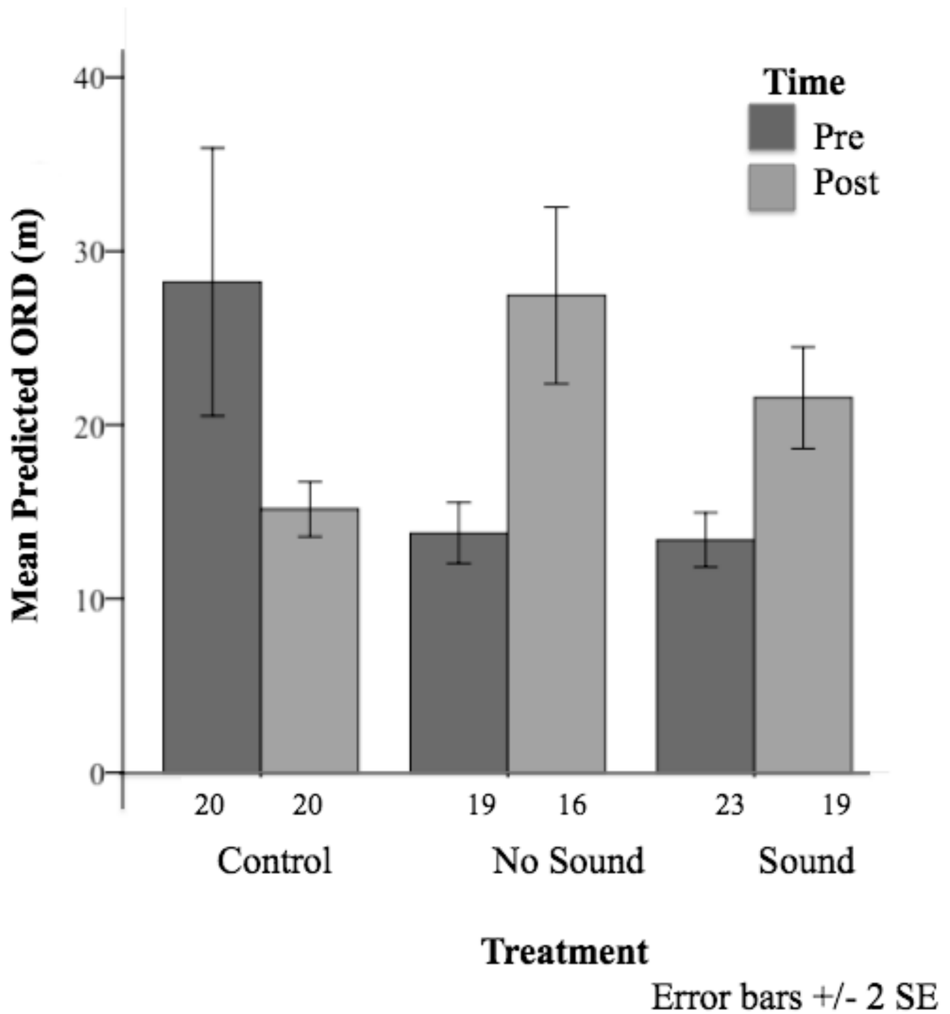

Figure 2-4. Overt Reaction Distance (ORD) of American black bears (*Ursus americanus*) to approaching humans before and after aversive conditioning programs in Whistler, British Columbia. ORDs to approaching researchers were compared between 3 treatment groups before (pre) and after (post) aversive conditioning using marbles fired from a slingshot and rubber bullets fired from a shotgun to determine if bears increased wariness toward humans after aversive conditioning. Bears were assigned to 3 treatment groups: aversive conditioning

with sound (a whistle paired with a rubber bullet or a marble), aversive conditioning with no sound (no whistle used) and controls. ORDs were predicted by removing the start distance covariate.

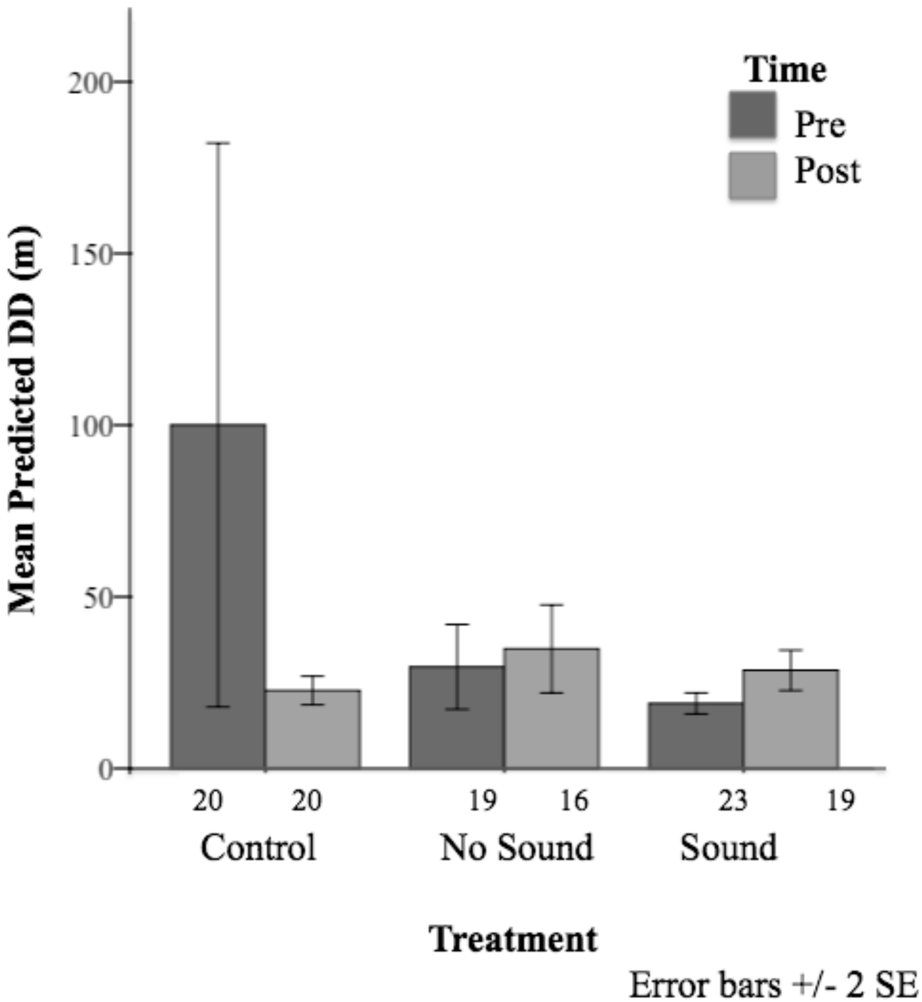

Figure 2-5. Displacement Distance (DD) of American black bears (*Ursus americanus*) to approaching humans before and after aversive conditioning programs in Whistler, British Columbia. DDs to approaching researchers were compared between 3 treatment groups before (pre) and after (post) aversive conditioning using marbles fired from a slingshot and rubber bullets fired from a shotgun to determine if bears increased wariness toward humans after aversive conditioning. Bears were assigned to 3 treatment groups: aversive conditioning with sound (a whistle paired with a rubber bullet or a marble), aversive

conditioning with no sound (no whistle used) and controls. DDs were predicted by removing the start distance covariate.

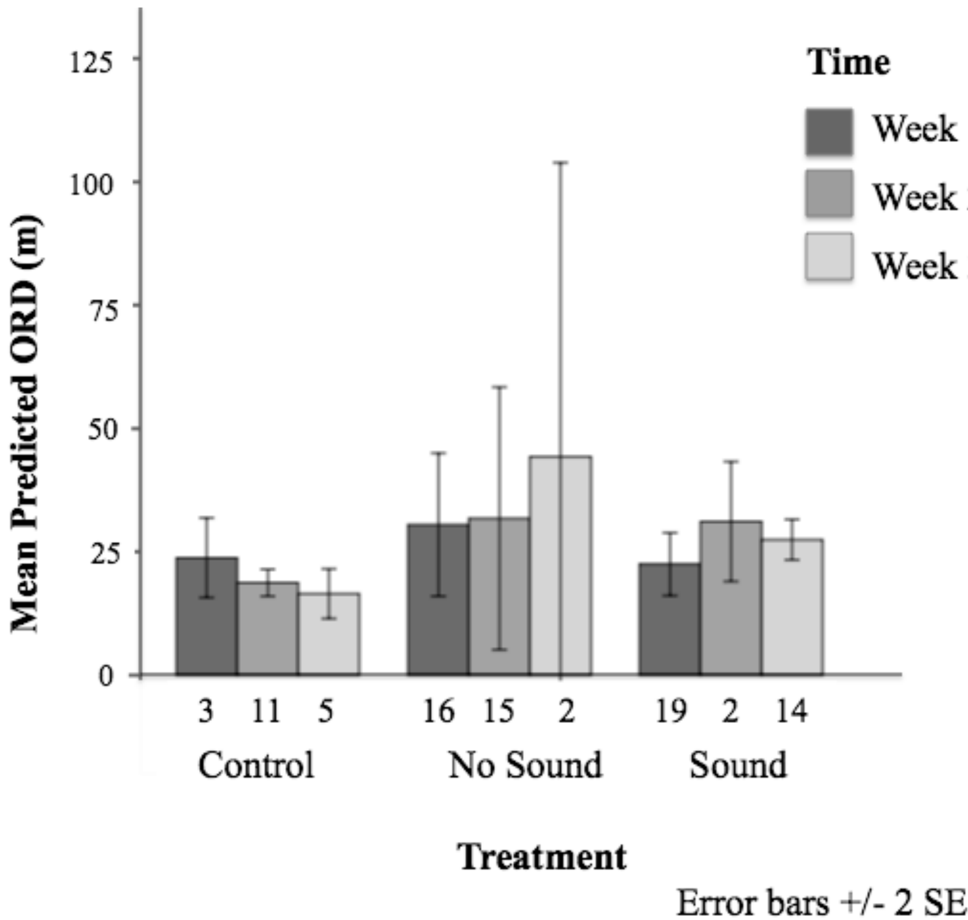

Figure 2-6. Overt Reaction Distance (ORD) of American black bears (*Ursus americanus*) to approaching humans in Whistler, British Columbia. ORDs to approaching researchers were compared between 3 treatment groups 1-3 weeks after aversive conditioning using marbles fired from a slingshot and rubber bullets fired from a shotgun to determine the length of time bears increased wariness toward humans after aversive conditioning. Bears were assigned to 3 treatment groups: aversive conditioning with sound (a whistle paired with a rubber bullet or a marble), aversive conditioning with no sound (no whistle used) and controls. ORDs were predicted by removing the start distance covariate.

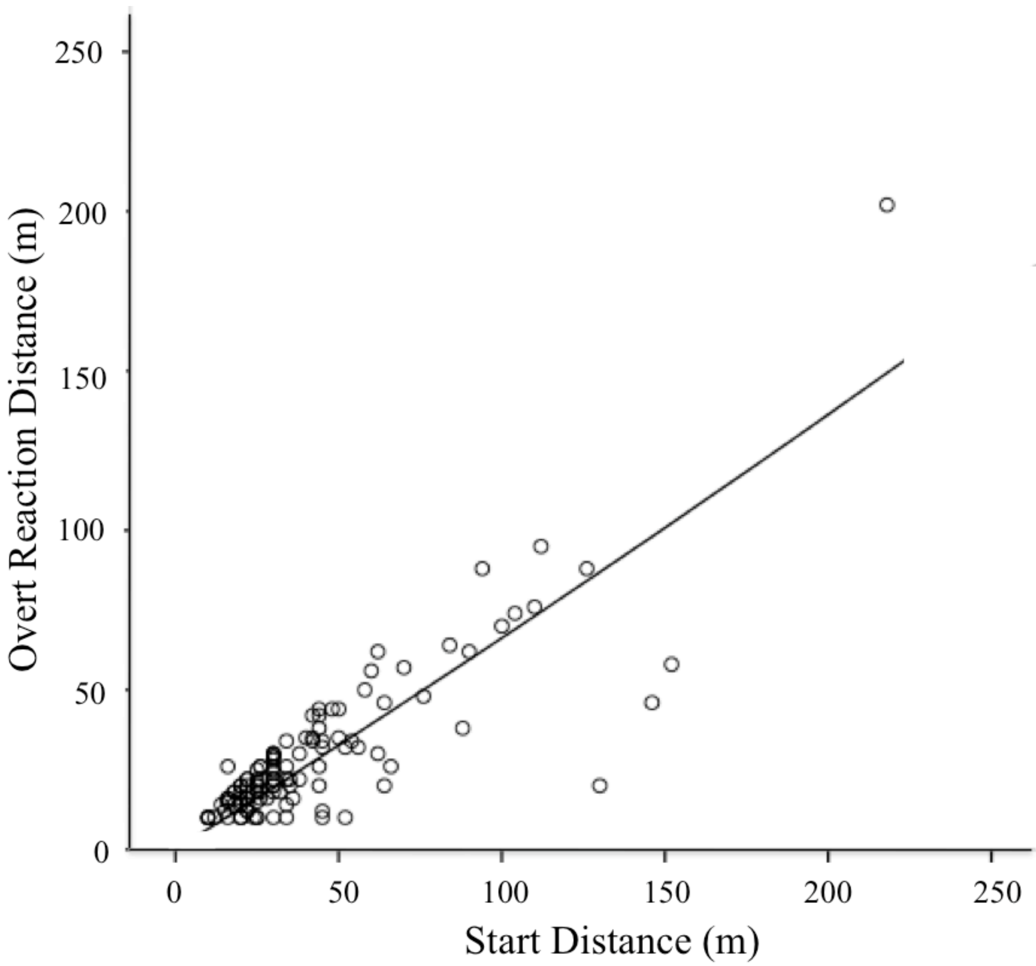

Figure 2-7. Regression of overt reaction distance (a measure of wariness) on the start distance of a person approaching American black bears (*Ursus americanus*) in Whistler, British Columbia. The distance researchers began their approach (start distance) was included as a covariate when comparing overt reaction distance in bears subjected to aversive conditioning to control bears.

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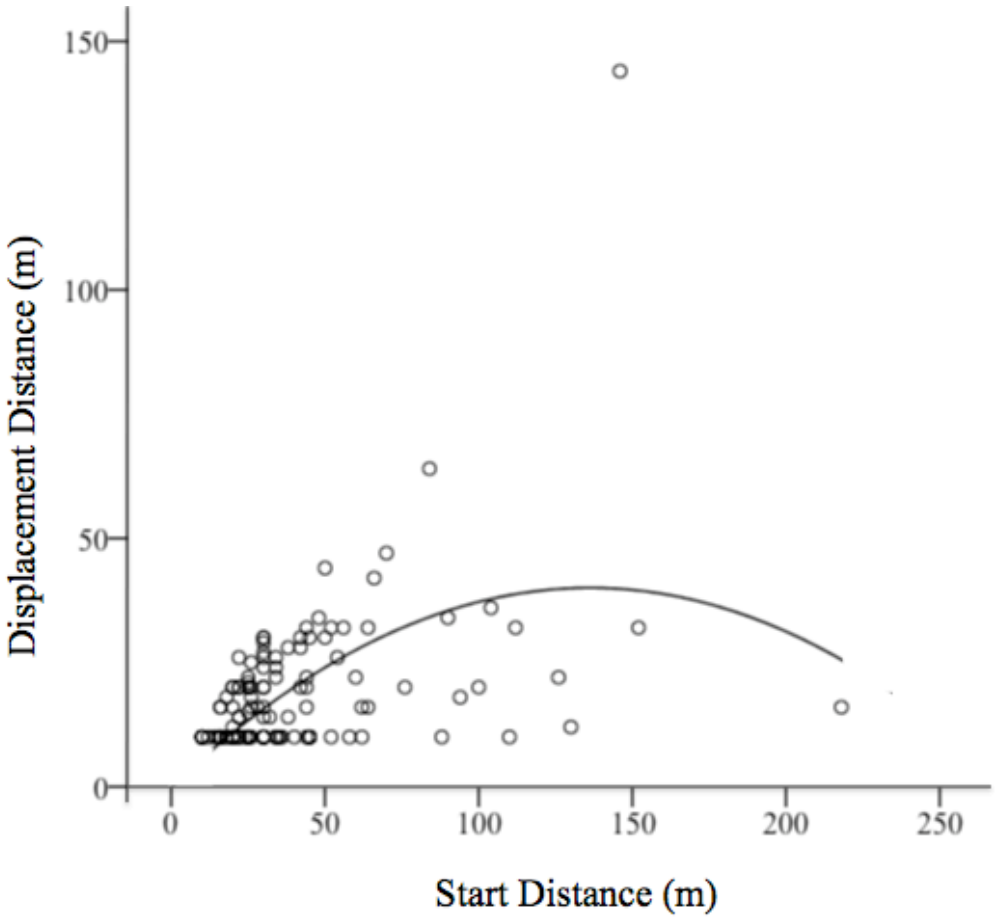

Figure 2-8. Regression of displacement distance (a measure of wariness) on the start distance of a person approaching American black bears (*Ursus americanus*) in Whistler, British Columbia. The distance researchers began their approach (start distance) was included as a covariate when comparing displacement distance in bears subjected to aversive conditioning to control bears.

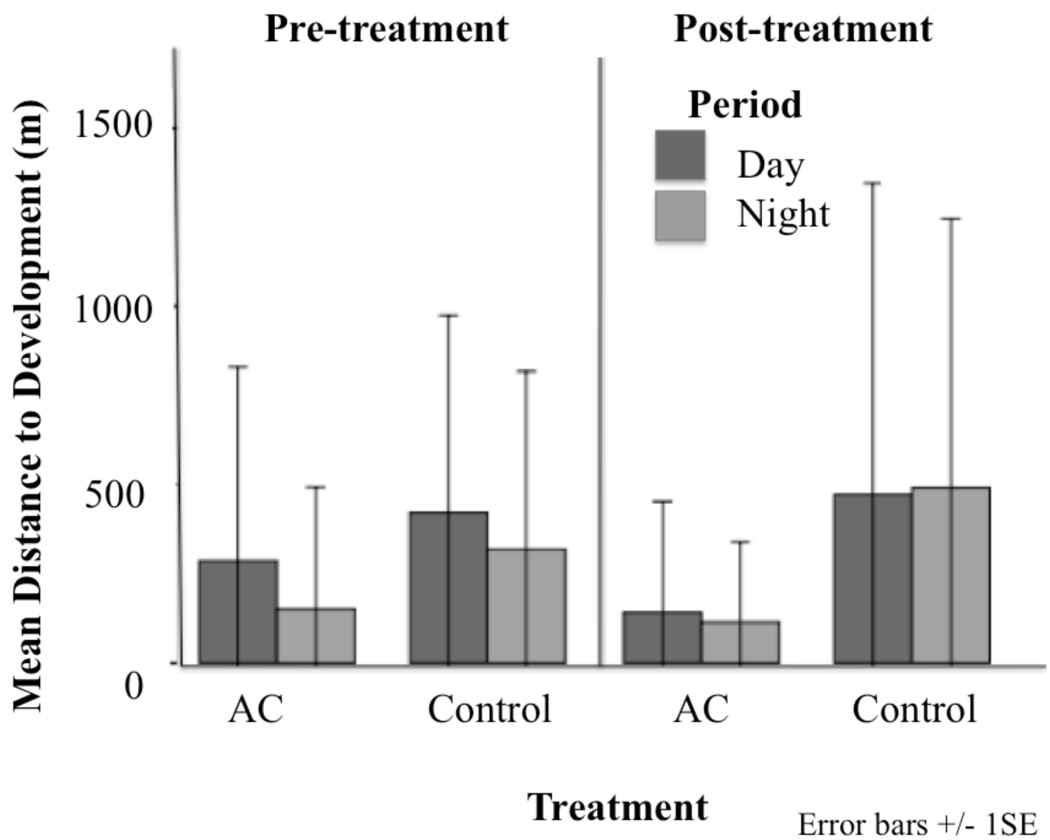

Figure 2-9. Mean distance to development from hourly locations of GPS-collared American black bears (*Ursus americanus*) before (pre-treatment) and after (post-treatment) aversive conditioning programs in Whistler, British Columbia during day and night periods (based on sunrise and sunset times).

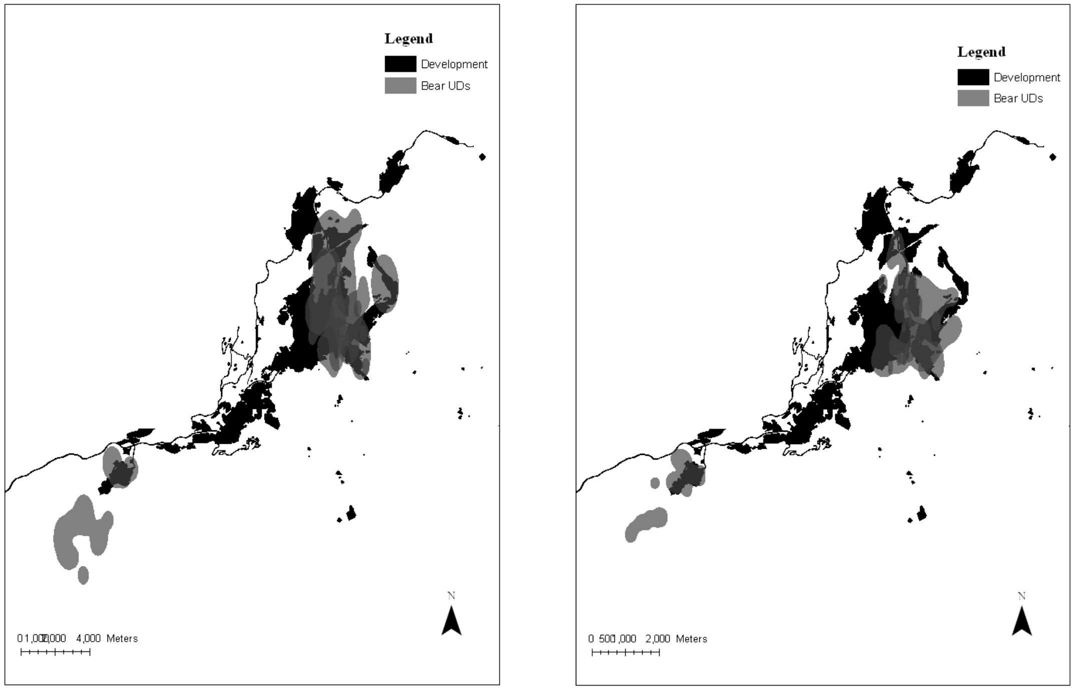

Figure 2-10. The similarity of the 95% contour of utilization distributions (UDs) of 4 GPS-collared black bears subjected to 3-5 days of aversive conditioning in Whistler, British Columbia during 3 days pre-treatment (left) and 3 days post-treatment (right).

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CHAPTER THREE

A PROTOCOL TO INDUCE CONDITIONED TASTE AVERSIONS IN AMERICAN BLACK BEARS USING THIABENDAZOLE, A DETECTABLE EMETIC

INTRODUCTION

Conflicts between wildlife and humans occur wherever actions by humans or wildlife inflict a negative impact on the other (Conover 2002). The nature of these conflicts frequently involves one of two situations; wildlife that do not display wariness toward humans (high human tolerance) or wildlife that are accessing anthropogenic attractants such as garbage (food conditioning). Both of these problems can lead to public safety concerns and property damage, particularly when they involve large carnivores such as bears (Herrero 1985).

For bears, tolerance to humans does not necessarily result in conflict, but food conditioning almost always does (Herrero *et al.* 2005). Food conditioned bears tend to interact with humans more aggressively and are more likely to cause property damage than non food conditioned bears (Herrero 1985). Managers often attempt to reduce the potential for human-bear conflict by using non-lethal management tools such as aversive conditioning (e.g., shooting bears with rubber bullets). Although food conditioned bears are more likely to be in situations that generate aversive conditioning, they are also far less likely to respond to this treatment than human-tolerant bears (Leigh and Chamberlain 2008, Mazur 2010).

As a result, food conditioned bears are more likely to be killed due to conflicts with humans (Herrero *et al.* 2005, Mazur 2010).

Lethal control is often unacceptable to the public (Beckman *et al.* 2004, Koval and Mertig 2004) and although most wildlife management agencies use non-lethal tools, very few of them collect data to evaluate its effectiveness (Spencer *et al*. 2007).   Well-designed studies of non-lethal management methods on free-ranging wildlife are consequently rare in the scientific literature, making it difficult to assess their efficacy in practical situations.

One promising tool for mitigating human-wildlife conflict is conditioned taste aversion (CTA), which occurs when an animal associates the taste or odour of a concealed ingested emetic in an attractant with a subsequent feeling of nausea, and thereafter avoids consuming the attractant (Baker *et al.* 2005). Forming a taste aversion involves the *area postrema* in the brain stem, making CTA a subconscious process (Roll and Smith 1972) that is well recognized in mammals (e.g. Semel and Nicolaus 1992, Macdonald and Baker 2004), birds (e.g. Conover 1984, Nicolaus and Lee 1999), and even invertebrates (Garcia *et al.* 1984). CTA has been most intensively studied in laboratory rats (e.g. Kalat and Rozin 1973, Galeff 1997) and it has presumably evolved to protect animals from poisoning (Gustavson 1977). CTAs can be powerful and long lasting; the taste of a substance can be associated with nausea that occurs up to 12 h after its ingestion (Cowan *et al.* 2000) and a single taste-illness pairing can be sufficient to create a CTA (Garcia *et al.* 1974). These features make CTA a promising tool for training wildlife to avoid specific attractants.

Despite the potential for CTA to mitigate human-wildlife conflict, wildlife managers seldom use it, likely due in part to the variability in the reported responses of wild animals. For example, Ellins *et al.* (1977) and Gustavson *et al.* (1982) successfully used lithium chloride to reduce coyote (*Canis latrans*) predation on sheep (*Ovis aries*), but many other studies were not successful in creating comparable associations, often due to difficulties in masking detectable emetics (reviewed by Gustavson and Nicolaus 1987). Emetics must be undetectable or the animal will distinguish between treated and untreated baits and continue to consume the untreated attractant in future (Nicolaus *et al.* 1989).

In addition to being undetectable, the ideal emetic should also be environmentally stable, have a low toxicity, cause nausea 1 to 12 hours after ingestion and be relatively affordable and accessible (Cowan *et al.* 2000). It is critical that the target animal receive an appropriate dose (usually orally), which can be difficult to measure and administer in the wild. If these requirements can be met, CTA could be an effective tool in non-lethal wildlife management. One of the most promising emetics for use in CTA is thiabendazole, a reportedly tasteless veterinary anthelminthic (Gill *et al.*1999).

The purpose of my study was to determine whether free-ranging black bears (*Ursus americanus*) could be treated with thiabendazole in Whistler, BC. There, and elsewhere in BC, frequent human-bear conflicts result when bears are attracted to unsecured anthropogenic attractants. In particular, I attempted to induce aversions to apples, restaurant grease, and paintballs. I chose these attractants based on their difficulty to secure from bears using other means, and their potential to contribute to human-bear conflict both locally and in other jurisdictions.

METHODS

As part of an ongoing study of human-bear conflict in Whistler, I ear-tagged and radio-collared black bears in Whistler. The British Columbia Conservation Officer Service captured bears for the project using aluminum swing gate culvert traps. Conservation officers used a jab stick to inject 100-300 mg/ml tiletamine – zolazepam hydrochloride (Telazol®) intramuscularly to immobilize the bears. I tagged each bear with a uniquely numbered and color-coded ear tag to identify the bears visually, and estimated body weight. I assigned them F for females and M for males, followed by a chronological number; for example F01. The University of Alberta Animal Care Committee approved my methods annually (protocol number 542905).

I established 6 bait sites near Whistler in 2008 and 2009. I chose site locations based on a lack of human activity (away from active roads and trails), and where I knew previously tagged bears were active. At each bait site, I hung two bear attractants, each in a 750 ml plastic container suspended approximately 1.5 metres above the ground. This position was used to prevent incidental treatment of other animals such as birds, canids, and squirrels. One container held 400 g of a treatment attractant (restaurant grease, paintballs or apples) and the other container held 50g of honey, which I used as a control attractant to encourage bears to return to the site (such that they had an opportunity to consume the focal attractant) in post-treatment. Between 1 and 3 Reconyx™ remote cameras recorded bear movement around baits (Figure 3-1). Cameras were set to record one frame per second for 10 seconds for each movement.

I identified bears on the remote camera images by their ear tags, or if the bear was not already marked, by distinguishing markings, such as unique chest blazes. I confirmed the identity of unmarked bears without distinguishing characteristics using DNA from hair caught in knee-high barbed wire strung around 4 trees surrounding the site. Wildlife Genetics in Nelson, British Columbia conducted the DNA analysis. I visited the bait sites daily to check for bear activity, to replace memory cards and batteries in the cameras, as well as consumed baits, and to collect hair samples, burning any remaining hairs caught in the barbs with a lighter.

Pre-treatment site visits began once a bear had successfully consumed the baits, andIcounted visits thereafter if the bear appeared at the site, and recorded whether the bear consumed the baits or avoided them. Remote cameras demontrated that bears that consumed baits always ate the entire bait. After at least 1 day of pre-treatment monitoring, I removed the honey and added 120 mg/kg thiabendazole to the treatment attractant (8 g – 24 g, depending on the bear's weight) in a single container. I calculated this dose based on an estimated bear weight at the time of capture, for each bear treated. For unmarked bears, I estimated bear weight based on the remote camera photos, comparing the relative size of the target bear to other marked bears for which I knew approximate weights. Given the low toxicity of thiabendazole (Gill *et al.* 1999), I tended to over-estimate weights because bears gain weight as the summer progresses (Noyce and Garshelis 1998), and a bear that consumed less than 120 mg/kg might not form a robust aversion to the attractant (Massei and Cowan 2002).

After the target bear consumed one full dose of thiabendazole-treated bait (hereafter called treated bait), I provided two containers for post-treatment monitoring. One contained the untreated attractant, which revealed whether or not a CTA had been formed, and one contained honey, which revealed a bear's willingness to return to the site. I then compared pre-treatment bait consumption to post-treatment bait consumption. This was protocol 1. I repeated the experiment for three attractants: restaurant grease, paintballs and apples. All three of these attractants cause human-bear conflict in Whistler or in nearby jurisdictions.

Because thiabendazole is assumed to be relatively tasteless (Ternent and Garshelis 1999), I concentrated our efforts in masking the texture of thiabendazole in baits. I treated each attractant slightly differently, in order to help mask the texture of thiabendazole in treatments. Thiabendazole tended to form small clumps whenImixed the powder with each attractant, but since the grease generally contained other clumps of food, I did not make any attempts to mask the clumps. For the paintballs, I sliced open approximately half the paintballs in all treatment periods so there would be both liquid and solid clumps in the container, and mixed in the thiabendazole on treatment days. For apples, I boiled and mashed them, and mixed in the thiabendazole on treatment days.

Upon review of the results using protocol 1, I suspected bears were either detecting the thiabendazole in the baits or were not consuming an adequate dose. Other authors have speculated on the detectability of thiabendazole (Polson 1983, Cowan *et al.* 2000), but I know of no studies designed to determine its detectability. Thus, in 2009 I tested only Granny Smith apples (which I minced), and for the first bearItreated, I used protocol 1 and added a post-treatment trial where I suspended one container of treated apples with one container of untreated apples simultaneously. This procedure was designed to determine whether the bear could detect thiabendazole in the bait. In the treatment for subsequent bears, I hung treated and untreated apples together on treatment days. I assumed that bears that were nauseated after consuming the treated bait would be unable to distinguish whether it was the treated or untreated bait that caused illness, circumstances that induced aversions to both green and white eggs in crows, although only green eggs contained an emetic (Dimmick and Nicolaus 1990). Because taste aversions appear to be more robust using higher doses of thiabendazole (200 mg/kg vs 150 mg/kg; Massei and Cowan 2002), I increased our target dosage in 2009. This was protocol 2.

I ran a chi square analysis in SPSS statistical software (version 17, Chicago, Illinois, USA) for my statistical analysis. Bears always either ate or avoided entire baits, so I coded the dependent variable as consumed or not consumed. Independent variables were treatment type (protocol) and time (pre- and post-treatment).

RESULTS

In 2008, I treated 6 bears with thiabendazole in 3 different attractants: 4 bears with restaurant grease, 3 with paintballs and 2 with boiled apples (Table 3-1). Three bears visited the bait sites to consume more than one type of attractant. Estimated dosages ranged from 80 mg/kg to 270 mg/kg except for one case where a bear consumed 450 mg/kg. The mean estimated dose was 183 mg/kg (Table 3-1). All bears continued to consume both control and untreated treatment baits after treatment with thiabendazole under protocol 1.

One experience in 2008 suggested that bears could detect thiabendazole in baits. Bear 8.4 appeared to consume a full dose on May 21, visited the site on May 23 and tasted the treated restaurant grease but left it hanging, and then returned on June 2 to consume untreated restaurant grease. This suggested that Bear 8.4 detected the thiabendazole in the grease. I explored this possibility further in 2009 by treating F22 with 10 g of TBZ in minced apples (as per protocol 1) and providing a post-treatment trial, simultaneously hanging treated and untreated bait. Before F22 ate the bait, F04 visited the site and consumed the contents of both containers. I repeated the post-treatment trial and F22 consumed untreated apples but rejected the treated apples, supporting my suspicion that she could detect the thiabendazole. However, F04 (the bear that had consumed untreated and treated apples simultaneously) also returned to the site and rejected both untreated and treated apples. I provided a second post-treatment trial, in which I mixed only 5g of thiabendazole in the apples. F22 rejected that bait as well. Together these results suggested that some bears can detect even small amounts of thiabendazole. By presenting treated and untreated baits simultaneously, protocol 2 prevented bears from knowing whether it was the thiabendazole or the attractant that caused the nausea.

In the remainder of 2009,Itreated 4 bears according to protocol 2 (Figure 3-2). I reused 1 bear, M35, who consumed treatments of grease and paintballs according to protocol 1 in 2008 and minced apples according to protocol 2 in 2009. Despite using a higher target dose with protocol 2, the mean estimated dose that bears consumed was 179 mg/kg (135 - 230 mg/kg). All 4 bears that I treated with protocol 2 avoided untreated apples in post-treatment, but continued to eat the control attractant, honey (χ^2 = 14.0, df = 3, P = 0.03) indicating that a CTA had been formed to the attractant, minced apples.

DISCUSSION

Using protocol 1, I was unable to establish any aversions to restaurant grease in 4 bears, paintballs in 3 bears, boiled apples in 2 bears, and minced apples in 1 bear using a dose that ranged from 80 mg/kg in a large adult male to an accidental dose in a subadult female of 450 mg/kg. In contrast, 4 bears developed complete aversions to minced apples using protocol 2. Under protocol 2, bears in post-treatment often sniffed the attractant containers and typically did not even taste the apples before rejecting them. This suggested that the bear rejected the apples based on odour cues, which has been documented in other studies (Rusiniak *et al.* 1979, Holm *et al.* 1988, Semel and Nicolaus 1992, Ternent and Garshelis 1999).

The strength of aversions is generally determined by dosage (Gustavson and Nicolaus 1987), and clarity of the source of the illness is normally necessary to induce taste aversions after a single trial (Gentle *et al.* 2006). When the source of illness is uncertain, however, severe illness has caused bait avoidance (Dimmick and Nicolaus 1990). The change in protocol both increased the dosage and obscured the presentation of thiabendazole.

Early in 2008, I suspected dosage was problematic because bears nearly always spilled the container contents when they pulled them to the ground. Restaurant grease in particular was partly absorbed by the ground when it spilled, although remote cameras revealed that bears entirely consumed spilled apples and paintballs. Moreover, removing the accidental overdose, the average estimated dose that bears consumed under protocol 1 was 154 mg/kg, more than adequate to produce a taste aversion in black bears. Black bears in Minnesota rejected prepackaged military rations after ingesting doses as low as 72 mg/kg (Ternent and Garshelis 1999), which is lower than my lowest dose of approximately 80 mg/kg. Taste aversions established using lower doses may not be as robust as aversions established using higher doses (Massei and Cowan 2002), but they should still be present. Thus, although I had some problems delivering an adequate dose in 2008 with restaurant grease, the dosages I used were sufficient to induce taste aversions, and differences in dosage cannot explain the differences in aversion success between the two protocols.

A second potential explanation for the different results from the two protocols is that bears were able to detect the thiabendazole and associated it, rather than the attractant, with nausea. A successful CTA requires emetics to be undetectable, because detectable emetics allow the animal to distinguish between treated and untreated baits and avoid illness by avoiding treated baits (Cowan *et al.* 2000). Because of my experiences with bears 8.4 and F22, I suspected that at least some black bears can detect thiabendazole in some attractants. Indeed, I provided an informal test of my suspicion by tasting the thiabendazole myself and found it to be slightly bitter. Bears have a much keener sense of smell than humans (Wilson and Stevenson 2006); therefore it is likely that if I can taste thiabendazole, bears can also taste it.

Although thiabendazole is assumed to be relatively tasteless (Ternent and Garshelis 1999), I could not find any studies that tested this assumption explicitly. Variation in detectability could be responsible for the inconsistent results with which thiabendazole forms CTAs. For example, thiabendazole successfully established CTAs in wolves (*Canis lupus*) to some foods, but not others (Ziegler *et al.* 1983). Endangered quolls (*Dasyurus hallucatus*) that consumed cane toads (*Bufo marinus*) treated with thiabendazole subsequently avoided them (O'Donnell *et al.* 2010). Previous studies of thiabendazole and black bears indicate that aversions can be formed to peanut butter (McCarthy and Seavoy 1994), and military rations (Ternent and Garshelis 1999). However, raccoons (*Procyon lotor*) did not learn to reject eggs (Conover 1989), sun bears (*Helarctos malayanus*) would not eat fruit treated with thiabendazole before treatment (Fredriksson 2005), and black bears continued to consume donuts after treatment with thiabendazole (Signor 2010). Differences in detectability could explain these results if detectability varies with the taste and texture of baits as well as different sensitivities among individuals. Bears likely recognized the thiabendazole in post-treatment baits in protocol 1, and acquired taste aversions to apples using protocol 2 due to the severity of nausea from high doses of thiabendazole, plus the simultaneous presentation of treated and untreated apples, which confounded the source of the illness.

Whether or not thiabendazole is detectable, it has a number of properties that make it an attractive choice as an emetic. Unlike lithium chloride, thiabendazole has a low toxicity, (Gill *et al.* 1999). The subadult female in Whistler that consumed a dose of approximately 450 mg/kg (intended for a large adult male) did not seem to suffer ill effects. She returned to the site the day following her treatment and consumed both the honey and the untreated attractant, and seemed healthy when I observed her in the spring and fall of 2009. Thiabendazole is also absorbed quickly (Rollo 1980), which reduces the time to the onset of illness to increase the ease of association (Nicolaus *et al.* 1989). It is completely metabolized in less than 48 hours (Rollo 1980). As a veterinary drug and pesticide, its effects are well researched and available (Cowan *et al.* 2000). While I did not test the extinction of the aversion, other work with black bears suggests that the aversion should last for at least one year (Ternent and Garshelis 1999). These attributes make thiabendazole worthy of further consideration for use as an emetic to induce CTAs, if the problems of detectability could be overcome.

MANAGEMENT IMPLICATIONS

My results indicate that taste aversions to untreated apples were created in the 4 black bears that consumed treated baits at the same time that they consumed untreated baits. I believe this protocol prevented the bears from knowing whether it was the thiabendazole or the untreated attractant that caused their nausea, and this along with the severity of their illness caused them to discontinue apple consumption. An equivalent effect might occur if thiabendazole were encapsulated in tasteless gel capsules within the attractant. Hanging attractants appeared to be a successful method for preventing unintended consumption by other animals. I suggest that use of CTA could be appropriate in situations where attractants have specific tastes but are difficult to secure. I do not recommend managers use CTA in place of using bear-resistant containers or electric fencing, but rather consider it only when these methods are not feasible. More research on both the detectability of thiabendazole and the potential of pairing treated and untreated attractants with higher doses of thiabendazole to induce aversions is warranted.

Figure 3-1: Remote camera image of an American black bear (*Ursus americanus*) consuming paintballs in a container at a bait site in Whistler, British Columbia in August, 2008. Bait sites were established to test the efficacy of thiabendazole as an emetic to create taste aversions to specific attractants. Note 2 additional remote cameras in the background, set to record 1 frame per second for 10 seconds whenever infrared sensors detect movement.

Table 3-1. Black bear (*Ursus americanus*) consumption (C) and avoidance (A) of 3 attractants after consuming 1-2 doses of thiabendazole in Whistler, British Columbia in 2008 and 2009 as part of efforts to induce taste aversions.

Bear	Protocol	Bait	B_T[a]	B_C[b]	Dose (mg/kg)
M35	1	Grease	C	C	125
Bear 8.4	1	Grease	C	C	125
M21	1	Grease	C	C	150
M36	1	Grease	C	C	160
Bear 08-0053 (F22)	1	Paintballs	C	C	150
M21	1	Paintballs	C	C	80, 180
F18	1	Paintballs	C	C	450
Bear 08-0053 (F22)	1	Boiled apples	C	C	150
F18	1	Boiled apples	C	C	270
F22	1	Minced apples	C	C	135
F04	2	Minced apples	A	C	135
M35	2	Minced apples	A	C	150
Bear A	2	Minced apples	A	C	230
M41	2	Minced apples	A	C	200

[a]Treatment bait (one of grease, paintballs, boiled apples or minced apples)

[b]Control bait (honey)

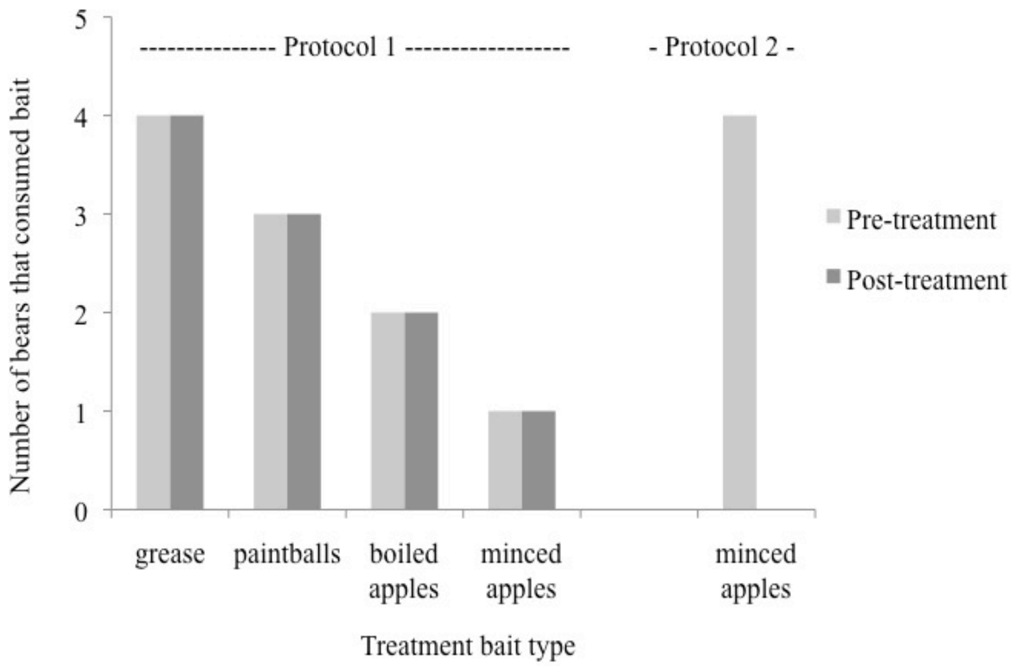

Figure 3-2. Bait consumption before and after bears ingested target doses of 120-200 mg/kg thiabendazole in an attempt to induce taste aversions in American black bears (*Ursus americanus*) to restaurant grease (grease), paintballs, boiled apples, and minced apples using two treatment protocols.

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CHAPTER FOUR

IMPLICATIONS OF AVERSIVE CONDITIONING AND CONDITIONED TASTE AVERSION FOR WILDLIFE MANAGERS

In this thesis, I examined bear responses to two non-lethal management tools, aversive conditioning (AC) and conditioned taste aversion (CTA) using thiabendazole as an emetic. When bears are managed lethally, the most common reasons stem from the combination of habituation to humans and food conditioning (Spencer *et al.* 2007). Human habituated bears display little or no overt response to human activities due to neutral past experiences with humans, while food conditioned bears have learned a positive association between humans and food (Hopkins *et al.* 2010). The BC Conservation Officer Service initiated research into the efficacy of AC in Whistler in 2005, where officers were already attempting AC and needed scientific research to ascertain the value of AC as a potential management application.

In chapter 2 I found that even short (3-5 days) AC programs applied during daylight hours seemed to increased black bear (*Ursus americanus*) wariness toward humans, but did not appear to reduce the time bears spend in human developments during daylight hours. AC programs altered bear behaviour, changing their response to approaching humans; bears that did not displace from approaching humans in pre-treatment were more likely to flee from approaching humans in post-treatment. AC also increased the distance at which bears began to notice approaching humans (Overt Reaction Distance), and the distance at which bears displaced from humans (Displacement Distance). Bears exhibited some increased wariness of approaching humans 3 weeks after their AC treatments compared to controls (for overt reaction distance measurements). In contrast, control bears not subjected to AC programs habituated to humans.

In chapter 3 I used thiabendazole, a reportedly undetectable emetic to induce conditioned taste aversions at bait sites. Evidence from this experiment suggested that bears detected the thiabendazole in the baits. Differences in bait taste, odour, or texture during treatment renders the emetic ineffective as target animals distinguish between treated and untreated baits and form an aversion to the emetic rather than the bait (Cowan *et al.* 2000). However, detectable emetics have potential use when the illness is severe and the source is in doubt.

CTA is most appropriate as a management tool when the attractant is difficult to secure, and is quite specific. For example, Ellins *et al.* (1977) and Gustavson *et al.* (1982) used lithium chloride to reduce coyote (*Canis latrans*) predation on sheep (*Ovis aries*). Ternent and Garshelis (1999) used thiabendazole to make military rations unpalatable to black bears. O'Donnell *et al.* (2010) used thiabendazole to reduce toxic cane toad (*Bufo marinus*) consumption in quolls (*Dasyurus hallucatus*). Using thiabendazole to induce taste aversions should have practical applications for crop raiding elephants (*Loxodonta Africana*), and for livestock depredation by canids, felids and ursids.

Taste aversions can be difficult to achieve in free-ranging wildlife, as critical requirements such as the delivery of appropriate doses can be challenging. In my experiment, some baits were more apt than others to spill (e.g. restaurant grease), and smaller bears visiting the bait site consumed more than the intended dose. Thiabendazole, with its low toxicity, was particularly useful for such situations (Gill *et al.* 1999); one subadult female consumed a dose of approximately 450 mg/kg and suffered no ill effects. This feature of thiabendazole makes it particularly useful to safely deliver non-toxic doses to animals of very different size (e.g. adults and young) and to sexually dimorphic species when one has little control over which particular animals ingest baits.

Another advantage of using CTA is that odour and taste cues are the triggers of the aversions, not location (Gustavson and Nicolaus 1987). CTA is also most effective when the bait is relatively novel and the source of the illness is clear; inducing a CTA to familiar foods that animals have experience with or when the source of the illness is not clear may require more than one nauseating experience unless the illness is severe (Dimmick and Nicolaus 1990).

Like CTA, AC is most effective when applied to relatively naïve animals. Applying AC after undesirable behaviours, particularly food-seeking behaviours, become established is less likely to reduce conflict behaviour (Beckman *et al.* 2004, Leigh and Chamberlain 2008, Mazur 2010). In fact, AC is unlikely to reduce food-seeking behaviour in the long term without continuous management application (Gallagher and Prince 2003, Shivik 2003, Cibilis *et al.* 2004, Wright *et al.* 2007). There appear to be few cases where AC seemed to curb undesired behaviour relating to food acquisition in wildlife. Park Rangers in Denali were able to stop food-seeking behaviour in five of six grizzly bears (*Ursus arctos*; Dalle-Molle and Van Horn 1989), and while researchers in Oregon were unable to use deterrents to curb salmonid consumption in pinnipeds, they did curb sturgeon (*Acipenser transmontanus*) consumption (Wright *et al.* 2007). The Denali rangers may have been successful in deterring food-seeking behaviour in grizzly bears due to the use of a very intense initial punishment before the unwanted behaviour became established. Other factors can influence the success of AC; shortages in natural food availability were closely correlated with increases in bear nuisance complaints (Howe *et al.* 2003), and proximity of predators influenced elk (*Cervus elaphus*) flight distances (Kloppers *et al.* 2005).

Several of the innovations in AC initiated in Whistler appeared to contribute to reducing conflict behaviour in bears. The addition of researchers using marbles fired from slingshots effectively increased bear wariness toward humans, partly because it removed the contingency of officer presence from punishment delivery. Some wildlife management agencies have attempted to make punishment less contingent on officer presence by delivering pain stimuli via officers or park rangers in plain clothes (Heuer 1993). However, anecdotal evidence in Whistler suggested that bears distinguished officers from the public based not on the uniform but on the presence of the shotgun. Using a variety of firearms, including those easily concealed from bears may allow bears to generalize wariness to include members of the public.

Bears also changed their behavioural response to humans after AC programs. AC-treated bears were more likely than control bears to avoid approaching humans by running away. Application of AC to other species may be useful to change how aggressive wildlife interact with humans during encounters. Injury and death to both humans and elephants are significant (Kioko *et al.* 2006). Yet, efforts to curb aggression and crop raiding behaviour are often hampered as noise deterrents unaccompanied by pain stimuli are ineffective (Tchamba 1996, Osborn and Parker 2002). Pairing a sound cue with pain stimuli in such situations may increase the effectiveness of noise deterrents.

Non-lethal management is not a panacea, but informed use of lethal measures to improve wildlife management practices is currently lacking in many management jurisdictions (Reddiex and Forsyth 2006). Lethal bear management in urban areas may create population sinks that make colonization of adjacent habitat unlikely (Beckman and Lackey 2008) and removal of adult animals may increase the population density of bears (Kemp 1974, Czetwertynski *et al.* 2007). Bears in areas without hunting also have longer lives and lower cub survival than those in areas subjected to hunting pressure (Czetwertynski *et al.* 2007). Maintaining a stable population of bears that have a level of habituation to humans which allows them to coexist with minimal conflicts with humans promotes increased public safety, as such bears are less likely to injure people in encounters than bears which are not habituated (Aumiller and Matt 1994, Herrero *et al.* 2005). In this scenario, lethal bear management is less necessary.

In the short term, lethal management is less costly than non-lethal management, but lethal management applied without knowledge or evaluation of its effectiveness may have unintended consequences and fail to provide solutions (Warburton and Norton 2009). Some species respond to culling by increasing reproductive rates and population density (Knowlton *et al.* 1999, McLeod and

Saunders 2001, Hanson *et al.* 2009). Even when lethal management practices successfully reduce population densities of the target species, a competitor species no longer constrained by the removed one may increase in numbers (Bodey *et al.* 2009). Disrupting the social structure of species that live in familial groups by removing adults may have unintended ecosystem consequences. Removal of adult elephants in South Africa altered social structure, affected sexual maturity and aggression in subadult males (Slotow and van Dyk 2001).

Human-wildlife conflict is projected to increase in the future as human populations expand (Spencer *et al.* 2007). The success of mitigation efforts depends on the ability of wildlife managers to address the causes of human-wildlife conflicts and to both evaluate and implement appropriate solutions in the short and long term. Conflicts between humans and wildlife rarely stem from a simple set of circumstances; therefore, solutions need be drawn from broad sources, beyond traditional wildlife management techniques. While lethal management will be necessary on occasion, the use of non-lethal management efforts, which tend to garner more public support, can make lethal management more acceptable to the public when it is necessary.

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