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Estimating Baseline Population Parameters of Urban and Wildland Black Bear Populations Using a DNA-Based Capture -Mark-Recapture Approach in Mono County, California

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ESTIMATING BASELINE POPULATION PARAMETERS OF URBAN AND WILDLAND

BLACK BEAR POPULATIONS USING A DNA-BASED CAPTURE-MARK-RECAPTURE

APPROACH IN MONO COUNTY, CALIFORNIA

by

Jonathan L. Fusaro

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Biology

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ABSTRACT

Estimating Baseline Population Parameters of Urban and Wildland Black Bear Populations Using

a DNA-based Capture-Mark-Recapture Approach in Mono County, California

by

Jonathan L. Fusaro, Master of Science

Utah State University, 2014

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Department: Wildland Resources

The black bear (*Ursus americanus*) population has tripled in the last 3 decades in California. Bears inhabit areas they formally never occurred (e.g., urban environments) and populations that were historically at low densities are now at high densities. California Department of Fish and Wildlife use statewide harvest data to monitor population trends of black bears. Statewide harvest data lack the ability to produce precise estimates of abundance and density at a local scale. Furthermore, an increase in urban development and recreation along with a growing bear population has resulted in an increase in human-bear conflicts. My study tested techniques to acquire local-scale population parameters prior to management actions. My objective was to develop DNA-based capture-mark-recapture (CMR) techniques in a wildland and urban environment in Mono County, California to acquire population size and density at local scales from 2010 to 2012. I also compared population density between the urban and wildland environment.

In Chapter 2, I determined that there is likely a difference in population density between the urban and wildland environment. Population density was 1.6 to 2.5 times higher in the urban compared to the wildland environment. Considering the negative impacts urban environments can have on wildland bear populations, this is a serious management concern.

In Chapter 3, I explained the DNA-based CMR field techniques that allowed me to successfully acquire population size and density of black bears in an urban environment. In the urban area, I reduced sampling grid cell sizes significantly, used non-consumable lures, modified hair-snares for public safety, included the public throughout the entire process, and surveyed in the urban wildland interface as well as the city center. My methods were efficient, having a high capture rate and recapture rate (>0.30) and precision (coefficient of variance ≤ 0.2) while maintaining human safety.

The densities I found were similar to those found in other urban and wildland black bear populations. The baseline data acquired from this study can be used as part of a long-term monitoring effort. By surveying additional years, population vital rates such as apparent survival, recruitment, movement, and finite rate of population change can be estimated.

(81 pages)

PUBLIC ABSTRACT

Estimating Baseline Population Parameters of Urban and Wildland Black Bear Populations Using

a DNA-based Capture-Mark-Recapture Approach in Mono County, California

by

Jonathan L. Fusaro

Prior to European settlement, black bear (*Ursus americanus*) were far less abundant in the state of California. Estimates from statewide harvest data indicate the California black bear population has tripled in the last 3 decades. Bears inhabit areas they formally never occurred (e.g., urban environments) and populations that were at historically low densities are now at high densities. Though harvest data are useful and widely used as an index for black bear population size and population demographics statewide, it lacks the ability to produce precise estimates of abundance and density at local scales or account for the numerous bears living in non-hunted areas. As the human population continues to expand into wildlife habitat, we are being forced to confront controversial issues about wildlife management and conservation. Habituated bears living in non-hunted, urban areas have been and continue to be a major concern for wildlife managers and the general public.

My objective was to develop DNA-based capture-mark-recapture (CMR) survey techniques in wildland and urban environments in Mono County, California to acquire population size and density at local scales from 2010 to 2012. I also compared population density between the urban and wildland environment.

To my knowledge, DNA-based CMR surveys for bears have only been implemented in wildland or rural environments. I made numerous modifications to the techniques used during wildland DNA-based CMR surveys to survey bears in an urban environment. I used a higher density of hair-snares than typically used in wildland studies, non-consumable lures, modified

hair-snares for public safety, included the public throughout the entire process, and surveyed in the urban-wildland interface as well as the city center. These methods were efficient and accurate while maintaining human safety.

I determined that there is likely a difference in population density between the urban and wildland environments. Population density was 1.6 to 2.5 times higher in the urban study area compared to the wildland study area. Considering the negative impacts urban environments can have on wildland bear populations, this is a serious management concern.

The densities I found were similar to those found in other urban and wildland black bear populations. The baseline data acquired from this study can be used as part of a long-term monitoring effort. By surveying additional years, population vital rates such as apparent survival, recruitment, movement, and finite rate of population change can be estimated.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Carnivores are expanding back into their historic ranges, and their populations are increasing throughout the United States (Conover 2008). Wildlife managers are faced with the difficult task of monitoring and managing carnivore populations for the public. One of the first steps of making informed management decisions for any species is obtaining reliable demographic and abundance estimates. The traditional methods of live-trapping to attain these population parameters for carnivores are invasive and often cost prohibitive (Woods et al. 1999, Waits and Paetkau 2005, Kendall and McKelvey 2008, Tredick and Vaughan 2009). However, recent advances in noninvasive DNA-based sampling have allowed wildlife managers to obtain cost effective and more reliable demographic and abundance estimates for species such as the lynx (*Lynx canadensis;* McDaniel et al. 2000), bobcat (*Lynx rufus;* Stricker et al. 2012), mountain lion (*Puma concolor*; Ernest et al. 2000), gray wolf (*Canis lupus*; Stenglein et al. 2010), wolverine (*Gulo gulo;* Magoun et al. 2011), grizzly bear (*Ursus arctos*; Woods et al. 1999, Boulanger et al. 2004, Kendall et al. 2009), and black bear (*U. americanus;* Settlage et al. 2008, Robinson et al. 2009, Coster et al. 2011).

The most cost effective and common method of obtaining population parameters for bears is through the application of DNA-based capture-mark-recapture (CMR) techniques from systematically collected hair samples (Woods et al. 1999, Mowat and Strobeck 2000, Kendall et al. 2009, Robinson et al. 2009). Woods et al. (1999) was among the first to implement DNA-based CMR techniques on bear using hair-snares. Since then, many improvements have been made to the tools and techniques of DNA-based CMR for bear species. Improvements include better hair-snare designs (Beier et al. 2005, Immell and Anthony 2008, Kendall and McKelvey 2008, Robinson et al. 2009), trapping arrays (Poole et al. 2001, Thompson 2004), bear lures and baits (Waits and Paetkau 2005, Kendall et al. 2009) , hair subsampling methods (Tredick et al.

2007, Dreher et al. 2009), genotyping techniques (Lukacs and Burnham 2005, Dreher et al. 2007), and statistical models (Kendall et al. 2009, Robinson et al. 2009, Gardner et al. 2010).

Though much of the bears' and other carnivores' historic ranges are still wildland areas, an increasing amount of their historic range has become urbanized. The traditional dogma was that bears and other carnivores avoid urban areas; it appears that this is no longer true. Many carnivore species, black bears in particular, can habituate to urbanization and take advantage of available anthropogenic resources (Beckmann and Lackey 2008, Gehrt et al. 2010). Hence, wildlife managers must monitor bears that inhabit wildland, rural, and urban landscapes.

Population estimates for California, generated from statewide harvest data, indicate the black bear population has nearly tripled over the last 2 decades (California Department of Fish and Wildlife 2012). Black bears now reside in places they formally never occurred (e.g., urban communities) and have increased in abundance in places where they historically were at low densities. Furthermore, human-bear conflicts are increasing in California as people develop more land in black bear habitat, recreate more in black bear habitat, and as the bear population increases. Bears living in and around urban environments that take advantage of anthropogenic food resources are a major concern to our wildlife managers and most of the general public who live with bears in their community. It is well documented these bears can be a threat to public safety and inflict major property damage (Baruch-Mordo et al. 2008, Herrero et al. 2011). Less documented, but also important to wildlife managers, is the fact that urban landscapes can negatively affect the health of wildland bear populations by functioning in a source-sink dynamic (Beckmann and Berger 2003*b*, Beckmann and Lackey 2008, Hostetler et al. 2009). The wildland, "source" population of bears are drawn into urban areas to obtain anthropogenic resources (e.g., garbage). While in the urban landscapes, sows experience higher age-specific fecundity rates than sows in the surrounding wildland areas; however, the urban sows have a higher mortality that exceeds their higher recruitment rates (Hostetler et al. 2009). The urban environment, therefore, acts as a "sink" or ecological trap. In addition, the urban habitat may produce a source of

habituated and food-conditioned bears that disperse to neighboring communities (Beckmann and Berger 2003*a*, Breck et al. 2008, Mazur and Seher 2008). If the urban bears exhibit typical demographic patterns, these dispersers will be juvenile males seeking home ranges away from their mother and female siblings (i.e., inbreeding avoidance; Greenwood 1980, Dobson and Jones 1985).

In chapter 2, I addressed the differences in population parameters between an urban and a wildland bear population in Mono County, California based on data obtained from DNA-based CMR. In chapter 3, I addressed the modifications to traditional DNA-based CMR surveys for black bear in wildland or rural habitats that are required to implement a DNA-based survey of black bear that frequent urban clusters (i.e., 2500 to 50000 people). The first objective of my study was to obtain ≥ 30 opportunistic DNA samples from known bears (i.e., road kill, hunter harvest, depredation, etc.) in my study area to define the population genetics (allele frequencies) of the bears in the area and determine genotyping error. The second objective was to test the plausibility of implementing a non-invasive CMR study in an urban area using a combination of traditional hair-snare CMR techniques as well as methods modified based on maintaining human safety, incorporating urban bear natural history, and general feasibility (i.e., obtaining private property access). The third objective was to compare the population densities and sex ratios obtained from a wildland study area and an urban study area.

THESIS FORMAT

Chapters 2 and 3 were written and formatted as individual manuscripts ready for publication in specific peer-reviewed scientific journals. Chapter 2 will be submitted to *Ursus* and chapter 3 will be submitted to *Human-wildlife Interactions.* Because my work was a collaboration among several other people and entities, co-authors are listed at the start of each chapter; thus, I shifted from the singular (e.g., "I") to the plural (e.g., "we") throughout the chapters 2 and 3.

LITERATURE CITED

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

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

———, and J. Berger. 2003b. Using black bears to test ideal-free distribution models experimentally. Journal of Mammalogy 84:594–606.

Beckmann, J. P., and C. W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: A case history of black bears. Human-Wildlife Interactions 2:168–174.

Beier, L. R., S. B. Lewis, R. W. Flynn, G. Pendleton, and T. V. Schumacher. 2005. A single-catch snare to collect brown bear hair for genetic mark-recapture studies. Wildlife Society Bulletin 33:766–773.

Boulanger, J., S. Himmer, and C. Swan. 2004. Monitoring of grizzly bear population trends and demography using DNA mark-recapture methods in the Owikeno Lake area of British Columbia. Canadian Journal of Zoology 82:1267–1277.

Breck, S. W., C. L. Williams, J. P. Beckmann, S. M. Matthews, C. W. Lackey, and J. J. Beecham. 2008. Using genetic relatedness to investigate the development of conflict behavior in black bears. Journal of Mammalogy 89:428–434.

California Department of Fish and Wildlife. 2012. Black bear population report. Sacramento, CA, USA. http://dfg.ca.gov/wildlife/hunting/bear/population.html, accessed 10 March 2012.

Conover, M. 2008. Why are so many people attacked by predators? Human-Wildlife Conflicts 2:139–140.

Coster, S. S., A. I. Kovach, P. J. Pekins, A. B. Cooper, and A. Timmins. 2011. Genetic mark-recapture population estimation in black bears and issues of scale. Journal of Wildlife Management 75:1128–1136.

Dobson, F. S., and W. T. Jones. 1985. Multiple causes of dispersal. American Naturalist 126:855–858.

Dreher, B. P., G. J. Rosa, P. M. Lukacs, K. T. Scribner, and S. R. Winterstein. 2009. Subsampling hair samples affects accuracy and precision of DNA-based population estimates. Journal of Wildlife Management 73:1184–1188.

———, S. R. Winterstein, K. T. Scribner, P. M. Lukacs, D. R. Etter, G. J. Rosa, V. A. Lopez, S. Libants, and K. B. Filcek. 2007. Noninvasive estimation of black bear abundance incorporating genotyping errors and harvested bear. Journal of Wildlife Management 71:2684–2693.

Ernest, H. B., M. C. T. Penedo, B. P. May, M. Syvanen, and W. M. Boyce. 2000. Molecular tracking of mountain lions in the Yosemite Valley region in California: Genetic analysis using microsatellites and faecel DNA. Molecular Ecology 9:433–442.

Gardner, B., J. A. Royle, M. T. Wegan, R. E. Rainboat, and P. D. Curtis. 2010. Estimating black bear density using DNA data from hair snares. Journal of Wildlife Management 74:318–325.

Gehrt, S. D., S. P. D. Riley, and B. L. Cypher, editors. 2010. Urban carnivores ecology, conflict, and conservation. Johns Hopkins University Press, Baltimore, Maryland, USA.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal behaviour 28:1140–1162.

Herrero, S., A. Higgins, J. E. Cardoza, L. I. Hajduk, and T. S. Smith. 2011. Fatal attacks by American black bear on people: 1900–2009. Journal of Wildlife Management 75:596–603.

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

Immell, D., and R. G. Anthony. 2008. Estimation of black bear abundance using a discrete DNA sampling device. Journal of Wildlife Management 72:324–330.

Kendall, K. C., and K. S. McKelvey. 2008. Hair collection. Pages 135–176 in R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey methods for carnivores. Island Press, Washington, DC, USA.

———, J. B. Stetz, J. Boulanger, A. C. Macleod, D. Paetkau, and G. C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management 73:3–16.

Lukacs, P. M., and K. P. Burnham. 2005. Estimating population size from DNA-based closed capture-recapture data incorporating genotyping error. Journal of Wildlife Management 69:396–403.

Magoun, A. J., C. D. Long, M. K. Schwartz, K. L. Pilgrim, R. E. Lowell, and P. Valkenburg. 2011. Integrating motion-detection cameras and hair snags for wolverine identification. Journal of Wildlife Management 75:731–739.

Mazur, R., and V. Seher. 2008. Socially learned foraging behaviour in wild black bears, *Ursus americanus*. Animal Behaviour 75:1503–1508.

McDaniel, G. W., K. S. McKelvey, J. R. Squires, and L. F. Ruggiero. 2000. Efficacy of lures and hair snares to detect lynx. Wildlife Society Bulletin 28:119–123.

Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64:183–193.

Poole, K. G., G. Mowat, and D. A. Fear. 2001. DNA-based population estimate for grizzly bears *Ursus arctos* in northeastern British Columbia, Canada. Wildlife Biology 7:105–115.

Robinson, S. J., L. P. Waits, and I. D. Martin. 2009. Estimating abundance of American black bears using DNA-based capture-mark-recapture models. Ursus 20:1–11.

Settlage, K. E., F. T. Manen, J. D. Clark, and T. L. King. 2008. Challenges of DNA-based mark-recapture studies of American black bears. Journal of Wildlife Management 72:1035–1042.

Stenglein, J. L., L. P. Waits, D. E. Ausband, P. Zager, and C. M. Mack. 2010. Efficient, noninvasive genetic sampling for monitoring reintroduced wolves. Journal of Wildlife Management 74:1050–1058.

Stricker, H. K., J. L. Belant, D. E. Beyer Jr, J. Kanefsky, K. T. Scribner, D. R. Etter, and J. Fierke. 2012. Use of modified snares to estimate bobcat abundance. Wildlife Society Bulletin 36:257–263.

Thompson, W. L., editor. 2004. Sampling rare or elusive species: Concepts, designs, and techniques for estimating population parameters. Island Press, Washington, DC, USA.

Tredick, C. A., and M. R. Vaughan. 2009. DNA-based population demographics of black bears in coastal North Carolina and Virginia. Journal of Wildlife Management 73:1031–1039.

———, M. R. Vaughan, D. F. Stauffer, S. L. Simek, and T. Eason. 2007. Sub-sampling genetic data to estimate black bear population size: A case study. Ursus 18:179–188.

Waits, L. P., and D. Paetkau. 2005. Noninvasive genetic sampling tools for wildlife biologists: A review of applications and recommendations for accurate data collection. Journal of Wildlife Management 69:1419–1433.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616–627.

CHAPTER 2

ESTIMATING BASELINE POPULATION PARAMETERS OF URBAN AND WILDLAND

BLACK BEAR POPULATIONS USING A DNA-BASED CAPTURE-MARK-RECAPTURE

APPROACH IN MONO COUNTY, CALIFORNIA[1]

ABSTRACT

The California Department of Fish and Wildlife monitors its black bear (*Ursus americanus*) population through harvest data at a statewide level, and this project was one of the initial stages in improving management of bears in the state by monitoring populations at local scales. The California black bear population has tripled over the last 3 decades. With human development moving further into bear habitat, bears readily habituating to these human-altered landscapes, and human-bear conflicts increasing, it is critical that managers acquire population parameters in both wildland and urban environments to help manage the bears. This project used genetic capture-mark-recapture through the use of hair-snares to acquire baseline estimates of population size and density in both a wildland and a human-altered, urban environment in the eastern Sierra Nevada, Mono County, California, USA. Hair-snares were deployed for a total of 6 weeks (7 day sessions) from June to July in 2010, 2011, and 2012. A total of 219 and 175 hair samples were genetically analyzed in the wildland and urban study areas, respectively. We used robust design closed population models and model averaging in Program MARK to estimate population size. The average population size was 61 and 33 in the wildland and urban study areas, respectively. Density estimates were 1.6 to 2.5 times smaller in the wildland study area compared to the urban study area. The results from this study can be used to guide future DNA-based black bear surveys in California and as baseline information for long-term monitoring of population trends.

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[1] Coauthored by Mary Conner and Michael R. Conover.

INTRODUCTION

The population estimate for black bear (*Ursus americanus*) in the state of California in 1982 was less than 15,000 but now exceeds 35,000, based on statewide harvest data (California Department of Fish and Wildlife 2012). Black bears now reside in places they historically never occurred (e.g., urban communities) and have increased in abundance in places they historically were at low densities. Several factors may account for to the proliferation of black bear numbers in California, including range expansion into habitat formerly occupied by the competitively dominant grizzly bear (Brown et al. 2009), more restrictive hunting regulations (California Department of Fish and Wildlife 1998), translocations of black bears (Burgduff 1935), and the availability of high-caloric-value anthropogenic food sources within urban landscapes (Beckmann and Berger 2003*a*, Beckmann and Lackey 2008).

Human-bear conflicts are increasing in California as development and recreation in black bear habitat, and bear populations, continue to increase. Habituated bears living in and around urban environments that take advantage of anthropogenic resources (i.e., acting food-conditioned) are a major concern to wildlife managers and most of the general public that live with bears in their community (Beckmann and Lackey 2008, Baruch-Mordo et al. 2011, Merkle et al. 2011). It has been well documented that these bears can be a threat to public safety and inflict major property damage (Baruch-Mordo et al. 2008, Herrero et al. 2011). Less documented, but equally important to wildlife managers, is the fact that urban landscapes can negatively affect the health of wildland bear populations by functioning in a source-sink dynamic (Beckmann and Berger 2003*b*, Beckmann and Lackey 2008, Hostetler et al. 2009). The wildland, "source" population of bears are drawn into urban areas to attain anthropogenic resources (e.g., garbage). While in the urban landscapes, bear sows experience higher age-specific fecundity rates than sows in the surrounding wildland areas; however, urban sows have higher mortality that exceeds recruitment rates (Hostetler et al. 2009). The urban environment, therefore, acts as a "sink." In addition, the urban environment may act as a training area for habituated and food-conditioned bears that

disperse to neighboring communities and cause human-bear conflicts (Beckmann and Berger 2003*a*, Breck et al. 2008, Mazur and Seher 2008). Extensive efforts across North America are being made to manage human-bear conflicts and to mitigate the negative effects urban environments have on bears.

One of the first steps in making informed management decisions for any species is obtaining reliable demographic and abundance estimates (Thompson et al. 1998, Williams et al. 2002). According to Coster et al. (2011), statewide harvest data lack the resolution needed to estimate demographic vital rates and abundance of black bear on a local scale. To improve management of California black bears, it has become critical that the California Department of Fish & Wildlife (CA DFW) monitor bear populations outside of hunting zones and at local scales, not just on a statewide scale using harvest data alone. The most cost effective and common method of monitoring bear populations to obtain local scale population parameters is via DNA-based capture-mark-recapture (CMR) techniques from systematically collected hair samples (Mowat and Strobeck 2000, Kendall and McKelvey 2008, Robinson et al. 2009).

The objective for this study was to conduct a multi-year DNA-based CMR through the use of hair-snares to obtain population sizes, densities and sex ratios of bears that inhabit the two main landscape types in our study area and then compare densities and sex ratios. Wildland with an interspersion of rural land, was one of the main landscape types in our study area. The other main landscape type was urban clusters (UCs). UCs are geographic areas (i.e., communities) that contain 2,500 - 50,000 people, while rural and wildland geographic areas have <2,500 people (U.S. Census Bureau 2010*a*). We hypothesized that our results would be similar to the study by Beckmann and Berger (2003*b*) where the wildland and rural environments would have lower densities and male to female sex ratios than the urban study area.

STUDY AREAS

Our 2 study areas were in Mono County, CA. Mono County occupies approximately 7884 km^2, and there are approximately 2 people/km^2 (U.S. Census Bureau 2010*b*). Most bear habitat is confined to the mountainous region located along the eastern escarpment of the Sierra Nevada. The marginal bear habitat to the east of the Sierra Nevada is the Great Basin Desert. Both of our study areas were along the eastern Sierra. Mammoth Lakes (ML), CA was the UC and Slinkard Valley Wildlife Area (SVWA) was the wildland study area (Fig. 2-1).

Wildland Study Area

The SVWA study area was 70 km^2 of CA DFW and U.S. Forest Service land located in the extreme northwest portion of Mono County ranging in elevation from 1800 to 2550 m (Figure 2-1). The nearest California communities are Coleville, Topaz, and Walker, located 6 to 9 km east of the center of SVWA, along the Highway 395 corridor. The combined population size for those communities is 1266 (U.S. Census Bureau 2010*b*). The average annual precipitation is 21 cm (Western U.S. Climate Historical Summaries 2013). Bear hunting is allowed in the area, however, not during the study period. Vehicle access to SVWA is prohibited by the public. Cattle grazing also occurs in SVWA. The area provides excellent bear habitat. Numerous permanent and intermittent creeks run in the large canyons, and the permanent Slinkard Valley creek runs down the center of the valley. Habitat types include: big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), pinyon pine (*Pinus monophylla*), aspen (*Populus tremuloides*), mixed-conifer forest, and irrigated pasture (Mayer and Laudenslayer 1988). These habitat types provide a variety of both hard and soft-mast crops, including pinyon pine, snowberry (*Symphoricarpos rotundifolius*), Sierra plum (*Prunus subcordata*), elderberry (*Sambucus* spp.), bittercherry (*Prunus emarginata*), wild rose (*Rosa woodsii*) and Sierra currant (*Ribes cereum*).

Urban Study Area

ML has had a long history (>3 decades) of habituated and food-conditioned bears living within city limits. Bears are known to hibernate within the city limits (California Fish and Wildlife, unpublished data). ML sits at the base of the Mammoth Mountain Ski Resort and ranges in elevation from 2200 to 2700 m. The average precipitation per year is 58 cm Western Regional Climate Center 2013). The community is located on the Inyo National Forest in southwestern Mono County, has 8,234 year-round residents (U.S. Census Bureau 2010*b*), and 1.5 million visitors during the spring and summer; the same time bears are most active (Town of Mammoth Lakes 2007). All hunting is prohibited within the city limits. The municipal city limits encompasses 60 km^2; however, most of the residents (7164, 87%) live in the 10 km^2 city center and the remaining 1073 (13%) live in the 34 km^2 urban-wildland interface (U.S. Census Bureau 2010*b*). Our study area (Fig. 2-1) encompassed only the 44 km^2 where there was presence of humans (>2,500), anthropogenic resources (e.g., trash), and anthropogenic structures.

Vegetation types occurring within the city center portion of the study area include fragmented patches of mixed conifer forest, montane chaparral, aspen (*Populus tremulodies*) and willow (*Salix* spp.) (Mayer and Laudenslayer 1988). In addition to residential and commercial development within the city center, there are also interspersions of open green-ways for recreational use, a large network of hiking and biking trails, 2 golf courses, and the Eastern Sierra Valentine Reserve (ESVR). The 0.63 km^2 ESVR is owned by the University of California and provides a refuge for wildlife and facilities for researchers. Mammoth creek runs year round through the city center from the UWI. There are numerous lakes and permanent and intermittent creeks in the UWI. The UWI is dominated by Jeffrey pine (*Pinus jeffreyi*), mixed conifer forest, aspen and montane chaparral. There are 5 lodges, 9 campgrounds, and a large network of hiking and biking trails within the UWI. In addition, there is a motocross track, pack station, and Mammoth Mountain Ski Resort that offers numerous spring and summer activities.

METHODS

CMR Sampling Design and Field Methods

We used hair-snares to collect DNA from individual bears from which we used CMR techniques to estimate population size, density, and sex ratios. The study was conducted for 3 field seasons (2010, 2011, and 2012), which ran from June to July. We used DNA-based CMR techniques that were similar to Woods et al. (1999), Boulanger et al. (2008), and Kendall and McKelvey (2008). To reduce geographic closure violations of the CMR models, ridgelines were used as boundaries of the SVWA assuming these geographic barriers would help reduce bear movement in and out of the study area (Boulanger et al. 2004*a*). We assumed there was limited closure violation in ML because 100% of the urban bears studied for 10 years in the Beckmann and Berger (2003*b*) study had >90% occupancy in urban communities similar to ML. That study was also conducted north of Mono County and in the interface of the Sierra Nevada and Great Basin Desert. Grid systems were used to ensure adequate sampling when using hair-snares, and grid cell sizes were determined by the average smallest home range of bears in the study area to reduce missing individual bears (Boulanger et al. 2004*a*). No studies have estimated home range size in our exact study areas; therefore, we determined cell sizes based on the estimates of the home ranges of urban and wildland bears in the Beckmann and Berger (2003*b*) study area. We subjectively reduced cell sizes further with the goal of over-sampling as opposed to under-sampling. In both study areas, we used small grid cells at high densities to reduce bias in our sampling design (Boulanger et al. 2004*a*).

In SVWA, we used 10-km^2 grid cells ($n = 7$) and maintained that cell size for all 3 field seasons (Fig. 2-1). For the 2010 ML field season, we used 5-km^2 grid cells ($n = 12$) and only put hair-snares on public land (i.e., UWI) because we assumed bears left the city center during the daytime. For the 2011 ML field season, we set up hair-snares on private land in the city center in addition to public land in the UWI. Due to the spatial distribution of the private property access,

we established a 2-km^2 circular buffer around each hair-snare ($n = 20$) instead of using a grid system. Buffers covered the entire study area with minimal overlap. However, for the 2012 ML field season, we secured adequate private property access and switched to 2-km^2 grid cells ($n = 22$, Fig. 2-1).

One corral hair-snare was placed in each cell or buffer every field season in both study areas (Fig. 2-1). The corral hair-snare (single strand) was adapted from Woods et al. (1999). To entice bears to go over or under the single strand of barbed wire, a non-consumable lure (0.5 L) was placed in the center of each hair corral on a pile of course woody debris. Lure was also sprayed on a rag and hung 4 m above the center of each hair corral as an aerial attractant. We used non-consumable, commercial lures to prevent food conditioning the bears and to thwart a trap-happy response by not providing a caloric reward. For all 3 seasons in the SVWA and during the 2010 field season in ML 2 lures: fish oil (Minnesota Trapline Products, Inc., Pennock, Minnesota) and anise (Bear Scents LLC., Lake Mills, Wisconsin) were rotated systematically at each hair corral to increase visitation by instilling the novelty of a new scent. In addition to using fish oil and anise during the 2011 ML field season, we also used hickory smoke and cherry lures (both Bear Scents LLC., Lake Mills, Wisconsin). During the 2012 ML field season, we rotated fish oil, anise, hickory smoke, anise with spent cooking oil (50:50 mixture), and hickory smoke with spent cooking oil (50:50 mixture) to all hair-snares.

In 2012, we also used alternative hair-snare designs in both study areas to reduce capture heterogeneity, increase recapture rates (Boulanger et al. 2008), and test hair-snare designs that were safer and required less area for setup in UCs (Fig. 2-1). In ML, we added 1 alternative hair-snare (natural rub, haphazard-wire snare, or a tennis ball snare) to each cell in addition to 1 corral per cell. In SVWA, we added 2 alternative hair-snare designs in addition to 1 corral per cell. Due to financial and logistical constraints, the tennis ball snare was not used in the SVWA. The natural rub design takes advantage of existing trees that bears routinely rub on and no lure is added. The 2 other alternative snare designs and the corral design require the use of lures (see

Chapter 3 for more details on snare designs). All lure-based hair-snares were set up near bear

sign (e.g., scat, trails, and tree scratches) and bear travel corridors when possible (Kendall and

McKelvey 2008).

Each field season, we collected hair samples and replenished the lure at each hair-snare

once every 7 days for 6 weeks. We used this sampling interval to minimize violations with

demographic and geographic closure for closed population models as well as to reduce sample

exposure to ultraviolet light and moisture, which degrade DNA (Kendall and McKelvey 2008).

We used several criteria to determine which samples would be analyzed. A sample consisted of a

tuft of hair on one barb. All samples with $\geq$5 bear hairs were collected. To reduce analyzing

samples from the same individual multiple times during the same session, we analyzed the

samples with the most hairs when bears left multiple samples on adjacent barbs (Tredick et al.

2007). In addition, we eliminated obvious non-target species samples (e.g., deer) in the field. Hair

samples were collected with sterilized hemostats and put in individual coin envelopes. Barbs that

contained hair samples were sterilized with a flame to prevent residual DNA mixing with future

samples. The envelopes were stored at room temperature in airtight containers with desiccant

beads until DNA extraction.

DNA Analysis

DNA extraction was performed at the University of California Davis (UCD) Wildlife

Population Health and Genetics Laboratory. Following methods from Brown et al. (2009), we

determined species, individual identity, and gender of bears through analysis of DNA extracted

from the follicles of the hair samples. Fourteen nuclear microsatellite loci were used to define

unique individuals: G1A, G10B, G10C, G10H, G10o, G1D, G10L (Brown et al. 2009), A007,

A002, B001, D103, D112, D116, and D118 (Meredith et al. 2009). Gender was assigned using

AME, SRY, and ZF markers (Xu et al. 2008, Pagès et al. 2009). Microsatellite and sex loci were

grouped into four multiplexes shown in Table 2-1.

Extensive effort was put forth to reduce genotyping errors. In addition to collecting hair samples for CMR, we also collected opportunistic hair samples from known bears year round from both study areas, as well as other areas of Mono County when they became available. These samples were collected from trapped, depredation (i.e., defense of life or property), road-kill, and hunter harvested bears. Reference databases of local DNA samples can be used to define allele frequencies and help reduce probability of identity $P_{(id)}$ and probability of identifying siblings $P_{(sib)}$ values by accounting for the population structure of the local bear population (Mills et al. 2000).

Consensus genotypes were analyzed using Microsatellite Toolkit (Park 2001) and Genalex (Peakall and Smouse 2012) software. Genotypic data were scored twice, by 2 people blind to the reads of the other, to insure correct and consistent allele calls. All DNA samples were run in at least triplicate to check for consistency, and each plate of DNA included both negative and positive controls for quality assurance. Expected heterozygosities at all loci were checked for deviations from Hardy-Weinberg equilibrium in order to ensure the absence of null alleles and significant allelic dropout. Samples that did not successfully amplify a bear genotype after the first round of testing were re-extracted (if there was sufficient sample remaining) and tested again. Samples that only amplified specific alleles at G1A and SRY loci were identified as dog (*Canis* spp.) based on known canine DNA profiles. Mixed samples occurred when hair from multiple bears was snagged on the same barb at the same time. We could not genetically differentiate the individual bears from those samples (i.e., more than 1 allele at multiple loci); thus, those samples were discarded.

Abundance Estimation

Similar to Pederson et al. (2012), we used Huggins (1989, 1991) robust design closed population models and model averaging in program MARK (Lukacs 2010*a*) to obtain population estimates for all field seasons and both study areas. However, we did not collect a sufficient

number of hair samples (n = 30) in ML during the 2010 field season, thus we did not submit those samples for genetic analysis. For both study areas and all years, we pooled the 6 (7 day) encounter occasions into 3 (14 day) encounter occasions due to low sample sizes and recapture rates <30% (Settlage et al. 2008). In addition, we pooled samples for both sexes for analyses due to low sample sizes of uniquely identified bears. Because we had to pool data, we were not able to estimate sex ratios within years or study areas. We tested 6 a priori models to evaluate potential differences in initial capture (p), recapture (c), year (year), encounter occasion (visit), and year and encounter occasion (year + visit). Similar to Dreher et al. (2007) and Boulanger et al. (2008), we also tested those same 6 models where all hair samples collected from alternative hair-snares, within each study area, were pooled as the final encounter occasion for 2012. We recognize the different alternative hair-snare designs likely had different capture probabilities, and that pooling can induce capture heterogeneity; however, we were forced to pool the samples due to low sample sizes. Furthermore, capture heterogeneity based on differences in sex and individuals is a concern with DNA-based CMR studies (Pollock et al. 1990, Boulanger et al. 2004b, Pederson et al. 2012). Heterogeneity models did not converge properly, we believe, mainly due to our sample sizes. Hence, we incorporated capture heterogeneity in our top model for both study areas for a basic evaluation of heterogeneity (Table 2-3). From the model average estimates, we calculated log-based confidence intervals using the model-averaged standard error and the minimum number of bears genetically identified (Lukacs 2010b). All models, except the heterogeneity models, were included when model averaging to reduce bias when estimating population size (n); however, top models were identified by having a low delta Akaike information criterion (Δ AIC ($\leq$2)) and high model weight ($w \geq 0.1$) to determine relative support for differences between years and capture rates (Burnham and Anderson 2002).

Density Estimation and Comparisons Between Study Areas

Density with in each study area was obtained by dividing the estimated abundance by the effective trapping area. We used the delta method (Seber 1982) to estimate the variance of the density, which included the uncertainty in both abundance and effective grid size (White et al. 1982). This allowed us to account for the "edge effect" bias. To estimate effective trapping area, based on estimates in the Beckmann and Berger (2003*b*) study, we first took the core (50%) home range estimates for both sexes combined and, to be conservative, added 1 standard deviation. The home ranges were estimated as 12.9 km^2 and 131.1 km^2 for the urban and wildland bears, respectively. Then we created a buffer using the buffer tool in ArcGIS^{TM} 10.2 (ESRI$^®$ Olympia, WA, USA) around each hair-snare independently for each year and dissolved all the buffers so they merged into 1 polygon; these polygons were used as the effective trapping areas for the urban and wildland study areas (Table 2-5). We used a Z-test to compare differences in densities within years between study areas.

RESULTS

Hair Collection and DNA Analysis

All 28 known bear samples collected opportunistically and submitted for genetic analysis were correctly identified in the lab. The number of matching alleles was $\geq$93% for all samples used for CMR. A reasonably low $P_{(id)}$ is <0.01 (Waits et al. 2001) and $P_{(Sib)}$ is <0.05 (Woods et al. 1999). The $P_{(id)}$ for all samples we used for CMR was $\geq$1.1e^8. The $P_{(Sib)}$ for all the samples we used for CMR was $\geq$1.2e^4.

Wildland Study Area

Overall, we collected 249 CMR samples during all 3 field seasons, and 219 were submitted for genetic analysis (Table 2-2). The mean number of bear samples collected per encounter occasion were 10, 10, and 16 in 2010, 2011, and 2012, respectively. The mean number

of bear samples collected per corral hair-snare per encounter were 8, 9, and 11 in 2010, 2011, and 2012, respectively. The mean number of individual bears identified per encounter occasion was 7 in 2010, 7 in 2011, and 9 in 2012. The number of individual bears identified only once was 19 (7 females, 12 males), 15 (1 females, 14 males), and 31 (12 females, 17 males, 2 unknown sex) in 2010, 2011, and 2012, respectively. Five of the same individual bears were genotyped in all three years (2 females, 3 males). Eight of the same individuals were genotyped in 2010 and 2011 (3 females, 5 males). Seven of the same individuals were genotyped in 2011 and 2012 (4 females, 3 males). Seven of the same individuals were genotyped in 2010 and 2012 (3 females, 4 males). Eighty individual bears were identified from all 3 years (26 females, 52 males, and 2 unknown sex).

We collected a sufficient number of hair samples each field season for CMR. At least 3 hair samples were collected from each corral hair-snare during the 6 weeks of sampling in 2010 and 2011. In 2012, the corral, natural rub, and haphazard-wire hair-snares collected 80, 8, and 12 hair samples, respectively. All 3 years, all 7 corral hair-snares were visited by a bear at least once and ≥ 6 bear hair samples were collected at each hair-snare. There were ≥ 1 hair samples collected from 6 of 9 natural rubs and 5 of 12 haphazard-wire snares. Genotyping success ranged from 87% to 90%, and only 3 canid (i.e., likely coyote, *Canis latrans*) samples were identified from 2012 hair samples (Table 2-2).

Urban Study Area

Overall, we collected 229 CMR samples during all 3 field seasons, and 175 were submitted for genetic analysis. The mean number of bear samples collected per encounter occasion and per corral hair-snare per encounter were 13.8 and 2.4 in 2011, respectively, and 18.8 and 3.3 in 2012, respectively. The mean number of individual bears identified per encounter occasion was 3.7 in 2011 and 8 in 2012. The number of individual bears identified only once was 8 (3 females and 5 males) and 22 (7 females, 14 males, and 1 unknown sex) in 2011 and 2012,

respectively. Over the course of both field seasons, a total of 40 individual bears (15 females, 24 males, and 1 unknown sex) were identified; 6 bears (3 females and 3 males) were identified in both (Table 2-2).

We collected 30 hair samples in the ML, urban study area during the 2010 field season. After subsampling, 18 were sufficient for DNA analysis; however, we did not analyze those samples because we assumed 18 samples would be insufficient for CMR. We collected a sufficient number of hair samples for genetic analysis in 2011 and 2012 (Table 2-2). All corral hair-snares were visited by at least one bear and $\geq$ 1 bear hair samples were collected in 2011. In 2012, the corral, natural rub, haphazard-wire, and tennis ball hair snares collected 83, 18, 3, and 0 hair samples, respectively. Nineteen of 22, 4 of 8, 3 of 7, and 0 of 6 corral hair-snares, natural rubs, haphazard-wire snares, and tennis ball snares, respectively, were visited by a bear at least once and $\geq$1 bear hair samples were collected. Genotyping success increased 32% from 2011 to 2012. Twice the number of canines were identified in 2012 compared to 2011.

Capture Rate and Abundance Estimates

Wildland Study Area

For the SVWA study area, there were 5 models (models 12-16, Table 2-3) with ΔAIC $\leq$2 which accounted for 88% of the total model weight. Only the fourth model (model 15) supported a difference in the encounter occasion where the alternative hair-snares were pooled together. However, , there was no support for a difference in capture and recapture rates in the top model and there was support for a difference between years in the second best model (Table 2-3). The capture rate from the top model was 0.20 and capture rates for the second best model were 0.23, 0.27, and 0.15 for 2010, 2011, and 2012, respectively. There was no strong evidence for capture heterogeneity; the top model with heterogeneity (model 19) had a ΔAIC of 5.6 and w_i =

0.02. Model averaged population estimates ($\hat{N}$) were similar for 2010 and 2011. However, the model averaged population estimate for 2012 was >20% higher (Table 2-4).

Urban Study Area

From the ML study area, there were 3 models with ΔAIC $\leq$2 (models 1-3, Table 2-3) that accounted for 87% of the total model weight.. All 3 models included support for a difference in capture rate for the fourth encounter in 2012 where the alternative hair-snares were pooled (i.e., & Diff. Alt. p=c). There was no support for a difference in initial capture (*p*) and recapture rates (*c*) for the 2 top models (total weight, w_i = 0.705). From the top model, the capture rate was 0.31 and 0.11 for the corral hair-snares and the alternative hair-snares, respectively. Model 2, ΔAIC = 1.73, and w_i = 0.209) showed some support for a difference in capture rates between years. The capture rates were 0.38 and 0.29 for 2011 and 2012, respectively. There was no strong evidence for capture heterogeneity; the top model with heterogeneity (model 5) had a ΔAIC of 5.94 and a w_i = 0.03. The population estimate was higher in 2012 ($\hat{N}$ = 46) than in 2011 ($\hat{N}$ = 20; Table 2-4).

Density Comparisons

The SVWA effective trapping area was 1.3 times larger than the ML effective trapping area (Table 2-5). The effective trapping areas for SVWA were 329 km^2 and 366 km^2 for 2011 and 2012, respectively (Table 2-5). Model averaged bear density for 2011 was 1.6 times higher in ML compared to SVWA; however, densities were not significantly different (*P* = 0.13). The model averaged bear density for 2012 was 2.5 times higher in ML compared to SVWA and densities were significantly different (*P* = 0.003, Table 2-5).

DISCUSSION

We found bear density to be 1.6 to 2.5 times higher in the urbanized study area compared to the wildland study area. Our results are similar to those of Beckmann and Berger (2003*b*),

who found that bears in the urban-wildland interface lived at 3 times higher densities than wildland bears. Although differences in bear densities were not statistically different (at $\alpha \leq$ 0.05).in 2011, ML bear density was 1.6 times higher. However, the ML population estimate from that year is likely biased low. It is likely that we missed identifying individual bears during that field season due to low genotyping success, using fewer hair-snares, and by collecting fewer hair samples. When these problems were corrected in 2012, the ML density estimate more than doubled due to our sampling improvements. Thus, this more reliable estimate supports the observation of biologists working at the urban-wildland interface that bear densities are higher in urban areas (Beckmann and Berger 2003*b*).

ML may have a higher density bear population compared to SVWA because of the abundance of high-caloric-value anthropogenic food resources available, learned behavior to exploit those resources, high human tolerance of bears living in ML, and the management of bears in ML. ML has good riparian corridors that provide natural food resources of both hard and soft-mast plants akin to SVWA; however, anthropogenic food resources (e.g., garbage, bird seed, ornamental plants, and pet food) are also accessible to bears. To obtain human food in ML, many bears have learned to break into vehicles and buildings, check if dumpsters are locked every day, cruise lake shorelines to find fishermen's stringers of fish, and obtain campers' food (T. Taylor, California Fish and Wildlife, unpublished report). Bears have been welcomed in town for over 3 decades and are a tourist attraction. Many community members have a high tolerance for bears living in their community, similar to how people feel about raccoons (*Procyon lotor*) in some communities in the U.S. (Gehrt et al. 2010). Raccoons are also known to live at higher densities in urban environments compared to wild environments (Randa and Yunger 2006).

Although popular with residents, local CA DFW biologists and game wardens spend on average 25 to 35% of their time annually mitigating human-bear conflicts throughout Mono County from June to October, and ML has the highest number of human-bear conflicts in the county (T. Taylor, California Fish and Wildlife, unpublished report). Like many state wildlife

agencies, CA DFW has limited resources to reduce human-bear conflicts. Biologists and game wardens are able to provide educational materials to help people mitigate human-bear conflicts. During extreme cases of property damage, depredation permits will be issued if people have taken the appropriate actions to prevent bears from damaging their property.

Since 1996, the town of ML has put forth a substantial effort to reduce human-bear conflicts by enforcing local trash management ordinances, education, and employing hazing techniques that are carried out by police officers and the town's wildlife manager (Peine 2001). Nevertheless, with 1.5 million tourists visiting each spring and summer who are ignorant to bear behavior, it is inevitable bears become food conditioned. Furthermore, Yosemite National Park is potentially a source population of bears for ML and the surrounding national forest. Numerous nuisance bears ear tagged in Yosemite National Park have traveled to ML and other communities in Mono County (California Department of Fish and Wildlife, unpublished report).

The population parameter results from this study need to be interpreted with caution. According to White et al. (1982), capture probabilities should be >0.30 to obtain reliable closed capture population models when populations are <100. Furthermore, we needed to attain a CV of <0.2 to obtain acceptable precision in population estimates (Pollock et al. 1990). These criteria were met for the ML study area but not for the SVWA. However, Boulanger et al. (2004*a*) suggests a capture probability of >0.20 with a population >50 will ensure reliable results. Our data suggest the SVWA bear population exceeds 50 bears and the capture probabilities were >0.20. Therefore, the SVWA results would fall with in Boulanger et al. (2004*a*) criteria. Nonetheless, we recognize that our small study areas were prone to geographic closure bias, which can result in reduced capture and recapture rates and decrease CV (Boulanger and McLellan 2001). In both study areas, we may have drawn in bears from outside the study area by using small grids and scent lures (Boulanger et al. 2004*a*). Due to logistical and financial constraints we had to make our study areas small. We attempted to correct for this bias by choosing study areas that were geographically isolated via ridgelines and surrounding marginal

habitats. As an index for movement in and out of our study areas, no bears identified from hair samples in the study areas were also identified outside of the study areas from the known bear hair samples we collected.

MANAGEMENT IMPLICATIONS

The data from this study supports the theory that bears occur at higher densities in urban areas, which is a management concern due to the negative impact urban landscapes can have on bear populations and the increase in human-bear conflicts. We recommend using our DNA-based CMR methods to monitor population parameters of bears in urban areas. The baseline data obtained in ML can be used for a Before-after Control-impact analysis to evaluate future management actions that seek to reduce human-bear conflicts by reducing the density of bears in ML. Furthermore, with additional survey years, this study can provide estimates of population vital rates, such as apparent survival, finite rate of population change, movement, and recruitment. Monitoring these vital rates can help elucidate if ML is function as a "sink" or ecological trap for bears. Additionally, the reference database of bear DNA we started can be used for future eastern Sierra black bear studies to help maintain low values of $P_{(id)}$ and $P_{(sib)}$.

LITERATURE CITED

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

———, ———, ———, and D. M. Theobald. 2008. Spatiotemporal distribution of black bear-human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

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

———, and ———. 2003b. Using black bears to test ideal-free distribution models experimentally. Journal of Mammalogy 84:594–606.

———, and C. W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: A case history of black bears. Human-Wildlife Interactions 2:168–174.

Boulanger, J., K. C. Kendall, J. B. Stetz, D. A. Roon, L. P. Waits, and D. Paetkau. 2008. Multiple data sources improve DNA-based mark-recapture population estimates of grizzly bears. Ecological Applications 18:577–589.

———, and B. N. McLellan. 2001. Closure violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology 79:642–651.

———, ———, J. G. Woods, M. F. Proctor, and C. Strobeck. 2004a. Sampling design and bias in DNA-based capture-mark-recapture population and density estimates of grizzly bears. Journal of Wildlife Management 68:457–469.

———, G. Stenhouse, and R. Munro. 2004b. Sources of heterogeneity bias when DNA mark-recapture sampling methods are applied to grizzly bear (*Ursus arctos*) populations. Journal of Mammalogy 85:618–624.

Breck, S. W., C. L. Williams, J. P. Beckmann, S. M. Matthews, C. W. Lackey, and J. J. Beecham. 2008. Using genetic relatedness to investigate the development of conflict behavior in black bears. Journal of Mammalogy 89:428–434.

Brown, S. K., J. M. Hull, D. R. Updike, S. R. Fain, and H. B. Ernest. 2009. Black bear population genetics in California: Signatures of population structure, competitive release, and historical translocation. Journal of Mammalogy 90:1066–1074.

Burgduff, A. 1935. Black bears released in Southern California. California Fish and Game 21:83–84.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

California Department of Fish and Wildlife. 1998. Black bear management plan. California Department of Fish and Wildlife, Sacramento, California, USA. http://www.dfg.ca.gov/wildlife/hunting/bear/docs/BlackBearMgmtPlan.pdf, accessed 15 May 2010.

———. 2012. Black bear population report. Sacramento, CA, USA. http://dfg.ca.gov/wildlife/hunting/bear/population.html, accessed 10 Mar 2012.

Coster, S. S., A. I. Kovach, P. J. Pekins, A. B. Cooper, and A. Timmins. 2011. Genetic mark-recapture population estimation in black bears and issues of scale. Journal of Wildlife Management 75:1128–1136.

Dreher, B. P., S. R. Winterstein, K. T. Scribner, P. M. Lukacs, D. R. Etter, G. J. Rosa, V. A. Lopez, S. Libants, and K. B. Filcek. 2007. Noninvasive estimation of black bear abundance incorporating genotyping errors and harvested bear. Journal of Wildlife Management 71:2684–2693.

Gehrt, S. D., S. P. D. Riley, and B. L. Cypher, editors. 2010. Urban carnivores ecology, conflict, and conservation. Johns Hopkins University Press, Baltimore, Maryland, USA.

Herrero, S., A. Higgins, J. E. Cardoza, L. I. Hajduk, and T. S. Smith. 2011. Fatal attacks by American black bear on people: 1900-2009. Journal of Wildlife Management 75:596–603.

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

Huggins, R. M. 1989. On the statistical analysis of capture experiments. Biometrika 76:133–140.

———. 1991. Some practical aspects of conditional likelihood approach to capture experiments. Biometrics 47:725–732.

Kendall, K. C., and K. S. McKelvey. 2008. Hair collection. Pages 135–176 in R. A. Long, P.

     MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey methods for

     carnivores. Island Press, Washington, DC USA.

Lukacs, P. M. 2010a. Closed population capture-recapture models. Pages 14-1–14-38 in E. Cooch

     and G. C. White, editors. Program MARK: a gentle introduction.

     http://www.phidot.org/software/mark/docs/book/, accessed 15 Apr 2010.

———. 2010b. Estimating CI for model averaged abundance estimates. Pages 14-31–14-36 in E.

     Cooch and G. C. White, editors. Program MARK: a gentle introduction.

     http://www.phidot.org/software/mark/docs/book/, accessed 15 Apr 2010.

Mayer, K. E., and W. F. Laudenslayer. 1988. Guide to wildlife habitats of California. California

     Department of Fish and Game, Sacramento, California, USA.

Mazur, R., and V. Seher. 2008. Socially learned foraging behaviour in wild black bears, *Ursus*

     americanus. Animal Behaviour 75:1503–1508.

Meredith, E. P., J. A. Rodzen, J. D. Banks, and K. C. Jones. 2009. Characterization of 29

     tetranucleotide microsatellite loci in black bear (*Ursus americanus*) for use in forensic

     and population applications. Conservation Genetics 10:693–696.

Merkle, J. A., P. R. Krausman, and M. M. Booth. 2011. Behavioral and attitudinal change of

     residents exposed to human-bear interactions. Ursus 22:74–83.

Mills, L. S., J. J. Citta, K. P. Lair, M. K. Schwartz, and D. A. Tallmon. 2000. Estimating animal

     abundance using noninvasive DNA sampling: Promise and pitfalls. Ecological

     Applications 10:283–294.

Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture,

     DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64:183–

     193.

Pagès, M., C. Maudet, E. Bellemain, P. Taberlet, S. Hughes, and C. Hänni. 2009. A system for sex determination from degraded DNA: A useful tool for palaeogenetics and conservation genetics of ursids. Conservation Genetics 10:897–907.

Park, S. D. E. 2001. Trypanotolerance in West African cattle and the population genetic effects of selection. Dissertation, University of Dublin, Dublin, Ireland. http://animalgenomics.ucd.ie/ sdepark/ms-toolkit/, accessed 19 Mar 2014.

Peakall, R., and P. E. Smouse. 2012. GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research—an update. Bioinformatics 28:2537–2539.

Pederson, J. C., K. D. Bunnell, M. M. Conner, and C. R. McLaughlin. 2012. A robust-design analysis to estimate American black bear population parameters in Utah. Ursus 23:104–116.

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

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:3–97.

Randa, L. A., and J. A. Yunger. 2006. Carnivore occurrence along an urban-rural gradient: A landscape-level analysis. Journal of Mammalogy 87:1154–1164.

Robinson, S. J., L. P. Waits, and I. D. Martin. 2009. Estimating abundance of American black bears using DNA-based capture-mark-recapture models. Ursus 20:1–11.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Second edition. New York, New York, USA.

Settlage, K. E., F. T. MANEN, J. D. Clark, and T. L. King. 2008. Challenges of DNA-based mark-recapture studies of American black bears. Journal of Wildlife Management 72:1035–1042.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California, USA.

Town of Mammoth Lakes. 2007. Fact Sheet. http://www.ci.mammoth-

    lakes.ca.us/documents/9/Mammoth%20Facts.PDF, accessed 15 May 2010.

Tredick, C. A., M. R. Vaughan, D. F. Stauffer, S. L. Simek, and T. Eason. 2007. Sub-sampling

    genetic data to estimate black bear population size: A case study. Ursus 18:179–188.

U.S. Census Bureau. 2010a. Urban and rural classification.

    wwww.census.gov/geo/reference/urban-rural.html, accessed 12 May 2011.

———. 2010b. 2010 census. U.S. Census Bureau. http://www.census.gov/2010census/data/,

    accessed 06 January 2011.

Waits, L.P., G. Luikart, and P. Taberlet. 2001. Estimating the probability of identity among

    genotypes in natural populations: Cautions and guidelines. Molecular Ecology 10:249–

    256.

Western Regional Climate Center. 2013. Western U.S. Climate Historical Summaries.

    http://www.wrcc.dri.edu/Climsum.html, accessed 19 Jan 2013.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and

    removal methods for sampling closed populations. Los Alamos National Laboratory, Los

    Alamos, New Mexico, USA.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal

    populations: modeling, estimation, and decision making. Academic Press, San Diego,

    California, USA.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic

    tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616–627.

Xu, X., L. Lin, Z. Zhang, F. Shen, L. Zhang, and B. Yue. 2008. A reliable, non-invasive PCR

    method for giant panda (*Ailuropoda melanoleuca*) sex identification. Conservation

    Genetics 9:739–741.

Table 2-1. Summary of 14 Microsatellite and 3 Sexing Loci used for genotyping individual samples during the Mono County, California, USA bear survey from June to July; 2010 to 2012.

Multiplex Name	Loci
Bear 1 A	G1A
	G10B
	G10C
	G10H
	G10o
Bear 1 B	G1D
	G10L
Bear Forensics	A007
	A002
	B001
	D103
	D112
	D116
	D118
Bear Sex	AME
	SRY
	ZF

Table 2-2. Summary of genetic results from hair samples collected for DNA-based capture-mark-recapture (CMR) during the Mono County, California, USA bear survey from June to July; 2010 to 2012.

Year	Samples[a]	Lab[b]	Dog (%)[c]	Genotyped (%)[d]	Male	Female	Unknown	Total
Mammoth Lakes (urban)								
2010	30	18*						
2011	81	71	7 (10)	31 (48)	7	7	0	14
2012	118	104	14 (13)	72 (80)	11	20	1	32
Slinkard Valley Wildlife Area (wildland)								
2010	62	57	0 (0)	51 (89)	20	9	0	29
2011	74	62	0 (0)	56 (90)	20	9	0	29
2012	113	100	3 (3)	84 (87)	21	17	2	40

* Not sent to the lab due to insufficient number of samples for CMR

[a] Suitable samples (>5 hairs) collected

[b] Samples sent to the lab after subsampling

[c] Samples identified as canine

[d] Bear samples genotyped

Table 2-3. The robust design closed capture models run in Program MARK for the wildland, Slinkard Valley Wildlife Area (SVWA) and the Mammoth Lakes (ML) study area in Mono County, California, USA, from June to July; 2010 to 2012 in SVWA and 2011 to 2012 in ML. Included are the model numbers and parameters, Akaike information criterion (AIC_c), delta AIC (ΔAIC_i), model weights (w_i), number of parameters (K), and deviance.

Model no. and parameters	AICc	ΔAIC_i	w_i	K	Deviance
Mammoth Lakes (urban)					
1. p(.)=c(.) & (Diff. Alt. p=c)	276.252	0.000	0.497	4	267.607
2. p(yr)=c(yr) & (Diff. Alt.. p=c)	277.987	1.735	0.209	5	267.003
3. p(.) c(.) & (Diff. Alt. p=c)	278.439	2.187	0.166	5	267.455
4. p(yr+visit)=c(yr+visit)	281.232	4.980	0.041	6	267.832
5. p(.)=c(.) & (Diff. Alt. p=c) & Heter.	282.187	5.935	*	8	263.705
6. p(.)=c(.)	282.403	6.151	0.023	3	276.022
7. p(yr+visit) c(yr+visit)	282.810	6.558	0.019	9	261.652
8. p(yr) c(yr) & (Diff. Alt. p=c)	282.861	6.608	0.018	7	266.962
9. p(yr)=c(yr)	282.979	6.727	0.017	4	274.334
10. p(.) c(.)	284.465	8.213	0.008	4	275.820
11. p(yr) c(yr)	287.364	11.112	0.002	6	273.964
Slinkard Valley Wildlife Area (wildland)					
12. p(.)=c(.)	637.607	0.000	0.326	5	627.099
13. p(yr)=c(yr)	638.904	1.297	0.171	7	623.938
14. p(yr+visit)=c(yr+visit)	639.332	1.725	0.138	8	622.080
15. p(.)=c(.) & (Diff. Alt. p=c)	639.498	1.891	0.127	6	626.780
16. p(.) c(.)	639.680	2.073	0.116	6	626.962
17. p(yr)=c(yr)& (Diff. Alt. p=c)	641.159	3.552	0.055	8	623.907
18. p(.) c(.) & (Diff. Alt. p=c)	641.735	4.128	0.041	7	626.770
19. p(.)=c(.) & Heter.	643.210	5.603	*	9	623.631
20. p(yr) c(yr)	643.356	5.749	0.018	10	621.409
21. p(yr+visit) c(yr+visit)	646.259	8.652	0.004	14	614.406
22. p(yr) c(yr) & (Diff. Alt. p=c)	646.459	8.852	0.004	11	622.102

* Heterogeneity models were not included in model averaging therefore model weights were not included in this table

Table 2-4. Year, abundance estimate (N), standard error (SE), 95% log-based confidence intervals (CI), model averaged capture rate (p), model averaged recapture rate (c), and coefficient of variance (CV) from Program MARK for black bears in Mammoth Lakes and Slinkard Valley Wildlife Area Mono County, California, USA June to July 2010 - 2012.

Year	N	SE	95% log-based CI		p	c	CV (%)
			Lower	Upper			
Mammoth Lakes (urban)							
2011	20	4.54	17	29	0.32	0.34	22
2012	46	7.45	39	58	0.31	0.31*	16
Slinkard Valley Wildlife Area (wildland)							
2010	56	12.24	44	76	0.22	0.21	22
2011	55	11.88	44	75	0.22	0.22	22
2012	72	20.60	55	108	0.20	0.20**	29

* Session 4 (pooled alternative hair-snares) p and c = 0.12

** Session 4 (pooled alternative hair-snares) p and c = 0.18

Table 2-5. Effective trapping area, model averaged bear density, z-score (Z), standard error (SE), and p-value (P) for black bear in Mammoth Lakes (ML) and Slinkard Valley Wildlife Area (SVWA) in Mono County, California, USA from June to July 2011 - 2012.

Year	Effective trapping area (km^2)		Model averaged bear density (bears/10 km^2)		SE (diff.)	Z	P
	ML	SVWA	ML	SVWA			
2011	74	329	2.75	1.67	0.711	1.514	0.130
2012	94	366	4.84	1.97	0.972	2.958	0.003
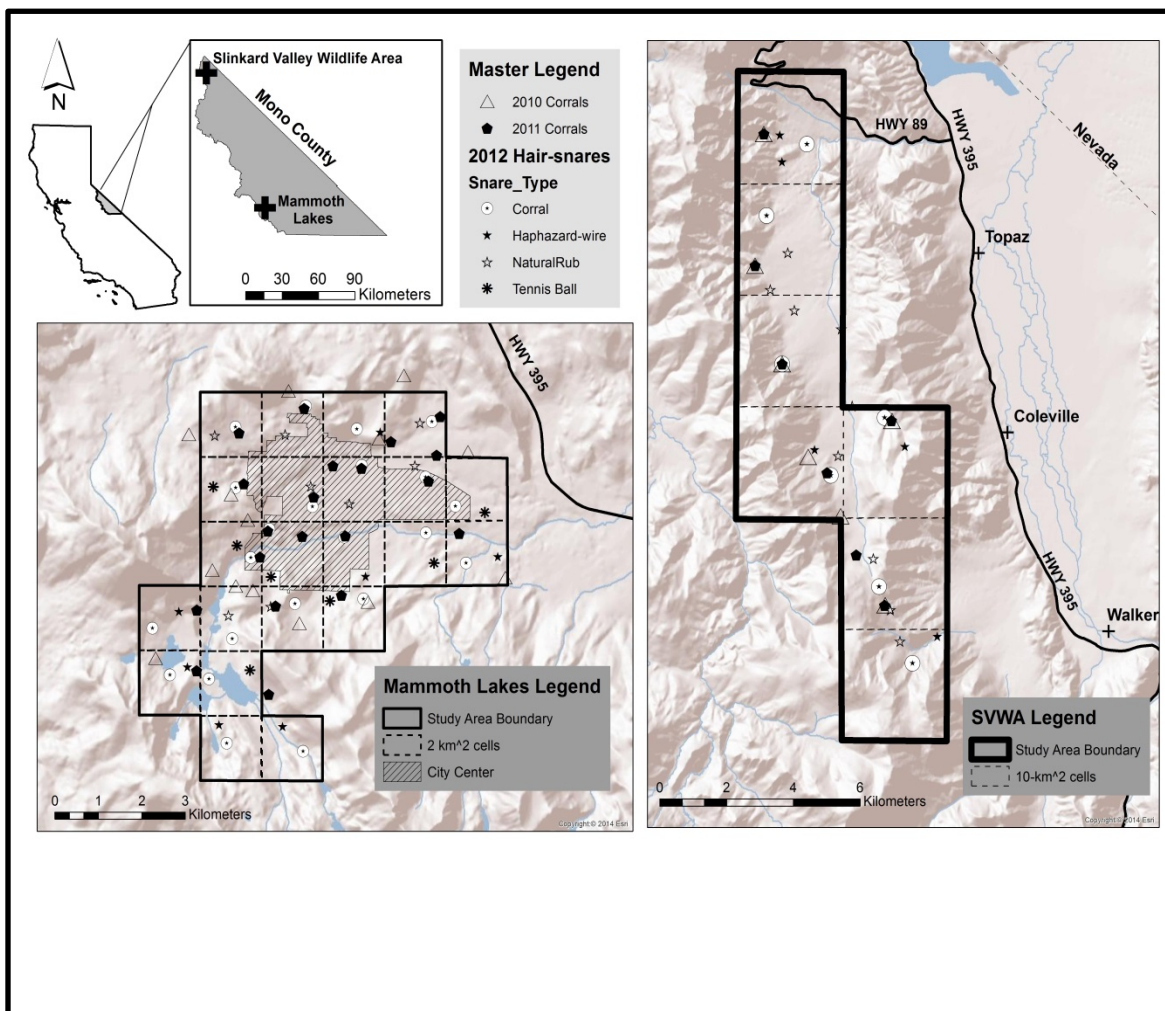
CHAPTER 3

BEST MANAGEMENT PRACTICES IN COUNTING URBAN BLACK BEARS[1]

ABSTRACT

DNA-based capture-mark-recapture (CMR) techniques are commonly used to obtain population parameters of black bears (*Ursus americanus*) in rural and wildland landscapes; however, these techniques have not been implemented in urban clusters (i.e., 2,500 to 50,000 residents). Black bears can readily habituate to urban clusters (UC), and wildlife managers need to monitor and manage these urban bear populations. We modified DNA-based CMR for black bear using hair-snares to take into account the small home ranges of urban bears, urban bear behavior, and human safety within Mammoth Lakes, California, USA. We conducted this study for 3 field seasons in 2010, 2011, and 2012 from June to July. Each field season, we implemented a CMR with 6 encounter occasions, each 7 days in length. We used the traditional corral hair-snare design modified for human safety and chose multiple non-consumable lure types to prevent food conditioning and a trap-happy response. Using multiple lures also prevented a trap-shy response by providing novelty from the new scent. In 2012, we also tested 4 hair-snare designs: corral, natural rub, haphazard-wire snare, and tennis ball snare. In 2010, we collected an insufficient number of hair samples for CMR by putting hair-snares in the urban wildland interface (UWI) encircling the city center. However, in 2011 and 2012, when we put hair-snares in the city center as well as the surrounding UWI, we obtained a sufficient amount of hair-samples to estimate population density using closed capture CMR models. Our methods were efficient, having a high capture rate and recapture rate (>0.30) and precision (coefficient of variation ≤ 0.2), while maintaining human safety.

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[1] Coauthored by Mary Conner and Michael R. Conover

INTRODUCTION

DNA-based capture-mark-recapture (CMR) survey techniques using hair-snares have been applied extensively for acquiring population parameters of black bears (*Ursus americanus*). Hair-snare studies can be more cost-effective and less invasive than traditional capturing and marking studies. They obtain more precise and accurate local-scale population parameter estimates than using hunter harvest and mortality data alone (Boersen et al. 2003, Coster et al. 2011). Traditional population parameters obtained with hair-snaring include estimates of sex ratios, population size, and population density (Woods et al. 1999, Robinson et al. 2009, Tredick and Vaughan 2009, Coster et al. 2011). Pederson et al. (2012) used these techniques in a 5-year study of black bears to obtain estimates of apparent survival and temporary emigration in addition to population size utilizing a closed-capture robust-design analysis. The same study also obtained estimates of finite rate of population change and recruitment using a robust-design Pradel model.

Hair-snare studies have been implemented in rural and wildland landscapes for black bears; however, we are unaware of any studies that used hair-snaring to estimate population parameters of black bears that frequent urban clusters (UCs). UCs are geographic areas (i.e., communities) that contain 2,500 to 50,000 people, while rural and wildland geographic areas have <2,500 people (U.S. Census Bureau 2010). It is important for wildlife managers to monitor urban bear populations because black bears in UCs can take advantage of anthropogenic resources, habituate to human presence, and become food-conditioned in places where they associate human landscapes with food (Beckmann and Berger 2003*a*, Madison 2008, Merkle et al. 2011). Urban bears can be a threat to public safety and inflict major property damage (Baruch-Mordo et al. 2008, Herrero et al. 2011). In addition, urban environments can negatively affect the health of wildland bear populations by functioning in a source-sink system where the urban environment acts as a sink or ecological trap (Beckmann and Berger 2003*b*, Beckmann and Lackey 2008, Hostetler et al. 2009). Extensive efforts across North America are being made to

manage human-bear conflicts and to mitigate the negative effects urban environments have on bears.

Our main objective was to obtain baseline population parameters of the bears in the study area prior to management actions (Robinson et al. 2009).We hypothesized that traditional hair-snaring techniques for black bear, as outlined in Woods et al. (1999), needed to be modified for the urban environment mainly due to differences in life history and behavior between urban and wildland bears (Beckmann and Berger 2003*a*) and due to the difficult nature of working in an urban environment (e.g., human safety and private property access). Therefore, we evaluated the overall efficacy of implementing a hair-snare study for black bears in a UC as part of the California Department of Fish and Wildlife (CDFW) Eastern Sierra Black Bear Project (ESBBP). We hypothesized our study area had a bear population of <50, which, according to White et al. (1982), would require capture probabilities >0.30 to obtain reliable closed capture population models. To obtain acceptable precision in our population estimates, we would need to obtain a coefficient of variation (CV) of <0.2 (Pollock et al. 1990). Thus, our objective was to ascertain if we could meet these criteria while maintaining human safety in a UC in Mono County, California.

STUDY AREA

We conducted our study in the mountain resort community of Mammoth Lakes (ML), California which has been frequented by black bears for over 3 decades (Figure 3-1). We hypothesized there were 25 to 30 resident bears ML each year. ML sits at the base of the Mammoth Mountain Ski Resort along the eastern escarpment of the Sierra Nevada at an elevation of 2,500 m. The community is located on the Inyo National Forest in southwestern Mono County, has 8,234 year-round residents (U.S. Census Bureau 2010), and 1.5 million visitors during the spring and summer, the same time bears are most active (Town of Mammoth Lakes 2007). The municipal city limits contain 60 km^2; while most of the residents (87%) live in the 10 km^2 city

center, the remaining 13% live in the 34 km^2 urban-wildland interface (U.S. Census Bureau 2010,

UWI). Our study area (Figure 3-1) encompassed only the 44 km^2 area that included presence of

humans (>2,500), anthropogenic resources (e.g., trash), and anthropogenic structures at all times.

We assumed the UWI had >2,500 people present at all times due to the 1073 permanent residents,

the large number of campgrounds, lodges/resorts, and overall number of tourists staying in the

area each summer. All hunting is prohibited within the city limits.

Vegetation types occurring within the city center portion of the study area include

fragmented patches of mixed conifer forest, montane chaparral, aspen (*Populus tremulodies*), and

willow (*Salix* spp.) (Mayer and Laudenslayer 1988). The average precipitation per year is 58 cm (

(Western Regional Climate Center 2013). In addition to residential and commercial development

within the city center, there are also interspersions of open green-ways for recreational use, 2 golf

courses, and the Eastern Sierra Valentine Reserve (ESVR). The 0.63 km^2 ESVR is owned by the

University of California and provides a refuge for wildlife and facilities for researchers. The UWI

is dominated by Jeffrey pine (*Pinus jeffreyi*), mixed conifer forest, aspen and montane chaparral.

There are 5 lodges/resorts, approximately 20 private cabins, 9 campgrounds, and network of

hiking and biking trails within the UWI.

Other mammalian species that could encounter the hair-snares included domestic dog

(*Canis lupus familiaris*), domestic cat (*Felis catus*), mountain lion (*Puma concolor*), mule deer

(*Odocoileus hemionus*), coyote (*Canis latrans*), and bobcat (*Lynx rufus*).

METHODS

We conducted this study for 3 field seasons (2010, 2011, and 2012), which ran from June

to July. During each field season, we collected bear hair from hair-snares for a DNA-based CMR.

We also collected bear hair opportunistically from dead and captured bears year-round within ML

and throughout Mono County and from bed sites and nuisance scenes only within in the study

area during CMR sampling. For the opportunistic samples, our objective was to collect ≥30

known individual bear hair samples. We used these samples to determine the population genetics

(i.e., allele frequencies) of the bears in our study area. The data were used to calculate the

probability of identity, probability of exclusion and similar indices. These probabilities helped the

DNA lab determine the likelihood of getting the same genetic profile from 2 different bears

(Woods et al. 1999). This whole process was important for obtaining accurate CMR estimates

(Waits and Paetkau 2005). The second and third reasons for collecting opportunistic samples

were to elucidate movement in and out of the study area and to estimate the number of

individuals in ML that we missed with the CMR methods. The fourth reason for collecting the

opportunistic samples was to identify bears that died during the study so we could factor that into

our CMR models.

For our 2010 field season, we laid a grid system using 5-km^2 grid cells ($n = 12$) over the

study area. No studies have estimated home range size in our study area; therefore, we

determined cell sizes based on the estimates of the home range of bears in the Beckmann and

Berger (2003b) study of 24 collared, urban black bears (>90% occupancy in an urban area for 10

years) in Lake Tahoe Basin, Nevada with a similar ecotype and towns as ML. We subjectively

reduced cell sizes further with the goal of over-sampling as opposed to under-sampling.

We put 1 hair-snare within each grid cell. The hair-snare design we used was a barbed

wire hair corral (single strand) adapted from Woods et al. (1999). Hair corrals were placed only

on USFS land surrounding ML. During 2010, we assumed bears left the city center during the day

to seek refuge in the UWI. The hair corrals were set up near bear sign (e.g., scat, trails, and tree

scratches) and bear travel corridors when possible. For human safety, we painted the barbed wire

hunter orange, hung orange flagging every 1 m on the wire, and put up ≥4 signs at each hair-snare

in Spanish and English alerting the public about the wire and potential bear activity in the area.

On public land, hair-snares were placed ≥32 m from roads and trails to reduce the chance of

domestic dogs visiting hair corrals while people walked their dogs. Corrals were not placed

across game trails because we wanted to reduce the number of mixed samples and to reduce the

chance that deer would knock down the wire and samples. A mixed sample occurs when hair from multiple bears is snagged on the same barb at the same time. We could not genetically differentiate the individual bears from these samples; thus, the sample became unusable.

To entice bears to go over or under the single strand of barbed wire, a non-consumable lure (0.5 L) was placed in the center of each hair corral on a pile of course woody debris. Lure was also sprayed on a rag and hung over the center of each hair corral at 4 m as an aerial attractant. We used non-consumable, commercial lures to prevent further food conditioning the bears and to thwart a trap-happy response by not providing a caloric reward. Due to the high rate of bears breaking into vehicles in ML, all lures were stored in bear canisters in the bed of field trucks while conducting field work. At each hair corral, 2 lures were rotated systematically to reduce a trap-shy type response by instilling the novelty of a new scent. We chose to use fish oil (Minnesota Trapline Products, Inc., Pennock, Minnesota) and anise (Bear Scents LLC., Lake Mills, Wisconsin) We collected hair samples and replenished the lure at each hair-snare once every 7 days for 6 encounter occasions. A short sampling interval was used to minimize violations with demographic and geographic closure for closed population models as well as to reduce sample exposure to ultraviolet light and moisture, which degrade DNA (Kendall and McKelvey 2008).

We used several criteria to determine which samples would be analyzed. A sample consisted of a tuft of hair on 1 barb (Figure 3-2). All samples with ≥ 5 bear hairs were collected; however, to reduce analyzing the same individual multiple times during the same session, we collected the samples with the most hairs when bears left multiple samples on adjacent barbs (Tredick et al. 2007). In addition, we eliminated obvious non-target species samples (e.g., deer) in the field. We sent all the hair samples to the University of California, Davis Wildlife Health and Genetics Lab for DNA extraction and sex and individual identification. See Chapter 2 for details on DNA analyses.

In 2011, we sampled in the 10-km^2 city center in addition to the UWI because we found bears were using refuges in the city center for extended periods of time (Figure 3-1). To secure private property access, we presented our project plans to the ML town council and wildlife management board. In addition to getting access on town property, members of the board put us in touch with numerous private landowners in the community, almost all of whom granted us access to their land to conduct our study. We doubled the number and density of hair corrals ($n = 20$) for the 2011 field season (Table 3-1). Due to the spatial distribution of the private property on which we had access, we established a 2-km^2 circular buffer around each hair corral instead of using a grid system. Buffers covered the entire study area with minimal overlap. In addition to using fish oil and anise this field season, we also used hickory smoke and cherry lures (both Bear Scents LLC., Lake Mills, Wisconsin). Each lure was randomly assigned to 5 hair corrals and used only at those hair corrals for the first 3 encounter occasions. The last 3 encounter occasions we only used fish oil.

In 2012, we had sufficient access to private property to place a 2-km^2 grid system with 22 cells over the study area (Figure 3-1, Table 3-1). We applied fish oil, anise, hickory smoke, anise with spent cooking oil (50:50 mixture), and hickory smoke with spent cooking oil (50:50 mixture) to the hair corrals. Spent cooking oil was obtained from a local restaurant. Lures were randomly assigned to hair corrals for the first encounter occasion then the lures were rotated systematically at each hair corral in a random order for the remaining 5 encounter occasions. Along with adding more lures during 2012, we also added 1 additional hair-snare to each cell. We set up 8 natural rubs (Boulanger et al. 2008), 7 haphazard-wire hair-snares (Figure 3-3), and 6 tennis ball hair-snares (Figure 3-4, Table 3-1). We did this to increase the number of samples collected, reduce capture heterogeneity, and to test hair-snare designs that are safer for use in public areas and required less area for setup.

We used Huggins (1989, 1991) robust design closed population models which were similar to Pederson et al. (2012) and model averaging in program MARK (Lukacs 2010) to obtain

population estimates for 2011 and 2012 data. For 2012, we tested additional models similar to Dreher et al. (2007) and Boulanger et al. (2008) that accounted for multiple detection methods in our hierarchical models of abundance. See chapter 2 for more detail on population estimation.

RESULTS

CMR Samples

       Overall, we collected 229 CMR samples during all 3 field seasons, and 175 were submitted for genetic analysis. The mean number of bear samples collected per encounter occasion and per corral hair-snare per encounter was 13.8 and 2.4 in 2011, respectively, and 18.8 and 3.3 in 2012, respectively. The mean number of individual bears identified per encounter occasion was 3.7 in 2011 and 8 in 2012. Over the course of both field seasons, a total of 40 individual bears (15 females, 24 males, and 1 unknown sex) were identified; 6 bears (3 females and 3 males) were identified in both (Table 3-1).

       In 2010, we collected 30 hair samples during the 6 encounter occasions, and 18 of those were suitable for DNA analysis after subsampling. We assumed those 18 samples would be insufficient for CMR estimates; therefore, we did not have DNA analysis performed on those samples. Numerous bears were seen in the city center during our 6 week sampling period. We decided to set up 2 hair corrals in the city center on the ESVR for 2 additional encounter occasions to test if we were missing bears by only sampling the UWI. During those 2 encounter occasions, we collected 20 hair samples sufficient for DNA analysis. Collecting 20 samples in just 2 sampling periods plus numerous reports of bears seen in the city center drove our decision to set hair-snares in the city center the following years.

       A sufficient number of hair samples for CMR were collected in 2011 and 2012 (Table 3-1). We collected 37 more hair samples in 2012 than in 2011. Genotyping success was 32% higher in 2012 compared to 2011. In 2011, no samples were mixed (i.e., ≥ 2 bears in 1 sample) and discarded in the laboratory. Samples that did not have enough DNA ($n = 8$) and only

amplified at 1 to 2 loci ($n = 25$) were considered failures (Table 3-1). In 2012, there were no

samples that did not have enough DNA, 4 samples were mixed, and 14 had degraded DNA (Table

3-1). Using our a priori models and model averaging in Program MARK (Lukacs 2010), we met

our criteria with the 2011 and 2012 data to obtained capture rates of $\geq$0.3. The CV obtained from

the 2011 data was close to our criteria and within our criteria for the 2012 data (Table 3-2). For

more detail on population models and estimates see Chapter 2.

In 2012, we collected 95, 20, 3, and 0 hair samples ($n = 118$) from the hair corrals,

natural rubs, haphazard-wire hair-snares, and tennis ball hair-snares, respectively (Table 3-1).

Nineteen of 22 corral hair-snares were visited by a bear at least once and $\geq$1 bear hair samples

were collected as were 4 of 8 natural rubs, 3 of 7 haphazard-wire snares, and 0 of 6 tennis ball

snares. In 2011, all corral hair-snares were visited by a bear and $\geq$1 hair samples were collected.

Lure Summary

There was $\geq$1 bear samples collected with each lure type. Cherry and hickory smoke

worked poorly to attract bears. Bears were more attracted to lures with spent cooking oil added as

opposed to lures that did not have spent cooking oil added. Interestingly, hickory smoke without

spent cooking oil attracted 0 bears in 2012, while and hickory smoke with spent cooking oil

attracted 11 individual bears and was the second best lure. During the first 3 sampling sessions of

2011, the greatest number of bear samples were collected from anise ($n = 16$) and fish oil ($n = 8$).

In 2012, anise and fish oil continued to do well by luring 4 and 15 bears to corral hair-snares.

Based on lure availability defined as number of site-days (i.e., number of sites $\times$ number of

sessions), for 2012 the highest proportion of bears captured per lure availability were with

hickory smoke with spent cooking oil (0.033) followed by fish oil (0.033), anise and spent oil

(0.027), anise (0.020), and hickory smoke (0.006; Table 3-3). Of the bears that were identified $\geq$2

times, 12 were attracted to multiple lures and 7 were attracted to 1 lure type. Two of the 6

individuals identified in both years and identified ≥ 2 times switched from visiting the same lure 1 year to visiting multiple lures the other year (Table 3-4). Canines (likely dogs) were attracted to all lure types.

Opportunistic Samples

We collected 65 opportunistic hair samples throughout Mono County, California and sent them to the lab; 29 were from known bears (28 dead and 1 captured bear) and 36 were collected in the ML study area not from known bears (e.g., bed sites and scenes of human-bear conflicts). Of the known bear samples, 4, 11, and 14 were from 2010, 2011, and 2012, respectively. Genotyping success was 81% for the unknown bear samples and 97% for the known bear samples. In support of our lab methods, all 28 genotyped, known bear samples were correctly identified to the individual bear.

Five of the known bear samples were collected in the study area (4 dead and 1 captured bear). None of these bears were identified in the CMR and no bears identified in town were also identified outside of the study area. In addition, none of the dead bears died during the periods of CMR, which helps support the assumption of demographic and geographic closure for closed population models. The total number of bears identified from opportunistic samples in the ML study area was 20, including known bears. There were 8 of the same bears identified in both opportunistic and CMR samples, 3 in 2011 and 5 in 2012. There were 11 bears identified from opportunistic samples in the study area that were not identified from hair-snares, 3 in 2011 and 8 2012.

DISCUSSION

Black bears readily habituate to urban landscapes (Beckmann and Berger 2003*b*), human-bear conflicts are increasing in many areas (Peine 2001, Beckmann and Berger 2003*a*, Beckmann et al. 2004, Baruch-Mordo et al. 2008), and the negative effects urban landscapes can have on of local bear populations are a serious management concern (Beckmann and Lackey 2008, Hostetler

et al. 2009). One of the first steps in making informed management decisions is to obtain population parameters of the local population of interest (Thompson et al. 1998, Williams et al. 2002). To our knowledge, no one has acquired population parameters of bears that frequent UC using DNA-based CMR techniques. We successfully developed DNA-based CMR techniques to acquire population parameters of bears that inhabit UC.

Setting hair-snares in the city center in addition to the UWI, putting at least one hair-snare per 2 km^2, and using multiple non-consumable lure types allowed us to collect a sufficient number of bear hair samples, and obtain high enough capture and recapture rates (≥ 0.3) to estimate population parameters in this study area with sufficiently high precision (CV ≤ 0.2, Table 3-2). The noninvasive nature of this project was appealing to the public. In addition, there were no reports of the public, pets, or bears being harmed by the hair-snares. All of our criteria for a successful survey of an urban black bear population were met. The techniques that this study developed to survey urban black bears noninvasively can be used as a model for similar studies throughout North America for other places where bears spend the majority of their time ($\geq 90\%$) in UC.

One of the important aspects to a successful wildlife study in urban areas is public acceptance. Lord and Cheng (2006) highlight the major barrier to public involvement (i.e., allowing private property access) is the public's lack of understanding on how state wildlife agencies make management decisions. Furthermore, public involvement improves studies through cooperation. Securing private property access was one of the most essential and challenging tasks of this study. In order to obtain private property access, it was critical that we earned the public's trust and respect. We gained that trust and respect by being transparent and presenting our ESBBP science-based management goals and objectives at town council meetings. In addition, we presented our final results to the general public and encouraged local media to summarize our findings. Furthermore, we always took the time to speak with the public while

doing fieldwork. Doing this often resulted in property access to set up hair-snares the following year and to search for opportunistic samples.

We suggest having town council members and well-known community members help gain access to private property. Some private landowners had us sign documents stating exactly what we would and would not do on their property. Painting the barbed wire hunter orange, hanging orange flagging every 1 m on the barbed wire, and putting ≥4 signs in Spanish and English around the hair-snares were simple yet effective safety modifications. People were more inclined to allow these snare devices on their property because they were highly visible and risk of injury was reduced. Establishing a good relationship with local law enforcement was also beneficial because we were able to collect hair samples from scenes of human-bear conflicts where the officers responded. Future studies may benefit from getting approval to set up hair-snares on utility companies' property. Utility companies often own property that is well distributed in a community. Bears often rub on utility poles and seek refuge in culverts. Hair-snares can be placed on or near these attractants.

Numerous DNA-based CMR bear studies have obtained higher capture and recapture rates and consequently lower CV than our study by using consumable baits (Immell and Anthony 2008, Gardner et al. 2010). Using consumable baits may have improved our recapture rates and lowered CV, but we did not want to further food condition the bears in the UC. There may, however, have been some caloric reward for the bears from the fish oil and spent cooking oil. Bears chewed on wood and dug up the ground only where these lures were placed. Our lure results are similar to those found in Pederson et al. (2012) where bears preferentially visited hair-snares with anise and fish oil. However, it appears as though urban bears are also attracted to lures with spent cooking oil. Cooking oil may be sought after in ML because bears often have access to spent cooking oil that is spilled on storage tanks.

The corral hair-snare design worked the best to collect bear hair samples; however, corral hair-snares take up a lot of space. In UC, space is limited. Though the alternative hair-snare

designs were not as effective as the corral hair-snare, they have their advantages over the corral design. The haphazard-wire hair-snare, natural rub, and tennis ball hair-snares can be set up easily by one person and take less time to set up. They also take less space than the corral design. Requiring less space allows you more flexibility when setting up the hair-snares on private land. The tennis ball hair-snare is a single-catch design; therefore, mixing of samples is unlikely. The tennis ball hair-snare can easily be set up next to anthropogenic attractants (e.g., dumpsters), and DNA degradation from ultraviolet light is minimized because direct sunlight is minimized. In spite of the advantages, the tennis ball hair-snare design was not successful at getting hair samples ($\geq$ 5 hairs). The ball was pulled out of 4 tennis ball hair-snares a total of 20 times; only 2 samples were left and those 2 samples did not have a sufficient amount of DNA to analyze. Hence, we cannot recommend the use of the tennis ball hair-snares to collect hair from bears. We plan to test additional hair snagging devices in the future (e.g., adhesives, surgical clips) to improve sample collection for the tennis ball hair-snare.

MANAGEMENT IMPLICATIONS

We have developed protocols and study design modifications that make estimating urban bear population abundance and vital rate parameters feasible. Prior to this study, population parameters of black bear in habitat types similar to ML had not been monitored using noninvasive, DNA-based CMR. The modifications we made to traditional DNA-based hair-snaring for black bear have the potential to be especially useful for long-term population monitoring as well as a way to evaluate mitigation of human-bear conflicts when the goal is to reduce the density of bears living in the urban environment. In addition, wildlife managers can use this survey method as part of a Before-after Control-impact analysis when evaluating management actions.

LITERATURE CITED

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

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

Beckmann, J. P., and J. Berger. 2003b. Using black bears to test ideal-free distribution models experimentally. Journal of Mammalogy 84:594–606.

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

Beckmann, J. P., and C. W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human-Wildlife Interactions 2:168–174.

Boersen, M. R., J. D. Clark, and T. L. King. 2003. Estimating black bear population density and genetic diversity at Tensas River, Louisiana using microsatellite DNA markers. Wildlife Society Bulletin 31:197–207.

Boulanger, J., K. C. Kendall, J. B. Stetz, D. A. Roon, L. P. Waits, and D. Paetkau. 2008. Multiple data sources improve DNA-based mark-recapture population estimates of grizzly bears. Ecological Applications 18:577–589.

Coster, S. S., A. I. Kovach, P. J. Pekins, A. B. Cooper, and A. Timmins. 2011. Genetic mark–recapture population estimation in black bears and issues of scale. Journal of Wildlife Management 75:1128–1136.

Dreher, B. P., S. R. Winterstein, K. T. Scribner, P. M. Lukacs, D. R. Etter, G. J. Rosa, V. A. Lopez, S. Libants, and K. B. Filcek. 2007. Noninvasive estimation of black bear abundance incorporating genotyping errors and harvested bear. Journal of Wildlife Management 71:2684–2693.

Gardner, B., J. A. Royle, M. T. Wegan, R. E. Rainboat, and P. D. Curtis. 2010. Estimating black bear density using DNA data from hair snares. Journal of Wildlife Management 74:318–325.

Herrero, S., A. Higgins, J. E. Cardoza, L. I. Hajduk, and T. S. Smith. 2011. Fatal attacks by American black bear on people: 1900–2009. Journal of Wildlife Management 75:596–603.

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

Huggins, R. M. 1989. On the statistical analysis of capture experiments. Biometrika 76:133–140.

Huggins, R. M. 1991. Some practical aspects of conditional likelihood approach to capture experiments. Biometrics 47:725–732.

Immell, D., and R. G. Anthony. 2008. Estimation of black bear abundance using a discrete DNA sampling device. Journal of Wildlife Management 72:324–330.

Kendall, K. C., and K. S. McKelvey. 2008. Hair collection. Pages 135–176 *in* R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey methods for carnivores. Island Press, Washington, DC, USA.

Lord, J. K., and A. S. Cheng. 2006. Public involvement in state fish and wildlife agencies in the U.S.: a thumbnail sketch of techniques and barriers. Human Dimensions of Wildlife 11:55–69.

Lukacs, P. M. 2010. Closed population capture-recapture models. Pages 14-1–14-38 *in* E. Cooch and G. C. White, editors. Program MARK: a gentle introduction. <http://www.phidot.org/software/mark/docs/book/>. Accessed 15 Apr 2010.

Madison, J. S. 2008. Yosemite National Park: the continuous evolution of human-black bear conflict management. Human-Wildlife Conflicts 2:160–167.

Merkle, J. A., P. R. Krausman, N. J. Decesare, and J. J. Jonkel. 2011. Predicting spatial distribution of human–black bear interactions in urban areas. Journal of Wildlife Management 75:1121–1127.

Pederson, J. C., K. D. Bunnell, M. M. Conner, and C. R. McLaughlin. 2012. A robust-design analysis to estimate American black bear population parameters in Utah. Ursus 23:104–116.

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

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:3–97.

Robinson, S. J., L. P. Waits, and I. D. Martin. 2009. Estimating abundance of American black bears using DNA-based capture-mark-recapture models. Ursus 20:1–11.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California, USA.

Town of Mammoth Lakes. 2007. Fact sheet. <http://www.ci.mammoth-lakes.ca.us/documents/9/Mammoth%20Facts.PDF>. Accessed 15 May 2010.

Tredick, C. A., M. R. Vaughan, D. F. Stauffer, S. L. Simek, and T. Eason. 2007. Sub-sampling genetic data to estimate black bear population size: a case study. Ursus 18:179–188.

Tredick, C. A., and M. R. Vaughan. 2009. DNA-based population demographics of black bears in coastal North Carolina and Virginia. Journal of Wildlife Management 73:1031–1039.

U.S. Census Bureau. 2010. Urban and rural classification. <wwww.census.gov/geo/reference/urban-rural.html>. Accessed 12 May 2011.

Waits, L. P., and D. Paetkau. 2005. Noninvasive genetic sampling tools for wildlife biologists: a review of applications and recommendations for accurate data collection. Journal of Wildlife Management 69:1419–1433.

Western Regional Climate Center. 2013. Western U.S. Climate Historical Summaries.

    <http://www.wrcc.dri.edu/Climsum.html>. Accessed 19 Jan 2013.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal

    populations: modeling, estimation, and decision making. Academic Press, San Diego,

    California, USA.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic

    tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616–627.

Table 3-1. Hair sample summary for the black bear (*Ursus americanus*) hair-snare study in Mammoth Lakes, California, USA June - July (2010, 2011, and 2012).

Year	Hair-snare	Samples[1]	Sites[2]	Lab[3]	Dog[4]	Bear[5]	Genotype[6]	Failed[7]	Individuals[8]	Unique[9]
2010	Corral	30	10	18[a]						
2011	Corral	81	20	71	7	47	31	33	14	14
	Corral	95	22	83	14	69	51	18	28	26
	H-wire[#]	3	7	3	0	3	3	0	2	0
2012	Natural rub	20	8	18	0	18	18	0	5	4
	Tennis ball	2[b]	7			20[c]				
	Total	118	44	104	14	90	72	18	35	
Grand total		229	74	175	21	137	103	51	40*	44

[1] Suitable samples (≥ 5 hairs) collected

[2] Sites where hair-snare was applied

[3] Samples sent to the lab after subsampling

[4] Domestic dog samples

[5] Samples identified as bear (mixed and samples that amplified only at 1-2 loci were also counted)

[6] Samples successfully genotyped

[7] Includes all samples that failed to genotype, mixed samples, or insufficient amount of DNA

[8] Total individual bears identified with hair-snare type specified

[9] Only bears identified just with hair-snare type specified

[a] Subsampling only, not sent to the lab

[b] < 5 hair, not sent to lab

[c] Total times ball was pulled out and an adquate sample was <u>not</u> left

* Adjusted by removing individuals that were identified multiple times

[#] Haphazard-wire

Table 3-2. Model averaged abundance estimates, confidence intervals, standard error, capture probability (p), recapture probability (c), and coefficient of variance from Program MARK for black bears in Mammoth Lakes, California, USA, June - July (2011-2012).

Year	Abundance estimate (N)	95% CI	SE (N)	p	c	CV (N)
2011	20	17-29	4	0.33	0.33	0.22
2012	46	39-58	7	0.30*	0.31*	0.16

* Capture and recapture for non-corral snares was 0.12.

Table 3-3. A summary of lure visitation by bears (*Ursus americanus*) during the Mammoth Lakes, California, USA field seasons from June to July 2011- 2012.

Lure	Availability[1]	Sites[2]	Samples[3]	Lab[4]	Dog[5]	Bear[6]	Failed[7]	Individuals[8]	Unique[9]	Recaptures[10]
2011 Field Season										
The 1st 3 sessions with all lures										
Anise	15	5	18	16	0	16	2	7	4	1
Fish Oil	15	5	13	11	1	8	6	3	2	0
Cherry	15	5	2	2	0	2	0	1	0	0
Hickory Smoke	15	5	3	3	0	1	3			
Total	60	20	36	32	1	27	11	11	6	1
The last 3 sessions with fish oil only										
Fish Oil	60	20	45	39	6	21	21	8	4*	4
2012 Field Season**										
Anise	20	20	11	11	3	8	3	4	3	1
Anise/SpentOil	24	22	19	17	3	14	5	7	3	1
Fish Oil	37	22	32	28	4	24	4	15	8	1
Hickory Smoke	13	14	3	2	1	1	1			
Hickory Smoke/SpentOil	29	22	30	24	3	21	2	11	7	1

[1] Available sessions where lure was applied

[2] Sites where lure was applied

[3] Suitable samples ($\geq$5 hairs) collected

[4] Samples sent to the lab after subsampling

[5] Domestic dog samples

[6] Samples identified as bear (mixed samples and samples identified at $\geq$1 locus but did not fully genotype were also counted)

[7] Includes all samples that failed to genotype due to DNA degradation, mixed samples, or insufficient amount of DNA

[8] Individual bears identified

[9] Individual bears only identified at the lure specified

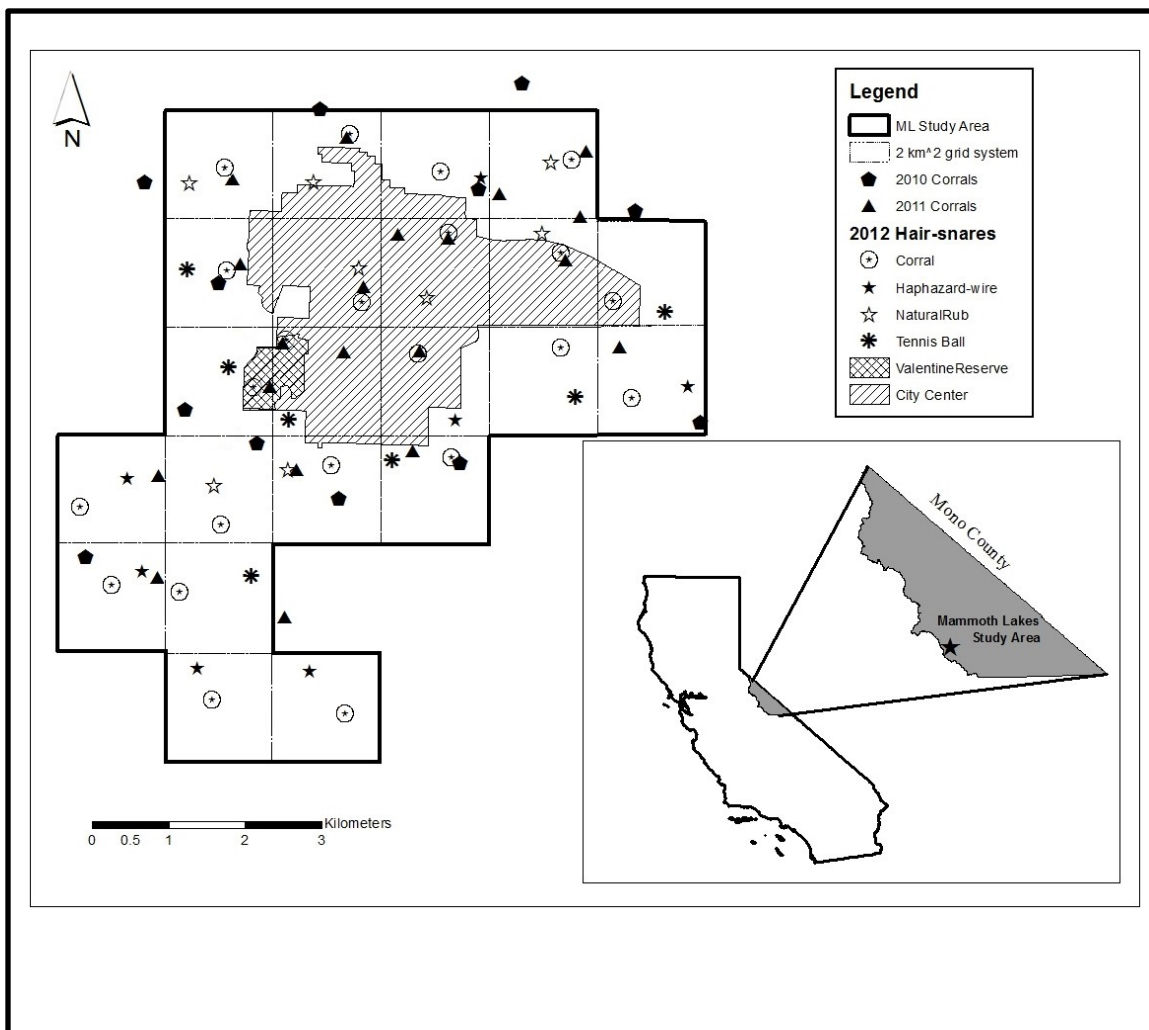[10] Recaptures of the same individual bear
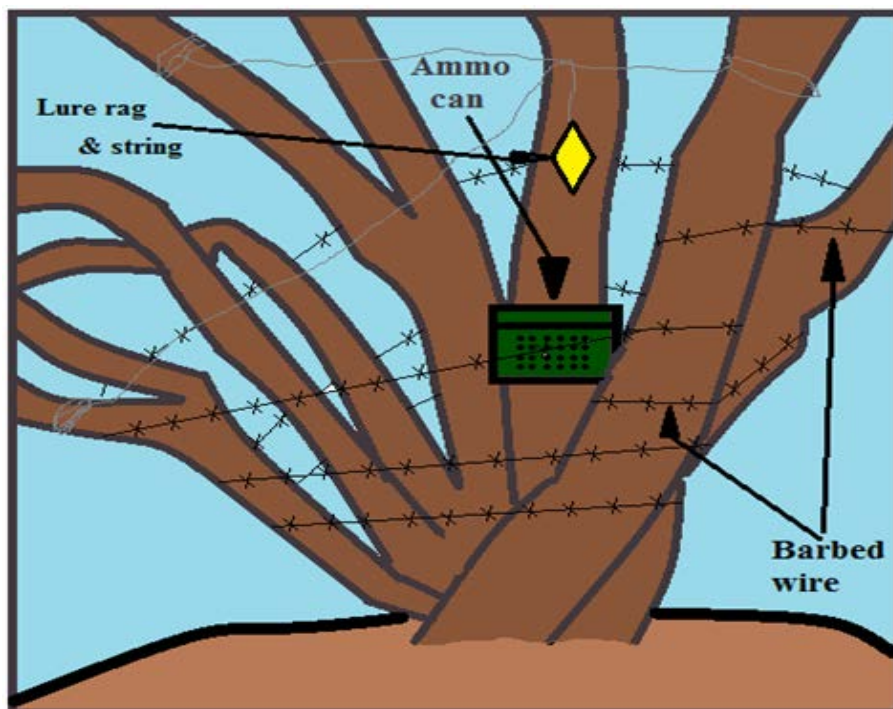
* Not identified in previous 3 sessions
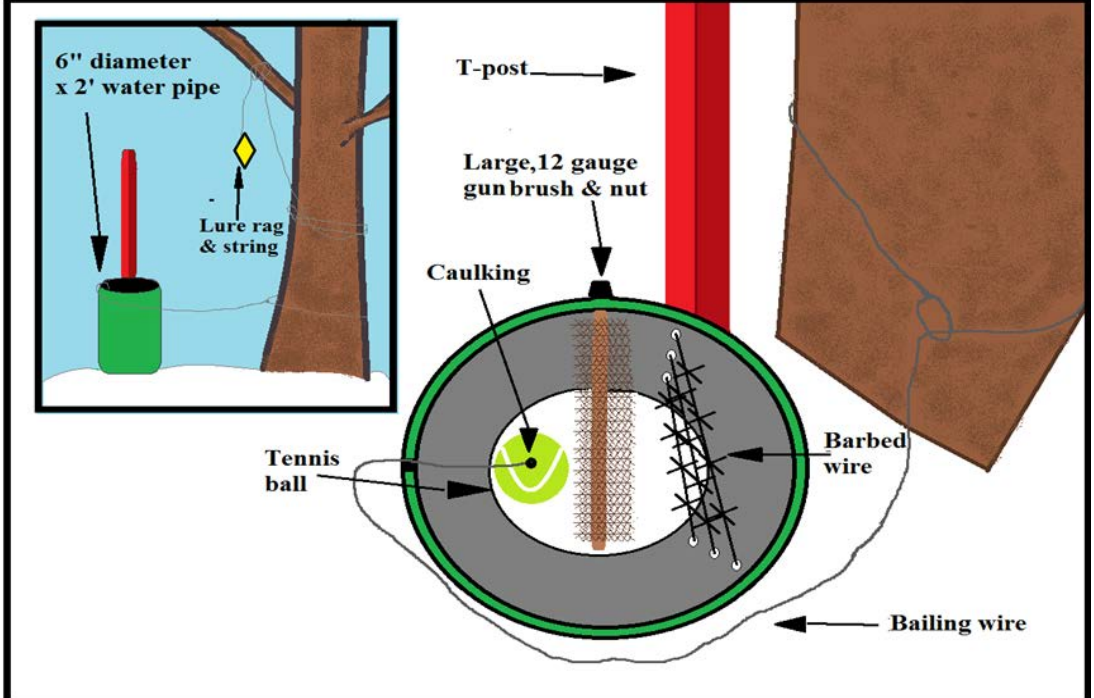
** Just corral design

Table 3-4. Summary of visitation to corral hair-snares by individual identification (ID), sex, year, and non-consumable lure type for an urban black bear study in Mammoth Lakes, California, USA (2011-2012).

ID	Sex	Year	Anise	Anise/Spent oil	Cherry	Fish oil	Hickory Smoke	Hickory Smoke/Spent oil
1	M	2011	1	*	0	1	0	*
2	M	2011	1	*	0	7	0	*
3	M	2011	0	*	0	2	0	*
4	M	2011	0	*	0	2	0	*
5	F	2011	1	*	1	0	0	*
6	F	2011	0	*	0	1	0	*
7	F	2011	0	*	0	1	0	*
8	F	2011	0	*	0	2	0	*
9	F	2011	2	*	0	0	0	*
9	F	2012	2	2	*	1	0	2
10	F	2011	1	*	0	1	0	*
10	F	2012	0	0	*	0	0	1
11	F	2011	0	*	0	2	0	*
11	F	2012	0	0	*	2	0	0
12	M	2011	1	*	0	0	0	*
12	M	2012	0	0	*	1	0	0
13	M	2011	1	*	0	4	0	*
13	M	2012	0	1	*	0	0	0
14	M	2011	0	*	0	4	0	*
14	M	2012	0	1	*	1	0	0
15	M	2012	0	1	*	1	0	0
16	M	2012	0	0	*	1	0	1
17	M	2012	0	0	*	1	0	1
18	M	2012	0	0	*	0	0	1
19	M	2012	0	0	*	1	0	1
20	M	2012	0	0	*	0	0	1
21	M	2012	0	0	*	0	0	1
22	M	2012	0	0	*	1	0	0
23	M	2012	0	0	*	1	0	0
24	M	2012	0	1	*	0	0	0
25	M	2012	0	0	*	0	0	1
26	M	2012	0	0	*	0	0	1
27	M	2012	1	0	*	0	0	0
28	M	2012	1	0	*	0	0	0
29	M	2012	0	0	*	0	0	1
30	F	2012	0	0	*	1	0	0
31	F	2012	1	0	*	0	0	0
32	F	2012	0	0	*	1	0	0
33	F	2012	0	1	*	1	0	1
34	F	2012	0	1	*	0	0	0
35	F	2012	0	0	*	1	0	0
36	F	2012	0	0	*	1	0	0

* Lure not used during that year

6" diameter x 2' water pipe

Lure rag & string

T-post

Large,12 gauge gun brush & nut

Caulking

Tennis ball

Barbed wire

Bailing wire

CHAPTER 4

CONCLUSIONS

Carnivores are returning to their historic ranges, and their populations are increasing throughout the United States (Conover 2008). Wildlife managers are faced with the difficult task of monitoring and managing their carnivore populations for the wellbeing of the public. One of the first steps in making informed management decisions for any species is obtaining reliable demographic and abundance estimates (Thompson et al. 1998, Williams et al. 2002). Traditional methods (e.g., live-trapping) to attain these population parameters for carnivores are often cost prohibitive and invasive (Woods et al. 1999, Waits and Paetkau 2005, Kendall and McKelvey 2008). However, recent advances in noninvasive DNA-based sampling have allowed wildlife managers to obtain cost effective and reliable demographic and abundance estimates for species such as lynx (*Lynx Canadensis;* McDaniel et al. 2000), bobcat (*Lynx rufus;* Stricker et al. 2012), mountain lion (*Puma concolor*; Ernest et al. 2000) gray wolves (*Canis lupus*; Stenglein et al. 2010), red fox (*Vulpes vulpes*), wolverine (*Gulo gulo;* Magoun et al. 2011), grizzly bear (*Ursus arctos*; Woods et al. 1999, Boulanger et al. 2004, Kendall et al. 2009), and black bear (*Ursus americanus;* Settlage et al. 2008, Robinson et al. 2009, Coster et al. 2011).

The most cost effective and common method of monitoring bear populations is through the application of DNA-based capture-mark-recapture (CMR) techniques from systematically collected hair samples (Woods et al. 1999, Mowat and Strobeck 2000, Kendall et al. 2009, Robinson et al. 2009). Woods et al. (1999) was among the first to implement DNA-based CMR techniques on bear using hair-snares. Since then, many improvements have been made to the tools and techniques of DNA-based CMR for bear species. Improvements include better hair-snare designs (Beier et al. 2005, Immell and Anthony 2008, Kendall and McKelvey 2008, Robinson et al. 2009), trapping arrays (Poole et al. 2001, Thompson 2004), bear lures and baits (Waits and Paetkau 2005, Kendall et al. 2009) , hair subsampling methods (Tredick et al. 2007,

Dreher et al. 2009), genotyping techniques (Lukacs and Burnham 2005, Dreher et al. 2007), and statistical models (Kendall et al. 2009, Robinson et al. 2009, Gardner et al. 2010). However, to my knowledge, DNA-based CMR studies for bear have solely been implemented in wildland or rural bear habitats.

Though much of the bears' and other carnivores' historic ranges are still wildland, an ever increasing amount of their historic range has become urbanized. The traditional dogma was that bears and other carnivores avoid urbanization. That dogma seems to have changed. Human-carnivore interactions are increasing as people develop more land, recreate more in the outdoors, and as the carnivore populations continue to increase (Conover 2002). Many carnivore species, black bears particularly, habituate to urbanization and take advantage of anthropogenic resources (Beckmann and Lackey 2008, Gehrt et al. 2010).

Population estimates for the state of California are generated from statewide harvest data and indicate the black bear population has nearly tripled over the last 3 decades (California Department of Fish and Wildlife 2012). Black bears now reside in places they formally never occurred (e.g., urban communities) and have increased in abundance where they historically were uncommon. Furthermore, human-bear conflicts are increasing in California as people develop more land in black bear habitat, recreate more in black bear habitat, and as the bear population continues to increase. Habituated bears living in and around urban areas that take advantage of anthropogenic resources (i.e., acting food-conditioned) are a major concern to our wildlife managers and most of the general public who live with bears in their community. It is well documented these bears can be a threat to public safety and inflict major property damage (Baruch-Mordo et al. 2008, Herrero et al. 2011). Less documented, but more important to wildlife managers, is the fact that urban landscapes can negatively affect the health of wildland bear populations by functioning in a source-sink dynamic (Beckmann and Berger 2003*b*, Beckmann and Lackey 2008, Hostetler et al. 2009). Bears in the wildland, "source" population are drawn into urban areas to attain anthropogenic resources (e.g., garbage). While in the urban landscapes,

sows experience higher fecundity rates than sows in the surrounding wildland areas; however, the urban sows have a higher risk of mortality, which exceeds recruitment rates. The urban environment, therefore, acts as a "sink" or ecological trap. In addition, the urban environment may act as a training area for habituated and food-conditioned bears that disperse to neighboring communities (Beckmann and Berger 2003*a*, Breck et al. 2008, Mazur and Seher 2008). Prior to investigating the solutions to alleviate human-bear conflicts, I sought to acquire reliable baseline demographic and abundance estimates for black bears.

My thesis addresses differences in population parameters between 1 urban bear population, Mammoth Lakes (ML), and 1 wildland bear population, Slinkard Valley Wildlife Area (SVWA), in Mono County, California. It also addresses which tools and techniques work best for a DNA-based CMR bear survey in an urban environment.

This studies objectives were to 1) obtain ≥20 opportunistic DNA samples from dead bears (i.e., road kill, hunter harvest, depredation, etc.) in our study area for the genetics lab to define the population genetics (allele frequencies) of the bears in the area and test lab methods 2) test the plausibility of implementing a noninvasive CMR study in an urban area via a comparison between a control, wildland, study area using traditional hair-snare CMR techniques and the experimental, urban, study area, and 3) use the DNA-based CMR estimates to compare population density and sex ratios of bears residing in the 2 study areas.

Corroborating my general impressions, I found bear density to be higher in the urbanized study area compared to the wildland study area (Table 2-5). Beckmann and Berger (2003*b*) found that bears in the urban-wildland interface lived at 3 times higher densities than wildland bears. Similarly, the results from my 2012 field season showed the density of the bear population in ML was 2.5 times higher than the SVWA. My data also indicated that densities were not significantly different. During 2011, ML bear density was 1.6 times higher than the SVWA though the densities were not significantly different. However, the ML population estimate from that year is likely conservative. I may have missed individual bears during that field season due to low

genotyping success and from collecting fewer hair samples.

ML may have a higher density bear population compared to SVWA because of the abundance of high-caloric-value, anthropogenic food resources available, learned behavior to exploit those resources, high human tolerance of bears living in ML, and the management of bears in ML. ML has numerous riparian corridors, which provide natural food resources of both hard and soft-mast plants akin to SVWA; however, anthropogenic food resources (e.g., garbage, bird seed, ornamental plants, and pet food) are also accessible to bears. To obtain human food in ML, many bears have learned to break into vehicles and buildings, check if dumpsters are locked, cruise lake shorelines to find fishermen's stringers of fish, and obtain campers' food (T. Taylor, California Fish and Wildlife, unpublished report). Bears have been welcomed in town for over 4 decades and are a major tourist attraction. Many community members have a high tolerance for bears living in their community, similar to how people feel about raccoons (*Procyon lotor*) in other parts of the U.S. (Gehrt et al. 2010). Raccoons are also known to live at higher densities in urban environments compared to wild environments (Randa and Yunger 2006).

Although popular with residents, local California Fish and Wildlife (CDFW) biologists and game wardens spend 25 to 35% of their time annually mitigating human-bear conflicts throughout Mono County from June to October, and ML has the highest number of human-bear conflicts in the county (T. Taylor, California Fish and Wildlife, unpublished report). Like many state wildlife agencies, CDFW has limited resources to reduce human-bear conflicts. Biologists and game wardens can provide educational materials to help people mitigate human-bear conflicts. During extreme cases of property damage, depredation permits can be issued if people have taken the appropriate actions to prevent bears from damaging their property. Depredation permits allow individuals to dispatch nuisance bears. Since 1996, the town of ML has put forth a substantial effort to reduce human-bear conflicts by enforcing local trash management ordinances, education, and employing hazing techniques that are carried out by police officers and the town's wildlife manager (Peine 2001). Nevertheless, with 1.5 million tourists visiting

each spring and summer who are ignorant to bear behavior, it is inevitable bears become food conditioned. Furthermore, Yosemite National Park is potentially a source population of bears for ML and the surrounding national forest. Numerous nuisance bears ear tagged in Yosemite National Park have traveled to ML and other communities in Mono County (California Department of Fish and Wildlife, unpublished report).

The population parameter results from this study need to be interpreted with caution. According to White et al. (1982), capture probabilities should be >0.30 to obtain reliable closed capture population models when populations are <100. Furthermore, I needed to attain a coefficient of variance (CV) of <0.2 to obtain acceptable precision in population estimates (Pollock et al. 1990). These criteria were met for the ML study area but not for the SVWA (Table 2-4). However, Boulanger et al. (2004) suggested that a capture probability of >0.20 with a population >50 will ensure reliable results. Our data suggest the SVWA bear population exceeds 50 bears, and the capture probabilities were >0.20. Therefore, the SVWA results would fall with in Boulanger et al. (2004) criteria. Nonetheless, I recognize that my small study areas were prone to geographic closure bias, which can result in reduced capture and recapture rates and decrease CV (Boulanger and McLellan 2001). In both study areas, I may have drawn in bears from outside the study area by using small grids and scent lures (Boulanger et al. 2004). Due to logistical and financial constraints, I had to make my study areas small. I attempted to correct for this bias by choosing study areas that were geographically isolated via ridgelines and surrounding marginal habitats (i.e., Great Basin Desert). As an index for movement in and out of my study areas, no bears identified from hair samples in the study areas were also identified outside of the study areas from the known bear hair samples I collected.

By setting at least one hair-snare per 2 km^2 in the city center in addition to the urban wildland interface (UWI), I was able to collect a sufficient number of bear hair samples, and obtain high enough capture and recapture rates ($\geq$0.3) to estimate population parameters in the ML study area with sufficiently high precision (CV $\leq$0.2, Table 3-2). The noninvasive nature of

this project was appealing to the public. In addition, there were no reports of the public, pets, or bears being harmed by the hair-snares. All of my criteria for a successful survey of an urban black bear population were met. The techniques that this study developed to survey urban black bears noninvasively can be used as a model for similar studies throughout North America where bears spend the majority of their time ($\geq$90%) in urban clusters ($\geq$2,500 residents).

Securing private property access was one of the most challenging tasks of this study. To obtain private property access, I had to earn the public's trust and respect by being transparent and presenting my science-based management goals and objectives at town council meetings. In addition, I presented my final results to the general public and encouraged local media to summarize my findings. Furthermore, I always took the time to speak with the public while doing fieldwork. Doing this often resulted in me obtaining access to private property to set up hair-snares the following year and to search for opportunistic samples.

I suggest having town council members and well-known community members help gain access to private property. Some private landowners had me sign documents stating exactly what I would and would not do on their property. Establishing a good relationship with local law enforcement was also beneficial because I was able to collect hair samples from scenes of human-bear conflicts where the officers responded. Future studies may benefit from getting approval to set up hair-snares on utility companies' property. Utility companies often own property that is well distributed in a community. Urban bears often rub on utility poles and seek refuge in culverts. Hair-snares can be placed on or near these attractants.

Painting the barbed wire hunter orange, hanging orange flagging every 1 m on the barbed wire, and putting $\geq$4 signs in Spanish and English around the hair-snares were simple yet effective safety modifications. People were more inclined to allow these snare devices on their property because they were highly visible and risk of injury was reduced. Using consumable lures may have improved our recapture rates, but we did not want to food condition the bears. There

may, however, have been some caloric reward for the bears from the fish oil and spent cooking oil. Bears chewed on wood and dug up the ground only where these lures were placed.

At least one bear investigated every lure although fish oil and lures combined with spent cooking oil had the highest visitation rate (Table 3-3, Table 3-4). My lure results are similar to those found in Pederson et al. (2012) where bears preferentially visited hair-snares with anise and fish oil. However, it appears as though urban bears are also attracted to lures with spent cooking oil.

The corral hair-snare design worked the best to collect bear hair samples. I did not experience a high percentage of mixed samples (Woods et al. 1999), which is usually an issue for dense bear populations when using corrals (Beier et al. 2005, Immell and Anthony 2008). Though the alternative hair-snare designs were not as effective as the corral hair-snare, they have their advantages over the corral design. The haphazard-wire hair-snare, natural rub, and tennis ball hair-snares can be set up easily by 1 person and take less time to set up. They also take less space than the corral design. Requiring less space allows more flexibility when setting up the hair-snares on private land. The tennis ball hair-snare is a single-catch design; therefore, mixing of samples is unlikely. The tennis ball hair-snare can easily be set up next to anthropogenic attractants (e.g., dumpsters), and DNA degradation from ultraviolet light is minimized because direct sunlight is minimized. In spite of the advantages, the tennis ball hair-snare design was not successful at getting hair samples (≥ 5 hairs). Four different tennis ball hair-snares were visited a total of 20 times by a bear where the bear successfully pulled out the tennis ball; however, only 2 samples were left and those 2 samples did not have a sufficient amount of DNA to analyze. Hence, I cannot recommend the use of the tennis ball hair-snares to collect hair from bears. I plan to test additional hair snagging devices in the future (e.g., adhesives, surgical clips) to improve sample collection for the tennis ball hair-snare.

Prior to this study, population parameters of black bear in habitat types similar to ML had not been monitored using noninvasive, DNA-based CMR surveys. The modifications I made to

traditional DNA-based hair-snaring for black bear have the potential to be especially useful for long-term population monitoring as well as a way to evaluate mitigation of human-bear conflicts when the goal is to reduce the density of bears living in the urban environment. In addition, wildlife managers can use this survey method as part of a Before-after Control-impact analysis when evaluating management actions.

The data from this study support the theory that bears may be occurring at higher densities in urban areas, which is a management concern due to the negative impact urban landscapes can have on bear populations and the potential for human-bear conflicts. I recommend using my DNA-based CMR methods to monitor population parameters of bears in urban areas. The baseline data obtained in ML can be used for a Before-after Control-impact analysis to evaluate future management actions that seek to reduce human-bear conflicts by reducing the density of bears in ML. Furthermore, with additional survey years, my data can provide estimates of population vital rates, such as apparent survival, finite rate of population change, movement, and recruitment. Monitoring these vital rates can help elucidate if ML is function as a "sink" or ecological trap for bears. Additionally, the reference database of bear DNA we started can be used for future eastern Sierra black bear studies to help maintain low values of $P_{(id)}$ and $P_{(sib)}$.

LITERATURE CITED

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

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

Beckmann, J. P., and J. Berger. 2003b. Using black bears to test ideal-free distribution models experimentally. Journal of Mammalogy 84:594–606.

Beckmann, J. P., and C. W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human-Wildlife Interactions 2:168–174.

Beier, L. R., S. B. Lewis, R. W. Flynn, G. Pendleton, and T. V. Schumacher. 2005. A single-catch snare to collect brown bear hair for genetic mark-recapture studies. Wildlife Society Bulletin 33:766–773.

Boulanger, J., B. N. McLellan, J. G. Woods, M. F. Proctor, and C. Strobeck. 2004. Sampling design and bias in DNA-based capture-mark-recapture population and density estimates of grizzly bears. Journal of Wildlife Management 68:457–469.

Boulanger, J., and B. N. McLellan. 2001. Closure violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology 79:642–651.

Breck, S. W., C. L. Williams, J. P. Beckmann, S. M. Matthews, C. W. Lackey, and J. J. Beecham. 2008. Using genetic relatedness to investigate the development of conflict behavior in black bears. Journal of Mammalogy 89:428–434.

California Department of Fish and Wildlife. 2012. Black bear population report. Sacramento,CA, USA. <http://dfg.ca.gov/wildlife/hunting/bear/population.html>. Accessed 10 Mar 2012.

Conover, M. 2002. Resolving human-wildlife conflicts: the science of wildlife damage management. Lewis, Boca Raton, Florida, USA.

Conover, M. 2008. Why are so many people attacked by predators? Human-Wildlife Conflicts 2:139–140.

Coster, S. S., A. I. Kovach, P. J. Pekins, A. B. Cooper, and A. Timmins. 2011. Genetic mark–recapture population estimation in black bears and issues of scale. Journal of Wildlife Management 75:1128–1136.

Dreher, B. P., G. J. Rosa, P. M. Lukacs, K. T. Scribner, and S. R. Winterstein. 2009. Subsampling hair samples affects accuracy and precision of DNA-based population estimates. Journal of Wildlife Management 73:1184–1188.

Ernest, H. B., M. C. T. Penedo, B. P. May, M. Syvanen, and W. M. Boyce. 2000. Molecular

tracking of mountain lions in the Yosemite Valley region in California: genetic analysis using microsatellites and faecel DNA. Molecular Ecology 9:433–442.

Gardner, B., J. A. Royle, M. T. Wegan, R. E. Rainboat, and P. D. Curtis. 2010. Estimating black bear density using DNA data from hair snares. Journal of Wildlife Management 74:318–325.

Gehrt, S. D., S. P. D. Riley, and B. L. Cypher, editors. 2010. Urban carnivores ecology, conflict, and conservation. Johns Hopkins University Press, Baltimore, Maryland, USA.

Herrero, S., A. Higgins, J. E. Cardoza, L. I. Hajduk, and T. S. Smith. 2011. Fatal attacks by American black bear on people: 1900–2009. Journal of Wildlife Management 75:596–603.

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

Immell, D., and R. G. Anthony. 2008. Estimation of black bear abundance using a discrete DNA sampling device. Journal of Wildlife Management 72:324–330.

Kendall, K. C., and K. S. McKelvey. 2008. Hair collection. Pages 135–176 in R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey methods for carnivores. Island Press, Washington, DC, USA.

Kendall, K. C., J. B. Stetz, J. Boulanger, A. C. Macleod, D. Paetkau, and G. C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management 73:3–16.

Lukacs, P. M., and K. P. Burnham. 2005. Estimating population size from DNA-based closed capture-recapture data incorporating genotyping error. Journal of Wildlife Management 69:396–403.

Magoun, A. J., C. D. Long, M. K. Schwartz, K. L. Pilgrim, R. E. Lowell, and P. Valkenburg. 2011. Integrating motion-detection cameras and hair snags for wolverine identification.

Journal of Wildlife Management 75:731–739.

Mazur, R., and V. Seher. 2008. Socially learned foraging behaviour in wild black bears, Ursus americanus. Animal Behaviour 75:1503–1508.

McDaniel, G. W., K. S. McKelvey, J. R. Squires, and L. F. Ruggiero. 2000. Efficacy of lures and hair snares to detect lynx. Wildlife Society Bulletin 28:119–123.

Mowat, G., and C. Strobeck. 2000. Estimating population size of grizzly bears using hair capture, DNA profiling, and mark-recapture analysis. Journal of Wildlife Management 64:183–193.

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

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:3–97.

Poole, K. G., G. Mowat, and D. A. Fear. 2001. DNA-based population estimate for grizzly bears *Ursus arctos* in northeastern British Columbia, Canada. Wildlife Biology 7:105–115.

Randa, L. A., and J. A. Yunger. 2006. Carnivore occurrence along an urban-rural gradient: a landscape-level analysis. Journal of Mammalogy 87:1154–1164.

Robinson, S. J., L. P. Waits, and I. D. Martin. 2009. Estimating abundance of American black bears using DNA-based capture-mark-recapture models. Ursus 20:1–11.

Settlage, K. E., F. T. Manen, J. D. Clark, and T. L. King. 2008. Challenges of DNA-based mark-recapture studies of American black bears. Journal of Wildlife Management 72:1035–1042.

Stenglein, J. L., L. P. Waits, D. E. Ausband, P. Zager, and C. M. Mack. 2010. Efficient, noninvasive genetic sampling for monitoring reintroduced wolves. Journal of Wildlife Management 74:1050–1058.

Stricker, H. K., J. L. Belant, D. E. Beyer Jr, J. Kanefsky, K. T. Scribner, D. R. Etter, and J. Fierke. 2012. Use of modified snares to estimate bobcat abundance. Wildlife Society

Bulletin 36:257–263.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California, USA.

Thompson, W. L., editor. 2004. Sampling rare or elusive species: concepts, designs, and techniques for estimating population parameters. Island Press, Washington, DC, USA.

Tredick, C. A., M. R. Vaughan, D. F. Stauffer, S. L. Simek, and T. Eason. 2007. Sub-sampling genetic data to estimate black bear population size: a case study. Ursus 18:179–188.

Waits, L. P., and D. Paetkau. 2005. Noninvasive genetic sampling tools for wildlife biologists: a review of applications and recommendations for accurate data collection. Journal of Wildlife Management 69:1419–1433.

White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

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

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616–627.